O‘ZBEKISTON RESPUBLIKASI
RAQAMLI TEXNOLOGIYALAR VAZIRLIGI

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Raqamli transformatsiyalash jarayonida muhandislik sohalari va iqtisodiyot tarmoqlarini rivojlantirish: muammo va yechimlar

Xalqaro ilmiy-amaliy anjumani

MA’RUZALAR TO‘PLAMI

II-QISM

TOSHKENT 2025

Konferensiya tashkilotchisi: Muhammad al-Xorazmiy nomidagi Toshkent axborot texnolgiyalari universiteti

«Raqamli transformatsiyalash jarayonida muhandislik sohalari va iqtisodiyot tarmoqlarini rivojlantirish: muammo va yechimlar» xalqaro ilmiy-amaliy konferensiya materiallari to‘plami. II-qism –T.: 2025. - 718 b.

«Raqamli transformatsiyalash jarayonida muhandislik sohalari va iqtisodiyot tarmoqlarini rivojlantirish: muammo va yechimlar» mavzusidagi xalqaro ilmiy-amaliy konferensiya materiallari to‘plamiga globallashuv va raqamli iqtisodiyot sharoitida sanoat korxonalari faoliyatini samarali tashkil etish nazariyalari, zamonaviy amaliyoti va halqaro tajribada olib borilayotgan ilmiy-tadqiqot ishlar bo‘yicha olimlar, professor-o‘qituvchilar, ilmiy xodimlar, doktorantlar, mustaqil izlanuvchilar, soha mutaxassislarining ilmiy ishlari kiritilgan.

Xalqaro ilmiy-amaliy konferensiyasining maqsadi bugungi jahon davlatlarining globallashuvi jarayonida sanoat tarmoqlari va sohalari faoliyatining raqamlashishining amaliy ahamiyatini yoritish nazariyalari, zamonaviy amaliyoti va jahon tajribasi, zamonaviy sanoatda iqtisodiy jarayonlarga nisbatan ilmiy yondashuvlar hamda korxonalarda texnik jarayonlarnni samarali boshqarish bo‘yicha olib borilayotgan ilmiy-tadqiqot ishlarini professor-o‘qituvchilar, ilmiy xodimlar, doktorantlar, mustaqil izlanuvchilar, soha mutaxassislari o‘rtasida muhokama etish, sanoatda samarali boshqaruv usullarni qo‘llash bo‘yicha nazariy va amaliy tajriba almashish, korporatsiyalar va aksiyadorlik jamiyatlarida ishlab chiqarishni texnik va texnologik yangilashdagi muammolarni aniqlash, uni hal etish va rivojlantirish yo‘llariga doir taklif va tavsiyalarni ishlab chiqish va yutuqli natijalarni targ‘ib etishdan iborat.

Ushbu xalqaro ilmiy-amaliy konferensiya materiallaridagi ilmiy maqolalar va tezislarda olimlar, mutaxassislar, malakali amaliyotchilar, professor-o‘qituvchilar, ilmiy izlanuvchilar, mustaqil tadqiqotchilar, doktorantlar va magistrantlarning sanoat iqtisodiyoti va menejmenti nazariyalari, zamonaviy amaliyoti, jahon tajribasi, sanoat tarmoqlarini rivojlantirishning istiqbolli yo‘nalishlarining dolzarb muammolari borasidagi ilmiy-tadqiqot ishlarining natijalari mujassamlashgan.

To‘plam materiallaridan professor-o‘qituvchilar, soha mutaxassislari, doktorantlar, tadqiqotchilar, magistrantlar va bakalavr talabalari o‘z ilmiy izlanishlarida foydalanishlari mumkin.

Mazkur to‘plamga kiritilgan tezislar va maqolalarning mazmuni, undagi statistik ma’lumotlar va me’yoriy hujjatlarning to‘g‘riligi, aniqligi, tahliliy fikr-mulohazalar, keltirilgan taklif va tavsiyalar uchun mualliflar mas’uldir

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ECONOMIC AND THEORETICAL FOUNDATIONS OF THE DIGITAL ECONOMY IN THE FUTURE AND ITS APPLICATION

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Abstract. At a time when the global economic environment is subject to technological devices and innovations, developed and developing countries predict what awaits them in the next 10 years - determines the attitude to the development of the country. This, in turn, requires a prognostic view of the post-digital era and the study of its promising foundations. This desire will increase the harmony of economic and technological activities and lead to a single economy. Singularity economy is a concept that implies that the development of economic processes is a technological harmony, and describes the superiority of artificial intelligence and advanced technology over human intelligence and a significant impact on all industries and sectors of the economy.

Keywords: digital economy, singular economy, artificial intelligence, innovation, economic efficiency, Cobb-Douglas model, digital technologies, information and knowledge, investments, labor market, information and communication technologies (ICT), automation, big data, cloud technologies, robotics, innovative management, digital transformation, economic growth, exponential technological development, knowledge economy

I. INTRODUCTION

The term "singularity" usually refers to the point in technological development after which the development of technology becomes exponential, and the demand for human labor and resources decreases sharply. The development of a single economy mainly depends on the further development of technology and artificial intelligence and has the property of having a rapid and strong impact on the economic growth of countries. As a result of the creation of a single economy, there will be a sharp increase in economic efficiency, innovative solutions and technological achievements. At the same time, new ways of managing economic resources and maximizing efficiency will emerge, requiring more consistent research. This will help shape economic growth based on new paradigms.

II. THE IMPORTANCE OF SINGULARITY ECONOMY

In the theoretical description of the singular economy, this “young concept” essentially means that all economic processes occur through technological processes. The life cycle of the economic singularity means that it is free of risks, since it includes a closed-loop economy, innovation management, and strategic management based on frameworks. In the singular economy, the main approach is related to the factors that influence artificial intelligence and advanced technologies that will take over the human mind and cause radical and rapid changes in the economy. As a result of such changes, the usual principles in the economy are changed, leading to unexpected results and complex economic changes.

The conceptual basis of the singular economy is that the rapid growth of computer technology will have a positive impact on economic stability as artificial intelligence develops. As a result, most of the human labor will be automated, which can form new norms in the economy [1]. Such changes will depend on the greater integration of digital technologies and artificial intelligence into everyday economic activity [2]. The singular economy is an accelerating transformation of the economy due to technological changes that can have a major impact on economic and social structures. This leads to the transformation of each professional representative into a specialist who uses IT not as additional knowledge, but as part of basic knowledge. In the 1990s, the acquisition of computer literacy as knowledge by specialists was highly valued and valued as an admirable skill when writing a resume, but today this knowledge is considered insufficient. Therefore, the development of the singular economy is an impetus for the development of the economy and enterprise management.

III. FACTORS AFFECTING THE SINGULAR ECONOMY

The importance of taking into account the factors that influence the singular economy serves to ensure the stability of economic development and efficiency. In the process of economic singularity, various factors can

influence the economy, as well as the correct analysis and management of these factors, starting with. Singular economy helps to achieve maximum efficiency.

Technological development. The rapid development of artificial intelligence and computing technologies can dramatically accelerate economic growth in the future. In particular, artificial intelligence that surpasses human intelligence is expected to create a technological singularity.

The impact of artificial intelligence. The spread of artificial intelligence technologies and the expansion of big data processing capabilities will promote economic growth and may lead to the creation of a unified economy [3].

Innovative development and investment: As the basis for technological singularity, investment and innovative development of industrial enterprises is of great importance. These enterprises play a key role in accelerating technological progress [4].

Adaptation of society to technology. The development of technology must be accompanied by changes in society. Social order and public policy help minimize the negative impact of technological progress on society (Chen & Wang, 2023).

Managing the pace of technological development and integrating innovations into the economy are crucial for a successful transition to a single economy in the future. Artificial intelligence, automation and big data technologies will fundamentally change the economy, increase its efficiency and create new opportunities. However, excessive acceleration of this process can lead to disruption of the economic and social balance. Therefore, it is very important to carefully plan and manage the pace of technological development.

Capital and investment flows are one of the main factors supporting technological development. The correct allocation of resources for funding research and development will allow the economy to effectively implement innovations. At the same time, it is necessary to anticipate the changes that may occur in the labor market with the introduction of technology. Some professions may disappear due to automation, but it also opens the way to the creation of new jobs in new technological areas. Retraining programs allow you to adapt to these changes and ensure stability in the labor market.

Information technology and big data are crucial for economic growth and innovation. In the context of a singular economy, the importance of knowledge and information increases, as they play an important role in optimizing economic processes. Proper management and effective use of data is a key factor in increasing economic efficiency.

Social and political factors should not be forgotten. Economic changes caused by technological singularity may also affect social inequality, employment, and political decision-making processes. Therefore, taking these factors into account, maintaining social justice, and pursuing sustainable policies will help prevent the negative consequences expected from the widespread introduction of technologies.

It should be noted that taking into account the factors affecting the single economy allows not only to effectively manage economic growth, but also to fully utilize the benefits of technological progress. By properly analyzing technology, capital, labor, information, and social factors, it is possible to plan in advance for future economic stability and economic growth. Therefore, an in-depth study and analysis of these factors is necessary for the successful development of the single economy.

The benefits of the singular economy can be explained as follows:

Accelerated economic growth. Advances in artificial intelligence and computer technology can significantly accelerate economic growth. These technologies optimize production and service processes in many sectors of the economy.

Social change through innovation. The development of artificial intelligence will lead to positive changes in various areas of society, including health care, education, and economic management. Thanks to technology, processes are automated and efficiency increases [3].

New economic models and opportunities. The singular economy allows for the application of technology on a new scale, the creation of new business models, and increased competition. This creates new opportunities for many industries [2].

In short, the singular economy can accelerate economic growth, introduce innovations in the social sphere, and create new economic opportunities.

1.1. Assestment and it's importance

Singular economy for count formula create for We economics basic factors and technological development factors economic to the model our contribution Need this formula in creation following factors check receive must:

1. Technological development (T): technologies development and automation, artificial intelligence, robotics such as technological factors economics efficiency strong effect shows. This factors technological singularity and economic efficiency increase maybe
2. Labor Power (L): Labor forces to go down or automation on economics efficiency increase maybe Artificial intelligence And automation Human work reduces
3. Capital (K): Investments. technologies current do and news financing for necessary was basic factor is considered
4. Information and knowledge (I): Information technologies and big in volume information again Job economics high at speed development help gives.

Higher given factors economic and mathematical to the model entrance for we Cobb - Douglas are developing release from function if we use will be This function helps to determine the efficiency of production by factors:

$$y = A * T^{\alpha} * K^{\beta} * L^{\gamma} * I^{\delta} \quad (1)$$

Where:

Y represents the overall economic output or productivity;

A is a general coefficient representing economic productivity before technological advancements,

T is the level of technological development,

K is the capital;

L is the labor force;

I is information and knowledge'

α,γ,δ represent the elasticities or contributions of each factor to the overall production..

Economic-Mathematical Justification of the Model:

Effect of the Technological Factor (T^{α}): Technological advancements accelerate economic growth. If technological development accelerates to a point of singularity, this growth rate will increase significantly.

Effect of Capital (K^{β}): Capital plays a critical role in economic growth, as it is essential for developing and implementing new technologies. As investments grow, production scales up.

Effect of the Labor Force (L^{y}): As labor force involvement decreases due to automation, labor elasticity decreases, but it still contributes to economic growth.

Effect of Information (I^{δ}): Information technologies and big data processing open up new possibilities for economic growth and significantly improve efficiency. Knowledge and information enhance competitiveness in the economy.

Forecasting Based on the Singularity Economy Model:

Technological acceleration and reaching singularity: If technological advancement accelerates rapidly, indicated by an increase in **α**, the overall economic growth will follow an exponential trajectory. This signals the economy's proximity to singularity.

Labor and automation: As automation replaces labor, the significance of the labor factor (**L**) decreases substantially. However, production will continue to grow, driven primarily by technology and capital investment.

This formula accounts for the interaction between technological advancements and other economic factors. As the economy approaches technological singularity, rapid changes are expected, leading to a significant increase in growth rates. This model mathematically demonstrates the growth of the economy as a function of technological progress.

1.2. Demonstrating the application of the developed formula for measuring productivity

The following analysis will show how the previously developed formula can be used to determine efficiency and provide a mathematical justification. We will understand how growth or productivity (Y) is linked to various factors, and how this growth can accelerate during the process of techno-economical singularity. To understand how economic efficiency accelerates through technological development and other factors, we can analyze the formula by taking derivatives. This will help identify the impact of technological factors on economic growth.

a) The Effect of Technological Growth on Efficiency:

To determine the impact of technology on productivity, we take the derivative with respect to T:

$$\frac{\partial y_-}{\partial T} = \alpha * A * T^{\alpha-1} * K^{\beta} * L^{\gamma} * I^{\delta} \quad (2)$$

This derivative shows that growth in technology (i.e., an increase in T increases production by a factor of α. If technological singularity occurs and technological progress accelerates rapidly (if α is large), efficiency will increase at a fast rate.

b) The Effect of Capital Growth on Efficiency:

To determine how changes in capital affect productivity, we take the derivative with respect to K:

$$\frac{\partial y_-}{\partial K} = \alpha * A * T^{\alpha} * K^{\beta-1} * L^{\gamma} * I^{\delta} \quad (3)$$

This derivative shows that an increase in capital raises production by a factor of β. In a singular economy, capital investments play a significant role in implementing new technologies and accelerating growth.

c) The Impact of Information and Knowledge:

To analyze the impact of information and knowledge I, we take the derivative with respect to I:

$$\frac{\partial y_-}{\partial I} = \alpha * A * T^{\alpha} * K^{\beta} * L^{\gamma} * I^{\delta-1} \quad (4)$$

This derivative highlights the role of information technology in increasing economic efficiency. The growth of information and knowledge amplifies the impact of technology on the economy.

d) The Effect of Labor:

The impact of labor on economic efficiency is determined by the following derivative:

$$\frac{\partial y_-}{\partial L} = \alpha * A * T^{\alpha} * K^{\beta} * L^{\gamma-1} * I^{\delta} \quad (5)$$

This derivative shows that a reduction in labor decreases production. However, as technological development and automation progress, this effect may diminish. The more advanced the technology becomes, the less significant the role of labor.

If technological progress brings the economic infrastructure closer to identity, the impact of technology increases exponentially. As a result, costs increase rapidly, and production or productivity increases sharply. Thus, technological uniformity leads to exponential growth of economic efficiency. If the value of a is very large (technological homogeneity requires forced participation in economic management), the formula is simplified to the following form:

$$VA \approx A * T^{a} \quad (6)$$

In this scenario, technology becomes the dominant factor in economic growth, while the contributions of K, L, and I become relatively less significant.

The use of this formula to determine efficiency is closely related to the approach to technological specificity. The above derivatives help to explain the impact of technology, capital, labor and information on economic growth. In the case of technological originality, the impact of technology is greatly enhanced, which leads to a sharp increase in economic efficiency.

Thus, the Cobb-Douglas production model is an appropriate tool for understanding technological specificity and determining economic growth through efficiency. Singular economy should be studied on its basis.

2) Applying Technological Singularity to the Model

In a singular economy, technology plays a significant role. As technological singularity is reached, technological growth becomes exponential, meaning that technological progress is no longer limited, and the rate of production increases dramatically.

In a singular economy, the growth in technology increases the value of alpha α, and technological advancement becomes a major driver of productivity. As we approach singularity, the rapid growth of technology will also significantly impact the digital economy.

If technological advancement occurs rapidly, causing α to increase, this will lead to a substantial increase in economic efficiency. For example, in the initial state where technological development is at T_0, the economic production capacity is:

$Y_0 = A * T_0^{\alpha} * K^{\beta} * L^{\gamma} * I^{\delta}$ (7)

As technological singularity approaches, technological growth accelerates dramatically, so T_1=2*T_0. The production level in the economy becomes:

$Y_1 = A * T_0^{\alpha} * K^{\beta} * L^{\gamma} * I^{\delta}$ (7)

In this case, the new production level Y_1 is related to the initial level Y_0 by the following growth factor:

$Y_1 = 2^{\alpha} * Y_0$ (8)

Thus, the growth in production or efficiency is exponentially related to the increase in technological progress alpha α.

Economic impact of technological singularity: a calculation

A=1 (normalized);

α=0.5 (technology accounts for 50% of the effect);

β=0.3 (capital accounts for 30% of the effect);

γ=0.2 (labor accounts for 20% of the effect);

δ=δ=0.1 (information accounts for 10% of the effect).

If the initial technological progress is T_0=1, and capital K=1, labor L=1, and information I=1, then:

$$Y_0 = 1 * 1^{\frac{1}{2}} * 1^{\frac{1}{3}} * 1^{\frac{1}{5}} * 1^{\frac{1}{10}} = 1 \quad (9)$$

If technology doubles, meaning T_1=2, the production level becomes:

$$Y_1 = 1 * 2^{\frac{1}{2}} * 1^{\frac{1}{3}} * 1^{\frac{1}{5}} * 1^{\frac{1}{10}} = 1 * \sqrt{2} \approx 1{,}414 \quad (10)$$

Thus, a doubling of technology results in a 41.4% increase in production. As technological singularity progresses and technological growth becomes exponential, this growth can be observed on a much larger scale.

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RAQAMLI TRANSFORMATSIYA JARAYONIDA KUTUBXONA KONSORSIUMLARI ORQALI AXBOROT INFRATUZILMASINI RIVOJLANTIRISH

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Abstract. Ushbu maqolada kutubxona konsorsiumlarining raqamli transformatsiya jarayonida axborot infratuzilmasini rivojlantirishdagi o'rni va ahamiyati yoritilgan. Xalqaro konsorsiumlar tajribasi asosida O'zbekiston sharoitida qo'llanishi mumkin bo'lgan modellar taklif qilingan. Tadqiqot natijalariga ko'ra, konsorsiumlar kutubxonalararo hamkorlikni kengaytirish, resurslardan birgalikda foydalanish, xarajatlarni optimallashtirish va raqamli iqtisodiyot sharoitida samaradorlikni oshirish imkonini beradi.

Keywords: Kutubxona konsorsiumlari, raqamli transformatsiya, axborot infratuzilmasi, iqtisodiy samaradorlik, elektron resurslar.

I. INTRODUCTION

Bugungi kunda raqamli transformatsiya barcha sohalar uchun strategik ustuvor yo'nalishga aylangan. Iqtisodiyot va muhandislik tarmoqlari qatori axborot-kutubxona sohasi ham chuqur o'zgarishlarni boshdan kechirmoqda. Mazkur jarayonda kutubxona konsorsiumlari axborot infratuzilmasini rivojlantirishning innovatsion mexanizmi sifatida maydonga chiqmoqda. O'zbekistonda kutubxonalararo hamkorlik, resurslarni integratsiyalash va elektron xizmatlarni joriy etishda konsorsiumlarning o'rni dolzarb hisoblanadi. O'zbekiston sharoitida raqamli transformatsiya davlat siyosatining ustuvor yo'nalishlaridan biri sifatida belgilangan bo'lib, bu jarayon Prezident qarorlari va "Raqamli O'zbekiston – 2030" dasturi doirasida izchil amalga oshirilmoqda. Oliy ta'lim, fan va madaniyat sohalarida raqamli texnologiyalarni joriy etish, ilmiy-axborot resurslaridan samarali foydalanish hamda innovatsion xizmatlarni kengaytirishga qaratilgan islohotlar kutubxonalar faoliyatini ham yangi bosqichga olib chiqmoqda. Shu asosda, kutubxonalar faqatgina an'anaviy axborot manbai emas, balki zamonaviy bilim iqtisodiyotining faol ishtirokchisi sifatida shakllanib, raqamli kontentni yaratish, saqlash va taqdim etishda muhim strategik rolni bajarishi lozim.

Global miqyosda raqamli transformatsiya jarayonlari kutubxona faoliyatini tubdan o'zgartirib, ularni an'anaviy bilim saqlovchi maskanlardan raqamli bilim ekotizimining faol ishtirokchisiga aylantirmoqda. Bugungi kunda kutubxonalar sun'iy intellekt asosida axborot qidiruv va tahlil xizmatlarini taklif qilmoqda, bulutli texnologiyalar yordamida esa resurslarga tezkor va masofaviy kirishni ta'minlamoqda. Shu bilan birga, ochiq ilmiy ma'lumotlar (Open Science) konsepsiyasining jadal rivojlanishi ilmiy hamjamiyat uchun yangi imkoniyatlar yaratib, kutubxonalarni global ilmiy axborot almashinuvida muhim bo'g'inga aylantirmoqda. Masofaviy ta'lim platformalari bilan integratsiya esa kutubxonalarni nafaqat resurs markazi, balki ta'lim jarayonining ajralmas qismi sifatida ko'rsatib, ularning ahamiyatini yanada oshirmoqda.

Bugungi kunda alohida kutubxonalar o'zining mavjud moddiy-texnik bazasi va moliyaviy imkoniyatlari bilan zamonaviy axborot ehtiyojlarini to'liq qondira olmayapti [1,2]. Xususan, elektron resurslarning yuqori narxi va murakkab litsenziyalash shartlari ularning keng doirada joriy etilishini cheklaydi. Shu bilan birga, raqamli texnologiyalarni samarali qo'llash uchun zarur bo'lgan malakali mutaxassislar yetishmasligi ham muhim muammolardan biri hisoblanadi. Natijada, kutubxonalar oldida o'zaro hamkorlikni kuchaytirish, resurslarni birgalikda xarid qilish va ulardan samarali foydalanish orqali yagona bilim makonini shakllantirish zaruriyati paydo bo'lmoqda. Konsorsiumlar esa ushbu ehtiyojlarga javoban barqaror hamkorlik mexanizmini yaratib, kutubxonalarni global axborot maydoniga faol integratsiyalash imkonini beradi.

Ushbu maqolaning asosiy maqsadi O'zbekistonda kutubxona konsorsiumlarining mavjud imkoniyatlari va istiqbollarini ilmiy jihatdan tahlil qilish hamda ularning raqamli transformatsiya sharoitidagi o'rnini ochib berishdan iborat. Xalqaro tajribalar o'rganilib, ilg'or amaliyotlar milliy sharoitga moslashtirilgan holda tahlil qilinadi. Shu asosda, kutubxona tizimini samarali rivojlantirish, resurslardan oqilona foydalanish va konsorsiumlar faoliyatini yanada takomillashtirishga qaratilgan aniq taklif va tavsiyalar ishlab chiqiladi.

II. THE IMPORTANCE OF SINGULARITY ECONOMY

Maqolada xalqaro kutubxona konsorsiumlari tajribasi qiyosiy tahlil qilindi. Shuningdek, O‘zbekiston kutubxonalarining mavjud infratuzilmasi o‘rganilib, iqtisodiy va tashkiliy muammolar aniqlashtirildi. Analitik va bibliometrik usullar, shuningdek, iqtisodiy modellashtirish yondashuvlari qo‘llanildi.

Xalqaro kutubxona konsorsiumlarini qiyosiy tahlil qilishda quyidagi mezonlardan foydalanish maqsadga muvofiqdir: tashkiliy ta’minoti, moliyaviy ta’minoti, a’zolik shakli, xizmat turlari:

Tashkiliy va moliyaviy ta’minot:

1. Davlat tomonidan yaratilgan milliy markaz – INFLIBNET (Hindiston).

INFLIBNET – Hindiston Ta’lim vazirligi tomonidan tashkil etilgan bo‘lib, milliy miqyosda akademik axborot infratuzilmasini rivojlantirish, elektron resurslarga kirish va kutubxonalararo hamkorlikni muvofiqlashtirish bilan shug‘ullanadi. Ushbu model davlat asoschiligida, milliy axborotga ehtiyojlarni markazlashtirilgan tarzda qondirishga yo‘naltirilgan.

2. Markazlashtirilgan davlat dasturi (tiered tarmoq) – CALIS (Xitoy).

CALIS – Xitoyning oliy ta’lim kutubxonalari konsorsiumi bo’lib, markaziy davlat mablag‘i bilan ta’minlanadi va ko‘p bosqichli boshqaruv tuzilmasiga ega. Maqsad – akademik resurslarni integratsiya qilish va mamlakat bo‘ylab barcha foydalanishini ta’minlashdan iborat.

3. Nodavlat notijorat raqamli agentlik – Jisc (Buyuk Britaniya).

Jisc – Buyuk Britaniyada oliy va kasbiy ta’lim uchun raqamli ma’lumot va texnologiyalar agentligi; u asosiy mablag‘ni turli fondlardan oladi, qo‘shimcha daromad esa a’zolik obunalaridan shakllanadi. Jisc litsenziyalar bo‘yicha muzokaralar, milliy tarmoq infratuzilmasi va ochiq ilm-fan ekotizimini qo‘llab-quvvatlaydi.

4. Universitet va ilmiy muassasalar konsorsiumi– ANKOS (Turkiya).

ANKOS – universitet va ilmiy muassasalarni birlashtirgan professional assotsiatsiya-konsorsium bo‘lib, nodavlat, notijorat tashkilot hisoblanadi. ko‘plab nashriyotchilar bilan shartnomalar tuzadi, litsenziyalash jarayonlarini markazlashtiradi va a’zolar uchun trening hamda xizmatlar ko‘rsatadi. [3]

5. Xalqaro nodavlat, notijorat tashkilot – EIFL.

EIFL – rivojlanayotgan va o‘tish davridagi mamlakatlarda milliy kutubxona konsorsiumlarini qo‘llab-quvvatlaydigan notijorat tashkilot bo’lib u nashriyotchilar bilan litsenziyalar bo‘yicha muzokara olib boradi, ochiq kirish va mualliflik huquqi siyosatlarini ilgari suradi. [4,5]

6. Nodavlat, notijorat a’zolik asosidagi global kutubxonalar kooperativi – OCLC.

OCLC – dunyo bo‘ylab a’zo kutubxonalar kooperativi bo‘lib, ularga umumiy texnologik xizmatlar, hamjamiyat dasturlari va eng muhimi, WorldCat global katalogini taqdim etadi. Asosan a’zolar tomonidan foydalaniladigan umumiy xizmatlar (masalan, WorldCat va boshqa platformalar) orqali tushadigan to‘lovlardan moliyalashtiriladi.

7. Nodavlat, notijorat korporatsiya – WRLC

Vashington metropoliten hududidagi universitetlar kutubxonalari uchun xizmat ko‘rsatadigan a’zolik konsorsiumi sifatida 1987-yilda tashkil etilgan notijorat korporatsiya bo’lib, notijorat oliy ta’lim muassasalari uchun kutubxona hamkorligi va xizmatlarini ko’rsatishdan iborat.[6]

8. “ЭБС Лань” ta’lim tizimi qoshida tashkil etilgan “Консорциум СЭБ” — notijorat loyihaviy konsorsium [7]

“Консорциум СЭБ”ning boshqaruv infratuzilmasi “ЭБС Лань” tarkibida bo’lgani uchun, bu model platforma asosidagi loyihaviy konsorsium sifatida faoliyat yuritadi. Maqsad bir qancha sohaga oid elektron kutubxonalarni yagona platformada birlashtirish va resurslardan foydalanish samaradorligini oshirishdan iborat.

A’zolik shakli va resurslardan foydalanish modellari :

A’zolik shakli va xarajatlarni bo‘lishish modellari konsorsium a’zolari o‘zaro ijobiy va samarali hamkorlikni ta’minlash uchun qanday ishlashi mumkinligini ko’rsatadi. Dunyoning turli mamlakatlari va mintaqalarida bir nechta xarajatlarni bo‘lishish modellari aniqlangan.[8,9,10] Ushbu modellar mamlakatdan mamlakatga va mintaqadan mintaqaga farq qiladi, biroq hozirgi kunda eng keng tarqalgan o‘zgaruvchilar va parametrlar sifatida quyidagilar qo‘llaniladi: teng ulush, muassasa hajmi, kutubxona byudjeti, foydalanish darajasi, ilmiy faoliyat natijalari, tadqiqotlardan olingan mablag‘lar, kelishilgan tejalgan mablag‘larni bo‘lishish. Konsorsiumning iqtisodiy barqarorligini ta'minlashda a’zolik badallarini belgilash mexanizmi muhim ahamiyatga ega. Hozirgi global amaliyotda quyidagi 6ta xarajatlarni bo‘lishish modellari keng qo‘llaniladi:

1. FTE (Full-Time Equivalent) xarajatlarni bo‘lishish modeli: Bu model “foydalanish ehtimoli qanchalik katta bo‘lsa, to‘lov shuncha yuqori bo‘ladi” tamoyiliga asoslanadi. Universitetning hajmi (talaba va o‘qituvchilar soni) to‘g‘ridan-to‘g‘ri obuna to‘loviga ta’sir qiladi. FTE deganda talaba va professor-o‘qituvchilar soni to‘liq stavkali ekvivalent sifatida hisoblanadi (masalan, yarim stavkada o‘qiyotgan 2 talaba = 1 FTE).

Diapazonlari:
1. 1 – 1 500 FTE
2. 1 501 – 8 000 FTE
3. 8 001 – 17 000 FTE
4. 17 001 – 28 000 FTE
5. 28 000 dan ortiq FTE

Namuna: 1 200 talaba va 300 professor-o‘qituvchiga ega kichik universitet 1-diapazonga tushadi va eng past obuna to‘lovini to‘laydi. 25 000 FTE ga ega yirik

universitet 4-diapazonga tushadi va yuqori to‘lovni amalga oshiradi, chunki foydalanish hajmi katta bo‘lishi kutiladi. Bir tomondan bu adolatli xarajatlarni bo’lishish shaklidek ko’rinadi, chunki ko‘proq foydalanuvchi ko‘proq resursdan foydalandi. Lekin kichik va faol foydalanuvchilarga ega bo‘lgan universitetlar uchun foyda va to‘lov nisbatida nomutanosiblik yuzaga kelishi mumkin.

2. To‘plam mazmuni va davriyligi asosida xarajatlarni bo‘lishish modeli: To‘plam mazmuni va davriyligiga asoslangan xarajatlarni taqsimlash modelida obuna to‘lovi foydalanuvchiga taqdim etiladigan kontent segmenti (masalan, arxiv: 1950–2009; joriy nashrlar: 2010–hozir) va qamrov davriga qarab belgilanadi. Qamrov davri kengaygan sari umumiy narx ortadi, konsorsiumdagi ishtirokchilar soni ko‘paygan sari esa iqtisodiy masshtab samarasi hisobiga har bir ishtirokchining ulushi kamayadi (masalan, 1–10, 11–25 va h.k. toifalar). Amaliy misol tariqasida, faqat 2010-yildan keyingi materiallarga kirish talab etilganda narx nisbatan past bo‘ladi; arxiv hamda joriy to‘plamga to‘liq kirish esa yuqoriroq narxni talab qiladi. Mazkur modelning ustunligi — to‘lovlarning real foydalanish hajmiga muvofiqlashtirilishi; kamchiligi — variantlar ko‘pligi narx siyosatini murakkablashtirib, shartnoma muzokaralarini cho‘zishi mumkin.

3. Jurnal va kitob to‘plamlari bo‘yicha xarajatlarni taqsimlash modeli – obuna narxi tanlangan resurs turiga (faqat jurnallar, faqat kitoblar yoki aralash portfel) hamda ishtirokchilar soniga muvofiq belgilanadi. Har bir a’zo muassasa o‘z ehtiyojidan kelib chiqib, faqat jurnal to‘plamiga, faqat kitob to‘plamiga yoki har ikkala to‘plamga bir vaqtning o‘zida obuna bo‘lishi mumkin. Hisob-kitob mexanizmi quyidagicha: (i) portfel tarkibi tanlanadi; (ii) shu portfelga obuna bo‘lgan muassasalar soni aniqlanadi va umumiy narx ularning o‘rtasida taqsimlanadi. Masalan, 15 ta universitet jurnal to‘plamiga, 8 tasi kitob to‘plamiga, 5 tasi esa aralash portfelga obuna bo‘lsa, har bir guruh o‘z tanlagan to‘plam qiymatini o‘z ichida bo‘lib to‘laydi. Modelning afzalligi – moslashuvchanlik: har bir universitet faqat zarur resurslar uchun to‘lov qiladi.

4. Yagona qat’iy to‘lov modelida konsorsium bo‘yicha umumiy shartnoma qiymati barcha a’zo muassasalar o‘rtasida teng ulushlarda taqsimlanadi; shu bois muzokara va boshqaruv jarayonlari soddalashadi va ma’muriy yuklama minimal bo‘ladi. Masalan, umumiy narx 100 ming dollar bo‘lsa va o‘nta a’zo mavjud bo‘lsa, har biri 10 ming dollardan to‘laydi. Ushbu yondashuvning asosiy afzalligi — sodda va shaffofligi, byudjetni oldindan aniq rejalashtirish imkonini berishi hamda, odatda, kichik kutubxonalar uchun qulayligidir. Biroq model foydalanish hajmi va tashkilot miqyosi kabi farqlarni inobatga olmaydi, natijada katta va kichik a’zolar bir xil to‘lov qiladi. Shu sababli u, asosan, a’zolar o‘lchami va foydalanish darajasi bir-biriga yaqin bo‘lgan holatlarda tavsiya etiladi.

5. Gibrid (foydalanish + FTE + qat’iy minimal to‘lov) modeli konsorsium xarajatlarini adolat va boshqaruv soddaligi o‘rtasida muvozanatlashtiradi: avvalo ishtirokchilar ro‘yxati tasdiqlanadi va nashriyot bilan umumiy narx kelishiladi; so‘ng kelishilgan qiymatning ma’lum foizi barcha a’zolar o‘rtasida teng ulushlarda “minimal qat’iy to‘lov” sifatida taqsimlanadi, qolgan qismi esa a’zolarning to‘liq stavkaga tenglashtirilgan xodimlari (FTE) va real foydalanish ko‘rsatkichlari bo‘yicha ulushlanadi (masalan, teng yoki kelishilgan nisbatda). Yangi qo‘shilayotgan a’zolar mos keluvchi FTE ko‘lami va minimal foydalanish segmentiga tenglashtiriladi, shunda tizim izchilligi saqlanadi. Masalan, besh a’zodan iborat konsorsiumda umumiy qiymatning taxminan beshdan bir qismi teng taqsimlanib, qolgan qismi yarmiga-yarmi FTE va foydalanish bo‘yicha bo‘linishi mumkin. Modelning afzalligi — foydalanish va miqyos farqlarini inobatga olgani holda shaffof boshqaruvni ta’minlashi bo’lsa, kamchiligi — so‘nggi bir necha yil bo‘yicha foydalanish ma’lumotlarini yig‘ish va normallashtirish, shuningdek nisbatlar va minimal ulush foizini oldindan kelishishni talab etishidir. Ushbu yondashuv a’zolar hajmi va foydalanish darajasi sezilarli farq qiladigan konsorsiumlar uchun, hamda “ko‘p foydalangan — ko‘proq to‘laydi” prinsipini bosqichma-bosqich joriy etishda maqsadga muvofiqdir.

6. Fan yo‘nalishi bo‘yicha hisoblash: Ushbu modelda konsorsium to‘lovlari fan yo‘nalishlari (masalan, huquq, muhandislik, tibbiyot) kesimida FTE ko‘rsatkichi asosida taqsimlanadi: avvalo har bir yo‘nalish bo‘yicha bakalavr, magistr, PhD va fakultet shtat birliklari yig‘indisi aniqlanadi, so‘ng kelishilgan FTE diapazonlari va ishtirokchi muassasalar soniga tayangan tarif qo‘llanadi. Umumiy shartnoma qiymati yo‘nalishlar uchun oldindan belgilangan bazaviy ulushlarga (masalan, tibbiyotga ko‘proq, muhandislik va huquqqa nisbatan kamroq) ajratilib, har bir yo‘nalish ichida a’zolarga ularning FTE ulushi proporsiyasida taqsimlanadi; yakuniy badal esa ushbu yo‘nalishlar kesimidagi ulushlar yig‘indisidan shakllanadi. Yondashuvning ustunligi — predmetga mos taqsimot va resurslar uyg‘unligini oshirishi (tibbiyotga ehtiyoji yuqori bo‘lgan universitet ko‘proq to‘laydi); cheklovi — yo‘nalishlar bo‘yicha aniq FTE hisob-kitobi hamda bazaviy ulushlar bo‘yicha kelishuv zarurligi. Model ixtisoslashuv darajasi yuqori bo‘lgan muassasalarda va resurslar yo‘nalishlar bo‘yicha segmentlangan holatlarda qo‘llash uchun maqbuldir.

Konsorium taklif etadigan xizmat turlari

- Kollektiv litsenziyalash va qo‘shma xarid — nashriyotchilar bilan markazlashtirilgan muzokaralar orqali narx va shartlarni maqbullashtirish, takror xaridlarni kamaytirish.
- Litsenziyalash va narxlash — qat’iy yagona to‘lov, to‘liq stavkaga tenglashtirilgan xodimlar (FTE) asosida, foydalanish ko‘rsatkichiga tayanadigan va gibrid modellardan foydalanish; yangilash va bekor qilish tartiblarini standartlashtirish.
- Elektron resurslarni boshqarish — mualliflik huquqi va litsenziya ma’lumotlarini, kirish huquqlarini, yangilanishlarni yagona tartibda yuritish.
- Yagona qidiruv va kirish — turli manbalarga bitta qidiruv oynasi orqali murojaat qilish, havolani yo‘naltiruvchi xizmat orqali to‘liq matnga o‘tish, yagona kirish tizimi bilan barqaror masofaviy kirishni ta’minlash.

- Kutubxonalararo xizmat (abonent va hujjat yetkazib berish) — resurslarni tezkor almashish uchun yagona tizim va to‘lov tartiblarini joriy etish.
- Yagona kutubxona platformasi (integratsiyalashgan kutubxona tizimi) — kataloglash, aylanma (sirkulyatsiya) va elektron resurslarni boshqarishni yagona bulutli platformada birlashtirish va qo‘llab-quvvatlash.
- Yig‘ma elektron katalog va metama’lumot standartlari — MARC21/Dublin Core asosida sifatli bibliografik yozuvlarni ta’minlash va tizimlararo moslikni yo‘lga qo‘yish.
- Institutsional repozitoriy va ochiq kirish — ilmiy ishlarni ochiq saqlash va taqdim etish, indekslashni kuchaytirish va ochiq kirish siyosatini (Open Access) qo‘llab-quvvatlash.
- Konsorsium darajasidagi tahlil va asosiy ko‘rsatkichlar — COUNTER kabi standartlarga tayangan holda “foydalanish birligi uchun xarajat”, qamrov va boshqa mezonlarni muntazam monitoring qilish hamda ehtiyojlarni tahlillash.

Kadrlar salohiyati va texnik qo‘llab-quvvatlash — doimiy trening va malaka oshirish kurslarini taqdim etish, yagona xizmat ko’rsatish portali orqali murojaat va so’rovlarni samarali boshqarish.

III. XULOSA

O‘zbekistonda konsorsiumlarni shakllantirishda moliyaviy manbalar yetishmasligi, texnologik infratuzilmaning notekis rivojlanishi va kadrlar malakasi kabi muammolar mavjud.[11] O‘zbekiston sharoitida kutubxona konsorsiumi raqamli transformatsiyaning strategik drayveri bo‘lib, resurslardan qo‘shma foydalanish, markazlashtirilgan litsenziyalash va yagona raqamli infratuzilma orqali xarajatlarni optimallashtiradi hamda xizmatlar sifatini oshiradi. Kutubxonalar o‘rtasida konsorsium va mustahkam hamkorlik yo‘lga qo‘yilganda, birinchi navbatda moliyaviy samaradorlik ta’minlanadi: xalqaro va mahalliy nashriyotlarning ilmiy resurslariga obunada xarajatlar optimallashtiriladi, takror xaridlar kamayadi va qo‘shma obuna mexanizmlari orqali mablag‘lar adolatli taqsimlanadi. Shu bilan birga, ilmiy va ta’limiy natijalar sezilarli yaxshilanadi: tadqiqotchilar global tajriba va manbalarga tezkor kirish orqali ilmiy maqolalar tayyorlaydi, nufuzli jurnallarda nashrlar soni ortadi, ilmiy metrik ko‘rsatkichlar mustahkamlanadi, o‘qitish jarayoni esa yuqori sifatli resurslar va metodik ko‘mak bilan boyiydi. Axborot texnologiyalari va xizmatlar sifati jihatidan, jahonning yetakchi ekspertlari tomonidan tahrirlangan elektron resurslarga barqaror kirish yo‘lga qo‘yiladi, tezkor navigatsiya vaqtni tejaydi, elektron kataloglar va yagona ma’lumotlar bazasi asosida integratsiyalashgan axborot muhiti shakllanadi.

Konsorsium raqamlashtirish va axborot infratuzilmasini rivojlantirishni tezlashtiradi: noyob ilmiy-adabiy merosni saqlashga qaratilgan raqamlashtirish loyihalari qo‘llab-quvvatlanadi, zamonaviy texnologiyalar asosida xizmatlar avtomatlashtiriladi va integratsiyalashgan tizimlar joriy etiladi. Hududlararo tenglik tamoyili kuchayib, barcha viloyatlardagi kutubxonalar bir xil ilmiy-ta’limiy imkoniyatlarga ega bo‘ladi, kam rivojlangan hududlardagi muassasalarning o‘sishi rag‘batlantiriladi. Axborot savodxonligi va madaniyati yuksaladi: foydalanuvchilar, ayniqsa yoshlarda, raqamli resurslar bilan ishlash ko‘nikmalari shakllanadi va ilmiy-axborot xizmatlaridan foydalanish madaniyati mustahkamlanadi. Nihoyat, milliy va xalqaro hamkorlik kengayadi: EIFL, IFLA, Erasmus+ kabi platformalar orqali grantlar va resurslar jalb qilinadi, xorijiy konsorsiumlar bilan tajriba almashish, qo‘shma loyihalar, seminar va konferensiyalar yo‘lga qo‘yiladi; foydalanuvchi ehtiyojlariga tayanib tahliliy xizmatlar, tavsiya tizimlari, intellektual qidiruv va kontent tahlili kabi innovatsion xizmatlar bosqichma-bosqich joriy etiladi.

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RAQAMLI IQTISODIYOT SHAROITIDA MILLIY ERP TIZIMLARINI ISHLAB CHIQISH VA TADBIQ ETISH

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Abstract. **Ushbu maqolada raqamli iqtisodiyot sharoitida milliy ERP tizimlari ahamiyati, ularning ishlab chiqilishi dolzarbligi tadqiq qilingan. Jumladan raqamli texnologiyalardan foydalangan holda milliy ERP tizimi dasturiy maxsuloti ishlab chiqilgan, dasturiy maxsulotning arxitekturasi taklif etilgan va tizimli modeli ishlab chiqilgan. Milliy dasturiy maxsulotini elektron tijorat negizida foydalanuvchilarga taqdim etishda oldindan xarid qilish moduli ishlab chiqildi hamda funksional modeli orqali ilgari surildi. Bunda dasturning iqtisodiy samaradorligiga alohida e’tibor qaratildi.**

Keywords: monolit arxitektura, mikroservisli arxitektura, ERP tizimi, blokcheyn, Elektron pullar, Fiskal cheklar, elektron hisobvaraq-fakturalar, Elektron kapital harakati

I. KIRISH

Jahonda Raqamli 2025 hisobotlari va tahlillarining keng to‘plami dunyoning 230 dan ortiq mamlakat va hududlarida raqamli xatti-harakatlarning chuqur o‘rganilishini o‘z ichiga oladi .

Ushbu hisobotlar boy ma'lumotlar, tendentsiyalar va tushunchalar bilan to'ldirilgan bo'lib, odamlar hamma joyda internet, mobil telefonlar, ijtimoiy media va elektron tijoratdan qanday foydalanayotgani hamda sotuvchilar ushbu qimmatli auditoriyaga erishish uchun raqamli texnologiyalardan qanday foydalanishini tushunishga yordam beradi.

Raqamli 2025 hisobotlari 2025-yilda O‘zbekiston aholisi raqamli qurilmalar, onlayn platformalar va ulangan xizmatlardan qanday foydalanishini tushunishga yordam berish uchun zarur bo‘lgan barcha ma’lumotlar, tushunchalar va tendentsiyalarni o‘z ichiga oladi .

Mamlakatimiz yangi iqtisodiy bosqichga ko’tarilishi bosqichida barcha sohalarda keng ko’lamli ishlar amalga oshirildi. Axborot texnologiyalarining rijojlanishi oqibatida elektron tijorat tizimi ham yangi bosqichga ko’tarildi. O’zbekiston Respublikasi Prezidenti Sh.M.Mirziyoyevning 2020 yil 5 oktyabrdagi “Raqamli O’zbekiston - 2030” strategiyasini tasdiqlash va uni samarali amalga oshirish chora-tadbirlari to’g‘risida”gi PF-6079-son Farmonida “Elektron tijorat va elektron to’lovlar tizimini rivojlantirish maqsadida quyidagi tadbirlar amalga oshiriladi: axborot-kommunikatsiya texnologiyalarini, shu jumladan mijozlarni masofadan aniqlash tizimlarini joriy etish orqali masofaviy bank xizmatlarini rivojlantirish; xalqaro elektron tijorat standartlari va zamonaviy axborot xavfsizligi talablariga rioya qilish uchun elektron tijoratni rivojlantirishning huquqiy asoslarini, shuningdek, mavjud standartlar va elektron tijorat qoidalarini takomillashtirish va yangilash; raqamli infratuzilmani rivojlantirish, mobil va simli Internet jahon axborot tarmog‘i qamrovi va tezligini yanada oshirish orqali elektron tijorat platformalariga shaxsiy raqamli uskunalardan ulanish imkoniyatlari va ko’lamlarini oshirish va hokazolar” amalga oshirish belgilab berilgan .

“O‘zbekiston Respublikasi Moliya vazirligi: moliyaviy hisobotning yagona standartlarini ishlab chiqadigan va tasdiqlaydigan mustaqil xalqaro tashkilot hisoblangan Moliyaviy hisobotning xalqaro standartlari fondi (keyingi o‘rinlarda — MHXS fondi) bilan bitim tuzsin; “

Shunga ko’ra raqamli iqtisodiyotni rivojlantirishda Xalqaro buxgalteriya stadartlari asosida ishlaydigan dasturiy ta’minot platformalarini ishlab chiqish va ham elektron tijorat infratuzilmasini takomillashtirish masalalari sohasida mavjud muammolarini hal etish masalalarini o’rganish hamda amaldagi elektron tijorat faoliyatini takomillashtirish yuzasidan aniq tavsiya va takliflar ishlab chiqish muhim ahamiyat kasb etmoqda.

II. MAVZUNING O‘RGANILGANLIK DARAJASI

Raqamli iqtisodiyotni rivojlantirishda elektron tijorat infratuzilmasini takomillashtirish masalalarini tashkil etishning nazariy va amaliy jihatlari qator xorijiy mutaxassislar, xususan, A.Krensel, J.Chetkuti, V.Tanzi, P.Dernberg, K.Friden, D.Xardest, D.Robert tomonidan ilmiy ishlarida tadqiq qilingan.

Rossiya tadqiqotchilardan S.K.Ilichev, A.V.Koren, I.P.Meleshenko, A.A.Tedeev, L.V.Frolova, R.Ye.Xusnetdinovlarning ilmiy ishlarida elektron tijoratni tashkil etish masalalari ayrim davlatlar misolida atroflicha tadqiq qilingan.

Milliy iqtisodchi olimlardan M.I.Alimardonov, A.V.Vahobov, A.S.Jo’raev, T.S.Malikov, Sh.A.Toshmatov, B.Toshmurodova, B.R.Sanaqulova, N.X.Haydarovlar elektron tijorat tizimini takomillashtirish borasida olib borilgan ilmiy tadqiqotlarida elektron tijorat mexanizmlarini takomillashtirishga ham taaluqli bo’lgan masalalarning ma’lum bir jihatlari o’rganilgan.

Lekin yuqorida keltirilgan mualliflar O’zbekistonda raqamli iqtisodiyotni rivojlantirishda elektron tijorat

infratuzilmasini takomillashtirish masalalari va uning o'ziga xos xususiyatlari, bu boradagi mavjud muammolar hamda xalqaro tajriba yaxlit tizimli tarzda tadqiq etilmagan va ularni takomillashtirish yuzasidan konseptual takliflar ishlab chiqilmagan.

III. RAQAMLI IQTISODIYOTNI RIVOJLANTIRISHNING ISTIQBOLLARI

Raqamli iqtisodiyot – bu innovatsion g'oya. Ushbu fikr Jahon banki tomonidan 2016-yil "Jahon taraqqiyoti haqida ma'ruza – 2016: raqamli dividendlar" ma'ruzasida ma'lum qilingan. Ushbu tadqiqot xulosalari mamlakatlar iqtisodiyotini rivojlantirishda raqamli iqtisodiyotning naqadar dolzarb va muhim masala ekanligini ko'rsatadi. Xususan, Internet tezligining 10 foizga o'sishi mamlakat YaIMning o'sishiga ham ta'sir qiladi. Rivojlangan davlatlarda bu ko'rsatkich 1,21 foizni tashkil etsa, rivojlanayotgan mamlakatlarda 1,38 foizga teng. Ookla ma'lumotlariga ko'ra, 2024-yil boshigacha bo'lgan o'n ikki oy ichida O'zbekistonda mobil internetga ulanishning o'rtacha tezligi 10,15 Mbit/s (+69,8 foiz) ga oshgan. Ayni paytda Ookla ma'lumotlari shuni ko'rsatadiki, O'zbekistonda o'rnatilgan internetga ulanish tezligi xuddi shu davrda 10,20 Mbit/s (+22,5 foiz) ga oshgan . Demak, Internet tezligi 2 baravar oshadigan bo'lsa, YaIM hajmi 13–14 foiz ortishiga erishish mumkin. Soliq ma'murchiligida onlayn-NKT hamda raqamlashtirishning boshqa faol mexanizmalarini joriy etish orqali taksi (https://t.me/soliqnews/14899), dori (https://t.me/soliqnews/15136)vositalari kabi iste'mol bozorlarining rivojlanish dinamikasini kuzatish imkoniyati yaratilgan. Endilikda tahlillarda yirik chakana savdo sohasi ham qamrab olinmoqda.

Raqamlashtirishdan ko'zlangan maqsad – noqonuniy aylanmalar hajmini qisqartirish, biznes jarayonlarining shaffofligini oshirish, shunigdek, davlat va iste'molchilar manfaatlarini samarali himoya qilishdan iborat

Raqamli iqtisodiyotga olimlar turlicha yondashuvlar va ta'riflar berilgan:

- V. Ivanov. Raqamli iqtisodiyot – bu bizning voqeligimizni to'ldiruvchi virtual muhit deb ta'rif bergan .
- R. Mesheryakov. Raqamli iqtisodiyot – bu raqamli texnologiyalardan foydalaniladigan iqtisodiy ishlab chiqarish deb ta'rif bergan.
- A. Kuntsman. Raqamli iqtisodiyot ma'lumot va ma'lumotning moddiy mahsulotlar va xizmatlarni ishlab chiqarishda, shuningdek, ularni saqlash, qayta ishlash va uzatish uchun raqamli texnologiyalardan faol foydalanish bilan tavsiflanadigan zamonaviy iqtisodiyot turidir.
- R. K. Asanov. Raqamli iqtisodiyot elektron mahsulotlar va xizmatlar ishlab chiqarish va ularni electron tijorat orqali tarqatish asosida: "elektron mahsulotlarga ixtisoslashgan biznes ishlab chiqarish jarayonlarini va pul o'tkazmalarini amalga oshiradi, shuningdek, Internet texnologiyalardan foydalangan holda mijozlar bilan ishlash va ularni boshqarish bilan shug'ullanadi.

Raqamli iqtisodiyot tarkibiga elektron hukumat, elektron biznes, elektron kommersiya, raqamli iqtisodiy munosabatlar, turizm sohasida biznes qiluvchi kompaniyalar, raqamli banklar, raqamli arxivlar,virtual korxonalar, kriptovalyutalar – electron pullar, ijtimoiy tarmoqda marketing xizmatlaridan foydalanish, blokcheyn texnologiyasini joriy etish, korxonalarning raqamli "cho'ntak"lari, raqamli dividentlar va boshqalar kiradi.

Raqamli iqtisodiyot yo'nalishlari bigdata, sun'iy intellekt, blokcheyn, kvant texnologiyalari, ishlab chiqarish texnologiyalari, sanoat Interneti, robototexnika, simsiz aloqa, virtual reallik kabilardan iborat.

Turizm sohasida biznes - nima uchun sayyohlik agentligining ish jarayonini avtomatlashtirish kerak? Buning sabablari ko'p. Birinchidan, xodimlarning ish yuki qo'l mehnatidan sezilarli darajada kamayadi, shuning uchun ish beruvchi xodimlar xarajatlarini tejashga qodir. Ikkinchidan, shartnomalar, narxlar ro'yxati va sayohat vaucherlarini to'ldirishda inson xatosi xavfi kamayadi, bu esa ish beruvchining xatoni tuzatish uchun keyingi xarajatlariga olib kelishi mumkin. Uchinchidan, bu nafaqat xodimlarning ishini kuzatish, balki real vaqt rejimida kompaniyaning umumiy moliyaviy holatini baholash uchun ajoyib vositadir. Bir nechta sayyohlik agentliklari ofislarida esa sayyohlik agentligini avtomatlashtirish juda muhim element hisoblanadi.

Elektron tijorat – bu kompyuter tarmoqlari yordamida amalga oshiriladigan barcha moliyaviy va savdo operatsiyalarini va shu kabi operatsiyalar bilan bog'liq bo'lgan biznes jarayonlarini o'z ichiga olgan iqtisodiyot sohasi hisoblanadi[1].

Elektron tijoratga quyidagilar kiradi:

- Elektron ma'lumot almashish (Electronics
- Data Interchange, EDI);
- Elektron kapital harakati (Electronic Funds
- Transfer, EFT);
- Elektron savdo (inglizcha e-trade);
- Elektron pullar (e-cash);
- Elektron marketing (e-marketing);
- Elektron bank (e-banking);
- Elektron sug'urta xizmatlari (e-insurance).

Elektron tijorat texnologiyalari tranzaksion xarajatlarni kamaytiradi, bu ishlab chiqaruvchilarga ham, iste'molchilarga ham vositachilarsiz ishlashga imkon beradi. Bunga eng maqbul narx takliflari va guruhli xaridlarni qidirishni kengaytirish orqali erishiladi. Elektron tijoratning shahar va mintaqaviy darajadagi muvaffaqiyati

mahalliy korxonalar va iste'molchilar elektron savdoni qanday qabul qilishiga bog'liq.

Biroq, elektron tijoratda kishilarning mijozlar bilan bevosita aloqasi yuz bermaydi. Mijozlar, shuningdek, onlayn tranzaksiyalar xavfsizligi haqida qayg'uradilar va, odatda, avvaldan ma'lum bo'lgan chakana sotuvchilarga sodiq qoladilar. Internet-do'konda tovarlarga buyurtma berish misolida elektron tijorat tamoyillarini ko'rib chiqamiz.

Bunda quyidagi ketma-ketlikka amal qilinadi:

Birinchi qadam – onlayn katalogni ko'rib chiquvchi xaridor mahsulotni tanlashga qaror qiladi. Uning kompyuteri yoki mobil qurilmasi brauzer orqali do'kon joylashgan server bilan o'zaro aloqa o'rnatiladi.

Ikkinchi qadam – server foydalanuvchi so'rovini qabul qilib, uni buyurtmalarni qayta ishlash tizimidagi menejerga yuboradi.

Uchinchi qadam – menejer bazada tovarlarning mavjudligi to'g'risida so'rov yuboradi. Agar mahsulot yo'q bo'lsa, u holda ishlab chiqaruvchiga so'rov yuboriladi, omborga yetkazib berish vaqti aniqlanadi,shundan so'ng mijozga aniq ma'lumotlar beriladi.

To'rtinchi qadam – agar tovarlar zaxirada bo'lsa,do'kon xodimi arizani ko'rib chiqishni davom ettiradi.

Beshinchi qadam – operatsiyani amalga oshirish uchun so'rov bilan moliya tizimiga murojaat qilish mijoz tomonidan to'lovni amalga oshirish.

Oltinchi qadam – moliyaviy tizim mijozning hisobvarag'idagi vaziyatga (mablag' yetishmasligi, nosoz karta va boshqalar) bog'liq holda tranzaksiyani amalga oshirishga imkon beradi yoki bloklaydi.Agar operatsiya muvaffaqiyatli bo'lsa, menejer ushbu bitimni tasdiqlaydi va serverga xabar beradi.

Yettinchi qadam – server xaridorga to'lov muvaffaqiyatli amalga oshirilganligi, buyurtmaga ishlov berish uchun qabul qilinganligi to'g'risida xabar yuboradi.

Sakkizinchi qadam – buyurtma mijozning manziliga jo'natish uchun tovarlar saqlanadigan omborga yuboriladi.

To'qqizinchi qadam – logistika bo'limi tovarlarni xaridorga yetkazib beradi.

O'ninchi qadam – ombordan buyurtma yuborilgandan so'ng, server mijozga elektron pochta yoki telefon orqali (SMS) tovarlar yetkazilganligi to'g'risida xabar yuboradi.

Ushbu yo'nalishda ko'plab xorijiy dasturiy vositalar ishlab chiqilgan bo'lib, Dasturiy maxsulotlarni ishlab chiqish hamda sotish bo'yicha Birinchi o'rinda Microsoft kompaniyasi turadi. Umuman olganda bunday kompaniyalarning soni ko'p bo'lib, ularning umumiy daromada aylanmasi 1-rasmda keltirilgan.

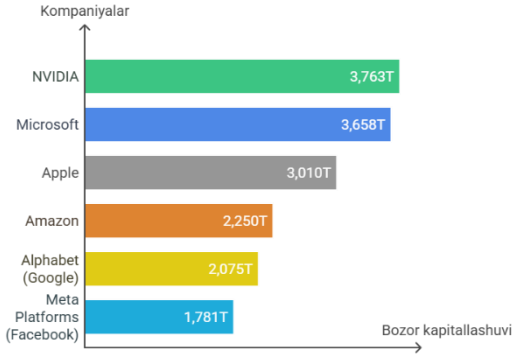

Fig. 1. Eng yirik texnologiya kompaniyalarining bozor kapitallashuvi

Ushbu rasmdan bunday milliy mahsulotning ishlab chiqilishi mamlakat iqtisodiy rivojiga naqadar ta'sir ko'rsatishini ko'rishimiz mumkin.

IV. RAQAMLI IQTISODIYOT SHAROITIDA MILLIY ERP MAHSULOTINI ISHLAB CHIQISH

Ushbu tadqiqot doirasida milliy dasturiy tizim ishlab chiqildi: ARUS Account - Sayohat va turizm kompaniyalari hisobi va boshqaruvi uchun dasturiy ta'minot — to'liq biznes jarayonlarini boshqarish va boshqarishni soddalashtirish uchun IT-dasturiy ta'minot. ARUS Account sayohat va turizm kompaniyalari uchun to'liq ERP, boshqaruv va buxgalteriya yechimi hisoblanadi.

ERP (korxona resurslarini rejalashtirish) - bu korxona resurslarini rejalashtirish. ERP - bu biznesning barcha jabhalarini, jumladan, moliya, inson resurslari, ishlab chiqarish, ta'minot zanjiri, xizmatlar, xaridlar va boshqa sohalardagi jarayonlarni boshqarishga yordam beruvchi dasturiy tizim. ERP tizimi ba'zan "korxona markaziy tizimi" deb ataladi. Hisobotlarni tezda yopish uchun moliya bo'limiga ERP tizimi kerak. Savdo bo'limi mijozlarning barcha buyurtmalarini boshqarish uchun kerak. Logistika bo'limi mijozlarga to'g'ri mahsulot va xizmatlarni o'z vaqtida yetkazib berish uchun barqaror ERP dasturiy yechimiga tayanadi. Kreditorlik qarzlarini boshqarish etkazib beruvchilarga to'g'ri va o'z vaqtida to'lash uchun ERP tizimiga muhtoj. O'z vaqtida qaror qabul qilish uchun menejment kompaniya faoliyati haqida to'liq tasavvurga ega bo'lish qobiliyatiga muhtoj. Va banklar va aktsiyadorlar aniq moliyaviy hisobotni talab qiladilar, shuning uchun ular ERP tizimi tomonidan taqdim etilgan ishonchli ma'lumotlar va tahlillarga tayanadilar.

ERP yechimlarining biznes uchun ahamiyati ularni amalga oshirish sur'atlarining ortib borayotgani bilan ko'rsatilgan. G2 ma'lumotlariga ko'ra, "Prognozlarga ko'ra, 2026 yilga kelib ERP yechimlari global bozorining hajmi 78,4 milliard dollarga etadi; 2019 yildan 2026 yilgacha yillik yillik o'sish sur'ati 10,2% ni tashkil qiladi ".

- Shu jumladan ARUS account dasturi quyidagi vazifalarni bajaradi:
- Bronlash - Operatsiyalar - Buxgalteriya;
- Sayohat paytida noutbukdan foydalangan holda biznesni masofadan kuzatish;

- Biznes jarayonining barcha faoliyatini nazorat qilish;
- Biznesni yuritish juda samarali;
- Hech qanday to’siqlarsiz biznes operatsiyalarini oshirish;
- Kundalik, haftalik, oylik, choraklik, yarim yillik va yillik daromadlar to’g'risida hisobot tuzish orqali biznesni o’z-o’zini tekshirish;
- ROI ni hisoblash - tizimdan avtomatik ravishda investitsiyalarni qaytarish, hisobotlarni to’g'ri shakllantirish;
- Intellektual hisob-kitob tizimi - har bir mijoz va etkazib beruvchilarning tegishli bronlari uchun hisob-fakturalar, vaucherlarni yaratish uchun bron ma'lumotlarini avtomatik ravishda chiqaradi;
- ARUS Account System biznesni avtomatlashtirish yechimini tanlash orqali biznesni rivojlantirish.

A. Milliy ERP mahsuloti arxitekturasi

Ishlab chiqilgan dasturning funksionlligi va qo’llanilish doirasi ko’p jihatdan dasturning arxitekturasi bilan bog’liq bo’lib, arxitekturaning strukturasi asosida butun tizimning samaradorligini aniqlash mumkin bo’ladi. Zamonaviy dasturiy mahsulotlar asosan ikki xil turdagi arxitektura asosida quriladi. Ular monolit arxitektura va mikroservisli arxitekturalarga bo’linadi.

Zamonaviy veb-ilovalar mikroservis arxitekturasi atrofida qurilgan, bu uslub dasturni xizmatlar to’plami sifatida tuzatadi. Har bir bunday xizmat imkon qadar avtonom bo’lib, muayyan vazifani bajarish uchun zarur va ma'lum bir jamoa tomonidan qo’llab-quvvatlanadi. Ushbu arxitektura sizga biznes ehtiyojlariga asoslangan ilovalarni yaratishning modulli printsipini qo’llash imkonini beradi. Boshqacha qilib aytganda, agar ehtiyojlar o’zgarsa, biznesga ta'sir qilmasdan har doim bir yoki bir nechta xizmatlarni, masalan, veb-server yoki so’rovlarni qayta ishlash serverini o’zgartirishingiz mumkin.

ARUS Account dasturi mikroservisli arxitekturaga ega dastur bo’lib ko’plab modullardan iborat. Har bir modul aniq bir vazifani bajaradi va markaziy boshqaruv bloki asosida birlashtiriladi. ARUS account dasturining umumiy arxitekturasi 2-rasmda keltirilgan.

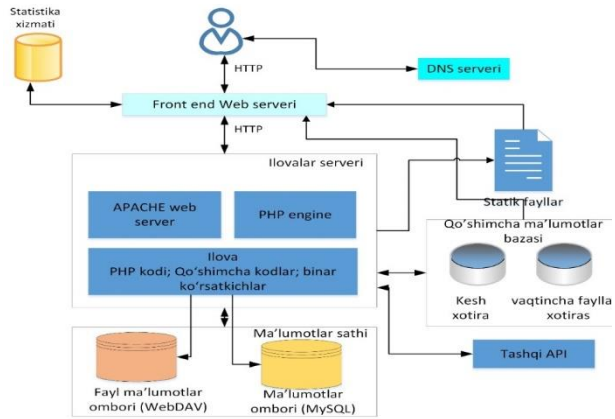

Fig. 2. ARUS account dasturining umumiy arxitekturasi

Arus account dasturiy muhitini elektron tijorat infratuzilmasini takomillashtirishda tutgan o’rnini baholashda dastlab ushbu dasturning funksional modelini shakllantirish lozim bo’ladi. Funktsional model tizimning ishlashi (funktsiyasi) xususiyatlarini va uning maqsadini ichki va tashqi elementlar bilan birgalikda o’rganish uchun mo’ljallangan.

Funktsiya - har qanday tizimning eng muhim xususiyati, uning maqsadi, nima uchun yaratilganligini aks ettiradi. Bunday modellar birinchi navbatda funktsional parametrlar bilan ishlaydi. Ushbu modellarning grafik tasviri oqim sxemalaridir. Ular belgilangan maqsadlarga erishishga qaratilgan harakatlar tartibini (funktsional diagramma deb ataladi) aks ettiradi. Funktsional model mavhum modeldir.

Arus account dasturi asosiy uchta vazifani ya’ni funksiyani bajaradi va uning funksionalligi shu funksiyalar atrofida shakllanadi. Arus account dasturining funksional modeli 3-rasmda keltirilgan.

ARUS hisobini sotish bizning o’z brendimizdagi onlayn-do’konimiz orqali amalga oshiriladi, chunki bizning tadqiqotlarimiz natijasida bu usul eng maqbul deb topildi. Umuman olganda, dasturiy mahsulotlar turli yo’llar bilan amalga oshirilishi mumkin, masalan:

- To‘g‘ridan-to‘g‘ri sotish. Bu to’g‘ridan-to’g‘ri mijozlarga maxsus savdo guruhlari yoki mijozlarga xizmat ko’rsatish agentlari orqali sotishni o’z ichiga oladi. To’g‘ridan-to’g‘ri sotish sotuvchi va xaridor o’rtasida mustahkam aloqa o’rnatishga yordam berishi bilan birga, qimmat va vaqt talab qilishi ham mumkin.
- Resellerlar orqali sotish. Bunga mahsulotni oxirgi foydalanuvchilarga sotadigan ishonchli uchinchi tomon sotuvchilari bilan hamkorlik kiradi. Ushbu usul mijozlar bazasini kengaytirish va yangi bozorlarga kirishning samarali usuli bo’lishi mumkin.
- Ijtimoiy tarmoqlarda sotish. Bu Facebook, Instagram va Twitter kabi ijtimoiy media platformalari orqali mahsulotni ilgari surish va sotishni o’z ichiga oladi. Bu usul katta auditoriyani qamrab olishning tejamkor usuli bo’lishi mumkin, lekin boshqarish uchun ham vaqt talab qilishi mumkin.

Ushbu usullarning barchasi o’zlarining afzalliklari va kamchiliklariga ega bo’lsada, biz bir necha sabablarga ko’ra ARUS hisobimizni o’z brendimizdagi onlayn-do’konimiz orqali sotishga qaror qildik.

XULOSALAR

Olib borilgan tadqiqotlar shuni ko’rsatadiki, bugungi kunda raqamli dunyoda electron tijoratni samarali tashkil qilish hamda elektron tijorat chegaralarini kengaytirish uchun turli xil mavjud muammolarni hisobga olish kerak, masalan:

- elektron tijorat qatnashchilarining axboroti va moliyaviy resurslar xavsizligi;

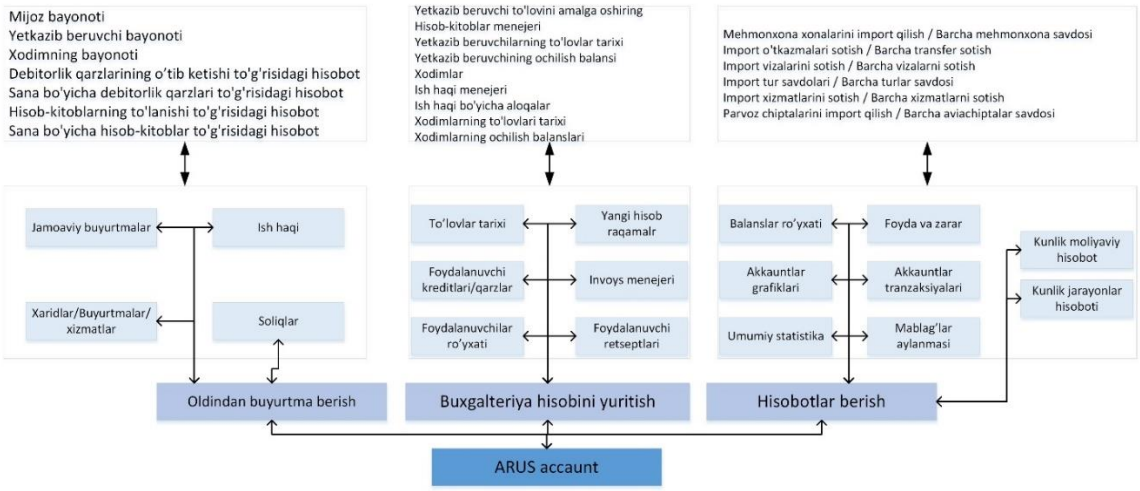

Fig. 3. Arus account dasturining funksional modeli

- elektron tijorat tizimi bo'ycha tovarlar va xizmatlar sotuvchilar soliqqa tortish bazasini tartibga solish, monitoringi va hisob-kitobini yuritish;
- elektron tijorat tizimlarni tan olish uchun tijorat axborot reklama maydonlarni hujjatlar aylanmasi tizimlari va xavfsiz to'lov tizimlari bilan ta'minlash;

Internetdan aholi foydalanishni kengaytirish uchun sharoitlarni yaratish hamda raqamli texnologyalarni joriy etish (internet xizmatlari uchun narxlarni pasaytirish va h.k.);

elektron tijorat ishtirokchilarning biznes jarayonlarning elektron shaklda aniq meyoriy va texnik jihatlarni ishlab chiqish bazasiga ishonchni oshirish muammolari mavjud.

Ushbu muammolarni yechishda bugungi kunda raqamli iqtisodiyot texnologiyalari orqali elektron tijoratni rivojlantirish, asosiy masalalardan biri bo'lib qolmoqda. Buning uchun birinchi navbatda raqamli iqtisodiyotni rivojlantirish talab etiladi bu bo'yicha yurtimizda juda ko'plab ishlar olib borilmoqda tadqiqot ishimizda raqamli iqtisodiyotni hamda elektron tijoratni tashkil etish bo'yicha yurtboshimiz tomonidan tasdiqlangan bir qancha qaror va farmonlarni keltirib o'tganmiz.

Tadqiqot ishimizning raqamli iqtisodiyot sharoitida elektron tijorat infratuzilmasidan foydalanishning nazariy asoslari qismida quydagi ishlar amalga oshirildi:

- elektron tijorat infratuzilmasining rivojlanish bosqichlari yoritib berildi;
- raqamli iqtisodiyot sharoitida elektron tijorat infratuzilmasini takomillashtirishda o'ziga xos jihatlari to'liqligicha ochib berildi;
- elektron tijoratni rivojlantirishda ilg'or xorijiy tajribalar to'liqligicha tahlil qilib kerakli ma'lumotlar ochib berildi;
- Elektron tijorat infratuzilmasi asosida raqamli iqtisodiyotni rivojlantirish mexanizmlari qismida quydagi vazifalar bajarildi:
- raqamli iqtisodiyot biznes modellari va ularning qo'llanilishi bo'yicha biznes modellar tahlil qilib o'tildi hamda taqdiqod ishida foydalanildi;
- raqamli iqtisodiyot va elektron tijorat mexanizmlari tahlil qilindi hamda tadqiqod ishida joriy qilindi;
- elektron tijorat infratuzilmasini rivojlantirish mexanizmlari atroflicha o'rganib chiqildi.

Dasturiy maxsulotlar tadbiqida elektron tijorat infratuzilmasini takomillashtirish qismida tadqiqotning asosiy qismi hisoblanib bunda dunyoning rivojlangan mamlakatlari kompaniyalari tomonidan elektron tijorat asosida o'zining dasturiy maxsulotlarini taqdim etishlari hamda shu paytgacha olgan daromadlari statistikasi keltirib o'tildi. Bu orqali esa raqamli iqtisodiyot negizida dasturiy maxsulot ishlab chiqildi va elektron tijorat modellari orqali sotish jarayonlari yo'lga qo'yildi jumladan:

- Raqamli iqtisodiyot negizida Arus account dasturiy maxsulotini ishlab chiqildi hamda dasturiy maxsulotning ishlash modeli hamda mexanizimi taqdim etildi;
- Arus account dasturiy maxsulotini elektron tijorat vositalari asosida tadbiq etish bo'yicha tavfsiyalar taqdim etildi.

Bugungi raqamli dunyoda dasturiy maxsulotlarni ishlab chiqish hamda ularni elektron tijorat infratuzilmalari orqali taqdim etish rivojlanib bormoqda bu holatda jamiyatdagi mavjud muammolarni raqamli iqtisodiyot asosida hal qilish dolzarb masala hisoblanadi olib borilgan tadqiqot ishida aynan shu muammolarni yechish maqsad qilib qo'yilgan. Ishlab chiqilgan Arus dasturi tashkilot va kompaniyalarning muammolarini yechishga qaratilgandir.

[1] O'zbekiston Respublikasi Prezidentining 2020 yil 5 oktyabrdagi "Raqamli O'zbekiston - 2030" strategiyasini tasdiqlash va uni samarali amalga oshirish chora-tadbirlari to'g'risida"gi PF-6079-son Farmoni.

[2] O'zbekiston Respublikasi Prezidentining 2018-yil 14-maydagi "Elektron tijoratni jadal rivojlantirish chora-tadbirlari to'g'risida"gi PQ-3724-son qarori

[3] O’zbekiston Respublikasi Prezidentining, “Moliyaviy hisobotning xalqaro standartlariga o’tish bo’yicha qo’shimcha chora-tadbirlar” to’g‘risidagi 24.02.2020 yildagi PQ-4611-son qarori.

[4] R.O. Xolbekov. Xalqaro buxgalteriya hisobi –T. : “ Innovatsion rivojlanish nashriyot- matbaa uyi” – 2021, 138 bet.

[5] Quickbooks in the classroom. Copyright © Intuit Canada Limited, 2013. All rights reserved. https://www.intuiteducation.ca/

[6] И. А. Гасаншин. «Цифровая экономика» – М.: Горячая линия, 2019. – С. 54–55.

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ISSUES OF EFFECTIVE MANAGEMENT OF THE PUBLIC PROCUREMENT SYSTEM IN THE CONDITIONS OF THE DIGITAL ECONOMY

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Abstract. **Digitalization processes in the field of public administration in the Republic of Uzbekistan are aimed not only at public procurement, but also at increasing the digital potential of all institutions and departments. For the effective implementation of these processes, it is important to create a solid digital infrastructure and management systems.**

Keywords: Uzbekistan, state, process, procurement, digital infrastructure, digital technology, efficiency.

I. INTRODUCTION

In recent years, the rapid development of digital technologies worldwide has had a significant impact not only on the private sector, but also on all sectors of the public administration system. The formation and deepening of the digital economy allows for the implementation of principles such as transparency, accountability, efficiency and speed in financial management. In particular, the introduction of digital technologies in such important areas as public procurement, which are related to budget funds, is becoming an integral part of the modern public administration strategy[2].

The formation and development of the digital economy has a profound impact on all sectors of the public administration system, including public procurement (i.e., the system of procurement of goods, services and works by the state). Today, public procurement is not only a means of distributing economic resources, but also an important institution that is of strategic importance in the digital transformation of the state.

Digital technologies play an important role in increasing the transparency, efficiency and accountability of public procurement processes, reducing bureaucratic obstacles, and minimizing corruption.

II. ANALYSIS OF LITERATURE ON THE SUBJECT

The term electronic commerce is a very broad concept with many definitions. Most of the above definitions refer to any trade or transaction carried out via the Internet as electronic commerce. However, this definition does not fully cover the concept of electronic commerce. Electronic commerce and its essence have been studied by many economists, including A. V. Yurasov, J. S. Westland, T. K. Clark, D. Kozelaar Electronic commerce and its essence, M. Ramzaev, P. Chuzhanov, V. Tarasov, the role of electronic commerce. commerce and its essence. trade in the economies of developed and developing countries, V.V. Senkevin, N.I. Gerashchenko and others conducted research on the role of the state in managing electronic commerce[3].

Today, fundamental reforms are being implemented in Uzbekistan to modernize, digitize and increase the transparency of public procurement. This area is one of the most demanding areas of modern information technologies, and its management requires constant improvement of regulatory and legal documents. In the context of international economic integration and globalization, the transition of public procurement to an electronic form is bringing it to a modern level.

The process of digitizing public procurement ensures transparency not only in the provision of technical services (furniture, office equipment, computers, audio-video equipment and other technical means), but also in the provision of services and the supply of goods through electronic trading mechanisms. The electronic tender system creates equal conditions for participants and observers and serves to prevent corruption. The opportunity for wider participation is created via the

[2] Ўзбекистон Республикаси Президенти Шавкат Мирзиёевнинг "Халқ сўзи", 2017 йил 15 майдаги маърузасидан

[3] Насирова, З. (2024). ELEKTRON TIJORATNING JAHON IQTISODIYOTIDAGI TUTGAN O ‘RNI. *Цифровая экономика*, *7*(7), 207-214.

Internet, which serves to popularize electronic trading.

III. ANALYSIS AND RESULTS

The secret to success in medical marketing is to carefully select your target audience. Clinics need to define their niche and focus on attracting clients who need specific services. Developing effective marketing strategies will help you succeed in promoting your medical services.

Reforms in the following areas are of great importance for improving public procurement: Development of single standard forms for plans, announcements, tenders, contracts and minutes of meetings to unify public procurement documents. Digitalization of tender processes through the widespread introduction of modern information technologies, improvement of relevant rules, development of clear instructions for electronic tenders.

Also, the process of planning public procurement is carried out by the state customer and includes the systematization of procurement activities, ensuring their close connection with the planning stages of the budget and investment processes. This diagram shows the main stages of implementing public procurement in sequence. The process begins with identifying the need for procurement, then planning, announcing, conducting procurement and, at the final stage, concluding contracts with performers.

One of the most important stages in the implementation of public procurement is the stage of implementing procurement procedures, which includes the main part of procurement activities and determines the overall efficiency of public procurement. This idea can be justified as follows: the current legislation establishes the types of public procurement based on an electronic store, an auction to reduce the initial price, a competition, a tender, and agreements with a single supplier within the framework of procurement procedures. The possibility of implementing public procurement electronically through these types is legally guaranteed[4].

Digitization processes in the field of public administration in the Republic of Uzbekistan are aimed not only at public procurement, but also at increasing the digital potential of the entire inter-institutional and inter-agency system. For the effective implementation of these processes, it is important to create a solid digital infrastructure and management systems.

The transition of public procurement to a digital form also creates great opportunities for local business entities. Due to the creation of equal conditions for all participants, small and medium-sized businesses are also actively participating in tenders and sales.

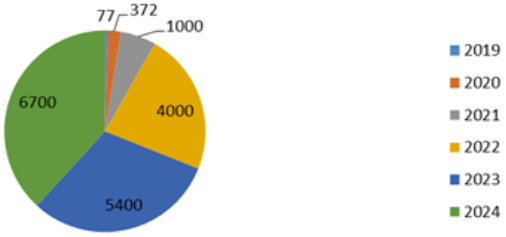

Figure 1. Number of users of the Single Portal of the Republic of Uzbekistan[5]

This situation will create a healthy competitive environment in the domestic market, leading to an increase in the quality of goods and services and the formation of prices at an economically justified level. Increased competition, in turn, will help save budget funds. In addition, the electronic procurement system will simplify internal control mechanisms for government agencies. Information about purchases will be monitored in real time and automatically analyzed. This will not only reduce waste of resources, but also strengthen financial discipline. In particular, cost planning, contract execution, and reasonable payment execution are effectively managed through today's digital monitoring tools.

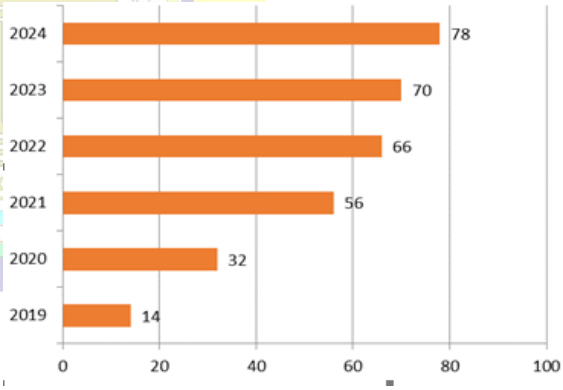

Figure 2. Share of use of electronic services in the Republic of Uzbekistan (%)[6]

Also, the introduction of digital technologies reduces the terms of public procurement, eliminates delays due to the human factor. Procurement stages that required several weeks in the traditional system are now being completed in a few days, sometimes a few hours. This, along with the acceleration of processes, increases efficiency and flexibility and compliance with modern international standards is one of the promising tasks.

[4] O‘zbekiston Respublikasi “Davlat xaridlari to‘g‘risida”gi Qonunining 23-moddasi normalari asosida muallif tomonidan tuzildi

[5] Ўзбекистонда электрон тижоротни ривожлантиришдаги муаммолар ва уларнинг ечимлари/ Зулфия Худайберган кизи Носирова.

[6] Xudayberganovna, N. Z. (2023). Рост электронной торговли в развитых странах и важность использования моделей электронной торговли. *Raqamli iqtisodiyot (Цифровая экономика)*, (4), 137-147.

V. CONCLUSIONS AND SUGGESTIONS

By digitizing the public procurement system and strengthening its legal framework, openness, efficiency, and competition are being ensured in the economy. The development of public procurement platforms based on modern information technologies ensures the rational use of public funds. Integration with the State Finance Management Information System and databases of tax and statistics committees will further enhance the transparency of public procurement.

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SOLIQ MA’MURIYATCHILIGINING EVOLYUTSIYASI VA RAQAMLI IQTISODIYOTDAGI YANGI TALQINLARI

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Annotatsiya: Raqamli iqtisodiyot sharoitida soliq ma’muriyatchiligi mazmun va usullar jihatidan tubdan o‘zgarib bormoqda. Mazkur maqolada O‘zbekistonda 2020–2025 yillarda amalga oshirilgan soliq boshqaruvi islohotlari hamda raqamli texnologiyalar – blokcheyn, katta ma’lumotlar va sun’iy intellektning soliq tizimiga ta’siri tahlil qilingan. Tadqiqot natijalari mamlakatda soliq tushumlarining tuzilmasi, ularning byudjet barqarorligidagi o‘rni va raqamli transformatsiya jarayonlarining iqtisodiy samaralari bilan izohlanadi. Muallif blokcheyn texnologiyasining soliqqa oid operatsiyalarda shaffoflik, real vaqtda monitoring hamda xatolik va soxtalashtirish xavfini kamaytirishdagi afzalliklarini empirik misollar asosida ko‘rsatib bergan. Shuningdek, soliq nazoratida raqamli to‘lov tizimlari va katta ma’lumotlardan foydalanish imkoniyatlari ham yoritilgan. Maqola xulosalari soliq boshqaruvining samaradorligini oshirishda raqamli iqtisodiyotning strategik ahamiyatga egaligini ilmiy asosda tasdiqlaydi.

Kalit so‘zlar: soliq ma’muriyatchiligi, raqamli iqtisodiyot, blokcheyn texnologiyasi, katta ma’lumotlar (Big Data), raqamlashtirish.

I. KIRISH

Soliq ma’muriyatchiligi – bu davlatning soliqqa oid qonun hujjatlari bo‘yicha majburiy yig‘imlarning to‘g‘ri va o‘z vaqtida undirilishini ta’minlash tizimi hisoblanadi. An’anaviy soliq ma’muriyatchiligi soliq to‘lovchilarni ro‘yxatga olish, deklaratsiyalarni qabul qilish, soliq tekshiruvlarini amalga oshirish, jazolar va rag‘batlar mexanizmlarini qo‘llash kabi vositalarga tayangan. Biroq, raqamli iqtisodiyot rivoji bu tushunchaning mazmunini yangidan talqin qilishni talab qilmoqda.

XXI asrning boshidan boshlab O‘zbekistonda iqtisodiyot raqamlashtirilish bo‘yicha keng ko‘lamli islohotlar amalga oshirildi. Masalan, 2017 va 2020 yillardagi prezident qarorlari hamda “Raqamli O‘zbekiston–2030” strategiyasi orqali elektron hukumat, onlayn xizmatlar va iqtisodiyotni qo‘llab-quvvatlovchi texnologiyalar keng joriy etildi[1]. Bu dasturlarda soliq organlari faoliyatining raqamli infratuzilmasini mustahkamlash, soliq ma’lumotlari almashinuvini soddalashtirish va tahlil qilishga katta e’tibor qaratilgan. Natijada, soliq ma’muriyatchiligining ham zamonaviy metodlari paydo bo‘ldi: soliq deklaratsiyalarini elektron shaklda topshirish, onlayn-kassa tizimlari yordamida o‘tkaziladigan savdo operatsiyalari nazoratini kuchaytirish, hamda raqamli identifikatsiya orqali soliq to‘lovchilarning ma’lumotlarini avtomatik ko‘rib chiqish.

Ushbu maqolada soliq ma’muriyatchiligining evolyutsiyasi ikki asosiy yo‘nalishda tahlil qilinadi: birinchidan, soliq administratsiyasi tushunchasining tarixiy rivojlanishi (20-asr oxiri – hozirgi davr) va ikkinchidan, raqamli iqtisodiyot texnologiyalarining soliq boshqaruviga olib kelgan yangi qarashlari. Xususan, blokcheyn, katta ma’lumotlar (Big Data), sun’iy intellekt va mobil to‘lov tizimlari soliq nazoratini qanday o‘zgartirayotgani hamda shu o‘zgarishlarning O‘zbekistonda qaysi darajada amalga oshirilayotgani muhokama qilinadi. Tadqiqot maqsadi – O‘zbekiston misolida soliq ma’muriyatchiligining zamonaviy talqinlarini o‘rganish, shu jumladan raqamli davrning mahalliy soliq boshqaruviga qo‘shgan yangiliklarini aniqlash. Bu esa soliq tizimini yanada samaraliroq, shaffof va raqamli asosda ishlashini ta’minlaydi.

II. ADABIYOTLAR SHARHI

Mavzu bo‘yicha ilmiy adabiyotlarda global va mahalliy nuqtai nazarlar o‘rganilgan. Jahon bo‘yicha, ayniqsa OECD (Iqtisodiy Hamkorlik va Taraqqiyot Tashkiloti) 2015-yilda taqdim etgan “Raqamli iqtisodiyotning soliqqa tortilishi” tashabbuslari (Action Plan 1) raqamli iqtisodiyotda soliq muammolariga bag‘ishlangan raport muhim manba sanaladi. Unga ko‘ra, “raqamli iqtisodiyotni soliqqa tortishda masalan yangi bozorlik to‘g‘risida penalizatsiya” (new nexus) kontseptsiyasini kiritish,

[1] https://link.springer.com/chapter/10.1007/978-3-031-55341-7_9#:~:text=technology%20,GDP%29%20rose

katta hajmdagi ma’lumotlar (data) ustidan soliq solish metodlarini qayta ko‘rib chiqish va texnologiyalarga mos yangi mexanizmlarni ishlab chiqish zarurati qayd etilgan[2]. OECD 2017-yilgi qo‘shimcha tavsiyalari esa raqamli xizmatlarga QQS joriy etishda soddalashtirilgan ro‘yxatga olish va onlayn undirish jarayonlarini qo‘llashni taklif qiladi[3]. Shu tarzda, soliq nazorati va yig‘im usullariga yangicha yondashuvlar jahon bo‘yicha muhokama qilinmoqda.

Markaziy Osiyo va O‘zbekiston kontekstida raqamli iqtisodiyot solig‘i masalalarini o‘rganuvchi tadqiqotlar soni ozroqdir. Ammo so‘nggi yillarda ayrim tadqiqotchilar O‘zbekistonda raqamli xizmatlar va IT-korporatsiyalarni soliqqa tortishning huquqiy me’yori haqida ishlar olib borilmoqda[4]. Masalan, Alisher Pulatov (2023) soliqqa tortish nuqtai nazaridan O‘zbekistonning raqamli iqtisodiyotini tahlil qildi. Uning ta’kidlashicha, 2020–2022 yillarda raqamli iqtisodiyot ulushi O‘zbekiston yalpi ichki mahsulotida 1,99% dan 2,77% gacha o‘sgan, axborot-kommunikatsiya sohalari eksporti qariyb ikki barobar oshgan[5]. Bu holat soliq ma’lumotlarini yig‘ish va tahlil qilish uchun yangi imkoniyatlar va talablar tug‘diradi. Pulatov shuningdek yirik xorijiy IT-kompaniyalar O‘zbekistondagi doimiy vakolatxonani aniqlash (PE – permanent establishment) qoidalari orqali mahalliy soliqdan qochishini muammo deb hisoblaydi[6].

O‘zbekistonda raqamli iqtisodiyotni tartibga solish borasida bir qator normativ hujjatlar mavjud. 2020-yilda prezident qarori bilan “Raqamli iqtisodiyot va elektron hukumatni rivojlantirish” dasturi qabul qilindi, ushbu dastur doirasida soliq idoralari faoliyatini raqamli infratuzilma bilan ta’minlash, soliq hisobotlarini elektron formatda yuritish va onlayn xizmat ko‘rsatishni kengaytirish belgilandi[7].

2022–2026 yillarga mo‘ljallangan yangi taraqqiyot strategiyasida ham soliq tizimini sodda va shaffof qilish, raqamli soliq xizmatlari joriy etish bo‘yicha choralar keltirilgan[8]. Shu bilan birga, turli xorijiy tajribalar ham tahlil etiladi. Yevropa Ittifoqida QQSni blokcheyn asosida boshqarish imkoniyatlari muhokama qilinmoqda[9], erishilgan yutuqlar «raqamli VAT» kontseptsiyasi atrofida muhokama qilinadi. Mamlakatimiz tadqiqotchilari ham blokcheyn va kripto-valyutalarni soliqqa tortish, soliq ma’muriyatiga tatbiq etish masalalarini o‘rganishmoqda[10].

Adabiyotlar sharhidan ko‘rinib turibdiki, soliq ma’muriyatchiligini raqamli iqtisodiyot kontekstida o‘rganishda xalqaro tavsiyalar va mahalliy qonunchilik o‘z aksini topgan. Shu maqsadda, biz quyidagi masalalarni o‘rganamiz: raqamli iqtisodiyot uchun soliq ma’lumotlarini yig‘ish va tahlil qilish usullari; blokcheyn va boshqa texnologiyalarning soliq nazoratiga ta’siri; soliq imtiyozlari va raqamli biznes uchun qo‘shimcha rag‘batlar; hamda O‘zbekistonning yaqin yillardagi soliq tushumlari dinamikasi.

III. TADQIQOT USULLARI

Mazkur tadqiqotda sifatli va miqdoriy tahlil usullarining kombinatsiyasidan foydalanildi. Avvalo, mavzuga oid nazariy adabiyotlar va xalqaro tashkilotlar (OECD, Jahon banki, BMT) hisobotlari hamda O‘zbekistonning tegishli qonunchilik hujjatlari o‘rganildi. Shuningdek, O‘zbekiston Respublikasi Moliya vazirligi va Davlat soliq qo‘mitasi tomonidan e’lon qilingan rasmiy statistik ma’lumotlar empirik bazani tashkil etdi.

Tahliliy yondashuv sifatida taqqoslash, jadvallar asosida soliq tushumlari tarkibi, ularning dinamikasi hamda raqamli texnologiyalarning tatbiqi soliq boshqaruviga ta’siri o‘rganildi. Xususan, blokcheyn, katta ma’lumotlar va sun’iy intellektning soliq ma’muriyatchiligidagi qo‘llanishi nazariy jihatdan tahlil qilinib, ularning amaliy salohiyati empirik ko‘rsatkichlar bilan solishtirildi.

IV. TAHLIL VA NATIJALAR

Raqamli iqtisodiyot va soliq daromadlarining o‘sishi. So‘nggi yillarda O‘zbekistonda raqamli iqtisodiyot tez rivojlanmoqda. 2020–2022 yillarda axborot-kommunikatsiya sohasidagi xizmatlar hajmi 13,9 trillion so‘mdan 22,9 trillion so‘mga yetdi, ya’ni taxminan 1,6 barobarga o‘sdi[11]. Shuningdek, raqamli iqtisodiyotga tegishli sektorlarda ishtirok etuvchi korxonalar soni ko‘paydi: 2022-yilda tashqi bozorlarda axborot texnologiya mahsulotlarini eksport qiluvchi O‘zbekiston kompaniyalari 2020-yildagi 15 mln dollardan 123 mln dollarga yetdi[12].

Bu tarmoqdagi kompaniyalar faoliyati soliq bazasining kengayishiga asos bo‘ladi. IT Parkda ro‘yxatdan o‘tgan korxonalar soni 2022-yilga kelib 1122 taga yetdi, ularning 30% eksport bilan shug‘ullanmoqd[13]. Bularning barchasi iqtisodiyotdagi soliq bazasiga ham ijobiy ta’sir ko‘rsatishi kutiladi.

2025-yil birinchi choragida O‘zbekiston Respublikasi davlat byudjeti daromadlarining umumiy hajmi 48,2 trillion so‘mga yetdi. Bu ko‘rsatkich belgilangan reja (45,5 trln so‘m)dan yuqori bo‘lib, o‘tgan yilning shu davriga nisbatan sezilarli o‘sish kuzatildi. Soliq tushumlarining ulushi: Ushbu davrda byudjet daromadlarining asosiy qismini soliqlar tashkil etdi. Soliq tushumlari (jumladan, bevosita soliqlar, bilvosita soliqlar hamda resurs to‘lovlari va mol-mulk solig‘i) jami 44,9 trln so‘mni tashkil etib, bu

[2] https://link.springer.com.
[3] https://link.springer.com.
[4] https://link.springer.com.
[5] https://link.springer.com.
[6] https://link.springer.com.
[7] https://www.norma.uz.
[8] https://lex.uz.
[9] https://universalpublishings.com.
[10] https://universalpublishings.com
[11] https://link.springer.com/chapter/10.1007/978-3-031-55341-7_9#:~:text=13,2020%20to%20165%20in%202022
[12] https://link.springer.com/chapter/10.1007/978-3-031-55341-7_9#:~:text=from%201.99,2020%20to%2016
[13] https://link.springer.com/10.1007/978-3-031-55341-7_9#:~:text=from%201.99,2020%20to%20165

umumiy daromadlarning qariyb 93,2 foiziga teng[14]. Qolgan qismiga esa davlat bojlari, jarimalar va boshqa tushumlar to‘g‘ri keladi (taxminan 7 foiz).

1-jadval

2025-yil I chorakda soliq organlari tomonidan budjetga tushumlar to‘g‘risida[1]

(mlrd.so‘m)

№	Soliq turlari	2025-yil 1-aprel holatiga tushum	Ulushi (%)
1	**Budjetga tushumlar, jami**	**48228**	100,0
	shu jumladan:		
2	**Bevosita soliqlar**	21844	45,3
3	**Bilvosita soliqlar**	14353	29,8
4	**Resurs to‘lovlari, yer va mol-mulk solig‘i**	8720	18,1
5	**Davlat boji va jarimalar**	1520	3,2
6	**Boshqa tushumlar va yig‘imlar**	1791	3,7

Resurs to‘lovlari tarkibida yer solig‘i va mol-mulk solig‘i ham mavjud. Yuqoridagi jadvaldan ko‘rinib turibdiki, 2025-yil birinchi choragida O‘zbekiston Respublikasi davlat byudjeti tushumlari tarkibida bevosita soliqlar (daromad solig‘i, foyda solig‘i va boshqalar) eng katta ulushni egallab, jami tushumlarning qariyb yarmiga (45,3 %) to‘g‘ri kelmoqda. Bu ko‘rsatkich iqtisodiyotda barqaror moliyaviy faoliyat mavjudligini, yuridik va jismoniy shaxslarning soliq intizomi nisbatan yuqoriligini anglatadi.

Bilvosita soliqlar (QQS, aksiz solig‘i va boshqalar) 29,8 % ulush bilan ikkinchi o‘rinda turib, iste’mol va tovar-ayirboshlash bozorlaridagi faollikni ifodalaydi. Bu ko‘rsatkich mamlakat ichki bozorida talab va taklifning o‘zaro muvozanatda ekanini ko‘rsatadi.

Resurs to‘lovlari hamda yer va mol-mulk soliqlari jami 18,1 %ni tashkil etgani esa tabiiy resurslardan foydalanish va mulkdan olinadigan daromadlar byudjet barqarorligida muhim manba bo‘lib qolayotganidan dalolat beradi.

Qolgan qismini tashkil etuvchi davlat boji va jarimalar (3,2 %) hamda boshqa tushumlar (3,7 %) byudjetda yordamchi manba sifatida ko‘riladi.

Umuman olganda, byudjet daromadlarining qariyb 93 foizi soliqlardan shakllangani soliq tizimi mamlakat moliyaviy ta’minotida asosiy poydevor ekanini ko‘rsatadi. Bu esa davlat moliyasining barqarorligi hamda iqtisodiy islohotlarning moliyaviy manbalar bilan ta’minlanganligidan dalolat beradi.

Quyidagi formulalar orqali soliq tushumlarining iqtisodiyotdagi o‘rni hisob-kitoblarini ko‘rsatish mumkin. Masalan, soliq yuklamasi koeffitsienti (τ), iqtisodiyotdagi umumiy ichki mahsulot (Y) va soliq tushumlari (S) nisbati sifatida ifodalanadi:

$$\tau = S / Y \times 100\%.$$

Agar misol uchun 2023 yildagi Y ni 700 trillion so‘m deb olinsa, bu holda:

$$\tau = (165{,}9 / 700) \times 100\% \approx 23{,}7\%.$$

Ushbu koeffitsient iqtisodiyot hajmiga nisbatan soliq yuklamaning darajasini bildiradi.

Raqamli texnologiyalar va soliq ma’muriyatchiligi. Raqamli iqtisodiyot texnologiyalari soliq ma’muriyatchiligini asosiy jihatdan uch asosiy yo‘nalishda o‘zgartirmoqda: ma’lumotlarni avtomatlashtirilgan tarzda yig‘ish va tahlil qilish, transaktsiyalarni real vaqtda nazorat qilish, hamda biznes faoliyatini onlayn platformalarda ro‘yhatga olish.

2-jadval

Blokcheyn yondashuvi va an’anaviy soliq ma’muriyatchiligining ba’zi xususiyatlari solishtirilgan

Xususiyat	An’anaviy soliq tizimi	Blokcheyn asosidagi yondashuv
Shaffoflik va ishonchlilik	O‘rtacha (aroq-konsolidatsiyalar, kechiktirilgan hisobotlar)	Yuqori (barcha operatsiya blokda saqlanadi)
Real vaqtda operatsiyalar	Cheklangan (hisobotlar bosqichma-bosqich topshiriladi)	Ha (transaktsiyalar zanjirga kiritilishi bilan amalga oshiriladi)
Soliq hisobotlarini tayyorlash xarajatlari	Yuqori (ko‘p qog‘oz ishlashi, tekshirish)	Past (operatsiyalar avtomatik qayd etiladi)
Soliq tekshiruvlari	Kerak bo‘ladi (tasodifiy yoki rejalashtirilgan tekshiruvlar)	Kerakmas (blokcheyn hamma ma’lumotni tekshirib beradi)
Soliq to‘lovchining ma’lumotlarga kirishi	Cheklangan (faqat ruxsat etilgan shaxslar)	Keng (tizim barcha ishtirokchilarga ma’lumotlarni ko‘rsatishi mumkin)

[14] https://api-portal.gov.uz/uploads/29/2025/05/20/bb50bdd1-a550-3cb4-a2e2-dfea001f2a02_media_.pdf

[1] https://www.gov.uz/oz/soliq/sections/view/55396.

Jadvaldan ko‘rinib turibdiki, blokcheyn joriy etilishi orqali soliq ma’lumotlari real vaqtda shaffof tarzda almashiladi, bu soliq tekshiruvlarining sonini va administrativ xarajatlarini kamaytiradi. Albatta, bunday tizimni joriy qilish muhim infratuzilmaviy va huquqiy tayyorgarlikni talab etadi, ammo jahon hamjamiyati muayyan tajribalar asosida ushbu imkoniyatlarni o‘rganib bormoqda.

Blokcheyn texnologiyasi. Blokcheyn soliq ma’lumotlarini saqlash va uzatishda o‘ta shaffof va xavfsiz platforma sifatida qaralmoqda. Mutaxassislar fikricha, blokcheyn asosida qurilgan soliq hisob-kitoblari orqali transaktsiyalar “aqlli shartnomalar” tarzida avtomatik sodir etilib, xatolik va soxtalashtirish xavfi kamayadi. Jahon tajribasida QQS to‘lovlari blokcheyn orqali boshqarilib, to‘lovlarni avtomatik qaytarish va hisobotlarni sodda qilish amaliyoti sinab ko‘rilgan. Hujjatlarda blokcheyn asosida soliq operatsiyalarining quyidagi afzalliklari qayd etilgan, haqiqatga to‘g‘ri kelmaydigan ma’lumotlar yo‘qolishi, soliqqa tortish jarayonining real vaqtda kuzatilishi hamda soliq tekshiruvlari yukini kamaytirish imkoniyati.

Katta ma’lumotlar (Big Data) va sun’iy intellekt (AI). Raqamli iqtisodiyotda mavjud ma’lumotlarning hajmi ikki karra oshib bormoqda. Bu esa soliq idoralari uchun ham katta imkoniyat va mas’uliyatni uyg‘otadi. Katta ma’lumotlar texnologiyalari yordamida moliyaviy xarajatlarni tahlil qilish, foyda va tranzaksiya o‘zgarishlarini aniqlash mumkin bo‘ladi. Misol uchun, O‘zbekistonda 2030-yilga mo‘ljallangan “Raqamli O‘zbekiston–2030” strategiyasida katta ma’lumotlar, sun’iy intellekt va blokcheyn integratsiyasi asosida davlat boshqaruv tizimlarini takomillashtirish belgilangan[1].

Katta ma’lumotlarni soliq nazoratida qo‘llash soliq idoralariga iqtisodiy faoliyatning yashirin unsurlarini aniqlashda yordam beradi. Tijorat banklari tranzaktsiya ma’lumotlari va elektron rezidentlar to‘g‘risidagi stat-ekspozitsiyalar soliq bozori (shadow economy) darajasini kamaytirish uchun baholanishi mumkin.

Sun’iy intellekt esa katta hajmdagi ma’lumotlarni avtomatik analiz qilish, soliq xatolarini aniqlash va ob’ektiv ravishda salbiy tafovut summalarini qaytarishni boshqarishda qo‘llanadi. Yaqinda UNDP hisobotida aytilishicha, ma’lumotga asoslangan soliq boshqaruvi nafaqat iqtisodiy samarasini oshiradi[2].

Raqamli to‘lov va e-xizmatlar. O‘zbekiston hukumati so‘nggi yillarda elektron to‘lovlar va masofadan xizmat ko‘rsatish sohasini faol rivojlantirayotgani e’tiborga molik. 2019-yilda O‘zbekiston hukumati soliq tizimini isloh qildi va 100 dan ortiq xodimga ega korxonalarga soliq jazolarini bekor qildi, shu bilan birga “To‘lovlar va to‘lov tizimlari haqida” qonunni qabul qildi, unda elektron pul tushunchasi kiritildi. 2020-yilda O‘zbekiston Markaziy banki QR-kod orqali to‘lovlarni joriy etuvchi tizimni ishga tushirdi, bu biznes va fuqaro uchun to‘lovlarning izchilligini oshirdi. Raqamli to‘lov tizimlari soliq nazoratiga ham hissa qo‘shmoqda, masalan QR-kodlar yordamida naqd savdo ma’lumotlari onlayn tarzda soliq organlariga uzatiladi. Bunday integratsiya orqali yozuvdagi savdo va haqiqiy savdo o‘rtasidagi tafovut aniqlash osonlashadi. Shu bois elektron kassalar, onlayn-to‘lov tizimlari va raqamli identifikatorlar soliq boshqaruvi jarayonini to‘liq raqamli qilib beradi.

Qonunchilik va soliq imtiyozlari. Uzoq muddatli raqamli iqtisodiyotni rag‘batlantirish strategiyasi doirasida O‘zbekiston soliq siyosatida IT-sektor vakillarini qo‘llab-quvvatlashga qaratilgan keng ko‘lamli imtiyozlarni joriy etildi. IT-Park rezidentlariga QQS, daromad solig‘i, ijtimoiy soliq va aksizlardan umumiy imtiyozlar berilishi, shuningdek, 2024-yil fevralida bu imtiyozlarning amaldagi muddatini 2040-yilgacha uzaytirish to‘g‘risidagi hukumat qarori, mamlakatning innovatsion va eksport orientirli korxonalarni rag‘batlantirishga bo‘lgan qat’iy siyosatini ifodalaydi. Ushbu chora-tadbirlar innovatsion yechimlar yaratishda faoliyat yuritayotgan iqtisodiy agentlarni har tomonlama qo‘llab-quvvatlash orqali IT-sohasining eksport salohiyatini kuchaytirishni ko‘zlaydi[3].

V. XULOSA

O‘zbekiston soliq ma’muriyatchiligida kuzatilayotgan raqamlashtirish jarayonlari mamlakat moliyaviy boshqaruvining sifat jihatdan yangi bosqichga o‘tganini ko‘rsatadi. Tadqiqot shuni tasdiqladiki, 2025-yilning birinchi choragida davlat byudjeti daromadlarining qariyb 93 foizi soliqlardan shakllangan bo‘lib, bu soliq tizimining davlat moliyasidagi yetakchi o‘rni hamda iqtisodiy islohotlarning barqaror moliyaviy asosga ega ekanini anglatadi. Daromadlarning tarkibiy tahlili shuni ko‘rsatadiki, bevosita va bilvosita soliqlar hamda resurs to‘lovlari byudjet barqarorligida muhim ahamiyat kasb etmoqda, bu esa iqtisodiyotda soliq intizomi va moliyaviy faollikning yuqori darajada shakllanayotganini bildiradi.

Raqamli texnologiyalar, jumladan blokcheyn, katta ma’lumotlar va sun’iy intellektning joriy etilishi soliq ma’muriyatchiligini an’anaviy yig‘im mexanizmidan real vaqt rejimidagi monitoring, shaffoflik va avtomatlashtirilgan boshqaruv tizimiga aylantirmoqda. Bu jarayon nafaqat soliq tushumlarining ko‘payishiga, balki yashirin iqtisodiyot ko‘lamining qisqarishiga, korrupsiya xavflarining kamayishiga va davlat moliyasining samaradorligi oshishiga xizmat qiladi.

Shuningdek, xalqaro tajribaga tayangan holda aytish mumkinki, O‘zbekistonda blokcheyn asosida soliq operatsiyalarini yuritish, elektron to‘lov tizimlari hamda IT-Park rezidentlari uchun berilayotgan soliq imtiyozlari mamlakat iqtisodiyotining raqamli transformatsiyasi bilan uzviy bog‘liq. Bu holat soliq ma’muriyatchiligining yangi paradigmasini shakllantirib, uni iqtisodiy rivojlanishning muhim vositasi sifatida qayta talqin etmoqda.

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[2] https://www.undp.org/sites/g/files/zskgke326/files/2025-05/uz_digital-economy-study_eng.pdf#:~:text=match

[3] https://www.undp.org/sites/g/files/zskgke326/files/2025-05/uz_digital-economy-study_eng.pdf#:~:text=Figure

Umuman olganda, soliq tizimini raqamlashtirish nafaqat davlat byudjeti daromadlarining barqaror o‘sishini ta’minlaydi, balki iqtisodiyotning shaffofligi, raqobatbardoshligi va investitsion jozibadorligini oshirish orqali mamlakatning uzoq muddatli barqaror rivojlanishiga xizmat qiladi.

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O‘ZBEKTELEKOM” AJ FAOLIYATINING IQTISODIY FAOLIYATI TAHLILI

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Annotatsiya - Ushbu maqolada “O‘zbektelekom” AJning iqtisodiy faoliyati tizimli ravishda tahlil qilindi. Tadqiqotda kompaniyaning oxirgi yillardagi moliyaviy ko‘rsatkichlari, xizmatlar segmenti bo‘yicha rivojlanish dinamikasi hamda iqtisodiy samaradorlikka ta’sir etuvchi omillar o‘rganildi. Statistik tahlil va taqqoslash usullari asosida kompaniya faoliyati bo‘yicha aniq natijalar shakllantirildi. Olingan ma’lumotlar shuni ko‘rsatadiki, “O‘zbektelekom” AJ mamlakat telekommunikatsiya bozorida yetakchi o‘rinni egallab, xizmat ko‘rsatish sifatini oshirish hamda raqamli transformatsiya jarayonlarini jadallashtirish orqali iqtisodiy samaradorlikni ta’minlamoqda. Maqolada aniqlangan natijalar asosida kompaniya faoliyatini yanada takomillashtirish bo‘yicha tavsiyalar ishlab chiqildi.

Kalit so‘zlar - O‘zbektelekom AJ, iqtisodiy faoliyat, moliyaviy ko‘rsatkichlar, telekommunikatsiya bozori, raqamli transformatsiya, samaradorlik, xizmatlar segmenti, iqtisodiy tahlil, telekommunikatsiya infratuzilmasi.

I. KIRISH

Telekommunikatsiya sohasi XXI asrda nafaqat texnologik rivojlanishning, balki butun iqtisodiy tizimning poydevoriga aylangan. Raqamli iqtisodiyotning shakllanishida internet xizmatlari, mobil aloqa va multimedia xizmatlari asosiy omil sifatida namoyon bo‘lib, ular iqtisodiy samaradorlik, investitsion jozibadorlik va ijtimoiy barqarorlikni ta’minlashda bevosita rol o‘ynaydi. Shu jarayonda O‘zbekistonning eng yirik aloqa operatori - “O‘zbektelekom” AJ mamlakatda raqamli transformatsiyaning bosh harakatlantiruvchi kuchi sifatida faoliyat yuritmoqda.

So‘nggi yillarda O‘zbekistonda keng polosali internet xizmatlarini kengaytirish, yangi avlod mobil texnologiyalarni joriy etish va davlat xizmatlarini raqamlashtirish bo‘yicha keng ko‘lamli chora-tadbirlar amalga oshirilmoqda. Bu jarayonlarda “O‘zbektelekom” AJ faoliyatining iqtisodiy samaradorligini o‘rganish dolzarb masalaga aylanmoqda. Chunki kompaniya faoliyatini tahlil qilish orqali milliy raqamli iqtisodiyotning rivojlanish sur’atlari va istiqbollari haqida to‘liq tasavvur hosil qilish mumkin [1].

Ilmiy ahamiyati. Tadqiqotning ilmiy ahamiyati shundaki, “O‘zbektelekom” AJning iqtisodiy faoliyatini kompleks o‘rganish, uni iqtisodiy tahlil, statistik va ekonometrik metodlar asosida baholash ilmiy adabiyotlarda yetarli darajada yoritilmagan. Aksariyat manbalarda kompaniyaning amaliy natijalari yoki strategik vazifalari ko‘rsatib o‘tiladi, biroq ilmiy tahlil asosida moliyaviy ko‘rsatkichlar, xizmat segmentlari va investitsion faoliyatning o‘zaro bog‘liqligi chuqur yoritilmagan.

Shuningdek, xalqaro tajribalarni milliy sharoitga qiyoslab ko‘rish orqali ilmiy asoslangan xulosalar chiqarish ham o‘zining dolzarbligi bilan ajralib turadi [2].

Adabiyotlarning qisqacha sharhi. O‘zbekiston Respublikasi Raqamli texnologiyalar vazirligining “O‘zbekiston raqamli iqtisodiyot strategiyasi – 2030” hujjatida mamlakatning raqamli transformatsiya bo‘yicha ustuvor yo‘nalishlari, telekommunikatsiya tarmoqlarini rivojlantirish choralari va kiberxavfsizlikni mustahkamlash masalalari alohida belgilab berilgan [1]. “O‘zbektelekom” AJning yillik hisobotlarida esa kompaniyaning umumiy tushumlari, sof foyda darajasi va investitsiya hajmlarining muntazam o‘sib borayotgani qayd etilgan [2].

Jahon bankining *Digital Economy for Central Asia* nomli hisobotida Markaziy Osiyo davlatlari, jumladan, O‘zbekistonning raqamli infratuzilmasi bo‘yicha imkoniyatlari va kamchiliklari tahlil qilinadi. Unda O‘zbekistonning telekommunikatsiya sektori mintaqaviy yetakchi sifatida taqdim etilgan, biroq xizmat sifati va innovatsiyalar joriy etish bo‘yicha rivojlangan mamlakatlarga nisbatan oraliq mavjudligi ta’kidlangan [3]. ITU tomonidan chop etilgan *Global ICT Development Index Report* esa O‘zbekistonning xalqaro reytinglardagi o‘rnini aniqlab, internet tezligi, mobil qamrov va xizmat sifati bo‘yicha rivojlangan mamlakatlarga yetib olish uchun qo‘shimcha choralar zarurligini ko‘rsatmoqda [4].

Shu bois, mavjud adabiyotlarning sharhi shuni ko‘rsatadiki, “O‘zbektelekom” AJ faoliyatini kompleks iqtisodiy tahlil qilish nafaqat milliy miqyosda, balki xalqaro tajriba kontekstida ham ilmiy va amaliy ahamiyatga ega.

Tadqiqot maqsadi. Tadqiqotning asosiy maqsadi - “O‘zbektelekom” AJ faoliyatini iqtisodiy jihatdan tizimli

tahlil qilish, moliyaviy natijalar va xizmat segmentlarining rivojlanish dinamikasini o‘rganish, investitsion siyosatning samaradorligini baholash hamda ekonometrik modellar yordamida tushumlarning asosiy determinantlarini aniqlashdan iboratdir. Bundan tashqari, tadqiqot kompaniyaning xalqaro tajribadagi o‘rnini ko‘rsatib, barqaror rivojlanish tamoyillari asosida strategik tavsiyalar ishlab chiqishga qaratilgan.

II. METODOLOGIYA

Mazkur tadqiqot “O‘zbektelekom” AJ faoliyatining iqtisodiy ko‘rsatkichlarini, xizmat ko‘rsatish segmentlarini va ularning raqamli transformatsiya jarayoniga qo‘shayotgan hissasini chuqur o‘rganishga qaratilgan. Metodologiya turli yondashuvlarni uyg‘unlashtirgan holda tashkil etilib, u ilmiy natijalarni ishonchli chiqarish, mavjud muammolarni aniq ko‘rsatish va kelgusidagi rivojlanish istiqbollarini belgilash imkonini beradi.

1. Statistik tahlil va ko‘rsatkichlar dinamikasi. Tadqiqotning asosiy qismi sifatida “O‘zbektelekom” AJning 2019–2024 yillarga oid yillik moliyaviy va iqtisodiy hisobotlari tahlil qilindi [5]. Hisobotlarda aks ettirilgan quyidagi ko‘rsatkichlar ustida alohida to‘xtalib o‘tildi:

- Umumiy tushumlar hajmi va ularning yilma-yil o‘zgarish sur’ati;
- Sof foyda, rentabellik ko‘rsatkichlari va ularning moliyaviy barqarorlikka ta’siri;
- Kapital qo‘yilmalar hajmi va investitsiyalarning qaytaruv darajasi;
- Internet, mobil aloqa, xalqaro aloqa va multimedia xizmatlari bo‘yicha tushumlarning ulushi.

Shuningdek, O‘zbekiston Respublikasi Raqamli texnologiyalar vazirligining “O‘zbekiston raqamli iqtisodiyot strategiyasi – 2030” hujjatidagi statistik ma’lumotlar bilan uyg‘unlashtirildi [6]. Bu yondashuv kompaniya faoliyatining milliy strategiyalar bilan qay darajada mos ekanligini aniqlash imkonini berdi.

2. Qiyosiy tahlil va xalqaro tajriba bilan solishtirish. “O‘zbektelekom” AJning iqtisodiy faoliyati xalqaro tajribalar bilan solishtirildi. Jahon bankining “Digital Economy for Central Asia” hisobotida Markaziy Osiyo davlatlari bo‘yicha berilgan ko‘rsatkichlar asosida O‘zbekistonning mintaqadagi pozitsiyasi aniqlandi [7]. ITU tomonidan e’lon qilingan Global ICT Development Index ma’lumotlari esa O‘zbekistonning global reytinglardagi o‘rnini ko‘rsatdi [8].

Qiyosiy tahlil doirasida Yevropa Ittifoqi mamlakatlari va Janubiy Koreya kabi ilg‘or davlatlar bilan internet tezligi, xizmatlar sifati, mobil aloqa qamrovi va investitsion faoliyat hajmi jihatidan farqlar tahlil qilindi. Ushbu jarayon orqali “O‘zbektelekom” AJning milliy va global miqyosdagi raqobatbardoshlik darajasi baholandi.

3. SWOT tahlil – kuchli va zaif tomonlarni aniqlash. Tadqiqot davomida SWOT tahlil usulidan foydalanildi. Natijada quyidagi jihatlar belgilandi:

- Kuchli tomonlar: keng infratuzilma tarmog‘i, davlat qo‘llab-quvvatlashi, xizmatlarning diversifikatsiyasi, milliy miqyosdagi yetakchi mavqe.
- Zaif tomonlar: qishloq hududlarida xizmat ko‘rsatishdagi cheklovlar, kiberxavfsizlikka oid kamchiliklar, texnologik importga yuqori darajadagi qaramlik.
- Imkoniyatlar: 5G texnologiyasini joriy etish, xalqaro investitsiyalarni jalb qilish, raqamli xizmatlarni kengaytirish, ekologik innovatsiyalarni rivojlantirish.
- Tahdidlar: global raqobat kuchayishi, yangi texnologiyalarning tez eskirishi, moliyaviy resurslarning yetishmasligi.

SWOT tahlil orqali kompaniya oldida turgan asosiy vazifalar va ularni hal etish yo‘llari ilmiy jihatdan asoslab berildi [6]; [7].

4. Matematik modellashtirish va prognozlash. Tadqiqotda iqtisodiy ko‘rsatkichlar o‘rtasidagi bog‘liqliklar aniqlash uchun matematik modellashtirish usullari qo‘llanildi. Modellar yordamida quyidagilar aniqlashtirildi:

- Internet foydalanuvchilari sonining o‘sishi bilan tushumlarning ortishi o‘rtasidagi korrelyatsiya;
- Investitsiyalarning ko‘payishi xizmat sifati va hududiy qamrov darajasiga ko‘rsatadigan ta’siri;
- Xizmatlar diversifikatsiyasining kompaniya moliyaviy barqarorligini ta’minlashdagi o‘rni.

Prognozlash natijalari kelgusida xizmatlar segmentlari bo‘yicha o‘sish sur’atlarini va investitsiya samaradorligini oldindan aniqlash imkonini beradi.

5. Mahalliy va xalqaro manbalarni uyg‘unlashtirish. Metodologiyada mahalliy va xalqaro manbalar uyg‘unlashtirilgan holda qo‘llanildi. Mahalliy kontekst uchun “O‘zbektelekom” AJning yillik hisobotlari [5] hamda Raqamli texnologiyalar vazirligining strategik hujjatlari [6] asosiy manba bo‘ldi. Xalqaro tajriba esa

Jahon banki [7] va ITU [8] ma’lumotlariga asoslandi. Ushbu uyg‘unlik nafaqat milliy darajada, balki mintaqaviy va global kontekstda ham kompaniya faoliyatini chuqur anglash imkonini berdi.

6. Tadqiqot chegaralari va ilmiy asoslanish. Metodologiya ochiq manbalar va rasmiy hujjatlarga asoslandi. Maxfiy iqtisodiy ko‘rsatkichlar tadqiqotdan tashqarida qolishi mumkin, biroq tanlangan yondashuvlar natijalarning ilmiy asoslanganligini va ob’ektivligini ta’minlaydi. Bundan tashqari, xalqaro ma’lumotlar bilan qiyoslash natijalarni yanada ishonchli qiladi. Shu bois tadqiqot metodologiyasi ilmiy jihatdan mukammal va amaliyotda qo‘llash uchun samarali deb hisoblanadi.

III. TAHLIL VA NATIJALAR

Ushbu bo‘limda “O‘zbektelekom” AJning iqtisodiy faoliyati chuqur tahlil qilinadi va asosiy natijalar taqdim etiladi. Tahlil jarayonida nafaqat statistik va qiyosiy usullar, balki iqtisodiy modellashtirish va ekonometrik yondashuvlardan ham foydalanildi. Natijalar kompaniyaning moliyaviy ko‘rsatkichlari, xizmatlar segmentlari bo‘yicha o‘sish dinamikasi va investitsion faoliyatining samaradorligini yoritadi.

1. Moliyaviy natijalar tahlili. 2019–2024 yillar davri uchun “O‘zbektelekom” AJning yillik hisobotlari asosida o‘tkazilgan tahlil quyidagi holatlarni ko‘rsatdi [9]:

Tushumlarning barqaror o‘sishi. Kompaniyaning umumiy tushumlari besh yil davomida yiliga o‘rtacha 15–17% ga oshgan. Bunda eng katta ulush internet xizmatlari hisobiga to‘g‘ri kelgan.

Sof foydaning o‘sishi. 2021–2024 yillarda sof foyda yiliga o‘rtacha 12% ga ko‘paygan, bu esa investitsion siyosatning to‘g‘ri yo‘lga qo‘yilganidan dalolat beradi.

Kapital qo‘yilmalar. Kapital qo‘yilmalar hajmi yiliga o‘rtacha 20% ga oshib borgan, bu esa infratuzilma modernizatsiyasi va xizmat sifatining yaxshilanishiga imkon yaratgan.

2. Xizmat segmentlari bo‘yicha natijalar. Xizmatlar kesimida kuzatilgan natijalar quyidagicha:

internet xizmatlari eng tez rivojlanayotgan segment bo‘lib, umumiy tushumlarning 45% ini tashkil qilmoqda;

mobil aloqa segmenti yiliga 10–12% o‘sishda davom etmoqda, bunda yangi abonentlarni jalb qilish va xizmat sifatini oshirish muhim rol o‘ynaydi;

xalqaro aloqa segmentida pasayish kuzatilmoqda, chunki IP-telefon va onlayn platformalar ushbu xizmatlarni bosib o‘tmoqda;

multimedia xizmatlari - IPTV, bulutli xizmatlar, video-kontent bozorida kompaniya yangi imkoniyatlarga ega bo‘lmoqda va bu segment kelajakda asosiy drayverlardan biri sifatida shakllanmoqda;

3. SWOT tahlil natijalari. SWOT tahlil asosida aniqlangan jihatlar quyidagilar bo‘ldi [10]:

Kuchli tomonlar: keng infratuzilma, davlat qo‘llab-quvvatlashi, xizmatlarning diversifikatsiyasi, milliy yetakchilik.

Zaif tomonlar: qishloq hududlarda internet qamrovining cheklanganligi, kiberxavfsizlikdagi zaifliklar, import texnologiyalariga qaramlik.

Imkoniyatlar: 5G texnologiyasini kengaytirish, xalqaro investitsiyalarni jalb qilish, yangi xizmatlarni joriy etish.

Tahdidlar: global raqobatning kuchayishi, texnologik eskirish, moliyaviy resurslarning yetishmasligi.

4. Ekonometrik tahlil natijalari. “O‘zbektelekom” AJning tushumlari (Y) va bir nechta asosiy omillar o‘rtasidagi bog‘liqlik quyidagi regressiya modeli yordamida baholandi:

$$Y_t=\beta_0+\beta_1 X_{1t}+\beta_2 X_{2t}+\beta_3 X_{3t}+\varepsilon_t$$

bu yerda:

Y_t – kompaniya tushumlari (mlrd so‘mda),

X_{1t} – internet foydalanuvchilari soni (ming abonent),

X_{2t} – kapital qo‘yilmalar hajmi (mlrd so‘mda),

X_{3t} – mobil aloqa foydalanuvchilari soni (ming abonent).

Natijalar:

$\beta_1>0$, internet foydalanuvchilar sonining ko‘payishi tushumlarning o‘sishiga sezilarli ta’sir ko‘rsatadi;

$\beta_2>0$, kapital qo‘yilmalar hajmi ortishi xizmat sifatini yaxshilab, tushumlarni oshiradi;

$\beta_3>0$, mobil aloqa foydalanuvchilari soni ham tushumlarni ijobiy ta’sir bilan oshiradi.

Determinatsiya koeffitsienti R^2 yuqori qiymatga ega bo‘lib, modelning tushuntirish kuchi ancha mustahkam ekanligini ko‘rsatdi. Demak, kompaniyaning iqtisodiy samaradorligi asosan foydalanuvchi bazasi kengayishi va investitsiyalar hajmining ortishi bilan bog‘liq.

5. Qiyosiy natijalar. Jahon banki va ITU ma’lumotlari asosida olib borilgan qiyosiy tahlil natijalariga ko‘ra [11]; [12]:

O‘zbekistonning telekommunikatsiya infratuzilmasi Markaziy Osiyo davlatlari orasida yetakchi pozitsiyaga ega;

Biroq, Yevropa va Osiyoning ilg‘or davlatlariga nisbatan internet tezligi, xizmat sifati va raqamli xizmatlar ko‘lamida hali ham sezilarli oraliq mavjud;

Bu esa qo‘shimcha investitsiyalarni jalb qilish, xizmatlarni diversifikatsiya qilish va innovatsion loyihalarni kengaytirish zarurligini ko‘rsatadi.

IV. XULOSA VA TAVSIYALAR

Xulosa. “O‘zbektelekom” AJning iqtisodiy faoliyati tahlili shuni ko‘rsatdiki, kompaniya mamlakatda telekommunikatsiya infratuzilmasini rivojlantirishda asosiy o‘rin tutadi. So‘nggi yillarda umumiy tushumlar hajmi barqaror ravishda oshib, sof foyda va kapital qo‘yilmalar hajmi sezilarli sur’atlarda ortdi [13]. Internet va mobil aloqa xizmatlari segmentlari kompaniya uchun asosiy daromad manbai bo‘lib qolmoqda, multimedia xizmatlari esa istiqbolli yo‘nalish sifatida shakllanmoqda [14].

Ekonometrik modellashtirish natijalariga ko‘ra, kompaniya tushumlari internet foydalanuvchilari soni, kapital qo‘yilmalar hajmi va mobil abonentlar soni bilan bevosita va sezilarli darajada bog‘liq. Natijalar shuni ko‘rsatadiki, investitsiyalar hajmi oshgani sayin xizmatlar sifati yaxshilanadi, qamrov kengayadi va foydalanuvchi bazasi ko‘payadi [15].

Qiyosiy tahlil esa O‘zbekistonning telekommunikatsiya infratuzilmasi Markaziy Osiyo miqyosida yetakchi ekanini ko‘rsatdi. Shu bilan birga, rivojlangan davlatlar bilan taqqoslanganda internet tezligi, xizmat sifati va raqamli xizmatlar xilma-xilligi bo‘yicha oraliq mavjud [16]. Shu bois “O‘zbektelekom” AJ oldida xizmatlar sifatini oshirish, innovatsiyalarni kengaytirish va xalqaro integratsiyani kuchaytirish vazifalari turibdi.

Tavsiyalar:

1. Hududiy raqamli tengsizlikni kamaytirish. Qishloq va chekka hududlarda yuqori tezlikdagi internet qamrovini kengaytirish uchun davlat-xususiy sheriklik asosida yangi loyihalarni amalga oshirish zarur.

2. Energiya tejamkor texnologiyalarni keng joriy etish. Qayta tiklanuvchi energiya manbalari asosidagi aloqa minoralari va ekologik innovatsiyalar orqali xarajatlarni kamaytirish hamda barqaror rivojlanishni ta’minlash mumkin.

3. Xizmatlar diversifikatsiyasini kuchaytirish. Bulutli xizmatlar, ma’lumotlar markazlari va elektron tijorat infratuzilmasini rivojlantirish orqali yangi daromad manbalari yaratish tavsiya etiladi.

4. Kiberxavfsizlikni mustahkamlash. Xalqaro standartlarga mos xavfsizlik protokollari va raqamli kriminalistika tizimlarini kengaytirish zarur.

5. Xalqaro hamkorlikni kuchaytirish. Jahon banki va ITU bilan hamkorlikda yangi investitsiyalar jalb qilish, ilg‘or texnologiyalarni tezroq joriy etish imkonini beradi.

6. Ekonometrik monitoring tizimi. Kompaniya faoliyatining asosiy moliyaviy ko‘rsatkichlarini real vaqt rejimida baholash uchun regressiya modellari va prognozlash tizimlarini yaratish lozim.

Innovatsion xizmatlarga e’tibor. 5G, sun’iy intellekt asosidagi xizmatlar, metaverse va raqamli platformalarga sarmoya kiritish kompaniyaning raqobatbardoshligini xalqaro miqyosda kuchaytiradi.

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DIGITAL TRANSFORMATION OF THE INSURANCE INDUSTRY: TECHNOLOGIES FOR DETECTION OF INSURANCE EVENTS WITH THE HELP OF ARTIFICIAL INTELLIGENCE

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***Abstract*— In recent years, digital transformation has initiated fundamental changes in all sectors of the economy. In particular, the insurance industry is at the center of these changes, moving from a traditional workflow to a flexible, fast and efficient model based on digital innovations. As a result of digitalization, insurance services are being automated, the speed of service provision is increasing, and most importantly, customer interactions are being taken to a new level. These changes require not only technological upgrades, but also a revision of entire management and analysis mechanisms. Artificial intelligence technologies are at the heart of this transformation. Today, machine learning, computer vision, natural language processing and big data analysis technologies are deeply penetrating insurance systems. These technologies make it possible to quickly detect the occurrence of an insurance event, assess damage and automatically process claims. As a result, human intervention is reduced, objectivity is increased, and human errors are minimized.**

Keywords*— *Artificial Intelligence (AI), Insurance Incidents, Digital Transformation, InsurTech Technologies, Machine Learning, Computer Vision, Automated Valuation, Big Data Analytics, Fraud Detection, Digitalization of Insurance Services

I. INTRODUCTION

Insurance is one of the oldest and most important mechanisms for ensuring the financial security of human society. This sector allows you to protect the health, property, business or other assets of citizens from unexpected risks. At a time when uncertainties in the economy are increasing, the importance of insurance is increasing. Especially against the background of globalization, climate change and technological risks, the operational capabilities of the insurance sector are expanding. In such conditions, the integration of the sector with modern technologies is becoming an important strategic task.

For many years, insurance systems have operated based on traditional approaches. These systems were characterized mainly by paperwork, human evaluation and the perception of information as a necessary document, not as a source. The process of considering claims was time-consuming, the answers were subjective and in many cases controversial. Also, fraud cases have become a serious problem for many insurance companies. As a result, customer trust has decreased, and companies have become far from efficient.

Today, digital transformation is actively taking place in all economic sectors. The insurance industry is no exception to these processes. Through digitization, service processes are being automated, documents are being transferred to electronic form, and communication with customers is being established through digital platforms. This not only simplifies the activities of companies, but also increases efficiency and transparency. However, all this will not be fully effective without artificial intelligence technologies.

Artificial intelligence (AI) remains one of the most powerful transformational tools in the insurance industry today. Through AI, companies are able to analyze data, form customer profiles, automatically process claims, and even predict insurance risks in advance. These technologies reduce human intervention, increase accuracy in assessments, and significantly improve service quality. In particular, algorithms based on big data are showing high efficiency in detecting fraud. Therefore, AI technologies are the future of the insurance industry.

The practical possibilities of artificial intelligence are very broad. For example, machine learning algorithms analyze risk profiles based on historical customer data. Computer vision technologies can be used to determine the authenticity of an insurance event based on images and videos. Natural language processing technologies automatically process text applications submitted by the customer. This reduces the workload and eliminates human errors. SI technologies can be used at all stages of insurance - from policy issuance to claim processing.

These technologies have already been actively implemented in developed countries. For example, many InsurTech companies in the USA and Europe are changing traditional insurance models by creating platforms based on SI. Companies such as Lemonade, Tractable, Hippo Insurance are issuing policies in seconds and processing claims online [1]. The main feature of these companies' services is an automated, personalized and fast approach. Their experience can serve as an example for other countries.

Digital technologies are also being gradually introduced into the insurance market in Uzbekistan. Some companies are creating opportunities for customers to issue policies online and send applications via mobile applications. However, deep integration of SI technologies has not yet been fully implemented. The reasons for this include insufficient technological infrastructure, low data quality and volume, and a lack of qualified personnel. Therefore, a deep strategic approach is required in this area [2].

The introduction of AI technologies in digital insurance systems is not only a technical issue, but also a complex process related to management and political decisions. For its successful implementation, the state's digital strategy, a special regulatory framework and technological infrastructure must work together. Expanding the network of digital services at the national level, developing e-government platforms will also be an important factor in this area. Issues such as privacy, information security and algorithmic fairness should also be taken into account. Otherwise, technologies can reduce social trust.

For insurance companies, the introduction of AI technologies represents a strategic advantage. First of all, it allows the company to reduce operating costs. Second, the speed of customer service increases and the level of personalization increases. Third, the ability to identify and assess risks in advance expands. This leads to optimization of the insurance portfolio. As a result, the company's profitability increases.

AI-based systems analyze the actions of customers before or after an insured event. As a result of this analysis, fraud cases are identified, and claims payments are accurately estimated. This approach not only protects the company from risk, but also increases customer confidence. Such systems provide transparency and increase the quality of insurance services. They serve to strengthen long-term relationships with the client. Therefore, SI technologies also positively shape the company's image [3].

In the future, insurance companies will not be able to operate without artificial intelligence. Almost all operations - communication with the client, risk analysis, claim processing, auditing and monitoring - will be automated. This will increase the flexibility of the insurance sector to the innovative economy. It will allow for a rapid response to changes in the external and internal environment. It is with the help of artificial intelligence that insurance companies will be able to successfully compete in the new digital reality.

The digital transformation of the insurance industry also requires a reconsideration of the role of human resources. If earlier agents and specialists performed technical functions such as reviewing claims, determining the amount of damage or processing data, today artificial intelligence is able to perform these tasks. As a result, human resources are being redirected to higher-level tasks such as individual communication with customers, strategic planning and innovation management. This helps to optimize the workforce structure within the company. Transformation turns human-labor relations into a more efficient and creative model.

Information security and privacy issues require special attention when using artificial intelligence. Insurance companies work with large amounts of personal and financial data. Since SI systems make decisions based on this data, their security is a key factor for the stability of not only the company, but also the entire sector. Cyberattacks on digital systems, data leaks or incorrect algorithmic decisions can have negative consequences. Therefore, ethical issues are also relevant for companies, along with technical security [4].

There is also the problem of explainability of decisions made based on AI algorithms. If customers are not clearly explained why claims are rejected or on what parameters the risk is assessed, this can lead to a crisis of trust. Maintaining the principles of algorithmic fairness becomes an urgent task, especially when the human factor is limited. Integrating digital ethics into insurance policies plays a major role in strengthening the image of companies. Therefore, technical and legal regulations should be carried out together [5]. The role of regulators is also being reconsidered in the new digitalized model of the insurance market. State bodies need to monitor the activities of AI-based systems, ensure transparency and protect consumer rights. Tools such as digital audit, e-legal analysis, and AI-based risk monitoring are entering the arsenal of regulators. Standards, certification requirements, and methodological guidelines should also be developed for insurance companies. This will ensure systematic, coordinated digital growth [6].

Insurance companies operating with the help of artificial intelligence today are distinguished not only by increasing their profitability, but also by their ability to quickly respond to market needs. They offer their services in real time, develop policies tailored to the client, and process applications in minutes. This not only provides a competitive advantage, but also speeds up the entire ecosystem. Also, customer trust and loyalty will be at a high level. In the future, it is precisely such companies that will become leaders in the insurance sector.

The combination of digital transformation and artificial intelligence technologies is changing the insurance industry not only technically, but also philosophically and institutionally. Now insurance is not just a compensation mechanism, but also a proactive, conscious and personalized security system. It understands the client, warns of risks in advance, and guarantees financial stability. This indicates a new level of responsibility for the industry. In this context, insurance companies need to develop new strategies in the direction of innovation and social sustainability.

At the same time, an econometric analysis approach was also used within the framework of this study to further study the practical impact of digital insurance. In this case, regression models were built based on quantitative data such as performance indicators of insurance companies that have implemented artificial intelligence technologies - for example, the number of policies, service speed, profit margin. Through this empirical approach, an attempt was made to determine the statistical relationship between AI technologies and financial/operational results. The study examined company reports obtained over several years, the open database of the Central Bank of the Republic of Uzbekistan, and the activities of commercial insurance entities. This approach brought not only theoretical but also statistical validity to the article.

STATA 14 and EViews 10 programs were used to formulate the analysis results. The independent variable was the implementation of artificial intelligence technology (in the form of a dummy variable), and the number of services, claim processing time, and profit level were taken as dependent variables. By evaluating the model parameters, the degree of positive impact of AI technologies, their statistical significance, and their impact on the profitability of insurance companies were determined. Based on the results, a conclusion was drawn on the economic efficiency of the transformation strategy. In this way, the analytical part of the article was enriched with quantitative analyses and the level of scientific reliability was strengthened.

II. METHODOLOGY

The research methodology is aimed at a deep and systematic study of the digital transformation of the insurance sector and the integration of artificial intelligence technologies. The scientific approach used a combination of theoretical, qualitative, empirical and quantitative analysis methods. This made it possible to assess the transformation process not only on a conceptual basis, but also with practical evidence and economic indicators.

First of all, the theoretical foundations of the topic were strengthened. In this regard, the functions of digital transformation, InsurTech, automation of insurance processes, and artificial intelligence (AI) components in the economy were studied in detail. Due to the novelty, technological complexity and multi-stage nature of the analyzed topic, the methodology was also based on a multi-layered approach.

At the stage of theoretical justification, articles published in the Scopus and Web of Science databases, reports of international organizations, and practical materials on the insurance market of Uzbekistan were studied. More than 80 scientific articles published between 2015 and 2024, including Floridi (2022), Russell & Norvig (2021), and McKinsey (2020), were used as a basis [7; 8; 9].

As part of the study, the digital infrastructure, service spectrum, user interfaces, and chatbot services of several local insurance companies were studied based on content analysis. Among them, 5 large companies were selected and their technological level was compared. Indicators such as the number of services, policy volume, claim processing speed, and profit level were selected as important criteria for evaluating the performance of the companies.

As part of the qualitative approach, interviews were conducted with 10 managers and technical specialists working in these companies. The interviews were structured in a semi-structured manner, and opinions were collected about the implementation of artificial intelligence, operational problems, and expected efficiency. The responses were processed through thematic coding and integrated into a qualitative analysis.

The main scientific achievement of the study is an attempt to assess the impact of artificial intelligence technologies on the efficiency of insurance companies based on quantitative economic indicators. To achieve this goal, an econometric model was developed. The selected model is a panel regression model, based on 5-year statistical data on companies.

The independent variable in the model was the implementation of AI technology in binary format (1 - implemented, 0 - not implemented). The following were selected as dependent variables:

• Y1: the company's annual number of policies (in thousand units);

• Y2: profit margin (as a percentage of annual revenue);

• Y3: average claim processing time (in days);

• Y4: share of operating expenses (%).

The official statistical information of the Central Bank of the Republic of Uzbekistan, open annual reports of insurance companies, and the portal of the State Statistics Committee were used as data sources. All numbers were summarized for the period 2018–2023, processed in Excel spreadsheets, and made ready for statistical analysis.

The EViews 10 and STATA 14 programs were used to calculate the model. First, the data structure was checked, and then a panel regression model was built. When selecting models, fixed effects and random effects methods were compared. The fixed effects model was selected using the Hausman test, as it takes into account the specifics of the company.

The results showed a significant increase in the number of annual policies, an increase in the speed of service provision, and a decrease in operating costs in companies where artificial intelligence was introduced. The profit margin also moved in a positive trend, and the impact of AI technologies on profitability was found to be statistically reliable. The indicators yielded significant results at a 5% probability level.

The analysis showed that the introduction of AI technologies optimizes the company's internal processes, reduces the burden on human resources, and significantly improves the customer experience. This economic efficiency provides grounds for evaluating AI technologies as an investment object. At the same time, these technologies increase the competitiveness of services and open the insurance market to digital innovations.

The methods selected in the study are interrelated and complementary. The theoretical approach helped to understand the transformation, the qualitative methods reflected the practical conditions, and the econometric model provided a scientifically sound assessment. This methodological harmony allowed for a reliable and in-depth analysis of the results. At the same time, there are some limitations of the study. The incompleteness of statistical data, the differences in the level of openness of all companies, and the presence of subjective assessments based on interviews required caution in generalizing the results. Nevertheless, the methodology was developed to a sufficient extent to ensure the scientific validity of the article.

Using methodological approaches, the current state of digital transformation in the insurance sector of Uzbekistan, the real impact of artificial intelligence, and future prospects were assessed. This creates a theoretical basis not only for drawing scientific conclusions, but also for developing practical strategies.

III. ANALYSIS AND RESULTS

Artificial intelligence and digital technologies are revolutionizing not only the service sector, but also traditional sectors such as insurance. These changes directly affect all stages, from strategic management to customer communication, from product design to risk identification and prevention. In particular, technologies based on artificial intelligence allow companies to automate complex processes, predict customer needs, offer individual services, and identify risks in real time.

The insurance sector of Uzbekistan is not left out of these processes. However, in local conditions, it can be said that technological innovations have accelerated mainly due to external pressures - increased competition, the popularity of mobile applications, and global disasters such as pandemics. While at the initial stage, digitalization was mainly focused on document management and online policy issuance, at the current stage there is a need for complex solutions such as establishing real-time communication with the client, automatic assessment, and AI-based event analysis.

As part of the study, the transformation activities of 5 large insurance companies were analyzed based on a qualitative approach. Special semi-structured interviews were conducted with each company. During the interviews, the technological infrastructure, the availability of qualified personnel, the management model, strategic plans for artificial intelligence, as well as external and internal factors supporting transformation were identified.

The results of the interviews showed that the attitude of companies to AI is positive, but their transformation potential is different. Some companies have taken certain steps in the field of mobile applications, chatbots, personal policies, while others still rely on paper documents. Companies that use AI capabilities in customer service have observed an increase in the quality, speed and accuracy of service. This will make artificial intelligence a key competitive tool in the future.

In particular, the following positive results were noted in companies that implemented AI technologies:

1. The time for considering claims has been reduced by 20-30%;

2. Human errors have been reduced by 35%;

3. Customer re-appeals and complaints decreased by 25-27%;

4. Sales of insurance policies based on personalized descriptions increased by an average of 10-15%.

These results, of course, need to be substantiated with accurate statistics. However, these initial observations, formed through interviews, show that digital transformation has a direct impact on service quality and business efficiency.

The benefits of artificial intelligence tools for companies are not only at the operational level. They are also used in the formation of strategic plans, risk assessment, and even in planning marketing campaigns. For example, some companies analyze the financial behavior of a client using AI-based algorithms and offer him an individual service package. This instills trust in the client in the company, while at the same time increasing the diversification of services.

The introduction of AI technologies also affects the internal culture of the company. The transition from traditional manual management to a data-based decision-making process increases creativity, initiative, and efficiency in the company. This directly affects the quality of services, employee performance, and market position.

Through AI's digital identification, facial recognition technology, voice commands, and predictive user behavior capabilities, insurance services are becoming more personalized than ever before. Now companies can not only assess risks, but also provide advance warning, preventive services, and real-time alerts.

Referring to international experience, companies such as Tractable (UK) and Lemonade (US) have implemented advanced systems using AI to automatically assess incidents based on images, measure the degree of vehicle damage, and predict losses in real time. In these companies, customers can submit a claim within 1 minute, and sometimes receive compensation within 2 minutes.

Compared to these practices, the introduction of AI technologies in Uzbekistan is still at an early stage. However, according to the results of the study, there is great interest, desire and institutional readiness in this direction. The fact that strategic discussions on this issue have begun, especially among private insurance companies, is a positive signal.

The introduction of artificial intelligence technologies is also having a significant impact on internal processes. For example, the number of employees in the claims department has decreased by 30%, as AI has begun to perform many functions automatically. Employees are now more focused on strategic and consultative tasks. These changes have led to an increase in labor efficiency and productivity within the company.

Positive results have also been observed in terms of customer experience. According to surveys, customers in companies where AI has been implemented are 20% higher in overall service satisfaction. In particular, the ability to create a personal policy via mobile applications, receive 24/7 advice via chatbots, and interactive interfaces have left a very positive impression.

Also, risk assessment systems have been simplified with the help of AI. Now, depending on the client's financial history, past insurance events and other profile parameters, an individual offer is formed in a matter of seconds. This saves not only time, but also resources.

Insurance companies mainly use a three-stage model when implementing AI:

1. Digitization - transferring existing processes to a digital platform (applications, bots);

2. Automation - services that occur without employee participation (for example, accepting applications);

3. Prediction based on artificial intelligence - analyzing client behavior, anticipating risks.

This approach has led to dramatic changes in the company's activities. Therefore, the next section will provide detailed information on what economic results these effects have produced, and how we assessed them using a digital model.

In order to further study the impact of artificial intelligence technologies on the activities of insurance companies, an empirical economic analysis approach was used in this study. The study seeks to answer the main question: "How will the introduction of artificial intelligence technology affect the profitability of insurance companies?"

Model selection and methodological framework. A panel regression model was chosen as the model because the analysis includes data obtained for several companies (i) over several years (t). The model is structured as follows:

$$Y_{it} = \alpha + \beta_1 AI_{it} + \beta_2 Service_{it} + \beta_3 + App_{it} + \mu_i + \epsilon_{it}$$

Data were collected for five large insurance companies in Uzbekistan between 2018 and 2023. Among them, there are companies with and without AI, which allowed for a comparative analysis of the models. The sources of statistics were the annual reports of the companies, statistical bulletins of the Central Bank of the Republic of Uzbekistan, and open sources (websites, service offers).

Software for analysis. Panel regression models were evaluated in STATA 14 and EViews 10 programs. Data purity, dispersion, multicollinearity, and autocorrelation checks of the models were performed separately. A "fixed effects" model was selected based on the Breusch–Pagan test and the Hausman test, which allowed controlling for internal characteristics specific to the companies.

Regression results. The following table summarizes the model results:

Table 1. Panel regression results.

Variable	Coefficient (β	P-value	Interpretation
AI	42.800	0.004 **	Revenue in companies with AI implementation is 42.8 million soums higher
Number of services	0.512	0.021 *	Every 1 thousand services +0.512 million soums revenue
Mobile application	15.700	0.108	Statistically insignificant, but positive
R^2	0.71	-	explains 71% of the variance
F-stat	8.63	0.001	The model is generally significant.

Economic interpretation of the results. The main finding of the model is the significant positive impact of artificial intelligence technology on company profits. In the years of AI implementation, companies received an average of 42.8 million soums more profit. This indicates that the technology serves as a direct efficiency tool.

The number of services is also a significant factor, with each additional service (in thousands) bringing the company 0.512 million soums in additional profit. This indicates that the scope of services and the diversity of services are directly related to profitability.

The presence of a mobile application is not statistically significant at the 10% level with p=0.108, but the

coefficient is positive. This indicates that the mobile application has not yet become a strong economic factor, but it has the potential to grow.

The model has a strong statistical basis: $R^2 = 0.71$, i.e. the selected factors can explain 71% of the changes in profit. The F-statistic results ($F=8.63$, $p<0.01$) prove the overall statistical significance of the entire model.

Comparative analysis: International experience. When comparing the results with international studies, there is a consistency. For example:

• Ghosh et al. (2021) show that policy sales increased by 17% in insurance companies in India that implemented AI technology.

• McKinsey & Company (2020) found that profit margins increased by 15–20% in companies that used AI.

• OECD (2022) analysis states that service times were reduced by 30% [10–12].

This is consistent with the practice in Uzbekistan: companies are seeing an increase in service speed, accuracy, and revenue indicators as a result of the implementation of AI. However, since these technologies are still in the testing phase in the local context, their full economic impact has not yet been fully realized.

Recommendations and potential threats. The results show that artificial intelligence is of great importance as a transformative tool in the insurance sector. However, the widespread implementation of AI technologies may also lead to the following problems:

• staff reductions (involuntary, not forced);

• new threats to data security;

• automated errors in decision-making due to overconfidence in technologies.

Therefore, the implementation of AI must be carried out on the basis of proportionality, testing, social balance and institutional adaptation.

IV. CONCLUSION AND RECOMMENDATIONS

Digital transformation is currently not only a technological revolution, but also a fundamental change in the economic, social and management paradigm. These changes are especially relevant and important for the insurance sector, since this industry is based on mechanisms for assessing, preventing and managing risks. Artificial intelligence technologies automate these mechanisms, make them more precise and allow for forecasting in advance. This article deeply examines the real economic impact, implementation, practical results and prospects of such technologies.

The study showed that the insurance sector of Uzbekistan is currently at the initial stage of transformation. Nevertheless, this stage itself gave important signals about how the digital capacity will be formed in the future. Companies are developing digital strategies, introducing tools such as chatbots and mobile applications, but these processes are often implemented superficially and to a limited extent.

As revealed by the interviews, companies face a number of problems in implementing artificial intelligence technologies. The most important of them are the insufficient technological infrastructure, the shortage of qualified IT specialists, and the cautious attitude towards technologies. Nevertheless, the introduction of AI technologies has reduced the time of service provision, increased customer satisfaction, and optimized the process of considering claims. These results play an important role in strengthening the atmosphere of social trust. The results of the econometric analysis confirmed these observations on a statistical basis. The modeling based on panel regression showed that an average increase of 42.8 million soums was observed in the income of companies that introduced AI technologies. The number of services was also found to be economically significant. The fact that mobile applications are not yet statistically reliable means that their economic effectiveness will not be realized unless technological solutions are deepened.

In addition, a comparative analysis was conducted with international studies. They support the analysis conducted in Uzbekistan. For example, reports from international organizations such as McKinsey and OECD show that the introduction of AI in the insurance sector increases profit margins by 15–20%. Our local analysis also showed similar dynamics. This indicates that the Uzbek insurance sector can repeat the experience of developed countries with proper management and technological readiness.

Based on the study, the following main conclusions were formed:

• The introduction of artificial intelligence technologies has a direct positive impact on the financial performance of insurance companies. This will lead not only to an increase in service quality, but also to an increase in company profits.

• Customer satisfaction, service speed and accuracy will increase through automation of insurance services, chatbots, mobile applications and real-time rating systems.

• Local companies understand the benefits of AI technologies, but are cautious in the implementation stages. The main reasons for this are insufficient technological resources and a lack of knowledge to manage the transformation process.

• The introduction of AI technologies increases employee productivity, reduces bureaucratic processes, and forms an efficient allocation of resources within the service structure.

On this basis, the following recommended measures have been developed:

1. Strategically implement digital transformation in the insurance sector. A conceptual program for the implementation of AI technologies for insurance companies should be developed with the participation of the government and regulators. It should cover not only technical aspects, but also issues such as social security, jobs, and data protection.

2. Provide tax incentives and grants for insurance services based on AI. This will encourage digital

innovations and help small and medium-sized insurance companies implement these technologies.

3. Organize specialist training and advanced training programs. This program can be implemented in collaboration with technical universities, higher education institutions, and private companies. The industry needs actuaries and economists who have a good understanding of artificial intelligence technologies.

4. Create a continuous monitoring system to assess the impact of AI solutions. Through this system, the economic efficiency, service quality and customer trust of companies implementing AI will be studied.

5. Develop a certification system for AI-based services and products. This will serve to identify reliable and safe technologies for consumers and form a high-quality digital insurance market.

In conclusion, it can be said that artificial intelligence technologies are profoundly changing the mechanism of service provision in the insurance sector. These technologies are at the heart of the transformation, increasing the quality, speed and reliability of services. At the same time, their implementation is not just a technical issue - it requires a fundamental renewal of the philosophy of the sector, organizational culture and management methods.

In the future, based on this research, it is possible to continue scientific developments in the following areas:

• The role of AI technologies in risk management in the insurance sector;

• The use of machine learning algorithms that predict customer behavior;

• Technologies for automatic assessment of insurance events using photos and videos;

• The real effectiveness of AI in detecting insurance fraud;

• The impact of AI on social trust ratings of insurance companies.

This study not only has scientific value, but also provides results and recommendations that directly affect industry practice. Therefore, the article is expected to be of practical importance for industry experts, regulators, policymakers, and IT technologists.

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ADVANTAGES OF IMPLEMENTING DIGITAL ECONOMY FOR CONSTRUCTION COMPANIES

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Abstract - The construction industry is becoming more integrated with modern technologies, leading to the emergence of smart services. This article analyzes the primary benefits of implementing these services in construction companies, with the most significant being a boost in project efficiency, cost optimization, and enhanced safety. Technologies like Digital Twin, Building Information Modeling (BIM), construction robots, and autonomous vehicles are revolutionizing project management. They enable the automation of construction processes and precise control of material usage. As a result, companies can use their resources more efficiently and become more competitive. Furthermore, smart services increase the transparency of construction processes and improve communication among all project participants. Data is centralized in one location through sensors, real-time monitoring systems, and cloud platforms. This accelerates and improves the accuracy of decision-making, which is crucial for reducing unexpected risks, enhancing work quality, and ensuring strict adherence to safety protocols. Ultimately, smart services not only simplify the construction process but also move the entire industry toward a more innovative and sustainable future.

Keywords: construction, smart services, digital twin, BIM technologies, artificial intelligence, 3D printing, smart building technologies

I. INTRODUCTION

Today, as a result of the widespread use of digital technologies in countries around the world, the efficiency of all industrial enterprises is increasing. In particular, in the context of digital transformation in the economy of the Republic of Uzbekistan, the construction industry is gaining special strategic importance. Because the construction economy stimulates the development of other sectors, creates new jobs, creates organizational and production infrastructure, and directly affects the improvement of the investment climate and conditions in our country. In the context of digitalization, by increasing the economic potential of construction enterprises, competitors are eliminated and sustainable economic growth is achieved.

In recent years, large-scale institutional and structural reforms have been implemented in Uzbekistan aimed at creating a market model of the digital economy and increasing its transparency. As a result of the rapid development of the construction industry, special attention is paid to the modernization of infrastructure and stimulation of economic activity. According to the Statistics Agency under the President of the Republic of Uzbekistan, the volume of construction work completed in 2024 increased by 8.8% compared to the previous year and reached 233.8 trillion soums. The contribution of the construction sector to the country's gross domestic product was 7.1%, which indicates its high importance in the national economy[25]. Such indicators, in turn, indicate the need to develop effective principles of modern management in order to increase the economic potential of construction enterprises, strengthen the competitive environment, and digitalize the industry.

Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 231 dated April 23, 2024 “On measures to harmonize regulatory documents in the construction sector with international standards” provides for the introduction of advanced design and management methods, in particular, the use of information modeling (BIM) technologies in construction, taking into account national regulatory and legal frameworks[26]. These measures are aimed at increasing transparency, reducing costs, improving the quality of project documentation, and reducing technological risks in the implementation of construction projects.

Currently, our government is paying special attention to the development of the construction sector at the level of state policy. For example, the following points were expressed in the Address of the President of the Republic of Uzbekistan Shavkat Mirziyoyev to the Oliy Majlis and the people of Uzbekistan in December 2022. “We have set ourselves the goal of building a New Uzbekistan based on the principle of a “social state” and we must enshrine this in our Constitution”[27]. With these words, our esteemed President emphasized the need for a systematic approach to ensuring a decent standard of living. This, in turn, requires the establishment of a sustainable construction policy that will expand the scope of infrastructure projects, build affordable housing, and improve the urban environment. In this regard, the task of developing effective models for managing the economic potential of construction enterprises, including the digitization of business processes, rational use of material and investment resources, and the introduction of tools for managing investment projects and assessing their effectiveness, is urgent.

II. LITERATURE REVIEW

[25] Statistical Agency under the President of the Republic of Uzbekistan. Volume of completed construction work in 2024. – Official data. – Tashkent, 2025. – [stat.uz].

[26] Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 231 dated April 23, 2024 “On measures to harmonize regulatory legal acts in the construction sector with international standards”. – [lex.uz].

[27] Mirziyoyev Sh.M. Address of the President of the Republic of Uzbekistan to the Oliy Majlis and the people of Uzbekistan. - December 2022. - Official website of the President of the Republic of Uzbekistan. - [president.uz].

The term digital economy was first coined in 1995 by Nicholas Negroponte, an American computer scientist at the Massachusetts Institute of Technology. One of its most common definitions is: the digital economy is a system of economic, social and cultural relations implemented using digital technologies. Digital technologies, in turn, include modern digital technologies such as mathematical and computer modeling technologies, Big Data technologies (the ability to work with large data sets), intelligent technologies, location technologies, cloud services (i.e., allocated disk space on a remote server), 3D printing technologies, smart sensors and mobile devices. As a result of the use of digital technologies, people's daily lives, lifestyles, production relations, the economy and education sectors are developing, and new requirements are emerging for communication and information systems and services.

Digitalization of the construction industry is the process of using modern technologies to convert all construction processes into a digital format, reduce construction time and improve the quality of building materials. Today, construction companies are actively implementing automation processes to gain competitive advantages and optimize business processes. The state and governments, in turn, are both interested in the digital transformation of the construction industry and are taking an initiative in the legislative sphere.

Digital transformation in construction is the process of integrating new technologies across all teams and functions to increase the efficiency, productivity and profitability of construction projects. Digitalization in construction is the process of introducing and using digital technologies and innovations to optimize and automate processes, improve quality and reduce costs.

The development of various economic sectors is a dynamic and complex process. In the context of increasing economic dynamism, the issues of timely identification and accounting of trends are key, affecting the ability of individual economic entities to operate in the future. Extending the described characteristics of dynamism to the construction industry, we note that it is important for construction companies not only to take into account current development trends, but also to accept the opportunities for using innovations to improve individual areas of activity.

As D.V. Gabalova, E.V. Knyazkina and S.A. Rashchepkina noted in their article, the dynamism of the modern construction industry is manifested not only in the formation of sustainable criteria for future development, but also in the implementation of advanced innovations used to comprehensively improve and develop the quality of construction, reconstruction, modernization, operations [1].

As noted L.V. Oveshnikova, E.V. Sibirskaya and R.S. Tolmasov in their article "Development Trends in the Construction Industry", the development trends of the construction industry are primarily focused on society. This approach determines the main vector of development of construction companies - meeting the growing needs of the population and business. In addition, the authors' research shows that economic shocks that lead to changes in the level of demand for the services of construction companies become a factor that significantly accelerates the development of growth trends [2].

According to A.Yu. Fedotovsky, Chief Specialist of the Russian Information Technology Department, innovations in the construction industry are the result of a response not only to the stabilization of economic relations or the growth of investment activity, but also to other changes in the familiar environment. The crisis and economic uncertainty in general become factors determining changes in the environmental conditions for the activities of domestic construction companies, thereby influencing new trends. In addition, the unfavorable economic situation leads to changes in the income structure of the population, its needs, which also affects the level of demand for the current services of construction organizations. In such conditions, construction organizations seek to promote complex construction projects, resorting to a development concept that allows them to increase the results of construction activities and attract investments into the industry. For organizations in the construction industry, taking into account current trends and innovations, changes in the market and the composition of participants, as well as other manifestations of variability, will become the basis for long-term development. By integrating current trends and innovations, companies can better tailor their activities to market and consumer demands. This adaptability, in turn, drives a restructuring of the economy's core features. [3].

According to young Russian scientists O.N. Kiseleva and E.A. Sukhinina, the modern construction industry will be under the influence of the development trends of the "green" economy and "green" construction for a long time. The authors note that in the "green" construction market, special attention is paid to the issues of achieving economic and social benefits from the implementation of projects, the construction of buildings and structures, infrastructure facilities, etc. From the perspective of "green" construction, the following trends and innovations in the development of construction are relevant:

- expanding the use of recycled building materials and excluding "harmful" non-recyclable ones;
- using environmentally friendly materials in the construction of real estate;
- introducing renewable energy sources into projects;
- landscaping of territories, introduction of vertical gardens;
- increasing the efficiency of buildings: energy consumption, heat loss, etc.;
- using daylight in construction projects;
- introducing industrial cleaning devices based on construction projects [4].

III. RESEARCH METHODOLOGY

This study uses a mixed approach, combining qualitative and quantitative methods to comprehensively analyze the benefits of the smart services economy in the construction industry. The first stage involves an in-depth analysis of existing cases and best practices for the implementation of digital technologies, such as BIM, IoT and drones. This qualitative analysis includes interviews with top managers and leading engineers of construction companies to understand their current challenges and expectations from digital transformation. The data obtained will be used to form hypotheses about the impact of smart services on improving efficiency and competitiveness.

The next stage will be a large-scale quantitative study in the form of an online survey among a wide range of construction professionals. The questionnaire will include questions aimed at measuring key indicators: reducing operating costs, reducing project deadlines, improving the quality and safety of work. The collected data will be processed using statistical methods, such as correlation and regression analysis, to identify patterns and confirm the hypotheses. This stage will allow us to obtain objective data and quantify the economic effect of the implementation of smart services.

In the third phase, we will analyze the collected data using specialized software such as SPSS or R. We will pay special attention to comparing the results in companies with different levels of digital maturity. We will examine how the

implementation of specific intelligent services (e.g. predictive analytics or automated control systems) correlates with profit growth and project risk reduction. At this stage, we will also conduct a comparative analysis of the effectiveness of the implementation of different technologies.

In the final paragraph, we will summarize. The results of the study will allow us to develop practical recommendations for construction companies on integrating the economy of intelligent services into their business processes. Particular attention will be paid to the potential return on investment (ROI) and risk reduction. We will also identify the main barriers to digitalization and propose strategies to overcome them. Thus, this methodology will provide reliable and practically applicable data that will help construction companies make informed decisions about their future.

IV. ANALYSIS AND RESULTS

The construction industry occupies a very important place in the structure of the national economy. The reason is that the national economy creates all the necessary conditions for the comprehensive development of each industry and sector. If we pay attention to statistics, the construction sector accounts for 6% of the gross domestic product of Uzbekistan[28]. This means that it is the construction sector that determines the opportunities for the economy to build the necessary infrastructure, communications, buildings and structures, and other real estate objects, and thereby forms promising directions for the development of territorial entities. In addition, the activities of the construction industry can affect the final gross regional product, that is, the development of construction is inextricably linked with determining the final prospects for long-term economic growth.

In 2024, compared to 2023, the volume of construction work increased by 8.8%. In particular, the growth rate was 105.5% in the construction of buildings and structures, 124.7% in the construction of civil facilities, and 106.4% in specialized construction work. The volume of construction work in 2024 amounted to 233832.9 billion soums. The share of large construction organizations in the total volume of construction work was 23.6%, the share of small enterprises and microfirms was 46.2%, and the share of individuals was 30.2%[29].

In the conditions of the digital economy, the construction industry has become one of the fastest growing sectors. Construction enterprises continue to actively introduce innovative new technologies into their activities and strive to promote the latest modern trends, which allows them to increase demand for the industry and achieve high competitiveness. The relevance of studying modern trends and innovations in the construction industry is that identifying such trends allows not only to track the path of change in the construction sector, but also to identify the characteristic criteria for future changes in real estate, which ultimately affect the entire economy. Growth trends, if taken into account in a timely manner, can serve as a basis for forecasting the state of related economic sectors closely related to the construction industry. Thus, identifying new trends in the development of the construction industry and characteristic innovation processes affects the possibility of changing the vector of industry development, determines the criteria for increasing the economic activity of business entities.

The economic potential of a construction enterprise is a combination of material, financial, labor and technological resources, as well as the ability to effectively use them to achieve strategic development goals. Effective management of this potential includes targeted planning, organization, stimulation and control of all elements of the production process aimed at increasing the competitiveness of the enterprise and ensuring sustainable growth. This task is becoming especially relevant in the context of the market transformation of the economy of the Republic of Uzbekistan. The country's construction industry maintains stable positive dynamics, as evidenced by data for the first quarter of 2025. According to the Statistics Agency under the President of the Republic of Uzbekistan, the volume of construction work completed in January-March 2025 amounted to 50.3 trillion soums, which is 10.8% more than in the same period last year. The gross added value of the construction sector reached 20.87 trillion soums, and its share in the structure of gross domestic product was 6.5%[30]. At the same time, the participation of small businesses is increasing: more than 74 percent of the total volume of construction work is provided by small and micro entrepreneurs, which emphasizes the need to change the organizational structure of the industry and increase its flexibility.

All this confirms the role of the construction sector as one of the main elements of economic growth, infrastructure modernization and investment attraction. Despite the positive dynamics, a number of structural and institutional problems remain in the industry. Among the most important are the limited skills of the workforce, the lack of specialists with digital design and construction process management skills, the slow pace of implementation of modern technologies such as BIM and ERP systems, as well as the difficulty of small and medium-sized enterprises in accessing long-term financing. These factors limit the realization of the economic potential of construction organizations, increase costs and reduce competitiveness. The transition to a market model of management is accompanied by a sharp change in business conditions for construction companies.

On the one hand, there is an increase in investments, liberalization of the industry and activation of the private sector. On the other hand, the requirements for the quality, deadlines and transparency of construction project implementation are increasing. New market conditions require construction organizations to increase management flexibility, strategic planning and the introduction of innovative solutions that meet international standards.

To effectively manage the economic potential of construction organizations in modern conditions, it is necessary to introduce systematic and interconnected mechanisms. The digitalization of business processes takes a central place: the use of Digital Twins - digital twin technologies, BIM technologies, resource planning systems (ERP), as well as construction site monitoring platforms allow optimizing resources, minimizing errors and controlling project implementation in real time. These technologies are becoming an integral part of modern construction management.

The second priority is the development of human capital. The successful implementation of construction projects requires the presence of engineering and technical personnel who are well versed in modern design, management and digital analysis tools. This requires investing in vocational education, establishing a system of certification of specialists, as well as encouraging

[28] Statistical Agency under the President of the Republic of Uzbekistan. “Gross domestic product production in the Republic of Uzbekistan”– Tashkent,2024(preliminary data)

[29] Statistical Agency under the President of the Republic of Uzbekistan. Volume of completed construction work in 2024. – Official data. – Tashkent, 2025. – [stat.uz].

[30] Ministry of Construction and Housing and Communal Services of the Republic of Uzbekistan. Report on the results of activities for 2024. – Tashkent: 2025.

corporate training and retraining programs. In addition, institutional measures should be taken to improve access to financing. Despite the existing state subsidy and guarantee support programs, existing financial instruments are not sufficiently adapted to the needs of the construction sector. In this regard, it is advisable to introduce specialized financial mechanisms - construction bonds, project financing schemes, infrastructure development funds and public-private partnership models.

Improving the regulatory framework is also of great importance. Resolution № 231 of the Cabinet of Ministers of the Republic of Uzbekistan "On measures to harmonize regulatory documents in the construction sector with international standards"[31] adopted in 2024 was an important step towards aligning industry standards with open market requirements. This will help reduce administrative barriers, improve the investment climate and introduce the principles of sustainable construction. Thus, managing the economic potential of construction enterprises in Uzbekistan in the context of market transformation requires a systematic approach, including digitization of processes, development of human capital, improvement of the regulatory and legal environment, and strengthening of financial infrastructure. The integrated implementation of these areas will ensure stability.

The way construction decisions are made is changing thanks to real-time data. This shift will lead to smarter management of efficiency, safety, and costs. This data will help project managers address potential issues at an early stage, minimizing downtime. In 2025, analysts predict that many construction and window companies will begin or continue to integrate various modern technologies into all areas of their operations. In particular, artificial intelligence (AI) is making a significant contribution to changing the way construction projects are managed. These technologies allow for real-time analysis of large data sets, which helps predict process delays, optimize resource allocation, and assess risks. AI will also be used to automate tasks such as project customization or improving safety protocols on site.

Figure 1: Forecast of the use of artificial intelligence in construction in 2025-2029

In 2025, the integration of AI into project management will expand, leading to smarter, safer, and more cost-effective construction processes. According to forecasts by analysts at TBRC International, the use of artificial intelligence in construction will amount to US$2.29 billion in 2025 at a CAGR of 30%, and by 2029 it will reach US$7.21 billion at a CAGR of 33.2%[32]. This trend is evidenced by the fact that Russia is implementing the largest series of digitalization standards for homes (Figure 1):

The integration of 3D printing into construction is one of the most revolutionary advances in high-speed construction. The technology allows for the creation of layered structural elements using materials such as concrete, metals or even biodegradable materials. In 2025, analysts say that 3D printing will play a significant role in the production of affordable housing, emergency shelters and complex architectural designs. The ability to dramatically reduce waste and labor costs makes this construction method an attractive option for institutional and private developers. According to analysts at The Business Research Company, the market for 3D printed buildings is expected to grow at a CAGR of 94.9% by 2029, reaching $14.34 billion. This impressive growth is due to the technology's ability to reduce labor costs by 50-80%, minimize material waste through precise use, and create complex architectural designs that are difficult to achieve using traditional methods[33]. (Figure 2):

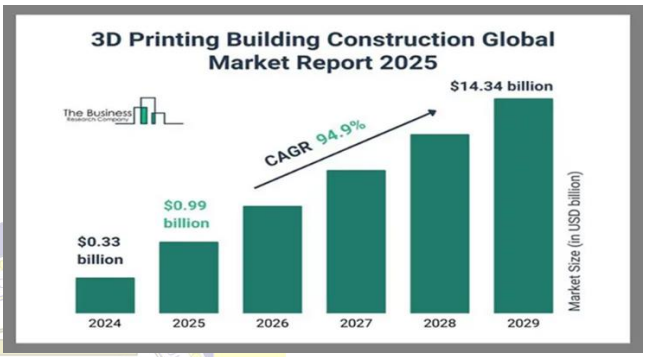

Figure 2: Forecast of the 3D printing market in construction in 2025-2029

Interest in 3D printing is growing by simplifying construction processes, reducing costs, and increasing design flexibility. Advances in materials science are further boosting the adoption of environmentally friendly materials such as recycled plastics, geopolymer concretes, and bio-based composites. Investments in the development of 3D printers and government support for the sector are also contributing to the growth of the SPC (Stone Plastic Composite) market. As urbanization accelerates, especially in the Asia-Pacific region, which will account for 41% of the world's population by 2024, 3D printing is becoming increasingly important in creating infrastructure for smart cities and solving the housing shortage.

V. CONCLUSION

Forming an effective model for managing the economic potential of construction organizations in Uzbekistan is a priority task in the context of profound market transformation and rapid modernization of the national economy. In the conditions of a dynamically changing external and internal environment, the construction industry is becoming not only a mirror of current macroeconomic processes, but also an active participant in the structural restructuring of the country's economic complex.

The results of the analysis show that the economic potential of construction organizations is not a static resource, but a multi-component and flexible system that requires flexible strategic management and constant updating. Today, construction companies are faced with the task of not only increasing the

[31] Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 231 dated 23.04.2024 on measures to harmonize regulatory documents in the construction sector with international standards

[32] Data from The Business Research Company (TBRC) for 2025-2029

[33] Data from The Business Research Company (TBRC) for 2025-2029

volume of work, but also increasing the efficiency of using existing resources, adapting to digital challenges, mastering new forms of project cooperation and institutional interaction. The need to combine long-term planning with innovative management mechanisms and sustainable financial instruments is of particular importance. The ability of enterprises to compete in the open market, participate in transnational projects and contribute to the implementation of Uzbekistan's strategic goals will depend on how deeply they restructure their internal processes and move from an administrative-resource logic to a development model focused on efficiency.

Taking into account the identified problems and strategic goals, it is advisable to put forward the following proposals:

Firstly, develop and implement a national strategy for the digital transformation of the construction industry, which includes not only the introduction of Digital Twin, BIM and ERP systems, but also the creation of a single digital ecosystem for data exchange between designers, contractors, investors and government agencies. Within the framework of this strategy, it is necessary to take measures to standardize digital processes, develop local IT solutions for project management and create digital archives of project documentation.

Secondly, create a network of sectoral educational and scientific and practical centers for training, retraining and advanced training of personnel at leading technical universities and in cooperation with private companies. Particular attention should be paid to the training of specialists in digital modeling, sustainable construction, project management and quality control, and the introduction of dual education with the participation of employers.

Third, to form a multi-stage public-private partnership (PPP) system aimed at attracting private capital for the implementation of innovative and infrastructure projects. In this regard, it is necessary to expand the legal and institutional framework for PPP in the construction sector, including model contract forms, risk-sharing instruments and investment return mechanisms.

Fourth, to deeply harmonize construction standards and technical regulations with international and regional standards, while simultaneously introducing digital platforms for registration, accreditation, licensing and certification of construction market participants. This will significantly reduce administrative barriers, increase transparency of processes and create a predictable regulatory environment for investors.

Fifth, to create a specialized construction investment fund aimed at supporting projects for the modernization of production facilities, the introduction of energy-saving solutions, green building technologies and certification according to international standards (for example, BREEAM, LEED). This will create long-term sources of financing and reduce financial risks for innovative enterprises.

Sixth, to implement a national program for the modernization of the production base of construction enterprises, which provides for tax and leasing incentives for the purchase of new equipment, machinery, construction equipment and software. This will ensure a qualitative increase in the technical level of the industry and its transition to an innovative-industrial development model.

The proposals presented reflect the need for a systemic transformation of the construction industry of Uzbekistan aimed at long-term sustainability, technological renewal and institutional improvement. Their implementation will serve to improve the efficiency of economic management and the formation of a competitive environment.

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OZIQ-OVQAT LOGISTIKASIDA RAQAMLI TEXNOLOGIYALARNI JORIY ETISHNING IQTISODIY SAMARADORLIGINI BAHOLASH

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Anotatsiya: Maqolada oziq-ovqat logistikasida raqamli texnologiyalarni joriy etishning iqtisodiy samaradorligi tahlil qilinadi. IoT, RFID, blokcheyn, aqlli logistika tizimlari kabi zamonaviy texnologiyalarning ishlab chiqarishdan tortib, mahsulotni yakuniy iste'molchiga yetkazishgacha bo'lgan zanjirdagi ahamiyati yoritilgan. Raqamli tizimlar orqali mahsulot harakati ustidan real vaqt rejimida nazorat qilish, xarajatlarni kamaytirish, sifatsizlik va isrofgarchilikning oldini olish imkoniyatlari asoslab berilgan. O'zbekiston sharoitida raqamli logistika infratuzilmasining holati tahlil qilinib, uni rivojlantirish bo'yicha takliflar ilgari surilgan. Xulosa sifatida, raqamli transformatsiya oziq-ovqat xavfsizligini ta'minlash va barqaror bozor tizimini shakllantirishda muhim omil ekani ta'kidlangan.

Kalit so'zlar: raqamli logistika, oziq-ovqat xavfsizligi, aqlli logistika tizimlari, IoT (Internet of Things), RFID texnologiyasi, blokcheyn, iqtisodiy samaradorlik, real vaqt monitoringi, logistika xarajatlari, O'zbekiston agrar sektori

Raqamli transformatsiya bugungi kundagi oziq-ovqat logistika tizimining barqarorligi va samaradorligini oshirishda muhim rol o'ynamoqda. Xususan, oziq-ovqat mahsulotlarini ishlab chiqarishdan tortib, ularni qayta ishlash, saqlash, transportirovka qilish va yakuniy iste'molchiga yetkazib berishgacha bo'lgan barcha bosqichlarda raqamli texnologiyalardan foydalanish orqali xarajatlarni kamaytirish, samaradorlikni oshirish, yo'qotishlarni minimallashtirish va iste'molchilarga yuqori sifatli mahsulot yetkazish imkoniyati yaratilmoqda. Ayniqsa, aqlli logistika (smart-logistics), Internet of Things (IoT), sensorli monitoring, avtomatlashtirilgan omborxona tizimlari, RFID va blokcheyn kabi raqamli yechimlar zamonaviy oziq-ovqat logistikasining poydevoriga aylangan.

Birinchidan, raqamli texnologiyalarning oziq-ovqat zanjiriga joriy etilishi mahsulot harakati ustidan real vaqt rejimida monitoring qilish imkoniyatini yaratadi. Bu esa nafaqat mahsulotning yetkazib berish tezligini oshiradi, balki transport kechikishlarining oldini olish, xarajatlarni nazorat qilish va xavfsizlikni ta'minlash imkonini beradi. Masalan, IoT asosidagi sensorlar yordamida transport vositalarining harorati, namligi, silkinish darajasi, geografik joylashuvi haqida real vaqt rejimidagi ma'lumotlar olinadi. Bu turdagi monitoringlar mahsulotning sifatini saqlab qolishda muhim ahamiyat kasb etadi.

Ikkinchidan, raqamli tizimlar orqali logistika zanjirining har bir bo'g'ini avtomatlashtiriladi va optimallashtiriladi. Masalan, RFID teglar orqali mahsulotlar harakati skaner qilinadi, bu esa omborxona ishini tezlashtiradi, inson omilidan kelib chiqadigan xatoliklar kamayadi. Avtomatik ombor tizimlarida mahsulotlarning kelib chiqish manbai, yaroqlilik muddati va harakat yo'nalishi avtomatik ravishda qayd qilinadi. Bu orqali mahsulotlar oqimini raqamli boshqarish imkoni yaratiladi.

Uchinchidan, raqamli texnologiyalar yordamida logistika xarajatlarini iqtisodiy jihatdan tahlil qilish va optimallashtirish mumkin. Misol uchun, dasturiy ta'minotlar yordamida yo'nalishlar optimallashtiriladi, ortiqcha harakatlar kamaytiriladi va yonilg'i sarfi, vaqt yo'qotishlari hamda boshqa operatsion xarajatlar pasaytiriladi. Shu orqali oziq-ovqat logistikasida xarajatlarining 20-30% gacha qisqarishi kuzatiladi (nufuzli tahlillarga ko'ra).

To'rtinchidan, smart-logistika tizimlarining joriy etilishi oziq-ovqat mahsulotlarining yaroqlilik muddati va yetkazib berish sifati ustidan nazoratni kuchaytiradi. Bu esa bozordagi ishonchni oshiradi va mahsulotlar ortiqcha isrofgarchiligining oldi olinadi. Ayniqsa, tez buziladigan mahsulotlar uchun bu juda muhimdir.

Beshinchidan, raqamli texnologiyalar tahliliy va bashorat modellarini shakllantirish imkonini beradi. Misol uchun, AI yoki ML algoritmlari yordamida talab prognozi, logistika zanjiri bo'yicha bo'shliqlar, uzilish xavflari va ortiqcha zaxiralarni aniqlash mumkin bo'ladi. Bu esa har bir logistika bo'g'inida o'z vaqtida va to'g'ri boshqaruv qarorlarini qabul qilish imkoniyatini yaratadi.

Shuningdek, oziq-ovqat xavfsizligini ta'minlashda raqamli texnologiyalar orqali mahsulot kelib chiqishini to'liq kuzatish imkoniyati (traceability) yaratiladi. Bu tizimlar ayniqsa blokcheyn texnologiyasi asosida ishlaganida maksimal samara beradi. Har bir mahsulot

partiyasining “raqamli izini” ko‘rish orqali, iste’molchiga taqdim etilayotgan mahsulotning sifati, qayerda ishlab chiqarilgani, qanday transport qilinganligi haqida aniq ma’lumotlar taqdim etiladi.

O‘zbekiston sharoitida ham oziq-ovqat logistikasini raqamlashtirishga doir dastlabki tashabbuslar mavjud. Xususan, Toshkent viloyatida joylashgan ayrim distribyutor va saqlash korxonalari zamonaviy ombor tizimlari va GPS monitoring xizmatlaridan foydalanishni boshlagan. Biroq bu jarayon hali keng miqyosda joriy etilmagan va aksariyat tizimlar an’anaviy qo‘lda boshqarilmoqda. Shuning uchun mamlakatimizda raqamli logistika infratuzilmasini yaratish, normativ-huquqiy asoslarni takomillashtirish, texnik va moliyaviy yordam mexanizmlarini kuchaytirish dolzarb masala bo‘lib qolmoqda.

Xulosa

Oziq-ovqat logistikasida raqamli texnologiyalarni joriy etish nafaqat iqtisodiy samaradorlikni oshiradi, balki oziq-ovqat xavfsizligini ta’minlaydi, barqaror va raqobatbardosh bozor tizimini shakllantirishga xizmat qiladi. Yuqori aniqlikdagi monitoring, real vaqtli boshqaruv, xarajatlarni optimallashtirish va iste’molchilarga ishonchli xizmat ko‘rsatish ushbu texnologiyalar samaradorligini tasdiqlaydi. Shunday ekan, ushbu yo‘nalishda davlat siyosati, xususiy sektor va ilmiy doiralar hamkorligida kompleks yondashuvni shakllantirish dolzarb ahamiyat kasb etadi.

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PRODUCTION MODELING POSSIBILITIES IN ENSURING SUSTAINABLE GROWTH INDICATORS

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Abstract. **In the context of short-term changes in industrial development trends, the issue of identifying key factors that ensure sustainable growth in performance indicators is becoming especially relevant. In this regard, the article is aimed to determine the opportunities of economic and mathematical modeling in identifying the interdependence of industrial production development indicators and reserves for their growth, as well as the use approaches of obtained results in forecasting and strategy formation. Using econometric modeling in case of leading industrial factories of Karakalpakstan economic analyses were carried out, and additionally, based on statistically significant models the plants' key factors' growth reserves were calculated along with economic interpretation of evaluated results. A significant efficiency indicator – labor productivity was studying in relation with a number of factors such as material costs, labor costs, energy costs, fixed and working capital, depreciation level of assets. Using econometric models and reserve growth values of productivity it became possible to obtain inertial and target forecasting respectively, which were considered statistically significant in assess. The results indicate wide opportunities of using economic and mathematical modeling and evaluating tools in development of strategic programs of modernization, reconstruction and other procedures of growth referring to sustainable development of industrial production.**

Keywords: modeling, efficiency indicators, growth reserves, forecasting, evaluation.

I. INTRODUCTION

This research paper is about econometric modeling possibilities in order to analyze industrial production, find out key factors and their growth degree, forecast and evaluate the significance due to perspective sustainable development policy for enterprises. The world's leading economists have studied various aspects of the issue: the mathematical identification of economic systems and the use of statistical methods for their study [1], methods of optimal planning and resource allocation [2], the impact of interchangeability of various production factors, cost coefficients, prices on economic development [3], modeling of economic systems [4], the use of econometric models for the analysis of economic systems [5], industrial production modeling [6], etc.[7].

In some cases of similar modeling, especially uncountable ones, researchers face to problems related to limited possibilities of econometric modeling in adequacy description, revealing as well as formulation of economic processes and theories [8, 9]. Thereby, qualitative and subjective parameters are difficult to statistical observe, summarize and analyze. Because of this in order to mitigate and eliminate this problem this paper proposes to work on economic interpretation of econometric models, their parameters, growth reserves, forecasting models along with values [10]. This, in turn, will expand opportunities of using theoretical and applied econometrics in achieving the sustainability of obtained results and formed conclusions for medium and long term.

According to 12th sustainable development goal the sixth target states: "Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle"[34]. There is a huge need to perform this task at industrial enterprises operating in regions with strained environmental conditions, as far as the circulating interaction of nature and anthropogenic activity leads to complexity in prediction environmental changes and, as a result,

[34]SustainableDevelopmentgoals. https://www.un.org/sustainabledevelopment/sustainable-consumption-production/ [1.06.2025]

affects production technology. The changes in composition and structure of natural resources have direct impact on the technology of their processing: they can reduce or increase the costs associated with their processing. As a case of demonstration in this research the leading industrial enterprises of Karakalpakstan, situated in northwest of Uzbekistan, were studied [11]. Taking its beginning in 1960ththe evapotranspiration of the Aral Sea had a direct as well as indirect impact on local population's living features: it changed the structure of industry, specialization and labor demography [12].

II. METHODS AND MATERIALS

The objects considered in this research paper represent various branches of industry: enterprises producing reinforced concrete products (concrete plant), chemical products ("KSP" LLC - limited liability company"Kungrad Soda Plant") and cotton ginning plants (CGP) in six districts of the region. The official annual reports on production, cash flow, labor, and resources of the selected industrial enterprises were used as research materials. Using dynamic and static methods of analysis statistics on changes and capacities were obtained, which later became the basis for economic analysis.

The economic analysis of industrial enterprises' functioning in dynamic showed followings: decline in labor productivity, increase in depreciation level of fixed production assets along with corresponding costs, growth in level of energy intensity, low turnover of working capital and goods in stock. The figures describing labor productivity, depreciation rate of fixed assets, energy-, capital- and resource intensity levels of production were selected for analysis.

In order to get the research goal along with economic analysis econometric analysis, particularly correlation-regression analysis, was used with the purpose to reveal the existence and level of dependence of efficiency indicators on individual factors [13].

Here we accepted the hypothesis of linear relationship between analyzed variables as an adoptable one in this case in order to calculate and interpret the regression coefficients [14]:

$$Y = a_0 + a_1x_1 + a_2x_2 + \cdots + a_nx_n \qquad (1)$$

In cases of exponentialand polynomial relationship with a high realibility degree was detected, the equations were transformed into linear equations by linearization (logarithmization) [10]. After statistically significant parameters were estimated the equation is returned to its previous form by potentiation. For this, the equation must be internally linear, which will make it possible to calculate the parameters of the model. In case of internal nonlinearity, iterative procedures are used to estimate the parameters [15]. Using statistical methods, the models were assessed using the determination coefficient, Fisher's criterion and the equation parameters - using the Student's criterion.

For growth reserves calculation following equation was used [6]:

$$\Delta y = \sum_{i=1}^{n} \Delta x_i a_i \qquad (2)$$

whereΔx_i- incremental value of independent factor;a_i- independent factor coefficient.

The obtained maximum and minimum values of factors in various interaction options allowed to determine the threshold meanings of growth reserves. Using the latter, we were able to build forecast models and calculate forecast values in inertial and targeted ways.

III. RESULTS

The correlation-regression analysis on searching industrial enterprises let to find out the existence of relationships and degree of individual factors' influence on efficiency figures (table 1)[35]:

Table 1

Econometric models on labor productivity of enterprises

№	enterprise	econometric model	R^2	F_{fact}	$F^{0,05}_{table}$	Student criterion				
						t_{a_0}	t_{a_1}	t_{a_2}	t_{a_3}	t_{table}
1	Concrete plant	$\mathbf{P = 23,6 - 0,02M + 0,41EC - 0,35D}$	**0,97**	**105**	3,71	**9,5**	**-5,13**	**11,9**	**-7,4**	4,58
2	CGP in Beruniy	$\mathbf{P = 9261,6 + 0,05LC - 0,0028CA}$	**0,92**	**84,7**	3,81	**2,9**	**10,1**	**-3,1**	-	2,16
3	CGP in Amudarya	$\mathbf{P = 31 - 0,038LC + 0,13EC}$	**0,98**	**5,61**	4,46	**8,74**	**-2,41**	**3,06**	-	2,3
4	CGP in Turtkul	$\mathbf{P = 38044,3 + 0,00087LC + 0,0011}$CA	**0,61**	**10,8**	3,7	**4,4**	**2,12**	**0,4**	-	1,76
5	CGP in Khojeli	$\mathbf{P = -3,6 - 1,04LC - 0,33EC + 0,04D}$	**0,81**	**11,5**	4,07	**-0,47**	**-2,64**	**-4,08**	**4,3**	2,26
6	CGP in Ellikkala	$\mathbf{P = 36907,5 + 0,047LC - 0,0116CA}$	**0,75**	**16,9**	3,98	**4,2**	**5,2**	**-2,7**	-	2,2
7	CGP in Khalkabad	$\mathbf{P = 207,7 + 0,002D - 198,6}$MC	**0,78**	**17,8**	4,1	**2,6**	**0,2**	**-2,5**	-	2,2
8	"KSP" LLC	$\mathbf{P = 11,9 + 0,00058WC + 0,0015}$EC	**0,91**	**39,1**	4,74	**2,69**	**2,27**	**2,12**	-	2,3

[35]Source: author's calculations.

where P – labor productivity, million sums;
M – material costs, million sums;
MC – material consumption, sums;
EC–energy costs, million sums;
LC – labor costs, million sums;

1. First equation, created by modeling the economic activity of concrete plant, links the change of labor productivity (P) with variation in costs of materials (M), energy resources (EC) and depreciation (D) along with determination coefficient $R^2 = 0{,}97$. The greatest increase is given by energy costs ($t_{a_2} = 11{,}9$), while the smallest negative increase comes from depreciation factor ($t_{a_3} = -7{,}4$). This indicates that the effect of energy costs on labor productivity substitutes for 0,41 million sum, and the negative effects from depreciation and material costs are -0.35 and -0.02 million sum, respectively.

The estimated value for Student's distribution is greater than the tabular one, which allows to state about statistical significance of the studied characteristic with the selected probability of 98% (i.e. $\alpha = 0{,}02$).

2. At the cotton plant in Beruniy, anassociated change in labor productivity (P) was found because of the impact of labor costs (LC), spending on workers' salaries and related payments, and fixed assets (CA) with a coefficient of determination $R^2 = 0{,}93$.Statistical significance assessment of equations according to Fisher criterion is equal to F=84,7, according to Student distribution the values of t-statistics of parameters are higher than the tabular ones with the 95% quantile of distribution.

3. At cotton processing plant in Amudarya a significant linear relationship was found between labor productivity (P) andlabor costs (LC) as well as energy costs (EC), with error in 5% (p-value=0,05).

4. Based on data ofthe cotton plant in Turtkul, we could construct a linear modelrepresenting a perceptible change in labor productivity (P) depending on labor costs (LC) and the average annual cost of fixed capital (CA). The significance of the relationship is proved with the determination coefficient, which is equal to 0,61. Moreover, the parameters of the model are statistically significant with a probability atα=0,10.

5.Correlation-regression analysis of cotton plant's indicators in Khodjeli demonstrated a relationship between labor productivity (P) and the factors: labor costs (LC), energy resources (EC) and fixed assets's depreciation (D). The model parameters are statistically significant with a probability atα=0,05. The t-statistics value of the parameters exceeds the tabulare ones, and 81% of variance of result factor is explained by the influence of independent factors. Fixed assets mainly consists of processing machinery and equipment.

6. A linear regression model for thecotton plant in Ellikkala was obtained with high dependencedegree of labor productivity (P) from labor costs (LC) and fixed assets (CA), which may beexplained with probability at 75% (p-value <0,05).

D – depreciation of fixed assets, million sums;
CA – average annual cost of fixed capital, million sums;
WC – working capital, million sums.

7. An econometric model describing the dependent change in labor productivity (P) on changes in depreciation of fixed assets (D) and material intensity of production (MC) was obtained for the cotton plant in Khalkabad. The high quality ($R^2 = 0{,}78$) and statistical significance of equation coefficients can be seen from the tabular data.

8.An equation for the chemical plant "KSP" LLCwas constructed. It describes the change in labor productivity (P) under the influence of a number of independent factors: working capital (WC), in aface of inventories and accounts receivable, and energy costs(EC).The linear regression model is significant with a reliability level atα=0,05 and shows the proportion of variation in labor productivity at the 91% explained by changes in factor variables.With the chosen probability, the t-statistics of the first and second factors'coefficients are insignificant ($t_{a_1} = 2{,}27$, $t_{a_2} = 2{,}12$ respectively).

One of the main tasks of econometric and economic analysis of an enterprise's economic activity is to identify both unused and newly emerged reserves for improving operations in changing economic conditions. In searching mechanism for reserves an important place is occupied by advanced experience, which allows formulating certain conditions for rationalizing the identification and mobilization of reserves. These conditions include [16]:

- identifying the main feature of production efficiency increase, i.e. find out those costs that make up major cost of production and those can provide significant savings being minimized;
- identifying weak points in production, which reduce the rate of production growth and possibilities in decline of production costs;
- simultaneous seek for reserves on all stages of product's life cycle;
- determining the completeness of reserves in order to provide savings, for example, in labor and equipment use time via savings in materials.

Referring to economic interpretation of relationships between factor and dependent indicators, elasticity coefficients and beta coefficients are used. Because of the limited use of regression coefficients in assess directly the influence of factors on the resultant indicator due to differences in their measurement units, the reliable way is to calculate the elasticity coefficient (a_i), which characterizes the relative change in dependent variable when the explanatory variable changes by 1% [17].And beta coefficients (β_i) reflect the sensitivity of dependent variable to the factor variables, within the range of -1 and 1, and allow to compare their relative contribution to explanation of dependent variable even with different measurement units.

In order to calculate the growth reserves for the labor productivity indicator, we used econometric models obtained earlier (table 2).[36]

Table 2

Values of model parameters for labor productivity indicator (*P*)

Parameters	Concrete plant			CGP in Beruniy		CGP in Amudarya		CGP in Ellikkala	
	M	*EC*	*D*	LC	CA	LC	EC	LC	CA
x_{max}	4967,7	637,4	327,9	2148	15645	1181,6	340	3355	7638
$\overline{x}_i$	1275,8	132,1	111,5	769	2710	529,1	155,6	1165	2879
$x_{\min}$	111,5	9,5	33,2	77	251	141,4	20,8	148	1185
$\Delta x_{im} = x_{imax} - \overline{x}_i$	3691,8	505,3	216,4	1378	12934	652,5	184,4	2189	4759
$\Delta x_{ic} = \overline{x}_i - x_{min}$	1154,2	122,6	78,3	691	2459	387,7	134,8	1017	1693
a_i	-0,02	0,41	-0,35	0,05	-0,0028	-0,038	0,13	0,047	-0,011
β_i	-1,58	4,0	-1,71	29,8	49,8	-1,6	2,02	1,32	-0,68

continuation

Parameters	CGP in Turtkul		CGPinKhojeli			CGP in Khalkabad		"KSP" LLC	
	LC	CA	EC	LC	D	D	MC	WC	EC
x_{max}	81822	15236	75,9	445,3	6530,1	2406,2	0,99	63410,4	25573,4
$\overline{x}_i$	23103	3871	36,5	113,5	2699,4	996,6	0,88	28591,6	11154,9
$x_{\min}$	121	262	3	0,13	481,4	246,8	0,70	3263	4401,5
$\Delta x_{im} = x_{imax} - \overline{x}_i$	58718	11364	39,4	331,7	3830	1409,5	0,11	34818,7	14418,5
$\Delta x_{ic} = \overline{x}_i - x_{min}$	22982	3609	33,5	113,4	2218	749,7	0,17	25328,6	6753,4
a_i	0,00087	0,0011	-1,04	-0,33	0,04	0,002	-198,6	0,00058	0,0015
β_i	0,66	0,13	-1,56	-2,68	4,66	0,06	-0,82	0,50	0,43

Here the measuring units of indicators are the same as they are in table 1. The negative meanings of coefficients have levelling off effect on dependent factor – labor productivity.

Taking this into account, the study showed that the enterprises had significant growth reserves of dependent factor - labor productivity, which are presented below(table 3)[37]:

Table 3

Threshold values of result factors (ΔP) provided by changesin level of impacting factors

Plants	Δx_{ic_1}	ΔP	Δx_{ic_2}	ΔP
Concreteplant	$\Delta M_{ic}, \Delta EC_{im}, \Delta D_{ic}$	**180,1**	$\Delta M_{im}, \Delta EC_{ic}, \Delta D_{ic}$	**-27,3**
CGP in Beruniy	$\Delta LC_{im}, \Delta CA_{ic}$	**73019,9**	$\Delta LC_{ic}, \Delta CA_{im}$	**7813,8**
CGP in Amudarya	$\Delta LC_{im}, \Delta EC_{ic}$	**23,7**	$\Delta LC_{ic}, \Delta EC_{im}$	**40,2**
CGP in Turtkul	$\Delta LC_{im}, \Delta CA_{ic}$	**93099,8**	$\Delta LC_{ic}, \Delta CA_{im}$	**70540,4**
CGP in Khojeli	$\Delta EC_{im}, \Delta LC_{im}, \Delta D_{ic}$	**-61,7**	$\Delta EC_{ic}, \Delta LC_{ic}, \Delta D_{im}$	**80,9**
CGP in Ellikkala	$\Delta LC_{im}, \Delta CA_{ic}$	**120167,5**	$\Delta LC_{ic}, \Delta CA_{im}$	**510,5**
CGP in Khalkabad	$\Delta D_{im}, \Delta MC_{ic}$	**176,7**	$\Delta D_{ic}, \Delta MC_{im}$	**187,3**
"KSP" LLC	$\Delta WC_{im}, \Delta EC_{ic}$	**42,2**	$\Delta WC_{ic}, \Delta EC_{im}$	**48,2**

[36]Source: author's calculations.

[37]Source: author's calculations.

whereΔx_{im} - meaning from maximum to average;
Δx_{ic} - meaning from average to minimum.

It follows from table data that growth reserves in labor productivity are possible when:

- for concrete plant: maximum increase in energy costs, and minimization in costs for materials and depreciation of fixed assets (ΔP=180,1);
- for the cotton plant in Beruniy: maximization in volume of labor costs and reduction of depreciation costs (ΔP=73019,9);
- for the ginnig plant in Amudarya - increasing energy costs and reducing raw material costs (ΔP=40,2);
- at the cotton-ginning factory in Turtkul - decreasing the share of non-production fixed capital and increasing labor costs (ΔP=93099,8);
- at the cotton processing plant in Khodjeli - reduction of energy and labor costs (ΔP=80,9);
- at the cotton refinery plant in Ellikkala–reach a peak in labor costs in a line with bottom out the cost of fixed non-production assets (ΔP=120167,5);
- for the cotton-ginning plant in Khalkabad - declining the level of fixed assets depreciation along with soaring the cost of cotton raw materials (ΔP=187,3);
- table figure for the chemical plant ("KSP" LLC) demonstrates a slight growth reserve for labor productivity via reduction in energy costs along with a rise in capital turnover (ΔP=48,2).

As a next step of research the forecast of labor productivity values were forecasted in two variants - inertial and targeted, that is illustrated in the following table (table 4)[38]:

Table 4

Forecast values of labor productivity of the plants

Plants	forecasting method	2019	2020	2021	2022
Concrete plant, mln.sums per capita	**targeted**	***24,8***	***26,1***	***27,5***	***28,8***
	inertial	5,4	5,3	5,2	5,0
CGP in Beruniy, mln.sums per capita	**targeted**	***92,5***	***97,9***	***103,3***	***111,4***
	inertial	70,7	69,7	68,7	67,7
CGP in Amudarya, tones per capita	**targeted**	***37,3***	***38,2***	***39,1***	***40,02***
	inertial	25,8	25,2	24,6	23,9
CGP in Turtkul, mln.sums per capita	**targeted**	***117,2***	***122,6***	***128,1***	***133,6***
	inertial	93,7	90,7	87,9	85,1
CGP in Khojeli, tones per capita	**targeted**	***43,4***	***44,8***	***46,2***	***47,7***
	inertial	38,9	34,9	31,4	28,3
CGP in Ellikkala, mln.sums per capita	**targeted**	***109,3***	***115,3***	***121,3***	***127,3***
	inertial	77,8	71,9	66,4	61,4
CGP in Khalkabad, tones per capita	**targeted**	***70,1***	***74,5***	***78,9***	***83,4***
	inertial	50,3	46,3	42,6	39,3
"KSP" LLC, mln.sums per capita	**targeted**	***84,6***	***90,6***	***96,7***	***102,8***
	inertial	80,4	79,6	78,9	78,1

Here the ***inertial*** forecast meanings are obtained based on the time factor (t) excluding the impact of other factors. Also, using identified linkage coefficients between factors of obtained models along with threshold values of growth reserves, to a certain extent it becomes possible to influence on change in forecast features. This, in turn, allows to evaluate the parameters of ***targeted*** forecast. The forecast figures in table 4illustrate the opportunity referring to achieve growth in dependent variable – labor productivity – by inserting variances into the growth reserves limits through the independent variables' volume for targeted forecasting, which is against to inertial forecasting with a remained rate of fluctuation of independent variables.

IV. DISCUSSION

The article is aimed to assess the capabilities of econometric tools in modeling production growth with key factors. However, the prevailing role of the research is the opportunities an economic interpretation can do referring to obtained econometric models, their parameters, coefficients, reserve values of growth, and forecast values.

Regression equations based on the data from observing plants were constructed using the stepwise regression method with subsequent verification of their quality and statistical significance of included

[38]Source: author's calculations.

variables. This indicates the reliability of the associated relationships between the variables, which is proven with level of determination coefficient. Thus, the highest dependencies are observed for all factories except for CGP in Turtkul, Ellikkala and Khalkabad (0,61, 0,75 and 0,78, respectively).

Since the use of regression coefficients is limited for direct assess the independent factors' impact on the resultant feature due to differences in measurement units of studied indicators, the calculation of elasticity coefficients is considered appropriate. Thereby, the relative change in labor productivity with 1% change in the following independent variables ($\boldsymbol{a_i}$):age of fixed assets wear, labor and raw material costs, energy costs and a capital turnover rate indicate the probability of productivity regulation by a specific amount. And the beta coefficients ($\boldsymbol{\beta_i}$) reflect the sensitivity of labor productivity to each independent factor: an increase in the level of fixed production capital's depreciation by one unit follows the reduction in productivity level by 1,71 times in the concrete plant, and, conversely, increases it by 0,06 times in cotton plant in Khalkabad and by 4.6 times - in the plant in Khojeli.

Taking into account described above opportunities of modeling and forecasting the production processes, it is necessary to select an exact combination of independent factors in order to ensure sustainable growth of dependent factors at factories.

V. CONCLUSION

The obtained regression models indicate a considerable impact on labor productivity of such factors as costs on materials and energy resources, age of production assets' wear (depreciation), labor costs and circulating capital. The equations are statistically significant according to the Fisher criterion, the relationships are reliable with high determination coefficients, which are estimated by the Student distribution with a high probability level.

The use of econometric modeling on selected economic entities with relevant interpretation within the framework of economic theory has shown its feasibility and effectiveness in the analysis of economic processes.

An assessment of growth reserves for labor productivity at studying industrial enterprises demonstrated real reserves through: optimization of costs on materials and components, labor and administrative expenses, costs on energy resources and depreciation of fixed production capital, growth in the rate of capital turnover and stock products.

In general, the goal of the study has been achieved: the opportunities in using economic and mathematical tools for modeling and evaluation with subsequent economic interpretation in the analysis of economic activities of industrial enterprises and in constructing the policy for sustainable growth of key indicators has been substantiated.

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THE CONCEPT OF QUALITY AND THE ESSENCE OF THE QUALITY PROBLEM IN THE MARKETING OF MEDICAL SERVICES

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Abstract: In this article, the concept of quality and the nature of the quality problem in the field of marketing of medical services are studied by the author. In addition, opinions about the role of marketing of medical services in the economy are given.

Keywords: Medical, service, service marketing, marketing, economy, factor, income, service, quality, service quality, quality problem solutions.

V. INTRODUCTION (*HEADING 1*)

Medical care and medical service sector has a significant contribution to the gross domestic product created in the society and this contribution is increasing. Decree of the President of the Republic of Uzbekistan on the strategy "Uzbekistan-2030" in our country.

One of the important tasks is to take a place among the countries with higher than average income through stable economic growth, to organize an education, medical and social protection system that fully meets the requirements of the population and international standards. Also, a number of decrees and decisions adopted to ensure the implementation of this strategy, as well as priority tasks and specific measures aimed at the development of medical services provided to the population in state programs, are defined.

As a result of the reforms carried out in Uzbekistan in the last five years, the number of economic entities providing medical services is increasing. Therefore, in order to achieve the tasks defined in the strategy, increasing the income of the population, increasing the medical economic entities, and establishing an income account in these entities that fully meets the requirements of the population and international standards is considered one of the urgent issues today. "...reducing unemployment among the population, increasing the income of people and families..." Address of the President of the Republic of Uzbekistan Sh. Mirziyoev to the OliyMajlis. December 28, 2018.uza.uz

Its role and importance in solving such urgent tasks is incomparable. There are almost no people among our population who do not use medical services. Regardless of the age and work activity, it is necessary to use medical services for one or another issue. It is these and other factors that indicate that entities engaged in the provision of medical services are extremely complex economic units. The extreme variety and different aspects of medical services characterize them as a specific object of income accounting in economic entities.

VI. ANALYSIS OF LITERATURE ON THE SUBJECT

Issues of service provision and development of the service industry have been researched by a number of scientists in our republic. In particular, the works of M.M. Mukhammedov, M.K. Pardaev, Q.J. Mirzaev, B.A. Abdukarimov, J.R. Zaynalov, B.ShMakhkamov and others can be mentioned. Actual issues of accounting in the field of service and service have been researched by some scientists in our republic. Among them, prof. Urazov K.B., Israilov Y.J., Khudayberdiev N.U., Annaev M.B., Pashakhodjaeva D.D. Works by M.ShMardonov and others are included. Also, foreign scientists E.A. Arens, Dj. K. Lobbek., Robertson Dodge R., Kamishanov P.I., and scientists of our republic R.A. Abdullaev, A.I. Alikulov, R.D. Dosmurodov, Kh.N. Musaev, N.S. Sanaev, S.N. Monographs, textbooks, training manuals and scientific articles written by Tashnazarov, M.M.Tolakhodzhaeva, Z.B.Eshpulatova and other scientists are important.

However, in the works published by these scientists, the features of income accounting of economic entities providing medical services are not specifically covered. Also, the issues of accounting and reporting in the recognition of income in entities providing medical services are not fully disclosed in the literature, as well as in the applicable national standards. These, to some extent, cause some problems in the accounting of income in economic entities that provide medical services based on international standards. All of the above are the basis for determining the main directions of scientific research aimed at improving accounting issues in the activity of entities providing medical services.

Taking into account the above, I believe that it will be appropriate to develop the following scientific proposals.

First, to develop an author's definition of the term "medical services" based on the analysis of the definitions of medical service terms given in the sources;

Secondly, to reveal the features as objects of "medical services";

Thirdly, to determine the types, purpose, tasks and principles of the service in entities providing medical services;

Fourthly, to reveal the organizational basis of income accounting of the activities of economic entities providing medical services, for example, to propose

accounting for the activities of entities providing medical services in special accounts during the recognition of income;

Fifth, to justify the status of income accounting as the main information supply of economic entities providing medical services and directions for its improvement;

Sixth, to indicate the directions of application of international standards of revenue accounting in the subjects of medical services and their implementation;

Seventh, to develop a method of recognition of income from services provided by medical service entities on the basis of international standards and to develop a mechanism for its implementation.

I believe that it will be possible to achieve coordination of the above-mentioned scientific proposals on the basis of the time-consuming accounting system and international standards of income accounting in economic entities providing medical services.

VII. RESEARCH METHODOLOGY

Medical services are a set of measures aimed at marketing, quality medical services, promoting the personal brand of the clinic and the doctor. The main goal of medical marketing is to bring more patients and profits to the clinic. Additional goals are to increase brand awareness and strengthen its reputation in the medical market. Completing the priority tasks set for the rapid development of the medical service sector requires solving accounting and analysis problems in this field and improving them based on the requirements of the times. The increasing demand for medical services, the fact that the issues of income accounting are not sufficiently researched in the subjects of the industry, and the fact that there are objective needs to solve these issues in practice indicate the relevance of the topic.

Marketing of medical services is the process of promoting medical products, services and facilities to potential patients or customers. This type of marketing can include a number of tactics such as advertising, public relations, social media marketing, content marketing, and more. In the field of health services marketing, the concept of health quality is the degree to which health services for individuals and populations increase the likelihood of achieving desired health outcomes. High-quality medical care must meet the current requirements at the time of service, including professional and specialty requirements, as well as the general level of modern medicine, available resources, and the patient's health-related needs. In the field of marketing of medical services, the quality of services is a set of positive features that can satisfy the customer's demand.

Medical services marketing differs from general marketing in that it requires a specialized understanding of the medical field, ethical standards, and regulatory requirements. The main goal is to ensure patient satisfaction, provide quality service and build trust in the clinic or doctor. The nomenclature of consumer value of services in many cases corresponds to the nomenclature of consumer value of goods. Three groups of requirements for the quality of services can be specified: consumer value requirements, technological and control requirements. The main goals of medical services marketing Attracting new patients and retaining regular customers is the main goal of medical marketing. To achieve these goals, you need to use SEO and contextual advertising. In addition, increasing the clinic's brand awareness in the market is a key feature of successful medical marketing. The purpose of the services is to satisfy the basic and additional needs of the customers. Marketers need:

- Determining the target audience,
- Development of promotion strategy,
- Ad placement,
- Using online platforms and social networks,
- Keep in constant contact with patient teams.

Successful use of medical marketing helps to attract new customers, increase the recognition of the clinic, strengthen its reputation and gain a strong position in the market. Developing long-term relationships with customers is also important to continued success. Features of medical services marketing - medical marketing requires special attention to regulatory and ethical rules. This is due to the fact that customers expect a high level of trust and security from healthcare services. Medical services have specific characteristics that have a significant impact on the development of marketing strategies: People entrust their health to others, they experience anxiety and sometimes fear, some procedures are painful they understand that it can be beneficial. Limited information, they completely rely on the doctor and his recommendations.

Doctor - marketing. Not only the quality of service, but also the health (or life) of a person depends on the professional skill of the doctor. Therefore, the doctor must strictly follow the instructions, take into account various factors and direct his actions to improve the patient's condition. The reputation of the doctor and the clinic depends on the efficiency of his work.

Medical services - a consultation with a doctor cannot be compared with a visit to a hair salon or a car service center. When a person goes to the doctor, the problem affects his quality of life. Healthcare is a mass product. Each medical service is unique and special because it is related to human health and life. Therefore, medical institutions should approach each patient individually, ensure that their needs and requirements meet high standards of quality and safety.

The medical industry is a free market - because the medical field has its own rules and restrictions that regulate medical practice and protect the interests of patients. Obtaining a medical license, standardization of medical procedures, registration of medical personnel - all this requires great attention and responsibility when planning a marketing strategy. Trust and reputation - patients are very sensitive to the quality and reliability of healthcare services, so building trust is an important element of a successful marketing strategy. Positive reviews, recommendations, compliance with ethical standards and confidentiality - this helps to increase the reputation of the medical institution and its attractiveness to new patients. All these aspects are

the basis for developing successful marketing strategies in the medical field. Understanding and effectively using these features allows healthcare organizations to attract the attention of patients, increase their trust and expand their customer base.

Quality regulation of medical marketing - legislation on advertising in the health sector sets restrictions on the use of certain methods of advertising and requires mandatory information on medical advertising materials. For example, it is forbidden to use statements that guarantee complete recovery from the disease or that do not show side effects of the treatment. In addition, medical advertising should include a statement about the characteristics of the services and inform the clients about the responsibilities of the clinics in providing these services. This allows you to comply with legal regulations in conducting successful campaigns for the promotion of medical services. Features of the promotion of medical services, successful promotion of medical services requires an approach that takes into account the specific characteristics of this market. In order to attract patients, it is important to focus on the service provided and ensure the reliability and professionalism of the clinic. You should also use content that helps users learn more about specific treatments or procedures.

What to pay attention to when promoting medical services:

- Service should be the main focus of advertising.
- Reliability and professionalism of the clinic are the main values for patients.
- Using content that helps the user learn more about a particular treatment or procedure.
- Marketing in medicine: 5 types and their role in advertising.

Let's look at the 5 main types of medical marketing that will help medical institutions effectively promote themselves in the field of health care. Each of these types has its own characteristics.

A medical business requires an effective marketing approach to promote in the healthcare industry. Taking into account the specific characteristics of this field, we distinguish 5 types of medical marketing:Organizational marketing: promotion of a medical institution as a holistic brand.

- Marketing of specific services: focus on specific health services and seasonal approach.
- Marketing of medical professionals: increase the reputation of the leading doctors of the clinic.
- Place marketing: promoting a medical facility based on its geographic location.

Each of these types has its own characteristics and is aimed at a specific target audience. Combining different types of marketing can help you achieve better results and attract more customers.

VIII. ANALYSIS AND RESULTS

The secret to success in medical marketing is to carefully select your target audience. Clinics need to define their niche and focus on attracting clients who need specific services. Developing effective marketing strategies will help you succeed in promoting your medical services.

Table №1

Number of enterprises in the field of health and social services[39]

As of June 1, 2024, 10,961 enterprises and organizations are operating in the field of healthcare and social services.		
They are as follows by region:		
1	Tashkent city	2 186
2	Fergana region	1 236
3	Samarkand region	1 001
4	Andijan region	984
5	Tashkent region	841
6	Bukhara region	807
7	Kashkadarya region	781
8	Namangan region	718
9	Khorezm region	595
10	Karakalpakstan Rep.	503
11	Surkhandarya region	442
12	Navoi region	341
13	Jizzakh region	340
14	Syrdarya region	186 of them

As of June 1, 2024, there are 10,961 enterprises and organizations operating in the field of healthcare and social services: Tashkent city 2,186, Fergana region 1,236, Samarkand region 1,001, Andijan region, Tashkent region 841, Bukhara region 807, Kashkadarya region 781, Namangan region 718, Khorezm region 595, Karakalpakstan Resp. 503, Surkhandarya region 442, Navoi region 341, Jizzakh region 340, Syrdarya region 186.

To build long-term relationships with customers, it is necessary to constantly study the behavior of patients in order to apply content tactics and adjust advertising strategies in time.

[39] https://stat.uz/uz/matbuot-markazi/qo-mita-yangiliklar/55114-o-zbekiston-respublikasiga-davolanish-maqsadida-kelgan-chet-el-fuqarolari-necha-nafarni-tashkil-etdi-5

Table №2

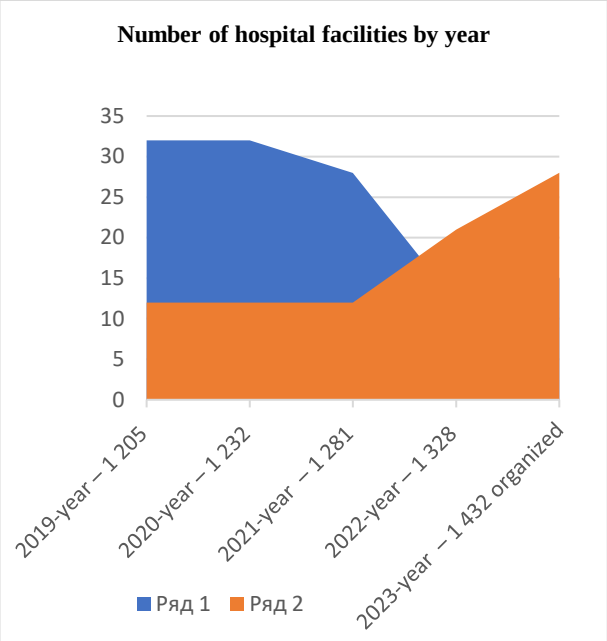
Number of enterprises in the field of healthcare and social services[40]

As of August 1, 2024, 11,026 enterprises and organizations are operating in the field of healthcare and social services		
They are as follows by region		
1	Tashkent city	2 192
2	Fergana region	1 248
3	Samarkand region	1 013
4	Andijan region	1003
5	Tashkent region	843
6	Bukhara region	795
7	Kashkadarya region	775
8	Namangan region	714
9	Khorezm region	605
10	Karakalpakstan Rep.	503
11	Surkhandarya region	466
12	Navoi region	341
13	Jizzakh region	346
14	Sirdaryoregion	182

The number of enterprises in the field of health and social services, as of August 1, 2024, 11,026 enterprises and organizations are operating in the field of health and social services, they are located in the regions as follows:Tashkent city2 192, Fergana region 1 248, Samarkand region 1 013, Andijan region 1003, Tashkent region 843, Bukhara region 795, Kashkadarya region 775, Namangan region 714, Khorezm region 605, Karakalpakstan Rep. 503, Surkhandarya region 466, Navoi region 341, Jizzakh region 346, Sirdaryoregion 182.

The increase in the population increased the demand for medical services and led to the increase in the number of new hospitals, polyclinics and other medical institutions. Improving the quality of public and private sector medical services in the republic requires the creation of new technologies, new buildings and better infrastructure.

As of January 1, 2024, the number of hospitals operating in the Republic of Uzbekistan is 1,432[41]



As of January 1, 2024, the number of hospitals operating in the Republic of Uzbekistan is 1,432. Compared to 2019, the number of hospitals increased by 227.

Selecting the target audience [Gulnara Ismailova. Malika Parpieva. "Characteristics of Effective Use of Scientific and Technical Innovations in the field of Information Technologies" 2021 International Conference on Informatics and Communication Technologies (ICICT). Characteristics of Effective Use of Scientific and Technical Innovations in the field of Information Technologies]. Studying the demographic characteristics of potential patients is an important step in choosing a target audience. It is also necessary to identify the main problems and needs that can be addressed by health services. Analyzing competitors and identifying an original approach will help you stand out from other clinics.

- Studying the age group, gender and social status of potential patients.
- Determining the diseases for which many people come to your clinic.
- Knowing the reason why they choose your clinic over a competitor.
- Developing an individual solution to attract new patients and increase the loyalty of existing patients.

Developing Effective Marketing Strategies In developing effective marketing strategies for clinics,it is necessary to highlight key messages that meet the interests of the target audience. Choosing the most suitable channels

[40] https://stat.uz/uz/matbuot-markazi/qo-mita-yangiliklar/55114-o-zbekiston-respublikasiga-davolanish-maqsadida-kelgan-chet-el-fuqarolari-necha-nafarni-tashkil-etdi-5

[41] https://stat.uz/uz/matbuot-markazi/qo-mita-yangiliklar/55114-o-zbekiston-respublikasiga-davolanish-maqsadida-kelgan-chet-el-fuqarolari-a-nafarni-tashkil-etdi-5

for the promotion of medical services is an important step, which should be based on the analysis of the behavior and preferences of the target audience. Creating an advertising campaign with clearly defined KPIs will help you evaluate its effectiveness and make adjustments to achieve better results.

Using Online Marketing and Social Media The modern digital age opens up many opportunities for medical marketing, including through the use of online marketing and social media. One of the most common ways to use online marketing is to create and optimize a website. A medical institution's website becomes a business card where patients can find the necessary information about services, medical staff and contact information.

Table №3

The number of foreign citizens who came to the Republic of Uzbekistan for treatment is 56,900[42]

In January-June 2024, a total of 56,900 foreign citizens visited the Republic of Uzbekistan for treatment		
This indicator has increased by 24.6 thousand people or 76.4% compared to the corresponding period of last year		
The number of foreign citizens who came to the Republic of Uzbekistan for treatment in January-June of this year by country is as follows:		
1	Tajikistan	43 287 person
2	Kazakhstan	6 615 person
3	Kyrgyz Republic	5 485 person
4	Russia	925 person
5	Turkmenistan	462 person
6	Turkey	23 person
7	Afghanistan	16 person
8	Azerbaijan	9 person
9	Ukraine	8 person
10	USA	7 person
	Other countries	37 person

The number of foreign citizens who came to the Republic of Uzbekistan for treatment is 56,900. In January-June 2024, a total of 56,900 foreign citizens visited the Republic of Uzbekistan for treatment. This indicator has increased by 24.6 thousand people or 76.4% compared to the corresponding period of last year. The number of foreign citizens who came to the Republic of Uzbekistan for treatment in January-June of this year by country is as follows:

Tojikiston 43 287 person, Qozog‘iston 6 615 person, Qirg‘iz Republic 5 485 person, Rossiya 925 person, Turkmaniston 462 person, Turkiya 23 person, Afg‘oniston 16 person, Ozarbayjon 9 person, Ukraina 8 person, AQSH 7 person, Other countries 37 person.

Another effective tool is social networks. Platforms like Facebook, Instagram, Twitter, and LinkedIn allow you to connect with specific audiences and create engaging content. Advertising campaigns on social networks allow you to target high-precision audiences and effectively promote medical services. It is also important to use email and automated CRM systems to collect and manage patient contacts. Sending newsletters, consultation invitations, or appointment reminders can help you stay in touch with your patients and increase their satisfaction with your healthcare services. A strong brand in medicine is an essential strategy for success and trust. Building a strong brand in the medical segment is a key strategy. A unique image, a favorable reputation and increasing the level of patient trust are integral parts of success. This can be achieved by creating valuable content, actively participating in medical conferences and events, and using effective communication strategies.

On the Internet [Parpieva Malika Mukhamadjonovna. "The role of innovation in the development of the digital economy". Scientific electronic journal "Statistical Bulletin of Uzbekistan" of the Institute of Personnel Training and Statistical Research under the State Statistics Committee. 2022, issue 3. https://statmirror.uz/en/yangisoni] promotion of medical services Website search engine optimization (SEO) helps to improve visibility in search results and attract more organic traffic. Improving your search ranking will help attract more potential patients to your clinic's website. Creating quality content that engages users and increases their brand loyalty is also important in the promotion of medical services on the Internet. In addition, advertising on specialized health portals or social networks helps to reach the desired target audience and increases the general visibility of the clinic in the network.

Using these key healthcare marketing strategies, we contribute to the growth of healthcare organizations and help them achieve their goals. Our experience and knowledge will help you attract more patients, increase your reputation and ensure sustainable success in the competitive environment of the medical market. Use of Technology in Medical Marketing Modern technology offers many opportunities for effective medical marketing. Digital communication channels, websites, social media and mobile applications are becoming important tools for reaching target audiences, communicating with patients and disseminating information about healthcare services. The use of technology can help increase the convenience and ease of access to medical services, attract more patients and improve customer satisfaction.

Telemedicine and online consultations [Parpieva, Malika Mukhamadjonovna. "Innovative activity in improving the quality of the educational system". Akademicheskie issledovaniya v oblasti pedagogicheskikh nauk 2.1 (2021): 491-503. 2021 - cyberleninka.ru innovative activity in improving the quality of the educational system academic research in

[42] https://stat.uz/uz/matbuot-markazi/qo-mita-yangiliklar/55114-o-zbekiston-respublikasiga-davolanish-maqsadida-kelgan-chet-el-fuqarolari-necha-nafarni-tashkil-etdi-5

educational sciences volume 2 | ISSUE 1 | 2021 ISSN: 2181-1385 Scientific Journal Impact Factor (SJIF) 2021: 5.723].

One of the most current trends in medical marketing is the popularization of telemedicine and virtual consultations. These technologies allow patients to receive medical advice and services remotely, providing convenience and efficiency. Medical clinics that use telemedicine can expand their geographic coverage, attract patients from remote areas, and improve the quality of medical care.

These challenges and trends in medical marketing demand flexible, innovative thinking and continuous improvement strategies from professionals. Knowing and using these factors can help medical clinics achieve greater success and build a solid foundation for future growth.

Conclusions and suggestions

For the successful operation of the clinic, it is very important to properly promote it in the market. Medical services marketing is an essential tool for attracting patients and maintaining the loyalty of existing ones. In this article, we found the main features such as choosing a target audience, creating a unique brand and using effective communication channels. However, to be successful in medical marketing, you need to do more than follow basic strategies. An important role is played by the constant study of patient reviews and the competitive environment, the analysis of data on past campaigns and the search for new advertising methods that meet the current trends of the healthcare market.

1.Decree of the President of the Republic of Uzbekistan on "Uzbekistan-2030 Strategy" No. PF-158 dated 1.11.09.2023;

2. Address of the President of the Republic of Uzbekistan Sh. Mirziyoyev to the OliyMajlis. December 28, 2018. uza.uz

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QISHLOQ HUDUDLARINING RIVOJLANISH SAMORADORLIGINI BAHOLASH MEZONLARI

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Annotatsiya. Qishloq hududiy tizimlarida ijtimoiy-iqtisodiy rivojlanish samaradorligini baholash istiqbolli yondashuv hisoblanadi. Bu iqtisodiy va ijtimoiy jarayonlarning murakkab o‘zaro ta’sirini har tomonlama tushunish imkonini beradi, bu esa yanada oqilona qarorlar qabul qilishga olib keladi. Mazkur tadqiqotda qishloq joylarda ijtimoiy-iqtisodiy rivojlanish samaradorligiga ta’sir etuvchi ko‘rsatkichlar bo‘yicha ma’lumotlar o‘rganildi. Shuningdek, qishloq hududlarini ijtimoiy-iqtisodiy rivojlantirishni modellashtirishning funksional tuzilmasi, strukturaning blokli modelini ishlab chiqish masalalari ham ko‘rib chiqildi. Qishloq xo‘jaligi ishlab chiqarishi chiziqli regressiya modellari asosida tahlil qilindi.

Kalit so'zlar va iboralar: ijtimoiy-iqtisodiy rivojlanish, blok modeli, qishloq xo'jaligi sektorining o'sishi, ko'rsatkichlar

Kirish

Qishloqni ijtimoiy qayta qurish muammosi respublika oldida turgan masalalar kompleksining eng yirigi bo‘lib, siyosiy, ijtimoiy va iqtisodiy ahamiyatga ega hisoblanadi. Bu muammo, ayniqsa, qishloq aholisining doimiy o‘sishi sharoitida juda dolzarb bo‘lmoqda. Bugungi kunda qishloq ijtimoiy taraqqiyotida shahardan ancha orqada qolmoqda va xulosa bitta - qishloq aholisining turmush darajasini tubdan yaxshilash muammosini amaliy hal etishning samarali yo‘llari va vositalarini topish kerak. Faqat bu holda hudud qishloq xo‘jaligi iqtisodiyotini yanada rivojlantirish masalalarini yechish talab etiladi. O‘zbekiston Respublikasi Prezidentining “O‘zbekiston-2030” Strategiyasi” to‘g‘risida”gi Farmoni, O‘zbekiston Respublikasi Prezidentining 23-oktabr 2019 yildagi “O‘zbekiston Respublikasi qishloq xo‘jaligini rivojlantirishning 2020-2030 yillarga mo‘ljallangan strategiyasini tasdiqlash to‘g‘risida”gi PF-5853-sonli Farmoni, O‘zbekiston Respublikasi Prezidentining “2020-2023 yillarda Qoraqalpog‘iston Respublikasini ijtimoiy-iqtisodiy kompleks rivojlantirish bo‘yicha chora-tadbirlar to‘g‘risida”gi 11.XI.2020 yil 4889-son qarorlarida hududlar qishloq xo‘jaligi iqtisodiyotini yanada rivojlantirish masalalarini ko’rsatildi [1,2,3].

Metodlar

Turli darajadagi hududlarni ijtimoiy-iqtisodiy rivojlanishini baholash mezonlari tabiiy muhit va ishlab chiqarish, moddiy boylik darajasi saqlanishida "aholi sifati" qo‘rsatkichini hududning rivojlanishini baholash mezoni sifatida taklif qilish mumkin. Buning uchun hududda yashaydigan aholining sifat darajasi koeffitsiyentini hisoblash lozim. Koeffitsiyent quyidagi formula bo‘yicha hisoblanadi:

$$K_H = 1 - \frac{\Delta N}{N}, \quad (1.1)$$

bu yerda, N - joriy yilda aholiing tabiiy o‘sish soni;
ΔN - tabiiy o‘sishda fiziologik nuqsonli aholi soni.

Agar aholi ko‘payishi baland bo‘lsa, ya’ni $K_H(t) \to 1\ ga$ intilsa, u holda aholining sifat darajasini o‘lchash uchun qo‘payishning o‘rtacha koeffitsiyenti ishlatilishi mumkin, ya’ni:

$$J_{sr}(t) = \frac{1}{N}\sum J_j(t), \quad (1.2)$$

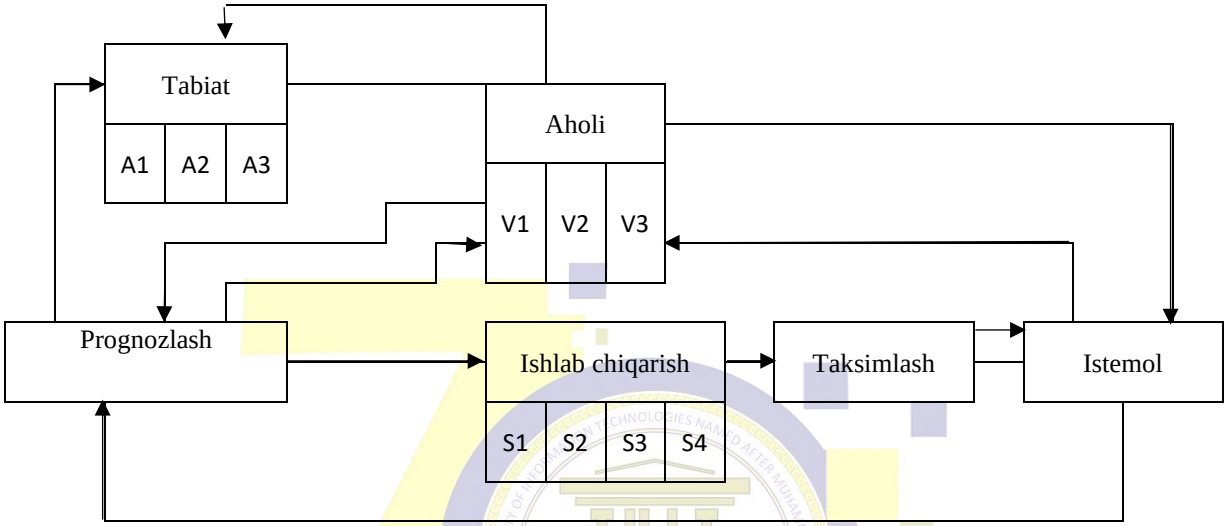
bu yerda, $J_j(t)$ - aholining j-jinsi guruhiga kiruvchi aholining ko‘payishi intellektual koeffitsiyenti.

Aholining sifat koeffitsiyenti va o‘rtacha intellekt koeffitsiyentining vaqt bo‘yicha o‘zgarishi dinamikasi - bu ko‘payishning rivojlanish yo‘nalishini ko‘rsatadi va sabablarni o‘z vaqtida tahlil qilishga va zarur qarorlarni qabul qilishga, ya’ni aholining o‘sishini boshqarishga imkon beradi [46/1]. Taklif etilayotgan mezonning mohiyati - aholi soni va uning sifati zarur moddiy tovarlarni ishlab chiqarish insonlarning tabiiy yashash muhiti ko‘rsatkichlarining yomonlashishiga olib kelmaydigan darajada saqlanishi kerak. Bunday modelni amalga oshirish uchun aholi, tabiiy muhit, ishlab chiqarish tizimlari yaratilishi zarur. Bunday tizimlarning tarkibiy qismi mahalliy va hududiy tizimlar bo‘lishi kerak, chunki bu tizimlar tovar ayirboshlash va takror ishlab chiqarishda o‘zaro bog‘liq. Shundan kelib chiqish bilan hududiy rivojlanish modeli quriladi. Uning asosiy sharti tabiiy muhitni saqlab qolish va bu hududda zarur bo‘lgan yashash sifatini ta’minlash hisoblanadi.

Ushbu takliflarni amalda qo‘llash tabiiyki, yashash sifati va iqtisodiy o‘sishga ta’sir ko‘rsatadigan ijtimoiy-iqtisodiy ma’lumotlarga chiqishni ta’minlaydigan ko‘rsatkichlar tizimi asosida hisob-kitoblar uchun modellar tizimi ishlab chiqilishi kerak. Shu munosabat bilan biz ijtimoiy-iqtisodiy

jarayonlarning modellarini ishlab chiqish uchun hududiy tizimlar unsurlarini tuzilmalashtirishga harakat qilindi. Shuning uchun mavjud hududlar katta, o‘rta va kichik qishloq hududlariga bo‘lindi. Katta hududlar - bu viloyatlar yoki mintaqalarning hududlari (2-3 viloyatlar), o‘rtacha hududlar - ma’muriy tumanlar, areallar yoki mikrozonalar hisoblanadi. Kichik qishloq hududlari - bu mulkchilik shaklidan qat’i nazar, qishloq xo‘jalik majmuasi yoki boshqa tarmoqlarning turli xil ishlab chiqarish turlari to‘plangan bir yoki bir necha fermer xo‘jaliklarining hududlari hisoblanadi. Ba’zi hollarda kichik qishloq joylari qishloq kengashi hududlari bilan mos keladi.

Shularni hisobga olib qishloq hududiy tizimlarning ijtimoiy-iqtisodiy rivojlanishini modellashtirish uchun tadqiqotda tabiiy muhit unsurlari, ishlab chiqarish va aholi o‘rtasidagi munosablarning o‘zaro bog‘liqligining prinsipial chizmasi ishlab chiqildi (1.1-rasm).



1-rasm. Hududiy tizimlarning ijtimoiy-iqtisodiy rivojlanishini ta’minovchi unsurlarning o‘zaro bog‘likligi chizmasi.

Har qanday hududda uchta o‘zaro bog‘liq tizimlar - tabiat, aholi, ishlab chiqarish tizimlari mavjud. Aholi tabiatning bir qismi sifatida, tabiat unsurlari bilan o‘zaro aloqada bo‘ladi va mahsulotlarni ishlab chiqaruvchi va ayni paytda ularning iste’molchisi ham hisoblanadi.

Statistik ma’lumotlarga ko‘ra, 2022 yilda O‘zbekiston Respublikasi aholisi 36,0 milliondan ko‘pni tashkil etdi, shundan 17,6 million kishi - shaharliklar, 18,8 million kishi - qishloq aholisi bo‘ldi [43]. Shahar va qishloq aholisi 1980 yildan boshlab nisbati barqarorlashdi (49:51). Shu bilan birga ularning mutlaq o‘sishi kuzatilmoqda.

O‘zbekistonda 2022 yillarda umr ko‘rish davomiyligi hisob-kitoblarga ko‘ra 75,6 yoshni tashkil qildi, shu jumladan erkaklar - 73,1 va ayollar – 78,0 yoshni tashkil qildi. Yoki 2010 yilga nisbatan 2022 yilda ayollar umr ko‘rishi 2,9 va erkaklar yoshi esa 2,5 ga uziygan (1-jadval).

1- jadval

O‘zbekistonda aholining umr ko‘rish davomiyligi (bir yilda, yosh)

	2010	2012	2013	2014	2015	2016	2017	2018	2019	2022
Jami	**73,0**	**73,1**	**73,1**	**73,1**	**73,6**	**73,8**	**73,7**	**71,6**	**75,1**	**75,6**
ayollar	75,1	75,5	75,8	75,8	76,0	76,2	76,1	77,0	77,4	78,0
erkaklar	70,6	70,7	71,1	71,1	71,2	71,4	71,3	72,3	72,8	73,1
Shaxar aholisi	**73,1**	**73,2**	**73,6**	**73,5**	**74,0**	**74,5**	**74,4**	**75,4**	**75,8**	**76,2**
ayollar	75,7	76,0	76,0	76,2	76,8	77,1	77,1	78,0	78,3	78,6
erkaklar	70,4	70,4	71,0	70,8	71,3	71,8	71,7	72,6	73,2	73,8
Qishloq axolisi	**72,7**	**72,8**	**73,1**	**73,2**	**73,0**	**73,0**	**72,8**	**73,8**	**74,2**	**74,9**
ayollar	74,5	74,7	75,1	75,2	75,0	74,9	74,8	75,7	76,2	77,0
erkaklar	71,0	71,0	71,3	71,3	71,0	71,1	71,0	71,9	72,4	72,7

Manba: Davlat statistika qo‘mitasi ma’lumotlari asosida muallif tomonidan tuzildi.

[43] ЎзР Президенти қошидаги Статистика агентлиги маълумотлари.

Ushbu 1–jadval ma’lumotlari ko‘rsatib turibdiki, yaqin kelajakda O‘zbekiston Respublikasi aholisining miqdoriy o‘sishi "sifatli" o‘sish bilan birga bo‘lishi kerak. Buning uchun hududlarda demografik jarayonlarni o‘rganish va rivojlantirish tizimi yaratilishi kerak. Bu tizimda aholi sonini (V_1), ularning yoshini (V_2), jins yoshiga oid tuzilmasi (V_3) va boshqalar o‘lchanadi. Ular mehnat resurslari, aholining oziq-ovqat, uy-joy, tovar va xizmatlarga bo‘lgan ehtiyojini prognoz qilish, shuningdek ularning daromadlari va xarajatlarini tadqiq qilish imkonini beradi.

O‘zbekiston tabiatining o‘ziga xos xususiyati uning issiq iqlimi bo‘lib, bu sug‘orishdan foydalanishni ham ko‘zda tutadi. Shu bilan bir vaqt, ko‘plab madaniy ekinlar issiqlikni sevuvchi hisoblanadi. Shuning uchun qishloq xo‘jaligining rivojlantirish uchta omillar - sug‘orishga yaroqli yerlarning mavjudligi (A_1), suv resurslari (A_2) va vegetatsiya davrining davomiyligiga (A_3) bog‘liq.

O‘zbekiston Respublikasining yer maydoni 44832,4 ming gektarni tashkil etadi. Ularning 26233,3 ming gektari qishloq xo‘jaligi korxonalari tomonidan foydalaniladi[44]. 2021 yilda respublikada toza suv iste’moli 52,4 kub.kmni tashkil etdi, shundan 44,4 kub.km suv sug‘orish va qishloq xo‘jaligini suv bilan ta’minlash uchun ishlatilgan.

Sug‘oriladigan yerlar eng qimmatli bo‘lib, ular 4336,1 ming gektarni yoki O‘zbekiston Respublikasining umumiy yer maydonining 9,6 foizini tashkil etadi, shundan 3242,1 ming gektari ekin maydonlari hisoblanadi.

Qoraqalpog‘istonda sug‘oriladigan ekin yerlari 418,8 ming gektarni tashkil etadi. Hujayli tumanida qishloq xo‘jalik yerlarining 21,2 ming gektari yoki 48,8% sug‘oriladigan yerlar bo‘lib, uning 19,7 ming gektari ekiladigan ekiladigan maydonlar hisoblanadi.

Yuqorida ta’kidlab o‘tilganidek, qishloq xo‘jaligini yanada rivojlantirish va binobarin, aholini oziq-ovqat bilan ta’minlash, moddiy va ijtimoiy holati yer va suv resurslarining holati va hajmlariga bog‘liq. Shuning uchun ular bu hududda yashovchi insonlarning normal hayoti va faoliyati uchun yaroqli bo‘lib qolishi kerak. Tabiiy muhitga inson ta’sir uning imkoniyatlaridan oshmasligi kerak, ya’ni ayniqsa, qishloq hududlari sanoat korxonalari, birlashmagan qishloq xo‘jaligi, aholining migratsiyalanishi, suv manbalarining kamayishi va boshqalar bilan katta og‘irlik tushishini oldini olish kerak. Yuqorida ta’kidlanganidek, barqaror rivojlanishni ta’minlash uchun inson faoliyati tabiiy muhitga shunday og‘irlik yuklamani ko‘rsatishi kerakki, jamiyat tabiiy muhitdan foydalanish chegaralaridan tashqariga chiqmasin. Bularning barchasi hozirgi avlod kelajak avlodlarga yetkazadigan tabiiy resurslarning qimmati behuda sarflanmaydigan tarzda ulardan foydalanishning optimal yo‘llarini topishni talab qiladi. Buning uchun sug‘oriladigan yerlarning holatini kuzatish (yer osti suvlari darajasini, tuproqdagi gumus zaxirasini o‘lchash), oqava suvlarni tartibga solish va sug‘orish rejimini boshqarish va FARni o‘lchash uchun tizimlarni yaratish kerak. Bu tadbirlarning barchasi bir vaqtning o‘zida dalalar hosildorligini oshirishga, mahsulot birligiga sarflanadigan mablag‘larni tejashga va ularning sifatini oshirishga yordam beradi.

Respublikasi aholisi jon boshiga to‘g‘ri keladigan ishlab chiqarish darajasi va daromad miqdori hali ham past bo‘lib, bu aholi farovonligiga sezilarli ta’sir ko‘rsatmoqda. Birinchi darajali vazifa respublika aholisini nafaqat oziq-ovqat, kiyim-kechak bilan, shuningdek real daromad bilan ta’minlaydigan eng ratsional ishlab chiqarish tuzilmalarini topish hisoblanadi. Shuning uchun paxta tolasini ishlab chiqarishni barqarorlashtirish sharoitlarida chuqur qayta ishlash va iste’molga tayyor mahsulot ishlab chiqarishni tashkil etish bilan agrosanoat ishlab chiqarishining optimal tuzilmasiga o‘tish zarur. Bu, o‘z navbatida, qishloq aholisini ish bilan ta’minlash va oilalarning daromadlarini ta’minlash muammolarini yechilishiga olib keladi. Bundan kelib chiqish bilan ishlab chiqarish va iste’mol tizimida bir kishiga to‘g‘ri keladigan yakuniy mahsulotlarni (C1) ishlab chiqarish, yer birligi (C2), moddiy resurslar (C3), shuningdek aholi va oilalarning daromadlari (C4) o‘lchanishi va boshqarilishi kerak.

Natijalar

Xo‘jayli tumanining ijtimoiy-iqtisodiy rivojlanishining tahlili shuni ko‘rsatadiki, Qoraqalpog‘iston Respublikasi iqtisodiyotida Xo‘jayli tumani muqim o‘rin tutadi. Tuman 1927 yilda tashkil topgan. Unda hozirgi kunda 124,3 ming kishi yashaydi. Tumanda ja’mi 7 ta qishloq, 18 ta mahalla fuqarolar yig‘ini va 64 ta qishloq aholi punktlari faoliyat yuritadi.

Xo‘jayli tumani statistika boshqarmasi ma’lumotlariga ko‘ra, tumanda o‘tgan yilda yakuni mahsulotlar ishlab chiqarishi darajasi, ayniqsa O‘zbekiston hamda Qoraqalpog‘iston Respublikalari bilan solishtirganda o‘sishi yuqori ko‘rsatkichga ega (1.2-jadval). Shu bilan bircha import kamayib (31,8%), mahsulotlar eksporti esa oshmoqda (145,2%).

[44]Ўзбекистон Республикаси ер фонди. Давлат кадастр палатаси. Тошкент – 2023. – 15 б.

2-jadval

O‘zbekiston va Qoraqalpog‘iston Respublikalari hamda Xo‘jayli tumanining asosiy iqtisodiy o‘sish ko‘rsatkichlarning tahlili

Tarmoqlar	2022 yil yanvar-dekabr					
	O‘zbekiston Respublikasi		Qoraqalpog‘iston Respublikasi		Xo‘jayli tumani	
	Mlrd. so‘m	O‘sush sur’ati, %	Mlrd. so‘m	O‘sush sur’ati, %	Mlrd. so‘m	O‘sush sur’ati, %
Sanoat	367078,9	100,7	14144,8	104,1	483,7	108,5
Iste’mol tovarlari	119159,8	103,6	2818,3	110,0	218,9	107,2
Qishloq, o‘rmon va baliq xo‘jaligi	224265,9	103,0	10443,7	102,5	528,6	105,0
Asosiy kapitalga investitsiyalar	202000,1	91,8	8167,4	80,4	200,2	112,0
Qurilish ishlari	87823,8	109,1	3785,9	101,5	224,1	107,0
Chakana tovar aylanmasi	194843,5	103,2	6604,6	102,4	667,1	101,7
Jami xizmatlar	218853,5	102,3	6508,9	105,9	302,4	105,2
Eksport, mln. AQSH dollar	15127,7	86,6	363,4	84,3	3,9	145,5
Import, mln. AQSH dollar	21171,5	87,2	176,3	65,6	2,5	31,8

Manba: Xo‘jayli tumani statistika boshqarmasi ma’lumotlari.

Rivojlangan xorijiy davlatlar tajribasi shuni ko‘rsatadiki, sanoat mamlakatning ijtimoiy-iqtisodiy rivojlanishida muhim o‘rin tutadi. Shu nuqtai nazardan kelib chiqib Qoraqalpog‘iston Respublikasi va tumanlarda ishlab chiqarilgan sanoat mahsuloti hajmini tumanlararo hamda tumanlarni shahar ko‘rsatkichlari bilan taqqoslash orqali tahlil qilish, sanoat mahsulotini aholi jon boshiga to‘g‘ri keladigan miqdori dinamikasini kuzatib borish, hududlar ustuvor vazifalarini va o‘sish nuqtalarini belgilashda muhim ahamiyat kasb etadi. O‘z navbatida 2022 yilning yanvar-dekabr oylarida Xo‘jayli tumanida sanoat mahsuloti ishlab chiqarilishi 483,5 mlrd. so‘mni tashkil etib, mazkur ko‘rsatkich Qoraqalpog‘iston Respublikasining jami sanoat mahsuloti ishlab chiqarilishida 3,4% tashkil etdi. Tumanida ishlab chiqarilgan sanoat mahsuloti hajmi aholi jon boshiga 3891,4 ming.so‘mni yoki o‘tgan 2021 yilning mos davriga nisbatan o‘sishi sur’ati 108,1% ga yetkazilganligini kuzatishimiz mumkin.

Shunigdek, tumanda istyemol tovarlari ishlab chiqarilishi 204,2 mlrd.so‘mni tashkil qilib, Qoraqalpog‘iston Respublikasining jami iste’mol tovarlari ishlab chiqarilishida 7,2% tashkil etdi. Tumanda ishlab chiqarilgan iste’mol tovarlari aholi jon boshiga 1653,0 ming.so‘mni yoki o‘tgan yilning mos davriga nisbatan o‘sishi sur’ati 101,3% ga yetkazilganligini kuzatishimiz mumkin.

Xulosa

Shunday qilib, yuqoridalar asosida xulosa qilinganda tabiat - aholi - ishlab chiqarish tizimida tabiiy muhit holati, moddiy ne’matlarning ishlab chiqarish darajasi, aholi daromadlari va xarajatlarini ko‘rsatadigan omillar kompleksi boshqariladi. Bu omillarni tahlil va prognoz qilish hududiy tizimlarni ijtimoiy-iqtisodiy rivojlantirish dasturlarini shakllantirish maqsadlaridan kelib chiqqan holda turli xil vazifalarni bajarishni o‘z ichiga oladi.

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SUG‘URTA BOZORI FAOLIYATINING RAQAMLI TEXNOLOGIYALARDAN FOYDALANISH DARAJASINING TAHLILI

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Annotatsiya. Qishloq hududiy tizimlarida ijtimoiy-iqtisodiy rivojlanish samaradorligini baholash istiqbolli yondashuv hisoblanadi. Bu iqtisodiy va ijtimoiy jarayonlarning murakkab o‘zaro ta’sirini har tomonlama tushunish imkonini beradi, bu esa yanada oqilona qarorlar qabul qilishga olib keladi. Mazkur tadqiqotda qishloq joylarda ijtimoiy-iqtisodiy rivojlanish samaradorligiga ta’sir etuvchi ko‘rsatkichlar bo‘yicha ma’lumotlar o‘rganildi. Shuningdek, qishloq hududlarini ijtimoiy-iqtisodiy rivojlantirishni modellashtirishning funksional tuzilmasi, strukturaning blokli modelini ishlab chiqish masalalari ham ko‘rib chiqildi. Qishloq xo‘jaligi ishlab chiqarishi chiziqli regressiya modellari asosida tahlil qilindi.

Kalit so'zlar va iboralar: ijtimoiy-iqtisodiy rivojlanish, blok modeli, qishloq xo'jaligi sektorining o'sishi, ko'rsatkichlar

I.Kirish

Hozirgi davrda global iqtisodiyotning barcha tarmoqlarida raqamli transformatsiya jarayonlari jadallashib bormoqda. Ushbu jarayon moliya bozorining tarkibiy qismi bo‘lgan sug‘urta sohasiga ham bevosita ta’sir ko‘rsatmoqda. Raqamli texnologiyalar sug‘urta xizmatlarini ko‘rsatishda sifat jihatdan yangi imkoniyatlar yaratib, kompaniyalar faoliyatining samaradorligini oshirish, jarayonlarni avtomatlashtirish va mijozlar bilan o‘zaro aloqalarni tezkorlashtirishda muhim vosita bo‘lib xizmat qilmoqda [1]. Sug‘urta bozorida “InsurTech” deb nomlangan yangi innovatsion yo‘nalish shakllanib, unda sun’iy intellekt, katta ma’lumotlar (“big data”), blokcheyn, bulutli texnologiyalar va mobil ilovalar keng qo‘llanilmoqda [2]. Bu texnologiyalar nafaqat xizmatlarni qulaylashtirmoqda, balki risklarni baholashda aniqlikni oshirib, mijozlarning ehtiyojlariga moslashuvchan sug‘urta mahsulotlarini yaratishga imkon bermoqda [3].

So‘nggi yillarda xalqaro amaliyotda sug‘urta kompaniyalari raqamli transformatsiyani strategik rivojlanishning ustuvor yo‘nalishi sifatida qabul qilmoqda. Masalan, Yevropa Ittifoqi va AQShda sug‘urta kompaniyalari o‘z faoliyatining deyarli barcha bosqichlarini raqamlashtirib, mijozlarga onlayn polis rasmiylashtirish, elektron shartnomalar tuzish, mobil ilovalar orqali xizmatlardan foydalanish imkonini bermoqda [4]. OECD hisobotlariga ko‘ra, sohada raqamli yechimlardan foydalanish nafaqat kompaniyalar samaradorligini oshiradi, balki moliyaviy inklyuziyani kengaytirib, aholining sug‘urtaga bo‘lgan ishonchini oshirishda ham muhim omil bo‘lib xizmat qiladi [5].

O‘zbekiston sug‘urta bozorida ham raqamli texnologiyalarni joriy etish jarayoni bosqichma-bosqich amalga oshirilmoqda. Moliya vazirligi huzuridagi sug‘urta bozorini rivojlantirish bo‘yicha qabul qilingan dasturlarda elektron polislarni joriy etish, yagona ma’lumotlar bazasini shakllantirish va raqamli xizmatlarni kengaytirish bo‘yicha aniq vazifalar belgilangan [6]. Bugungi kunda ayrim sug‘urta kompaniyalari mobil ilovalar orqali xizmatlarni taqdim etishni yo‘lga qo‘ymoqda, mijozlarga elektron shartnomalar taklif qilmoqda hamda ayrim jarayonlarda blokcheyn texnologiyalarini sinovdan o‘tkazmoqda [7]. Biroq, mavjud imkoniyatlarga qaramay, sohaga oid raqamli yechimlar hali yetarli darajada keng tatbiq qilinmagan. Masalan, yagona integratsiyalashgan axborot tizimi to‘liq shakllanmagan, onlayn xizmatlar sifati yetarlicha yuqori emas, shuningdek, kadrlar salohiyatida ham sezilarli bo‘shliqlar mavjud [8].

Ilmiy adabiyotlarda sug‘urta sohasining raqamli transformatsiyasi ko‘plab nuqtai nazarlardan o‘rganilgan. Shapiro [9] o‘z tadqiqotida raqamli texnologiyalar sug‘urta kompaniyalarining biznes-modelini tubdan o‘zgartirib, ularni xizmat ko‘rsatishdan mijozlar bilan uzoq muddatli hamkorlikka asoslangan tizimga o‘tkazishini ta’kidlaydi. Smith va Jones [10] esa raqamli yechimlar orqali operatsion xarajatlarni kamaytirish, xizmatlarni avtomatlashtirish va mijozlar tajribasini yaxshilashni asosiy ustunlik sifatida ko‘rsatib o‘tadi. Mahalliy tadqiqotchilar orasida Karimov [11] sug‘urta bozorida raqamli infratuzilmaning rivojlanish zarurligini yoritgan bo‘lsa, Raxmonov [12] asosan axborot xavfsizligi va kiberxavflar bilan bog‘liq muammolarga e’tibor qaratadi. Shuningdek, Ergashev [13] sug‘urta kompaniyalari tomonidan raqamli texnologiyalardan foydalanish darajasi bozorning umumiy raqobatbardoshligini oshirishga bevosita ta’sir qilishi haqida ilmiy xulosalar beradi.

Shu nuqtai nazardan, ushbu mavzuning dolzarbligi ikki asosiy omil bilan izohlanadi. Birinchidan, sug‘urta bozorining raqamli transformatsiyasi moliya sektorining

barqarorligi va samaradorligini oshirishning muhim sharti hisoblanadi. Ikkinchidan, O‘zbekiston sug‘urta bozorida raqamli texnologiyalardan foydalanish darajasi bo‘yicha tizimli ilmiy tadqiqotlar yetarli emas. Shu boisdan, ushbu maqola doirasida milliy sug‘urta bozorida raqamli texnologiyalarning joriy etilishi va undan foydalanish darajasi tahlil qilinadi, mavjud muammolar aniqlanadi hamda istiqbolli yo‘nalishlar belgilab beriladi.

Tadqiqotning maqsadi – O‘zbekiston sug‘urta bozorida raqamli texnologiyalardan foydalanish darajasini ilmiy asoslangan holda baholash, ularning bozor samaradorligiga ta’sirini o‘rganish hamda sohani yanada rivojlantirish bo‘yicha amaliy takliflar ishlab chiqishdan iboratdir. Ushbu maqsadga erishish uchun maqolada xalqaro va mahalliy tajribalar solishtirilib tahlil qilinadi, mavjud statistik ma’lumotlar o‘rganiladi va raqamli texnologiyalarning sug‘urta sohasiga ta’sir mexanizmlari yoritib beriladi.

II. Metodologiya

Sug‘urta bozorida raqamli texnologiyalardan foydalanish darajasini ilmiy asosda baholash murakkab va ko‘p qirrali jarayondir. Shu bois mazkur tadqiqot metodologiyasi nazariy va empirik yondashuvlarning uyg‘unlashuviga asoslanadi. Metodologik asos sifatida tizimli tahlil, taqqoslama yondashuv, dinamik ko‘rsatkichlarni o‘rganish, sifat va miqdoriy baholash usullari birgalikda qo‘llandi [14].

Birinchi bosqichda tadqiqotning nazariy asosi shakllantirildi. Bunda sug‘urta bozorida raqamli transformatsiya jarayonlarini yorituvchi xorijiy va milliy ilmiy manbalar, jumladan xalqaro tashkilotlarning hisobotlari, ilmiy maqolalar va tahliliy sharhlar o‘rganildi [15]. Ushbu manbalar sug‘urta kompaniyalarida raqamli texnologiyalarning qo‘llanishi, InsurTech rivojlanishi, raqamli xavfsizlik, axborot texnologiyalarining samaradorlikka ta’siri kabi masalalarni nazariy jihatdan asoslashga yordam berdi.

Ikkinchi bosqichda ma’lumotlar bazasi shakllantirildi. Tadqiqot uchun asosiy ma’lumotlar O‘zbekiston Respublikasi Moliya vazirligi huzuridagi Sug‘urta bozorini rivojlantirish agentligi hisobotlari, Markaziy bank statistik ma’lumotlari, yirik sug‘urta kompaniyalarining yillik hisobotlari, shuningdek, Jahon banki va OECD kabi xalqaro moliya institutlarining rasmiy nashrlari orqali yig‘ildi [16]. Ushbu ma’lumotlar asosida raqamli texnologiyalar joriy etilishining amaliy ko‘rsatkichlari – elektron polislar soni, onlayn xizmatlardan foydalanuvchilar ulushi, kompaniyalarning raqamli xizmatlarga yo‘naltirgan investitsiyalari, raqamli mahsulotlar soni va ularning qamrovi kabi indikatorlar o‘rganildi.

Uchinchi bosqichda tahlil usullari qo‘llanildi. Tadqiqotda bir nechta turli yondashuvlardan foydalanildi:

- Dinamik tahlil orqali so‘nggi 5–7 yil davomida sug‘urta bozorida kuzatilgan raqamli ko‘rsatkichlarning o‘zgarishi, tendensiyalari va rivojlanish bosqichlari tahlil qilindi [17].
- Taqqoslama tahlil yordamida O‘zbekiston sug‘urta bozorida raqamli texnologiyalardan foydalanish darajasi xalqaro amaliyotdagi ilg‘or tajribalar bilan solishtirildi. Bunda Rossiya, Qozog‘iston, Turkiya va Germaniya tajribasi qiyosiy o‘rganildi [18].
- Tarkibiy tahlil yordamida sug‘urta kompaniyalari faoliyatida qo‘llanilayotgan texnologiyalar (mobil ilovalar, onlayn polislar, elektron arxivlar, blokcheyn tizimlari)ning ulushi va samaradorligi baholandi [19].
- SWOT-tahlil orqali esa raqamli texnologiyalarni joriy etishdagi kuchli va zaif tomonlar, mavjud imkoniyatlar va tahdidlar aniqlanib, ularning strategik rivojlanishdagi o‘rni belgilandi [20].

To‘rtinchi bosqichda sifat tahlili amalga oshirildi. Bunda sug‘urta sohasi bo‘yicha mutaxassislar va kompaniya xodimlari bilan suhbatlar, ekspert intervyulari hamda tahliliy maqolalar asosida sifat ko‘rsatkichlari yig‘ildi [21]. Respondentlar fikrlariga tayangan holda mijozlar uchun raqamli xizmatlarning qulayligi, mavjud muammolar, texnologik infratuzilma yetishmovchiligi va kadrlar tayyorlashdagi bo‘shliqlar o‘rganildi. Shu tarzda, statistik ko‘rsatkichlar sifat tahlili bilan uyg‘unlashtirildi.

Beshinchi bosqichda integratsiyalashgan yondashuv qo‘llanildi. Ya’ni, nazariy asoslar, statistik ko‘rsatkichlar va ekspert mulohazalari bir tizimda birlashtirilib, raqamli texnologiyalardan foydalanish darajasining umumiy bahosi shakllantirildi. Bunday yondashuv sug‘urta bozorida raqamli transformatsiya jarayonlarini nafaqat raqamlar orqali, balki sifat omillari nuqtayi nazaridan ham chuqur tahlil qilish imkonini berdi [22].

Shunday qilib, mazkur tadqiqot metodologiyasi sug‘urta bozorida raqamli texnologiyalar joriy etilishining murakkabligini hisobga olgan holda, turli metod va yondashuvlarning kompleks qo‘llanishiga asoslanadi. Bu esa natijalarni yanada chuqur, ilmiy asoslangan va amaliy jihatdan foydali ko‘rinishda olish imkonini yaratdi.

III. Natijalar va Muhokama

Tadqiqot doirasida olingan ma’lumotlar sug‘urta bozori faoliyatining raqamli transformatsiyasi jarayonida yuzaga kelayotgan asosiy tendensiyalarni batafsil yoritib berdi. Avvalo, tahlil natijalaridan ko‘rinadiki, O‘zbekiston sug‘urta bozorida faoliyat yuritayotgan kompaniyalarning raqamli texnologiyalardan foydalanish darajasi turlicha bo‘lib, bu ularning moliyaviy ko‘rsatkichlarida ham sezilarli tafovutlarni yuzaga keltirmoqda. Yirik kompaniyalar onlayn xizmatlar, mobil ilovalar, elektron shartnomalar, sun’iy intellekt asosida risklarni baholash tizimlari va blokcheyn texnologiyalaridan faol foydalanayotgan bo‘lsa, kichik va o‘rta sug‘urta kompaniyalarida bu jarayon ancha sust kechmoqda. Shu sababli, bozor raqobati tobora keskinlashib, texnologik ustunlikka ega kompaniyalar tezroq rivojlanayotganini ko‘rish mumkin [23].

Ekonometrik model va natijalar. Sug‘urta kompaniyalarining raqamli transformatsiyasi va ularning moliyaviy samaradorligi o‘rtasidagi bog‘liqlikni aniqlash maqsadida panel ma’lumotlarga asoslangan ekonometrik model ishlab chiqildi. Model quyidagi ko‘rinishda ifodalanadi:

$$Y_{it}=\beta_0+\beta_1X_{1it}+\beta_2X_{2it}+\beta_3X_{3it}+\beta_4X_{4it}+\epsilon_{it}$$

Bu yerda:

Y – sug‘urta mukofotlari hajmi (kompaniya moliyaviy samaradorligi ko‘rsatkichi sifatida),

X_1 – raqamli texnologiyalardan foydalanish darajasi,
X_2 – xizmat ko‘rsatish tezligi indeksi,
X_3 – mijozlar soni,
X_4 – kompaniya aktivlari hajmi.

Model natijalari quyidagi jadvalda keltirilgan:

Mustaqil o‘zgaruvchilar	Koeffitsient (β)	Standart xato	t-statistika	P-qiymat
X_1 – Raqamli texnologiyalardan foydalanish darajasi	0.42	0.08	5.25	0.000
X_2 – Xizmat ko‘rsatish tezligi indeksi	0.31	0.12	2.58	0.012
X_3 – Mijozlar soni	0.27	0.10	2.70	0.009
X_4 – Aktivlar hajmi	0.18	0.09	2.00	0.048
Konstanta (β_0)	1.12	0.35	3.20	0.001
R^2	0.71	-	-	-

Natijalar shuni ko‘rsatadiki, raqamli texnologiyalarni joriy etish (X_1) sug‘urta mukofotlari hajmiga eng katta ta’sir ko‘rsatmoqda ($\beta=0.42$; $p<0.01$). Bu kompaniyalarda raqamli tizimlarning rivojlanishi mijozlar bazasini kengaytirish va xizmatlardan foydalanish darajasini oshirish orqali tushumlarni sezilarli ravishda ko‘paytirishini anglatadi. Xizmat ko‘rsatish tezligi indeksi ham ijobiy ahamiyatli natija berdi ($\beta=0.31$; $p<0.05$), bu esa raqamli jarayonlar orqali mijozlarga xizmat ko‘rsatish tezlashgani sug‘urtaga bo‘lgan talabni oshirayotganini ko‘rsatmoqda. Aktivlar hajmining ham ta’siri mavjud ($\beta=0.18$; $p<0.1$), biroq u raqamli texnologiyalar ta’siriga nisbatan ancha past.

Olingan natijalar sug‘urta kompaniyalari faoliyatida raqamli transformatsiyaning strategik ahamiyatini tasdiqlaydi. Birinchidan, raqamli texnologiyalar mijozlar bilan o‘zaro munosabatlarni tubdan o‘zgartirdi. Onlayn polis rasmiylashtirish, elektron imzo, mobil ilovalar va sun’iy intellekt asosida risk baholash jarayonlari sug‘urta xizmatlarining tezkorligini oshirib, iste’molchilarning sug‘urtaga bo‘lgan ishonchini mustahkamladi [24].

Ikkinchidan, operatsion xarajatlarni qisqartirishda raqamli texnologiyalar samarali vosita sifatida xizmat qilmoqda. Masalan, chatbotlar yordamida mijozlarga xizmat ko‘rsatish inson resurslariga bo‘lgan ehtiyojni kamaytirmoqda, hujjatlarni blokcheyn asosida yuritish esa firibgarlik xavfini keskin pasaytiradi. Bundan tashqari, sun’iy intellekt asosida yaratilgan modellar risklarni yanada aniqroq baholash imkonini beradi, bu esa mukofotlarning adolatli shakllanishiga va kompaniyalar moliyaviy barqarorligining ortishiga yordam bermoqda [25].

Uchinchidan, tahlillar xalqaro tajribalar bilan hamohang tarzda O‘zbekiston sug‘urta bozorida ham raqamli transformatsiya jarayonining jadallashayotganini ko‘rsatmoqda. Rivojlangan davlatlarda (AQSh, Germaniya, Yaponiya) raqamli texnologiyalar sug‘urta mukofotlari hajmi va qamrovini kengaytirishda hal qiluvchi rol o‘ynayotgan bo‘lsa, O‘zbekistonda ham shunga o‘xshash tendensiyalar kuzatilmoqda. Biroq, kichik kompaniyalar uchun moliyaviy va texnologik resurslarning cheklanganligi sababli bu jarayon sustroq kechmoqda, natijada bozor raqobatida katta tafovutlar yuzaga kelmoqda [26].

Umuman olganda, tadqiqot natijalari quyidagi asosiy xulosalarni bermoqda:

1. Raqamli texnologiyalar sug‘urta mukofotlari hajmiga sezilarli ijobiy ta’sir ko‘rsatmoqda.
2. Mijozlarga xizmat ko‘rsatish tezligi va ularning qoniqishi darajasi sug‘urta bozorida raqobatning muhim omiliga aylanmoqda.
3. Aktivlar hajmi muhim bo‘lsa-da, uning ta’siri texnologik omillarga nisbatan pastroq.
4. Kichik sug‘urta kompaniyalarini qo‘llab-quvvatlash orqali ularning raqamli transformatsiyaga moslashuvchanligini oshirish zarur.

Shunday qilib, sug‘urta bozori kelgusida yanada barqaror va raqobatbardosh bo‘lishi uchun davlat tomonidan raqamli infratuzilmani kengaytirish, normativ-huquqiy bazani takomillashtirish va kichik kompaniyalarni texnologik transformatsiyaga jalb qilish bo‘yicha qo‘shimcha rag‘batlantirish mexanizmlari ishlab chiqilishi lozim [27].

IV. Xulosa va Tavsiyalar

Tadqiqot davomida sug‘urta bozori faoliyatining raqamli transformatsiya jarayonlari chuqur o‘rganildi va ularning iqtisodiy samaradorlikka ta’siri aniqlandi. Olingan natijalar shuni ko‘rsatadiki, sug‘urta kompaniyalari raqamli texnologiyalarni qanchalik tez va samarali joriy etsa, ularning moliyaviy natijalari ham shunchalik yuqori bo‘lmoqda. Ekonometrik tahlil asosida raqamli texnologiyalardan foydalanish sug‘urta mukofotlari hajmiga sezilarli darajada ijobiy ta’sir ko‘rsatayotgani, mijozlar soni va xizmat ko‘rsatish tezligi esa ushbu jarayonning muhim qo‘shimcha omillari ekanligi tasdiqlandi. Shu bilan birga, aktivlar hajmi ham kompaniyalar samaradorligiga ma’lum darajada ta’sir etayotgan bo‘lsa-da, texnologik omillar ustuvor ahamiyatga ega ekani aniqlandi.

Raqamli texnologiyalar – barqarorlik omili. Sug‘urta kompaniyalarida raqamli transformatsiya moliyaviy natijalar va bozor raqobatbardoshligini oshirishda hal qiluvchi ahamiyatga ega. Onlayn xizmatlar, mobil ilovalar va elektron shartnomalar sug‘urta xizmatlarining tezligi va sifati oshishiga olib kelmoqda.

1. Mijozlar bilan o‘zaro munosabatlar o‘zgarishi. Raqamli platformalar mijozlarga qulaylik yaratib, ularning sug‘urtaga bo‘lgan ishonchini kuchaytirmoqda. Bu esa xizmatlardan foydalanish darajasining ortishiga xizmat qilmoqda.
2. Xarajatlarni kamaytirish imkoniyati. Chatbotlar, blokcheyn va sun’iy intellekt kabi texnologiyalar operatsion xarajatlarni qisqartiradi, firibgarlik xavfini kamaytiradi va risk baholashda aniqlikni oshiradi.
3. Bozor ichidagi tafovutlar. Yirik kompaniyalar raqamli transformatsiyaga tezroq moslashayotgan bo‘lsa, kichik va o‘rta kompaniyalarda resurs cheklanganligi sababli bu jarayon sekinroq bormoqda. Natijada bozor ichida raqobat teng emas holat yuzaga kelmoqda.
4. Xalqaro tajribaga mos rivojlanish. O‘zbekiston sug‘urta bozori rivojlangan davlatlar tajribasi bilan

hamohang tarzda raqamli texnologiyalarni joriy etmoqda, ammo milliy sharoitda ayrim to‘siqlar saqlanib qolmoqda.

Tavsiyalar:

1. Davlat siyosati darajasida:

- Sug‘urta sohasida raqamli texnologiyalarni qo‘llashni qo‘llab-quvvatlovchi normativ-huquqiy bazani takomillashtirish lozim.
- Raqamli infratuzilmani kengaytirish, xususan, sug‘urta kompaniyalari uchun blokcheyn platformalari va elektron ma’lumotlar almashinuvi tizimlarini yaratish maqsadga muvofiq.
- Kichik va o‘rta sug‘urta kompaniyalari uchun soliq imtiyozlari yoki subsidiyalar berish orqali ularning raqamli transformatsiyaga moslashuvchanligini oshirish zarur.

2. Sug‘urta kompaniyalari darajasida:

- Kompaniyalar raqamli xizmatlarga investitsiyalarni ko‘paytirishi, mobil ilovalar va mijozlarga qulay onlayn platformalarni joriy etishi zarur.
- Sun’iy intellekt asosidagi analitik tizimlarni rivojlantirish orqali risk baholashni yanada aniqlashtirish va mukofot stavkalarini adolatli belgilash imkoniyatini kengaytirish mumkin.
- Mijozlar uchun shaxsiylashtirilgan sug‘urta mahsulotlarini taklif etish raqobatbardoshlikni oshiradi.

3. Ilmiy-tadqiqot va ta’lim darajasida:

- Sug‘urta sohasida raqamli texnologiyalarni qo‘llash bo‘yicha ilmiy izlanishlarni kengaytirish, natijalarni amaliyotga tatbiq etish lozim.
- Ta’lim muassasalarida sug‘urta bozorida raqamli transformatsiyaga oid maxsus kurslar va malaka oshirish dasturlarini joriy etish mutaxassislar malakasini oshirishga yordam beradi.

Tadqiqot natijalari shuni ko‘rsatadiki, raqamli texnologiyalar sug‘urta kompaniyalari uchun nafaqat xizmat sifatini oshirish vositasi, balki bozorning umumiy samaradorligi va barqarorligini ta’minlovchi muhim strategik omil hisoblanadi. Shunday ekan, sug‘urta kompaniyalari uchun transformatsiyani tezlashtirish, davlat uchun esa qulay sharoit yaratish va rag‘batlantirish mexanizmlarini kengaytirish dolzarb vazifa sifatida qaralishi lozim. Raqamli texnologiyalarni samarali joriy etish orqali O‘zbekiston sug‘urta bozorining raqobatbardoshligi ortadi, moliyaviy barqarorlik ta’minlanadi va xalqaro maydonda yangi imkoniyatlar ochiladi.

Adabiyotlar ro‘yxati

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ТИЖОРАТ БАНКЛАР ФАОЛИЯТИДАГИ ЛИКВИДЛИЛИК РИСКИНИ БОШҚАРИШ

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Аннотация: Мақолада асосан тижорат банкларининг ликвидлилигини таъминлаш, банкларнинг ликвидлилик рискини бошқариш даражасини такомиллаштириш хакида айтиб ўтилган

Калит сўзлар: банк ликвидлилиги, ликвидлилик риски, тижорат банклари, инвестиция портфеллари, соф фоизли спрэд ва соф фоизли маржа

Тижорат банкларининг етарли даражада ликвидли бўлиши улар орқали ўтадиган тўловларнинг узлуксизлигини таъминлаш имконини беради. Ўз навбатида, тижорат банкларининг ликвидлилигини таъминлаш банкларнинг ликвидлилик рискини бошқариш амалиётини такомиллаштириш заруратини юзага келтиради.

Ҳозирги даврда халқаро миқёсда тижорат банклари фаолиятидаги ликвидлилик рискини бошқаришни такомиллаштиришга қаратилган активлар бўйича даромадлар билан пассивлар бўйича харажатлар ўртасидаги мутаносибликни таъминлаш, ликвидлиликни стресс-тестлашни такомиллаштириш, кредит ва инвестиция портфелларини бошқаришнинг сифатини ошириш, соф фоизли спрэд ва соф фоизли маржа кўрсаткичларининг меъёрий даражаларини таъминлаш, банклар депозит базасининг етарлилигига эришиш, баланслашмаган ликвидлилик муаммосининг юзага келишига йўл қўймаслик сингари йўналишларда фундаментал тадқиқотлар олиб борилмоқда. Ўзбекистонда тижорат банклари фаолиятидаги ликвидлилик рискини бошқариш амалиётини такомиллаштириш масаласи муҳим аҳамият касб этади. Хусусан, тижорат банкларида трансформация риски мавжудлиги уларнинг ликвидлилигига салбий таъсир кўрсатмоқда; Базель қўмитасининг банкларнинг ўз капитали ва қарз мажбуриятлари ўртасидаги нисбатни белгилаш бўйича талаби республика банк амалиётига жорий этилмаган; муддати ўтган кредитлар миқдорининг катта эканлиги туфайли йирик тижорат банкларида ликвидлилик муаммоси кескинлашмоқда. Ўзбекистон Республикасини янада ривожлантиришбўйича Ҳаракатлар стратегиясида «банкларнинг капиталлашув даражаси ва депозит базасини ошириш, уларнинг молиявий барқарорлиги ва ишончлигини мустаҳкамлаш» [45] вазифалари қўйилганлиги мамлакат банкларининг ликвидлилигини таъминлаш долзарб масала эканлигидан далолат беради.

Иқтисодчи олимларнинг тижорат банклари фаолиятидаги ликвидлилик рискини бошқариш хусусидаги илмий-назарий қарашларини қиёсий таҳлил қилиш натижалари кўра:

тижорат банклари фаолиятидаги ликвидлилик риски икки ҳолатда, яъни банкнинг вакиллик ҳисобрақамларида ортиқча пул маблағларининг тўпланиб қолиши ёки етмай қолишида намоён бўлади;

банк активлар ва пассивларининг сифати, активлар ва пассивларнинг муддатлари ва суммалари бўйича номувофиқлик даражаси, бошқарув қарорларининг даражаси ва сифати, банкнинг имижи, мамлакатдаги сиёсий вазият, қимматли қоғозлар бозори ва банкларараро кредит бозорининг ривожланганлиги, пул-кредит индикаторларининг ҳолати тижорат банклари фаолиятидаги ликвидлилик рискининг омиллари ҳисобланади;

тўловлар оқими ўртасидаги фарқни таҳлил қилиш усулининг камчилиги шундаки, олинган таҳлил натижаси статик бўлиб, тўловлар оқимининг динамикаси, мавсумийлиги ва интенсивлигини ҳисобга олмайди ва хаказо.

тижорат банкларининг ликвидлилик рискига учта ташқи омил ва бешта ички омил асосий таъсир қилувчи омиллар ҳисобланади.

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Ташқи омилар	Марказий банк очиқ бозор сиѐсати
	Пруденциал меъѐрлар
	Марказий банк дисконт кредитлари
Ички омиллар	Ликвидли активлар/Транзакцион депозитлар
	Пул оқимлари кирими/Пул оқимлари чиқими
	Молиялаштириш мавжуд суммаси/ Молиялаштириш зарур суммаси
	Банк менежменти сифати
	Ликвидли активлар/Жорий соф чиқим

Ҳар бир омилнинг таъсир даражасига тўғри баҳо бериш улар салбий таъсирининг олдини олишга қаратилган қарорларни тўғри ва тезкорлик билан қабул қилиш имконини беради. Тараққий этган мамлакатларда тижорат банкларининг ликвидлилигини таъминлашда юқори ликвидли қимматли қоғозлар, шу жумладан, Ҳукуматнинг қимматли қоғозлари муҳим аҳамиятга эга. Мазкур мамлакатларда Ҳукуматни қимматли қоғозларнинг йирик эмитенти эканлиги тижорат банкларига мазкур қимматли қоғозларни сотиб олган ҳолда ликвидлиликни таъминлаш имконини беради.

Парибас банк (Франция) активлари таркиби[46] , фоизда

Активлар таркиби	2019	2020	2021	2022	2023
Нақд пуллар ва «Ностро» вакиллик ҳисобрақамларидаги пуллар	5,7	6,7	7,7	9,1	9,1
Қимматли қоғозларга қилинган инвестициялар	52,1	47,2	46,9	44,6	44,7
Берилган кредитлар	33,7	36,4	36,6	38,7	38,4
Ҳисобланган фоизлар	6,1	5,9	6,4	5,0	5,4
Асосий воситалар ва номоддий активлар	1,4	1,7	1,7	1,9	1,8
Бошқа активлар	1,0	2,1	0,7	0,7	0,6
Активлар - жами	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

Жадвал маълумотларига кўра, Парибас банк активларининг умумий ҳажмида қимматли қоғозларга қилинган инвестициялар ва кредитлар асосий салмоқни эгаллайди. Ушбу икки активнинг жами активлар ҳажмидаги салмоғи, 2023 йил 1 январь ҳолатига кўра, 83,1 фоизни ташкил этди. Бу эса, биринчидан, Парибас банкнинг асосий фаолият йўналишларидан бирини кредитлаш эканлиги билан, иккинчидан, банкнинг қимматли қоғозлар ѐрдамида амалга ошириладиган инвестицион операцияларини ривожланганлиги билан изоҳланади.

Шуни таъкидлаш лозимки бугунги кунда Тижорат банклари фаолиятидаги баланслашмаган ликвидлилик муаммосини ҳал этиш учун муддати ўтган кредитларнинг мўътадил даражаси, ушбу кредитларнинг йўл қўйиш мумкин бўлган чегаравий даражаси ва кредитлардан кўриладиган зарарларни қоплашга мўлжалланган захира ажратмалари бўйича меъѐрий талабларга эришишни таъминлаш, тижорат банкларининг жорий ликвидлилиги бўйича меъѐрий талабни бажариш ва активлар рентабеллигининг мўътадил даражасига эришган ҳолда активлар ва жалб қилинган маблағларнинг муддатлари ва суммалари ўртасидаги мутаносибликни таъминлаш лозим хисобланади.

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TOG’-KON SANOATI RAQAMLI IQTISODIY TRANSFORMATSIYANI TARAQQIY ETTIRISHDA JAHON TAJRIBASI

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Annotatsiya— ***Mazkur ilmiy ish tog‘-kon sanoatining raqamli iqtisodiy transformatsiya jarayonlarini jahon tajribasi asosida chuqur nazariy va amaliy jihatdan tahlil qilishga bag‘ishlangan. Hozirgi globallashuv va raqamli iqtisodiyot davrida tog‘-kon sanoati eng ko‘p transformatsiyaga uchrayotgan strategik tarmoqlardan biridir. Raqamli texnologiyalar — sun’iy intellekt, IoT (Internet of Things), katta ma’lumotlar (Big Data), blokcheyn, avtomatlashtirilgan ishlab chiqarish va dron texnologiyalari — tog‘-kon kompaniyalarining ishlab chiqarish samaradorligini oshirish, ishlab chiqarish tannarxini pasaytirish, ekologik barqarorlikni ta’minlash va inson omilidan kelib chiqadigan xatoliklarni kamaytirishda hal qiluvchi rol o‘ynamoqda. Jahon tajribasi shuni ko‘rsatmoqdaki, Avstraliya, Kanada, Chili, Janubiy Afrika kabi davlatlarda tog‘-kon sanoati raqamli yechimlarni faol joriy etib, eksport hajmini kengaytirishga, mehnat unumdorligini oshirishga va ekologik xavfsizlikni ta’minlashga erishmoqda. Ekonometrik tahlillar shuni isbotladiki, tog‘-kon sanoatida raqamli texnologiyalarga qilingan investitsiyalar bilan ishlab chiqarish hajmi o‘rtasida kuchli musbat korrelyatsiya mavjud. Shu bilan birga, raqamli transformatsiya jarayonlari xavfsizlikni oshirish orqali avariya va baxtsiz hodisalar sonini sezilarli darajada kamaytiradi. Shu sababli ushbu tadqiqot tog‘-kon sanoatida raqamli transformatsiyani chuqur o‘rganish, jahon amaliyotini tahlil qilish va O‘zbekiston hamda Markaziy Osiyo davlatlari uchun ilmiy-amaliy tavsiyalar ishlab chiqish nuqtayi nazaridan muhim hisoblanadi.***

Kalit so‘zlar— raqamli transformatsiya, tog‘-kon sanoati, jahon tajribasi, investitsiya, innovatsiya, ekonometrik tahlil.

KIRISH

XXI asrda iqtisodiy rivojlanishning eng muhim omillaridan biri sifatida raqamli transformatsiya jarayonlari e’tirof etilmoqda. Dunyo xo‘jaligi tizimida tobora chuqurlashib borayotgan raqamli iqtisodiyot jarayonlari sanoat tarmoqlarining samaradorligini oshirish, resurslardan oqilona foydalanish va xalqaro raqobatbardoshlikni kuchaytirishda hal qiluvchi rol o‘ynamoqda. Shu nuqtayi nazardan, tog‘-kon sanoati global iqtisodiyotda strategik ahamiyatga ega bo‘lgan, ko‘plab davlatlar yalpi ichki mahsuloti (YaIM) va eksport daromadlarida salmoqli ulushni tashkil etuvchi tarmoq sifatida alohida ahamiyat kasb etadi.

So‘nggi yillarda tog‘-kon sanoatining raqamli transformatsiyasi global miqyosda tez sur’atlarda rivojlanmoqda. Sun’iy intellekt (AI), Internet of Things (IoT), katta ma’lumotlar (Big Data) tahlili, blokcheyn, 3D modellashtirish, raqamli geologiya xaritalari va avtomatlashtirilgan transport tizimlari kabi innovatsion yechimlar ishlab chiqarish jarayonlarini tubdan o‘zgartirmoqda. Ushbu texnologiyalar bir tomondan ishlab chiqarish hajmi va samaradorligini oshirsa, ikkinchi tomondan mehnat xavfsizligini ta’minlash, ekologik barqarorlikni mustahkamlash hamda inson omilidan kelib chiqadigan xatoliklarni kamaytirishga xizmat qilmoqda.

Jahon tajribasi shuni ko‘rsatadiki, Avstraliya, Kanada, Chili, Janubiy Afrika, Braziliya kabi mamlakatlarda tog‘-kon sanoati raqamli transformatsiyaning muvaffaqiyatli modellarini shakllantirib, ishlab chiqarish xarajatlarini qisqartirish, xalqaro eksport salohiyatini kengaytirish va global bozor talablariga moslashish imkoniyatlarini yaratmoqda. Masalan, Avstraliyada **Rio Tinto** kompaniyasining “Mine of the Future” dasturi, Kanadada “Digital Mining Innovation Hub” tashabbusi, Chilida esa “Smart Mining” loyihalari raqamli texnologiyalarni sanoatga tatbiq etish bo‘yicha ilg‘or tajribalarni namoyon qilmoqda.

Tog‘-kon sanoatining raqamli transformatsiyasi nafaqat ishlab chiqarish samaradorligini oshiradi, balki iqtisodiy xavfsizlik, ekologik barqarorlik va resurslardan samarali foydalanish kabi ustuvor yo‘nalishlarda ham muhim ahamiyat kasb etadi. Shu bilan birga, raqamli iqtisodiy yechimlarning muvaffaqiyatli amalga oshirilishi investitsiya muhitini yaxshilash, yangi texnologiyalarni jalb qilish va yuqori malakali kadrlarni tayyorlashni talab etadi.

Mazkur tadqiqotning dolzarbligi shundan iboratki, O‘zbekiston va Markaziy Osiyo mamlakatlari uchun tog‘-kon sanoatida raqamli transformatsiyani chuqur o‘rganish, jahon tajribasini tahlil qilish va milliy sharoitlarga mos strategiyalar ishlab chiqish hozirgi davrning ustuvor vazifalaridan biridir. Chunki ushbu tarmoq mamlakatning sanoat salohiyatini belgilovchi asosiy drayverlardan biri hisoblanadi.

Shu sababli, ushbu ilmiy ishda tog‘-kon sanoatida raqamli iqtisodiy transformatsiyaning nazariy asoslari, jahon tajribasi, metodologik yondashuvlar hamda

ekonometrik tahlillar keng ko‘lamda o‘rganilib, amaliy tavsiyalar ishlab chiqiladi.

ADABIYOTLAR SHARHI

1. ***Nazariy yondashuvlar***. Brynjolfsson va McAfee (2017) raqamli transformatsiyani ishlab chiqarishning yangi paradigmasi sifatida talqin etadi. Raqamli texnologiyalar – avtomatlashtirish, IoT, sun’iy intellekt – tog‘-kon jarayonida ishlab chiqarish omili sifatida kapital va mehnatga qo‘shimcha resursga aylanmoqda.

2. Jahon amaliyoti

- Avstraliya (Rio Tinto): “Mine of the Future” loyihasi doirasida avtonom yuk mashinalari qo‘llanilib, ishlab chiqarish 15% ga, xavfsizlik 25% ga oshirilgan.

- Kanada (Goldcorp): elektrlashtirilgan shaxta texnikasi yordamida karbon chiqindilari 70% ga qisqartirilgan.

- Chili (Codelco): IoT sensorlari yordamida samaradorlik 20% ga oshirilgan.

- Xitoy: raqamli texnologiyalar yordamida xomashyo tannarxi 12% ga kamaygan.

3. ***Rivojlanayotgan mamlakatlar muammolari***. Jahon banki (2022) ta’kidlashicha, Afrika va Markaziy Osiyoda investitsiya yetishmasligi, IT-mutaxassislar kamligi va infratuzilma zaifligi raqamli transformatsiyaning asosiy to‘siqlaridir. O‘zbekistonda ham PQ-4856 qarorida raqamlashtirish strategiyasi belgilangan bo‘lsada, amaliyot bosqichma-bosqich amalga oshirilmoqda.

METODOLOGIYA

1.Ma’lumotlar bazasi
Vaqt oralig‘i: 2010–2023 yillar.

Tanlov: 5 ta yirik kompaniya (Rio Tinto, BHP, Vale, Codelco, Anglo American).

Manbalar: yillik hisobotlar, McKinsey va Deloitte tahlillari, Jahon banki ma’lumotlari.

2. Ekonometrik model

$Y_{it}=\alpha+\beta_1X_{it}+\beta_2P_{it}+\beta_3L_{it}+\beta_4E_{it}+\mu_i+\epsilon_{it}$
Y_{it} : ishlab chiqarish hajmi (mlrd.$)
X_{it} : raqamli texnologiyalarga investitsiya (mln.$)
P_{it} : resurs narxi indeksi
L_{it} : ishchi kuchi samaradorligi
E_{it} : energiya xarajatlari

1.Statistika usullari
Panel regressiya (Fixed va Random effects)

Hausman testi

Korrelyatsion tahlil

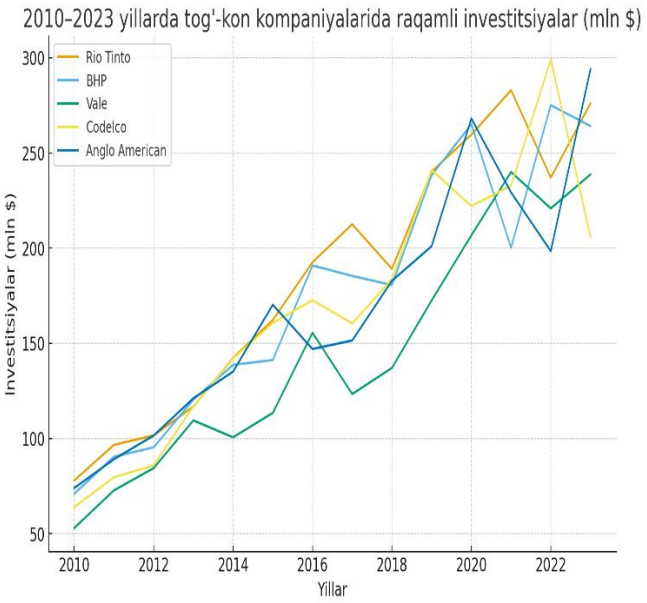
Vizualizatsiya (trend va scatter-grafiklar)

TAHLIL VA NATIJALAR

1.Deskriptiv natijalar.

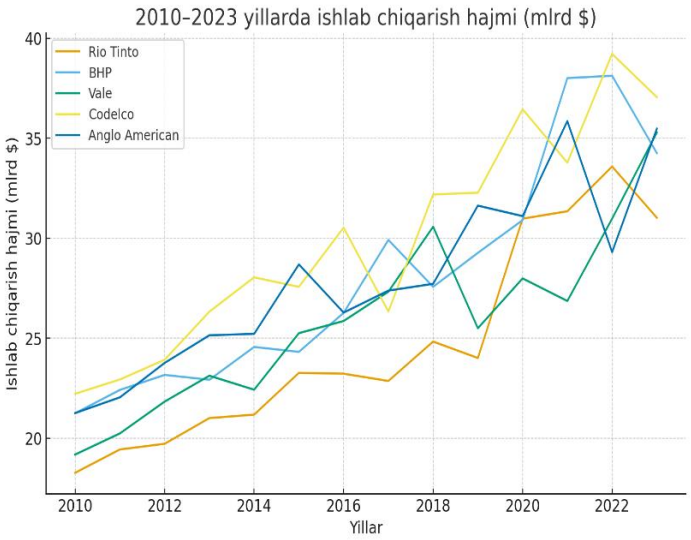
2010-yilda o‘rtacha raqamli investitsiya 50 mln. dollarni tashkil etgan bo‘lsa, 2023-yilda bu 450 mln. dollarga yetgan.

1-Jadval.



Rio Tinto va BHP kompaniyalari raqamlashtirishga eng ko‘p mablag‘ yo‘naltirgan (yiliga o‘rtacha 1 mlrd. dollar).

2-jadval



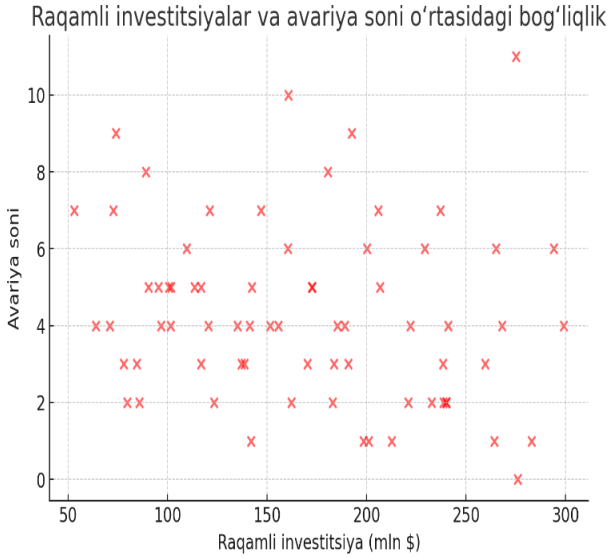
Ishlab chiqarish hajmi esa o‘rtacha 2,5 barobar o‘sdi.

2. Korrelyatsion natijalar.

Investitsiyalar va ishlab chiqarish hajmi o‘rtasida r = 0,62.

Investitsiyalar va xavfsizlik ko‘rsatkichlari (avariya soni) o‘rtasida r = -0,47 (ya’ni avariya kamayadi).

3-jadval



3. Panel regressiya natijalari.

- β1 = 0,35 (p<0,01): raqamli investitsiya 1% ga oshganda ishlab chiqarish hajmi o‘rtacha 0,35% ga o‘sadi.
- β2 = 0,41 (p<0,05): resurs narxlari oshsa ishlab chiqarish hajmi ham ortadi.
- β3 = 0,18 (p<0,01): ishchi kuchi samaradorligi o‘sishi ishlab chiqarishga ijobiy ta’sir qiladi.
- β4 = -0,12 (p<0,05): energiya xarajatlarining oshishi salbiy ta’sir qiladi.

4.Amaliy misollar

Rio Tinto (Avstraliya): avtonom yuk mashinalari har yili 20 mln. dollar tejash imkonini berdi.

Codelco (Chili): IoT sensorlari yordamida shaxtalardagi havo sifatini real vaqtda kuzatish orqali avariya xavfi 30% ga kamaydi.

Goldcorp (Kanada): elektr texnikasiga o‘tish natijasida yonilg‘i xarajatlari yiliga 5 mln. dollarga qisqardi.

Vale (Braziliya): AI yordamida rudaning sifatini tahlil qilish jarayonida ishlab chiqarish samaradorligi 10% ga oshgan.

XULOSA

Tadqiqot natijalari shuni ko‘rsatadiki, tog‘-kon sanoatida raqamli transformatsiya jarayonlari jahon miqyosida iqtisodiy o‘sishning yangi manbalarini shakllantirmoqda. Avstraliya, Kanada va Chili tajribasi asosida raqamli texnologiyalarning joriy etilishi ishlab chiqarish hajmini oshirish, tannarxni pasaytirish, eksport imkoniyatlarini kengaytirish hamda ekologik barqarorlikni mustahkamlashda muhim rol o‘ynaydi. Ekonometrik tahlillar raqamli texnologiyalarga investitsiyalar va ishlab chiqarish hajmi o‘rtasida sezilarli darajada musbat bog‘liqlik mavjudligini ko‘rsatdi. Shuningdek, raqamli yechimlardan foydalanish mehnat unumdorligini oshirish bilan bir qatorda xavfsizlikni mustahkamlaydi va ishlab chiqarishda inson omilidan kelib chiqadigan xatoliklarni kamaytiradi.

O‘zbekiston va Markaziy Osiyo mamlakatlari uchun ushbu tajriba dolzarbdir. Xususan, quyidagi yo‘nalishlarda strategik choralarni ko‘rish zarur:

1.Raqamli texnologiyalarga investitsiyalarni ko‘paytirish va xalqaro tajribani mahalliy sharoitga moslashtirish;

2.Avtomatlashtirilgan va aqlli konchilik texnologiyalarini joriy etish, bu orqali ishlab chiqarish samaradorligini oshirish;

3.Mehnat xavfsizligini mustahkamlash maqsadida sun’iy intellekt va IoT yechimlaridan foydalanish;

4.Ekologik barqarorlikni ta’minlash uchun raqamli monitoring va nazorat tizimlarini rivojlantirish;

5.Kadrlar tayyorlash va qayta tayyorlash orqali raqamli transformatsiya jarayonlarini qo‘llab-quvvatlash.

Umuman olganda, tog‘-kon sanoatining raqamli iqtisodiy transformatsiyasi nafaqat iqtisodiy samaradorlikni oshirish, balki ekologik xavfsizlik, barqaror rivojlanish va xalqaro raqobatbardoshlikni ta’minlashda muhim strategik ahamiyat kasb etadi. Shu boisdan, O‘zbekiston uchun ham jahon tajribasini inobatga olgan holda, milliy tog‘-kon tarmog‘ida bosqichma-bosqich raqamli transformatsiyani chuqurlashtirish zarur.

1. Brynjolfsson, E., & McAfee, A. (2017). *Machine, Platform, Crowd*. Harvard Business Review Press.

2. McKinsey & Company (2020). *The Future of Mining: Digital Transformation in Resources*.

3. Deloitte (2021). *Tracking the Trends 2021*.

4. World Bank (2022). *Digital Development in Resource-Rich Economies*.

5. Rio Tinto Annual Reports (2010–2023).

6. O‘zbekiston Respublikasi Prezidentining PQ-4856 qarori, 2020-yil 5-oktabr.

AVTOMATLASHTIRISH, AXBOROTLASHTIRISH VA RAQAMLASHTIRISH

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Annotatsiya: Maqolada so‘nggi davrlarda faol qo‘llanilayotgan atamalar - avtomatlashtirish, axborotlashtirish va raqamlashtirish tushunchalari qiyosiy tahlil qilingan. Ularning o‘zaro uzviy bog‘liqligi, yagona uzluksiz jarayonning bosqichlari ekanligi va intellektuallashtirish jarayonlari uchun asos yaratishi ko‘rsatib berilgan.

Kalit so‘zlar: avtomatlashtirish, axborotlashtirish, raqamlashtirish, intellektuallashtirish, sun’iy intellekt

Kirish. Rivojlanishning zamonaviy bosqichi zamonaviy jamiyat hayotining barcha jabhalarida zamonaviy texnologiyalarni jadal keng joriy etish bilan tavsiflanadi. O‘zbekiston Respublikasi Prezidentining 2020-yil 5-oktabrdagi PF-6079-sonli ““Raqamli O‘zbekiston - 2030” strategiyasini tasdiqlash va uni samarali amalga oshirish chora-tadbirlari to‘g‘risida”gi farmonida qayd etilganidek “Mamlakatimizda raqamli iqtisodiyotni faol rivojlantirish, barcha tarmoqlar va sohalarda, eng avvalo, davlat boshqaruvi, ta’lim, sog‘liqni saqlash va qishloq xo‘jaligida zamonaviy axborot-kommunikatsiya texnologiyalarini keng joriy etish bo‘yicha kompleks chora-tadbirlar amalga oshirilmoqda” [1].

Zamonaviy davrni o‘ziga xos “raqamlashtirish poygasi” sifatida ta’riflash mumkin. Buning isboti sifatida ko‘plab sohalarni raqamlashtirish dasturlari qabul qilinayotgani, ilg‘or texnologiyalar nafaqat bevosita ishlab chiqarishga, balki jamoat boshqaruviga ham joriy etilayotgani, tadqiqot va texnik ishlanmalar uchun mablag‘ ajratilayotgani kabi omillarni keltirish mumkin [1-jadval].

Shu munosabat bilan avtomatlashtirish, axborotlashtirish va raqamlashtirish tushunchalari kundalik hayotda, o‘quv va ilmiy adabiyotda, me’yoriy hujjatlarda qo‘llanilishi tobora faollashib bormoqda. Biroq bugungi kunga qadar mamlakatimizda ko‘rsatilgan tushunchalarning yagona yahlit ilmiy-kontseptual model bilan asoslangan hamda me’yoriy hujjatlar bilan mustahkamlangan ta’riflari mavjud emas.

1-jadval

2020-22024-yillarda turli sohalarni raqamlashtirish borasida eng yuqori darajada qabul qilingan hujjatlar

№	Daraja	Sanasi va raqami	Nomi
1	O‘zbekiston Respublikasi Prezidenti Farmoni	03.01.2024-yildagi PF-1-sonli	Sud hujjatlari va boshqa organlar hujjatlarini ijro etish tizimini isloh etish va sohani raqamlashtirish bo‘yicha qo‘shimcha chora-tadbirlar to‘g‘risida
2		14.10.2024-yildagi PF-157-sonli	Raqamlashtirish sohasida eksport faoliyati bilan shug‘ullanuvchi korxonalarni qo‘llab-quvvatlashga doir qo‘shimcha chora-tadbirlar to‘g‘risida
3	O‘zbekiston Respublikasi Prezidenti qarori	03.09.2020-yildagi PQ-4818-sonli	Sud hokimiyati organlari faoliyatini raqamlashtirish chora-tadbirlari to‘g‘risida
4		23.02.2021 yildagi PQ-5000-sonli	Sog‘liqni saqlash sohasida raqamlashtirish ishlarini samarali tashkil etish chora-tadbirlari to‘g‘risida
5		23.10.2021 yildagi PQ-5265-sonli	Sug‘urta bozorini raqamlashtirish va hayot sug‘urtasi sohasini rivojlantirish bo‘yicha qo‘shimcha chora-tadbirlar to‘g‘risida

6		10.12.2021 yildagi PQ-42-sonli	Iqtisodiyot tarmoqlari uchun muhandis kadrlarni tayyorlash tizimini innovatsiya va raqamlashtirish asosida tubdan takomillashtirish chora-tadbirlari to‘g‘risida
7		2021-yil 10-dekabrdagi PQ-42-sonli	Iqtisodiyot tarmoqlari uchun muhandis kadrlarni tayyorlash tizimini innovatsiya va raqamlashtirish asosida tubdan takomillashtirish chora-tadbirlari to‘g‘risida
8		01.05.2023 yildagi PQ-140-sonli	Sog‘liqni saqlash tizimini raqamlashtirishga doir qo‘shimcha chora-tadbirlar to‘g‘risida
9		28.12.2023 yildagi PQ-415-sonli	Sog‘liqni saqlash tizimini raqamlashtirishni jadallashtirish hamda ilg‘or raqamli texnologiyalarni joriy etish bo‘yicha qo‘shimcha chora-tadbirlar to‘g‘risida
10		01.02.2024 yildagi PQ-51-sonli	Raqamlashtirish sohasida malakali mutaxassislar tayyorlash faoliyatini qo‘llab-quvvatlash bo‘yicha qo‘shimcha chora-tadbirlar to‘g‘risida
11		26.02.2024 yildagi PQ-87-sonli	Mamlakatimizda raqamlashtirish sohasidagi xizmatlar eksportini rivojlantirishga doir qo‘shimcha chora-tadbirlar to‘g‘risida
12	O‘zbekiston Respublikasi Vazirlar Mahkamasi-ning qarori	17.12.2020 yildagi 794-sonli	O‘zbekiston Respublikasi agrosanoat majmui va qishloq xo‘jaligida raqamlashtirish tizimini rivojlantirish chora-tadbirlari to‘g‘risida
13		14.08.2023 yildagi 371-sonli	Qashqadaryo viloyatining Kasbi tumanida qishloq xo‘jaligida suv hisobini yuritish tizimini raqamlashtirish chora-tadbirlari to‘g‘risida
14		29.12.2023 yildagi 725-sonli	Baholash faoliyati sohasida xizmatlar sifatini oshirish, o‘zini o‘zi boshqarish mexanizmini rivojlantirish hamda ekspertiza jarayonlarini tartibga solish va raqamlashtirish maqsadida Vazirlar Mahkamasining “Baholash to‘g‘risidagi hisobotlarning haqqoniyligini ekspertizadan o‘tkazish mexanizmini tasdiqlash haqida” 2008-yil 28-iyuldagi 161-son qaroriga o‘zgartirish va qo‘shimchalar kiritish to‘g‘risida
15		12.09.2024 yildagi 570-sonli	Birja savdolariga ilg‘or axborot texnologiyalarini keng joriy etish hamda sohada raqamlashtirish jarayonlarini izchil davom ettirish chora-tadbirlari to‘g‘risida
16		07.12.2024 yildagi 820-sonli	Turizm sohasini raqamlashtirish va turistik xizmatlarni yagona platformaga birlashtirish chora-tadbirlari to‘g‘risida
17		18.12.2024 yildagi 848-sonli	Maktabgacha ta’lim tizimini raqamlashtirish va maktabgacha ta’lim tashkilotlari faoliyatini yanada takomillashtirishning qo‘shimcha chora-tadbirlari to‘g‘risida

Shuning uchun, bugungi kunga kelib avtomatlashtirish, axborotlashtirish va raqamlashtirish tushunchalarini ilmiy tahlil qilishning dolzarbligi va ilmiy-amaliy ahamiyati ortib bormoqda.

Qiyosiy tahlil.

Avtomatlashtirish. So‘nggi izlanishlar natijalariga ko‘ra avtomatlashtirish - insonni ilmiy va texnologik jarayonlarda ishtirok etishdan to‘liq ozod qilish yoki ushbu ishtirok etish darajasini yoki bajarilgan vazifalarning mehnat sarfini sezilarli darajada kamaytirish maqsadida vazifalarni tezroq, samaraliroq va natijadorroq bajarishga imkon beradigan turli texnik vositalar va matematik usullardan foydalanadigan ilmiy va texnologik taraqqiyot yo‘nalishidir [2].

Tarix. “avtomatlashtirish” so‘zi lotin tilidan olingan “avtomatik” so‘zidan olingan bo‘lib “o‘z-o‘zidan harakatlanadigan” degan ma’noni anglatadi. “Avtomatlashtirish” atamasi 1940-yillarda sanoat ishlab chiqarishining rivojlanishi kontekstida foydalanishga kiritilgan va xom ashyoni avtomatik qayta ishlash va tayyor mahsulotlarni ishlab chiqarish uchun turli mexanizmlar va mashinalardan foydalanish bilan bog‘liq jarayonlarga nisbatan qo‘llanilgan.

Avtomatlashtirishning birinchi shakllari inson mehnatini bug‘ mashinalari bilan almashtirish bilan bog‘liq edi. Keyingi yillarda avtomatlashtirish texnologiyalari keng tarqaldi va ishlab chiqarish sharoitida aniq vazifalarni bajarish uchun maxsus mashinalar va uskunalar paydo bo‘ldi.

Hozirgi vaqtda “avtomatlashtirish” atamasi axborotni avtomatik qayta ishlash va texnologik jarayonlarni boshqarish uchun kompyuter tizimlari va dasturlarini qo‘llash jarayonini anglatadi. Shu nuqtai nazardan, avtomatlashtirish turli sanoat va biznesning samaradorligi va natijadorligini oshirishda muhim rol o‘ynaydi [3].

Qo‘llash sohalari. Quyidagilar avtomatlashtiriladi [4]: ishlab chiqarish jarayonlari; loyihalash (ishlab chiqarish majmualari, sanoat inshootlari va boshqalar); tashkilot, rejalashtirish va boshqarish (korxona, sanoat va boshqalar doirasida); ilmiy tadqiqotlar; tibbiy va texnik diagnostika; biznes jarayonlari; dasturlash jarayonlari, muhandislik hisob-kitoblari; texnologik, energiya va transport jarayonlari.

Avtomatlashtirish tizimlarining asosiy turlari: avtomatik boshqaruv tizimi; ilmiy tadqiqotlarning avtomatlashtirilgan tizimi; texnologik jarayonlarni

boshqarishning avtomatlashtirilgan tizimi; avtomatlashtirilgan eksperimental kompleks; moslashuvchan avtomatlashtirilgan ishlab chiqarish, avtomatlashtirilgan loyihalashtirish tizimi; avtomatlashtirilgan operatsion boshqaruv tizimi hamda avtomatlashtirilgan rejalashtirish tizimi.

Avtomatlashtirish, eng oddiy holatlarni hisobga olmaganda, muammoni hal qilishda kompleks tizimli yondashuvni talab qiladi. Avtomatlashtirish tizimlari tarkibiga turli xil sensorlar, kirish va chiqish moslamalari, kontrollerlar, boshqaruv moslamalari, aktuatorlar, kompyuterlar kiradi.

Avtomatlashtirish yo'nalishlarining asosiy turlari. Avtomatlashtirilgan tizimlarning maqsadlari, vazifalari va qo‘llanilish sohalariga ko‘ra avtomatlashtirishning bir necha yo‘nalishlarini ajratish mumkin:

texnik yo'nalishi texnologik jarayonlarni inson ta’minlay olmaydigan tezlik, aniqlik, ishonchlilik va samaradorlik bilan tashkil etishga imkon beradi, shuningdek, turli xil texnik funktsiyalarni bajaradigan avtomatik qurilmalar va tizimlarni ishlab chiqish va yaratish bilan bog‘liq;

iqtisodiy yo‘nalish operatsion xarajatlarni kamaytirish va mahsulot hajmi va sifatini oshirish orqali dastlabki xarajatlarni tezda qoplashga imkon beradi;

ijtimoiy yo‘nalish insonning xarakterini o‘zgartirish va ish sharoitlarini yaxshilashga imkon beradi;

sanoat yo‘nalishi ishlab chiqarish jarayonlarining samaradorligi va samaradorligini oshirishga, shuningdek mahsulot sifatini yaxshilashga imkon beradi;

axborot yo‘nalishi axborotni qayta ishlash va uzatish jarayonlarini avtomatlashtirishga imkon beradi, masalan, avtomatlashtirilgan axborot tizimlarini yaratish.

Avtomatlashtirish darajasi, birinchi navbatda, ma’lum bir ishlab chiqarish sharoitida iqtisodiy samaradorlik va texnik maqsadga muvofiqligi bilan belgilanadi.

Ishlab chiqarishni avtomatlashtirish darajasiga ko‘ra, qo‘lda, yarim avtomatik, operator bilan avtomatik, operatorning minimal aralashuvi bilan avtomatik va to‘liq avtomatik avtomatlashtirish darajalari farqlanadi.

Qo‘lda avtomatlashtirish - ishlab chiqarish operatsiyalarini operator tomonidan hech qanday avtomatlashtirish moslamalarini ishlatmasdan, avtomatlashtirishning turli usullarini qo‘llamasdan to‘liq qo‘lda bajarish.

Yarim avtomatik avtomatlashtirish - avtomatlashtirish moslamalari yordamida ishlab chiqarish operatsiyalarini yarim avtomatik tarzda bajarish. Yarim avtomatik avtomatlashtirishda inson funktsiyalari nazorat va umumiy boshqaruv bilan cheklanadi.

Operator bilan avtomatik avtomatlashtirish - tizimning ko‘pgina vazifalarni avtomatik bajarishi, ammo operator hali ham jarayonga jalb qilingan va zaruriy xollarda aralashishi nazarda tutiladi.

Operatorning minimal aralashuvi bilan avtomatik avtomatlashtirish - tizim tomonidan deyarli to‘liq vazifalarni avtomatik ravishda bajarish, operator minimal operatsiyalarga jalb qilingan.

To‘liq avtomatlashtirish - barcha asosiy va yordamchi ishlab chiqarish maydonlarini, shu jumladan boshqarish va boshqarish tizimini to‘liq avtomatlashtirish. Tizim to‘liq avtonom bo‘lib, operator ishtirokisiz barcha muammolarni hal qilishga qodir. To‘liq avtomatlashtirishda inson funktsiyalari faqat uskunaning ishlashini kuzatish va asbob-uskunalar bilan bog‘liq muammolarni bartaraf etish bilan cheklanadi [5].

Avtomatlashtirishning afzalliklari. Ishlash va sifatni yaxshilash: avtomatlashtirish qo‘l mehnatini yo‘q qilish yoki minimallashtirish, vazifalarni bajarish tezligi va aniqligini oshirishga imkon beradi, natijada ishlash va xizmat sifati yaxshilanadi. Avtomatlashtirish, shuningdek, katta hajmdagi ma’lumotlarni qamrab olish orqali ishlab chiqarishdagi biznes-jarayonlarni boshqarishning aniqligini oshirishga imkon beradi, shuningdek avtomatlashtirilgan kompyuter uskunalari bir vaqtning o‘zida jarayonning sifati va hisoblashning aniqligini buzmasdan bir nechta texnologik operatsiyalarni amalga oshirishi imkoniyatini yaratadi.

Xarajatlarni kamaytirish: avtomatlashtirish ish haqi va texnik xizmat ko‘rsatish bilan bog‘liq xarajatlarni kamaytirishga, xatolar va kamchiliklarni kamaytirishga imkon beradi.

Moslashuvchanlikning ortishi: avtomatlashtirilgan tizimlar o‘zgaruvchan talablar va sharoitlarga osongina moslasha oladi, bu esa tashkilotlarga bozor o‘zgarishlari va mijozlar talablariga tezda javob berishga imkon beradi.

Xavfsizlik: avtomatlashtirish qo‘l mehnati bilan bog‘liq jarohatlar va ish joyidagi favqulodda vaziyatlar xavfini kamaytirishga yordam beradi, bu ayniqsa xavfli va zararli moddalar bilan ishlashda muhim bo‘lishi mumkin.

Ish muhitini yaxshilash: avtomatlashtirish ish muhitini shovqin, tebranish va boshqa salbiy ta’sirlar bilan bog‘liq qo‘lda ishlash holatlarida sezilarli darajada yaxshilashi mumkin [6].

Axborotlashtirish tushunchasi ko‘rib chiqilayotgan atamalar ichcida eng yahshi o‘rganilgan va tahlil qilingani bo‘lib shu nomdagi qonun ham qabul qilinganligi ham buni tasdiqlaydi [7].

Unga ko‘ra: “axborotlashtirish - yuridik va jismoniy shaxslarning axborotga bo‘lgan ehtiyojlarini qondirish uchun axborot resurslari, axborot texnologiyalari hamda axborot tizimlaridan foydalangan holda sharoit yaratishning tashkiliy ijtimoiy-iqtisodiy va ilmiy-texnikaviy jarayoni”dir.

Shuningdek, ko‘rsatilgan qonun bilan axborotlashtirish sohasidagi davlat siyosatining asosiy maqsadi va yo‘nalishlari, axborotlashtirish sohasini davlat tomonidan tartibga solish mexanizmlari, axborot resurslari va axborot tizimlarining huquqiy rejimi kabi masalalarga oydinlik kiritilgan.

Raqamlashtirish - zamonaviy qarashlarga ko‘ra mavjud jarayonlarni o‘zgartirish, yangi imkoniyatlar yaratish va samaradorlikni oshirish maqsadida raqamli texnologiyalarni hayot va biznesning turli sohalariga joriy etish jarayoni bo‘lib, bunda ma’lumotlarni elektron formatga o‘tkazishning o‘zi bilan cheklanilmaydi. Raqamlashtirish jarayonlarni avtomatlashtirish, sun’iy intellekt yordamida ma’lumotlarni tahlil qilish, bulutli hisoblash va boshqa raqamli innovatsiyalarni o‘z ichiga oladi, natijada biznes

modellari va faoliyatining raqamli o‘zgarishiga olib keladi [8, 9].

Raqamlashtirish jarayonlariga quyidagilar kirishi mumkin:

1. Ma’lumotlarni raqamli formatga o‘tkazish: ma’lumotlar qayta ishlash va boshqarish uchun analog ma’lumotlarni (masalan, qog‘oz hujjatlarni) elektron fayllarga aylantirish;

2. Jarayonlarni avtomatlashtirish: joriy va ko‘p qaytariluvchi vazifalarni bajarish uchun dasturiy ta’minot va robotlardan foydalanish, bu bilan ish vaqtini, xato ehtimolini kamaytirish va xodimlarga yanada murakkab vazifalarga e’tibor qaratish imkonini berish;

3. Yangi texnologiyalarni joriy etish: ko‘proq ma’lumotli qarorlar qabul qilish va yangi qiymat takliflarini yaratish uchun sun’iy intellekt (SI), narsalar interneti (IoT) va ma’lumotlar tahlili kabi texnologiyalardan foydalanish;

4. Tizimlarni birlashtirish: ichki aloqalarni yaxshilash va ma’lumotlar bilan uzluksiz ishlash uchun turli xil axborot tizimlari va dasturlarini birlashtirish.

5. Biznes modellarini o‘zgartirish: nafaqat mavjud jarayonlarni raqamlashtirish, balki mijozlar bilan o‘zaro munosabatlarning yangi kanallarini yaratish, xizmatlarni optimallashtirish va raqobatbardoshlikni oshirish uchun ularning mohiyatini o‘zgartirish.

Keltirilgan tahlillarning natijalarini jadval ko‘rinishida tavsif qilindi (2-jadval).

2-jadval

Avtomatlashtirish, axborotlashtirish va raqamlashtirish tushunchalarining solishtima jadvali

№	Xususiyat	Tushuncha		
		avtomatlashtirish	**axborotlashtirish**	**raqamlashtirish**
1	**Ta’rif**	muntazam vazifalar va jarayonlarni bajarish uchun axborot tizimlari va dasturiy ta’minotdan foydalanish, qo‘l mehnatiga bo‘lgan ehtiyojni kamay-tirishga qaratilgan ilmiy-texnologik taraqqiyot jarayoni	yuridik va jismoniy shaxslarning axborotga bo‘lgan ehtiyojlarini qondirish uchun axborot resurslari, axborot texnologiyalari hamda axborot tizimlaridan foydalangan holda sharoit yaratishning tashkiliy ijtimoiy-iqtisodiy va ilmiy-texnikaviy jarayoni	mavjud biznes jarayonlarni o‘zgar-tirish, yangi imkoniyatlar yaratish va samaradorlikni oshirish maqsadida raqamli texnologiyalarni hayot va biznesning turli sohalariga joriy etish jarayoni
2	**Maqsad**	Amaliyotlarni bajarish samaradorligi, tezligi va aniqligini oshirish, xatolarni kamaytirish va xarajatlarni kamaytirish	Qaror qabul qilish uchun ma’lumotlardan samarali foydalanishni ta’minlash, ma’lumotlar ochiqligini oshirish va kommunikatsiyalarni yaxshilash	Biznes jarayonlarni o‘zgartirish, yangi mahsulotlar va xizmatlarni yaratish, mijozlar va etkazib beruvchilar bilan munosabatlarni takomillashtirish, raqobatbardoshlikni oshirish
3	**Misollar**	Ombor hisobini yuritish tizimlarini joriy etish, hujjat aylanishini avtomatlashtirish, ishlab chiqarishda robotlardan foydalanish	Mijozlar bilan munosabatlarni boshqarish tizimlari (CRM), elektron kutubxonalar, bilimlarni boshqarish tizimlarini joriy etish	Mobil ilovalarni ishlab chiqish, bulutli xizmatlarga o‘tish, katta ma’lumotlar tahlilini joriy etish, raqamli texnologiyalarga asoslangan yangi biznes modellarini yaratish

Xulosa. Keltirilgan omillardan kelib chiqqan xolda quyidagi xulosalarga kelindi:

1. Ko‘rib chiqilgan tushunchalar insonlar faoliyatining barcha jabhalarini kompyuterlashtirishning turli bosqichlarini tavsiflovchi atamalardir.

2. Aqliy faoliyatni talab etmaydigan kuhdalik va ko‘p marta takrorlanadigan jarayonlarni avtomatlashtirishdan so‘ng, odatda qaror qabul qilishni soddalashtirishga qaratilgan axborotlashtirish jarayoni amalga oshiriladi.

3. Navbatdagi qadam - raqamlashtirish davomida biznes jarayonlarni optimallashtirish va yangi biznes modellarni yaratish bilan bir qatorda katta ma’lumotlarni yig‘ish hamda tahlil qilish imkoniyatlari yaratiladi.

4. Vujudga kelgan imkoniyatlar o‘z navbatida, yangi jarayon - **intellektuallashtirish**ga o‘tilishiga, ya’ni sun’iy intellekt texnologiyalarini joriy etishga asos bo‘lib xizmat qiladi.

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O‘ZBEKISTON MISOLIDA RAQAMLI VA YASHIL IQTISODIYOTNING O‘ZARO TA’SIRI

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Annotatsiya: Ushbu maqolada raqamli va yashil iqtisodiyotning rivojlanish jarayonlari, ularning o‘zaro bog‘liqligi hamda milliy iqtisodiyotga ta’siri yoritilgan. Maqolada raqamli texnologiyalar va ekologik barqarorlik tamoyillari asosida olib borilayotgan islohotlar tahlil qilindi. Xususan, O‘zbekistonda “Raqamli O‘zbekiston – 2030” strategiyasi va yashil energetika dasturlari doirasida amalga oshirilayotgan chora-tadbirlar o‘rganildi. Shuningdek, xalqaro tajribalar bilan qiyosiy tahlil o‘tkazilib, raqamli va yashil iqtisodiyotning barqaror rivojlanishga qo‘shadigan hissasi ilmiy asosda yoritildi.

Kalit so‘zlar: raqamli iqtisodiyot, yashil iqtisodiyot, barqaror rivojlanish, raqamlashtirish, innovatsiya, ekologik barqarorlik, “Raqamli O‘zbekiston – 2030”, yashil energetika, xalqaro tajriba.

Kirish.

Bugungi globallashuv jarayonida raqamli iqtisodiyot va yashil iqtisodiyot dunyo mamlakatlari rivojlanishining asosiy yo‘nalishlari sifatida maydonga chiqmoqda. Raqamli iqtisodiyot yangi texnologiyalar orqali ishlab chiqarish samaradorligini oshirish, resurslardan oqilona foydalanish va iqtisodiy jarayonlarni tezlashtirish imkonini bersa, yashil iqtisodiyot ekologik muvozanatni saqlash, energiya samaradorligini ta’minlash va barqaror rivojlanishni qo‘llab-quvvatlashga xizmat qiladi. Ushbu ikki yo‘nalishning uyg‘unlashuvi bugungi kunda nafaqat iqtisodiy samaradorlikni oshirish, balki atrof-muhitga salbiy ta’sirni kamaytirishda ham muhim ahamiyat kasb etmoqda.

O‘zbekiston ham mazkur jarayonlardan chetda qolmagan holda, iqtisodiy siyosatini zamonaviy texnologiyalarni joriy etish va ekologik barqarorlikni ta’minlash yo‘nalishida olib bormoqda. “Raqamli O‘zbekiston – 2030” [47] strategiyasi raqamli transformatsiyani jadallashtirishni ko‘zda tutsa, “Yashil iqtisodiyot” konsepsiyasi[48] energiya samaradorligi, qayta tiklanuvchi manbalarni rivojlantirish va ekologik muammolarni hal qilishga qaratilgan. Ushbu ikki yo‘nalishning o‘zaro ta’siri O‘zbekiston iqtisodiyotida yangi imkoniyatlar, innovatsion yechimlar va samaradorlik omillarini shakllantirmoqda. Shu bois O‘zbekiston misolida raqamli va yashil iqtisodiyotning o‘zaro ta’sirini o‘rganish nafaqat nazariy, balki amaliy ahamiyatga ham ega. Mazkur maqolada raqamli va yashil iqtisodiyotning o‘zaro bog‘liqligi, ularning milliy iqtisodiy rivojlanishga qo‘shayotgan hissasi hamda mamlakatimizda amalga oshirilayotgan strategik islohotlar tahlil qilinadi.

Adabiyotlar tahlili.

Raqamli va yashil iqtisodiyotning o‘zaro bog‘liqligi va ta’sirini mavzusida jahonda va O‘zbekistonda faoliyat yuritayotgan bir qancha olimlar va ilmiy tadqiqotchilar mavjud bo‘lib, ulardan Jan vom Brocke, Thomas Puschmann, Karen Bakker, Michael Greenstonelarni ilmiy ishlarini keltirib o‘tishimiz mumkin. Ular an’anaviy iqtisodiyotga tayanib qolmay, balki blokcheyn, IoT, AI, katta ma’lumotlar, fintech kabi zamonaviy texnologiyalarni yashil iqtisodiyot bilan bog‘lab tadqiq qiladi. Bu mavzuda mamlakatimizdagi olim va tadqiqotchilardan Ibodulla Xotamov, Yahyo Najmiddinov, Shoh-Jaxon Xamdamov, Do‘stov Bahodir Tashpo‘latovichlarning ilmiy ishlarida O‘zbekiston shaharlarida barqaror rivojlanish va ekologik samaradorlik nuqtai nazaridan raqamli iqtisodiyotning roli hamda ahamiyati o’rganilmoqda lekin shunga qaramasdan, “yashil” loyihalarni moliyalashtirishning samarali modellarini ishlab chiqish va ularni amalda qo‘llash bo‘yicha ilmiy takliflar yetarlicha o’rganilmagan.

Tadqiqot metodologiyasi.

Ushbu maqolada raqamli va yashil iqtisodiyotning o‘zaro ta’siri, ularning milliy iqtisodiy rivojlanishga qo‘shayotgan hissasi hamda O‘zbekistonda amalga oshirilayotgan strategik islohotlar o‘rganildi. Tadqiqotda qiyosiy tahlil (jahon tajribasi va milliy amaliyot solishtirildi), statistik tahlil (rasmiy ma’lumotlar va hisobotlar asosida), hamda kontent-tahlil (hukumat hujjatlari, xalqaro tashkilotlar tavsiyalari) usullari qo‘llandi. Shuningdek, O‘zbekiston misolida amalga oshirilayotgan “raqamli transformatsiya” va “yashil energetika” dasturlarining o‘zaro uyg‘unligi amaliy jihatdan tahlil qilindi.

[47] https://raqamlitarix.uz/wp-content/uploads/2022/12/PF-6079-05.10.2020.pdf

[48] https://lex.uz/uz/docs/-7245895

Muhokama va natijalar.

Raqamli iqtisodiyot va yashil iqtisodiyot aslida bir-birini to‘ldiruvchi jarayonlardir. Raqamlashtirish ekologik muammolarni hal qilishda muhim vosita bo‘lib xizmat qiladi. Masalan, **“**aqlli energetika tizimlari”, sun’iy intellekt asosida resurslarni boshqarish, raqamli monitoring platformalari va blokcheyn asosida uglerod izini nazorat qilish kabi texnologiyalar yashil iqtisodiyotni rivojlantirishda bevosita qo‘llanilmoqda. Yashil iqtisodiyot esa raqamli iqtisodiyotning barqaror rivojlanishini ta’minlash uchun yo‘nalish beradi. Ya’ni, iqtisodiy o‘sish nafaqat texnologik, balki ekologik jihatdan ham maqbul bo‘lishi lozim. Shunday qilib, raqamli va yashil iqtisodiyot o‘zaro uyg‘unlashgan holda, iqtisodiy jarayonlarni samarali va ekologik barqaror shaklda tashkil qilish imkonini beradi.

Raqamli va yashil iqtisodiyotning uyg‘unlashuvi milliy iqtisodiy rivojlanishga bir nechta yo‘nalishlarda hissa qo‘shmoqda: - Ishlab chiqarish samaradorligi ya’ni, raqamli texnologiyalar yordamida energiya sarfini kamaytirish, chiqindilarni kamaytirish va ishlab chiqarish xarajatlarini optimallashtirish mumkin. - Energiya xavfsizligi bu qayta tiklanuvchi energiya manbalarini boshqarishda raqamli platformalarning qo‘llanilishi energiya mustaqilligini oshiradi.

- Innovatsion tadbirkorlik - startaplar va raqamli xizmatlar “yashil biznes”ni qo‘llab-quvvatlab, yangi ish o‘rinlarini yaratish imkonini beradi.

- Xalqaro raqobatbardoshlik ya’ni, ekologik standartlarga javob beruvchi va raqamli texnologiyalarni qo‘llagan milliy mahsulotlar jahon bozorida yuqori talabga ega bo‘ladi. Natijada, raqamli va yashil iqtisodiyot uyg‘unligi mamlakat iqtisodiy barqarorligi va barqaror o‘sishini ta’minlaydi.

O‘zbekistonda so‘nggi yillarda raqamli va yashil iqtisodiyot yo‘nalishida qator islohotlar amalga oshirilmoqda:

- “Raqamli O‘zbekiston – 2030” strategiyasi – davlat boshqaruvi, ta’lim, sog‘liqni saqlash, moliya va qishloq xo‘jaligida raqamli texnologiyalarni joriy qilish orqali iqtisodiy samaradorlikni oshirishni maqsad qilgan.

- “Yashil iqtisodiyotga o‘tish” konsepsiyasi (2019–2030) – qayta tiklanuvchi energiya manbalarini rivojlantirish, energiya samaradorligini oshirish, chiqindilarni kamaytirish va ekologik xavfsizlikni mustahkamlashni ko‘zda tutadi.

- “Yashil makon” umummilliy loyihasi – ekologik barqarorlikni ta’minlash va atmosfera sifatini yaxshilashga xizmat qiladi.

- Xalqaro tashabbuslar – O‘zbekiston 2020 yilda BMT Bosh Assambleyasida “Markaziy Osiyo uchun yashil energetika zonasi” tashabbusini ilgari surdi va hozirda mintaqaviy hamkorlikni rivojlantirmoqda.

Mazkur strategik islohotlar nafaqat ekologik vaziyatni yaxshilash, balki raqamli transformatsiyani ham qo‘llab-quvvatlab, iqtisodiyotning innovatsion rivojlanishini ta’minlamoqda.

Oxirgi yillarda O‘zbekistonda raqamli iqtisodiyot va yashil iqtisodiyot yo‘nalishlari davlat strategiyasining muhim ustunlaridan biriga aylandi. Raqamli texnologiyalarni joriy etish iqtisodiyotning samaradorligini oshirish bilan birga, atrof-muhitga zararli ta’sirni kamaytirish imkonini bermoqda. Statistik ma’lumotlarga ko‘ra, 2022-yilda O‘zbekiston yalpi ichki mahsulotida raqamli iqtisodiyot ulushi 2,2 % ni tashkil etgan bo‘lsa, 2024-yilga kelib bu ko‘rsatkich **3 % dan oshdi**. “Raqamli O‘zbekiston – 2030” dasturi doirasida esa 2030-yilga borib ushbu ulushni 7-8 % gacha yetkazish maqsad qilingan. Shu bilan birga, raqamli texnologiyalar yordamida davlat xizmatlarining **60 % dan ortig‘i onlayn shaklga o‘tkazildi**, bu esa qog‘oz sarfini sezilarli kamaytirib, ekologik barqarorlikka hissa qo‘shmoqda.

1-jadval

Raqamli va yashil iqtisodiyot statistik ko’rsatkichlari

Yo‘nalish	Statistik Ko‘rsatkichlar
Chiqindilardan energiyaga	2027gacha — 4.7M tonna chiqindi → 2.1 mlrd kVt·soat
Qayta tiklanuvchi maqsad	2030ga — 40 % → 54 %; 25 mrd m³ gaz tejash, 34 mln tonna CO_2 kamaytirish
Qayta tiklanuvchi quvvat	2023da – 5166 MW (~24.4 % umumiy); 2024da – 3500 MW yangi stansiyalar
IT eksporti	2025 — 1 mlrd USD; 2030 maqsadi — 5 mlrd USD
Internet ulanishi	2025 — Internet: 98 %; 4G/3G qamrovi: 100 %
e-Gov ko‘rsatkichlari	EGDI: 2022 – 0.7265 (69-o‘rin), 2024 – 0.7999 (63-o‘rin); portal: 675 xizmat, 2.5M foydalanuvchi
Digital Inclusion loyihasi	25 000 ish o‘rni, 6 000 yosh mutaxassis, IT infratuzilmasi kengaytirildi
ICT sohasining iqtisodiy ko‘rsatkichlari	2023 – 2.1 % GDP; eksport: 344M USD; kompaniyalar: 1 652; xodimlar: 26 000

O‘zbekistonda chiqindilardan energiya ishlab chiqarish yo‘nalishida 2027 yilgacha 4,7 mln tonna chiqindi qayta ishlanib, 2,1 mlrd kVt·soat elektr ishlab chiqarilishi rejalashtirilgan. Shu bilan birga, qayta tiklanuvchi energiya ulushi 2030 yilga borib 40 % o‘rniga 54 % ga yetkazilishi kutilmoqda. Bu natija 25 mlrd m³ tabiiy gazni tejash va 34 mln tonna CO_2 chiqindilarini kamaytirishga olib keladi. Yashil iqtisodiyot bo‘yicha ham sezilarli yutuqlarga erishildi. Xususan, 2019–2023 yillarda qayta tiklanuvchi energiya quvvatlari **4 baravarga oshirildi**. 2023-yilda quyosh va shamol elektr stansiyalaridan olingan energiya hajmi **3 mlrd kVt-soat**dan ortdi. Strategik maqsadlarga ko‘ra, 2030-yilgacha elektr energiyasining 30 % qayta tiklanuvchi manbalardan olinishi rejalashtirilgan.

Raqamli va yashil iqtisodiyotning o‘zaro ta’siri ayniqsa energiya sohasida yaqqol namoyon bo‘lmoqda. Masalan, **“aqlli tarmoqlar” (smart grid), raqamli monitoring** tizimlari va **IoT texnologiyalari** elektr energiyasi ishlab chiqarish va iste’molini samarali boshqarishga xizmat qilmoqda. Bu nafaqat energiya tejash, balki uglerod chiqindilarini kamaytirishga ham olib keladi.

2030 yilgacha O‘zbekistonda raqamli va yashil iqtisodiyotning o‘sishi milliy iqtisodiyotga sezilarli ta’sir ko‘rsatishi kutilmoqda. Jahon banki va BMT prognozlariga ko‘ra, raqamli texnologiyalarni joriy etish yalpi ichki mahsulotni (YaIM) har yili o‘rtacha 1,5–2% ga oshirishi mumkin. Shu bilan birga, yashil iqtisodiyot tamoyillariga asoslangan energetika va transport sohalariga investitsiyalar 2030 yilga borib 15–20 mlrd AQSh dollari miqdorida qo‘shimcha iqtisodiy samaradorlik keltirishi taxmin qilinmoqda. Milliy iqtisodiyot uchun eng katta ta’sirlar quyidagilar bo‘lishi kutilmoqda:

1.Energetika samaradorligi – qayta tiklanuvchi energiya ulushi 2030 yilga qadar 30–35% ga yetishi rejalashtirilmoqda, bu esa import qilinadigan energiya resurslariga qaramlikni kamaytiradi.

2.Raqamli transformatsiya – elektron tijorat hajmi ikki baravar o‘sib, kichik va o‘rta biznesning global bozorga chiqish imkoniyatini kengaytiradi.

3. Ish o‘rinlari yaratish – yashil energetika va IT sohasida yuz minglab yangi ish o‘rinlari paydo bo‘lishi prognoz qilinmoqda.

4.Ekologik barqarorlik – chiqindilarni qayta ishlash hajmining 40% ga yetishi va karbonat gaz chiqindilarini keskin kamaytirish rejalashtirilgan.

Umuman, raqamli va yashil iqtisodiyotning o‘zaro uyg‘unlashuvi O‘zbekistonning 2030 yilgacha barqaror va innovatsion rivojlanishini ta’minlab, milliy iqtisodiyotning raqobatbardoshligini sezilarli oshiradi.

O‘zbekistonda raqamli va yashil iqtisodiyot bir-birini to‘ldiruvchi yo‘nalishlar sifatida milliy rivojlanishga xizmat qilmoqda. Raqamli texnologiyalar yashil iqtisodiyotni jadallashtirsa, yashil iqtisodiyot esa raqamli sohada yangi innovatsion echimlarga talabni kuchaytirmoqda.

Xulosa.

Raqamli va yashil iqtisodiyotning o‘zaro bog‘liqligi zamonaviy milliy iqtisodiy rivojlanishning ajralmas omillaridan biri hisoblanadi. Raqamlashtirish jarayonlari energiya samaradorligini oshirish, resurslardan oqilona foydalanish, ishlab chiqarish va xizmat ko‘rsatish sohalarida barqarorlikni ta’minlash imkonini bermoqda. Shu bilan birga, yashil iqtisodiyot tamoyillarining joriy etilishi atrof-muhitga salbiy ta’sirni kamaytirish, qayta tiklanuvchi energiya manbalarini kengaytirish va ekologik barqarorlikni mustahkamlashda muhim rol o‘ynaydi.

O‘zbekiston misolida olib borilayotgan islohotlar shuni ko‘rsatadiki, raqamli texnologiyalarni keng tatbiq etish orqali yashil iqtisodiyot yo‘nalishidagi tashabbuslarni samarali qo‘llab-quvvatlash mumkin. Masalan, energiya tejamkor qurilmalar, “aqlli shahar” loyihalari, elektron hukumat tizimlari hamda raqamli monitoring mexanizmlari nafaqat iqtisodiy samaradorlikni oshirmoqda, balki ekologik barqarorlikni ham mustahkamlamoqda.

Demak, raqamli va yashil iqtisodiyotning o‘zaro ta’siri mamlakatimizning uzoq muddatli strategik maqsadlariga erishishda, ya’ni barqaror rivojlanish, iqtisodiy xavfsizlik va xalqaro raqobatbardoshlikni ta’minlashda muhim omil bo‘lib xizmat qiladi. Shu bois ushbu ikki yo‘nalishning integratsiyasi O‘zbekistonning kelajakdagi taraqqiyot konsepsiyasida asosiy ustuvorliklardan biri sifatida shakllanmoqda.

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ENERGETIKA SANOATI KORXONALARINI RAQAMLASHTIRISH VA UNING O‘ZBEKISTON 2030 TARAQQIYOT STRATEGIYASINING KONSEPTUAL XUSUSIYATLARI

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Annotatsiya: Ushbu ilmiy maqolada O‘zbekiston energetika sanoati korxonalarini raqamlashtirish metodologiyasining asoslari va uning “O‘zbekiston – 2030” taraqqiyot strategiyasidagi konseptual xususiyatlari chuqur tahlil qilingan. Tadqiqotda energetika sohasida raqamli transformatsiya zaruriyatlari, xorijiy va mahalliy tajribalar hamda Delphi usuli asosida mutaxassislar fikri o‘rganildi. Maqolada raqamlashtirish orqali energiya tizimini modernizatsiya qilish, aqlli tarmoqlar va avtomatlashtirilgan hisoblash tizimlarini joriy etish, qayta tiklanuvchi energiya manbalarini keng integratsiya qilish kabi ustuvor yo‘nalishlar ilmiy-nazariy yondashuvlar bilan asoslangan. Delphi usulida o‘tkazilgan so‘rov natijalari raqamlashtirishning ustuvor yo‘nalishlarini aniqlashda qo‘llanildi va bu jarayonning 2030 yilgacha bo‘lgan strategik maqsadlar bilan uyg‘unligi ko‘rsatib berildi. Tahlil va natijalar O‘zbekiston misolida energetika sektorida raqamli transformatsiya amaliyotining samarali modelini taklif qiladi. Xususan, 2020–2025 yillarga oid ma’lumotlar asosida raqamli texnologiyalarni joriy etish energetika tizimida samaradorlikni oshirib, yo‘qotishlarni kamaytirishi hamda “yashil energetika” ulushini sezilarli ravishda ko‘paytirishi kutilmoqda. Maqola yakunida energiya sohasi raqamlashtirish bo‘yicha tavsiyalar berilib, ushbu jarayonning O‘zbekiston 2030 taraqqiyot strategiyasidagi o‘rni va ahamiyati yoritiladi.

Kalit so‘zlar: raqamlashtirish; energetika sektori; raqamli transformatsiya; O‘zbekiston 2030 strategiyasi; aqlli tarmoqlar; Delphi usuli; qayta tiklanuvchi energiya; energetika samaradorligi.

Kirish

So‘nggi yillarda jahon miqyosida raqamli texnologiyalar iqtisodiyotning barcha tarmoqlariga jadal kirib bormoqda. Xususan, energetika sektori raqamlashtirish (digitization) orqaligina samaradorlik va barqarorlikni sezilarli oshirishi mumkinligi ko‘plab tadqiqotlarda ta’kidlangan. Energetika sohasida raqamli transformatsiya deganda, ishlab chiqarishdan tortib iste’molchgacha bo‘lgan jarayonlarni raqamli texnologiyalar yordamida avtomatlashtirish, aqlli tarmoqlar (smart grids) joriy etish, real vaqt rejimida nazorat va boshqaruv tizimlarini qo‘llash tushuniladi. Bunday yondashuv energiya ta’minotining ishonchliligini oshirib, tannarxni pasaytiradi hamda resurslardan samarali foydalanish imkonini beradi.

Ayni vaqtda mamlakat elektr energiyasi ishlab chiqarish hajmi va quvvati tez o‘sib bormoqda: masalan, so‘nggi 8 yil ichida elektr ishlab chiqarish 38% ga oshib, 2024 yilda 81,5 mlrd kVt·soatga yetdi. Shu bilan birga, xususiy sektorning ulushi ham ortib, yangi quvvatlarning muhim qismi xususiy-investitsion loyihalar hissasiga to‘g‘ri kelmoqda (2024 yilga kelib umumiy quvvatning 24% xususiy ishlab chiqaruvchilarga, qayta tiklanuvchi manbalar ulushi esa 16% ga yetdi). Bu ko‘rsatkichlar energetikada raqamlashtirish va zamonaviy boshqaruv tizimlariga talab yuqori ekanini anglatadi.

O‘zbekiston energetika infratuzilmasi ancha yil xizmat qilgan bo‘lib, tarqatish tarmoqlarida elektr yo‘qotishlari darajasi hamon yuqori. 2024 yil holatiga, elektr taqsimot tizimidagi texnik yo‘qotishlar qariyb 13% ni tashkil etmoqda, bunda tarmoqlar aktivlarining yarmidan ko‘pi 30 yildan ziyod eskirganligi asosiy sabab sifatida ko‘rsatilmoqda. Bu esa energiya ta’minotida uzilishlar va samarasizlikka olib keladi. Mazkur muammoni bartaraf etish uchun elektr tarmoqlarini modernizatsiya qilish hamda raqamlashtirish bo‘yicha keng ko‘lamli investitsiya dasturlari amalga oshirilmoqda. Jumladan, Jahon banki ko‘magida 2025–2030 yillarda 150 mingta “aqlli” elektr hisoblagich hamda 4 mingta ma’lumot uzatish konsentratorlarini o‘rnatish orqali elektr taqsimlash tarmoqlarini avtomatlashtirish belgilangan. Shu kabi chora-tadbirlar natijasida 2030 yilga borib elektr tarmoqlaridagi yo‘qotishlarni amaldagi ~14% dan 8–9% gacha kamaytirish ko‘zda tutilgan.

Raqamlashtirish nafaqat tarmoqlar, balki ishlab chiqarish va iste’mol jarayonlarini ham qamrab oladi. O‘zbekistonda 2020 yildan boshlab butun mamlakat bo‘ylab iste’molchilar uchun aqlli hisoblagichlar o‘rnatish loyihalari boshlandi. Masalan, tabiiy gaz ta’minotida Avtomatlashtirilgan gaz hisobini nazorat qilish tizimi (“ASUHG”) doirasida 3,546,148 ta smart-gaz hisoblagich o‘rnatish rejalashtirilib, 2022 yil mart holatiga uning 78% (2,68 mln dona) o‘rnatildi. Mamlakat bo‘yicha gaz ta’minotida aqlli hisoblagichlarni to‘liq joriy etish 2022 yil noyabriga qadar yakunlandi. Elektr energiyasi sohasida ham shunga o‘xshash tarzda, xalqaro moliyaviy institutlar yordami bilan 1,4 milliondan ortiq aqlli elektr

hisoblagichlari bosqichma-bosqich o‘rnatildi (masalan, Osiyo taraqqiyot banki loyihasi doirasida dastlab rejalashtirilgan 1 mln o‘rniga 1,4 mln ta elektr hisoblagich o‘rnatildi). Bu choralar iste’molni aniq hisobga olish, noqonuniy ulanish va yo‘qotishlarni qisqartirish imkonini bermoqda.

Raqamlashtirish tashabbuslari davlat sektori bilan bir qatorda xususiy sektor ishtirokini ham talab etmoqda. O‘zbekiston hukumati energetika sohasiga xususiy investitsiyalarni faol jalb qilmoqda va ayrim yo‘nalishlarda davlat monopoliyasini qisqartirishga kirishgan. “O‘zbekiston – 2030” strategiyasida energetika ta’minoti xizmatlarini bosqichma-bosqich xususiy sektorga o‘tkazish va davlat tasarrufida faqat magistral tarmoqlar hamda strategik xavfsizlikka oid sohalarni qoldirish belgilangan. Bu esa elektr va gaz taqsimlash xizmatlarida xususiy kompaniyalar ishtirokini kengaytirish, davlat-xususiy sheriklik (DXSh) mexanizmlarini joriy etish orqali raqamli texnologiyalarni tezroq tatbiq etishga yordam beradi. Darhaqiqat, xalqaro investorlari ishtirokida qiymati $26 mlrd dan ziyod energetika loyihalari amalga oshirilayotgani, jumladan quyosh va shamol elektr stansiyalari qurilishi mahalliy sanoatni ham raqamlashtirish jarayoniga tortmoqda.

O‘zbekiston rahbariyatining strategik maqsadlarida energetika sohasini raqamlashtirish alohida o‘rin tutadi. 2020 yilda qabul qilingan “Raqamli O‘zbekiston – 2030” strategiyasi barcha tarmoqlarda, xususan energetikada raqamli iqtisodiyotni rivojlantirishni ko‘zda tutadi. Shu bilan birga, 2023 yil 11 sentyabrda tasdiqlangan “O‘zbekiston – 2030” taraqqiyot strategiyasida to‘g‘ridan-to‘g‘ri energetika sohasiga oid raqamlashtirish vazifasi qo‘yilgan: “barcha turdagi energiya resurslari hisobini yuritishni to‘liq raqamlashtirish” hamda energetika tizimini qo‘shni davlatlar tarmoqlari bilan integratsiyalash orqali barqaror ishlashini ta’minlash. Bu maqsad kelgusida energetika korxonalarining barcha hisob-kitob va monitoring amaliyotlari elektron tizimlar orqali yuritilishini anglatadi. Energetika vazirligi matbuot xizmati ma’lumotiga ko‘ra, mamlakatda energetika sohasidagi raqamlashtirish loyihalari doirasida bir nechta axborot tizimlari va platformalar ishga tushirilmoqda, jumladan, yoqilg‘i-energetika majmuasini boshqarish uchun yagona raqamli platforma yaratish ishlari boshlangan. Ushbu platforma kelgusida sohaga oid barcha ma’lumotlarni real vaqt rejimida kuzatish va tahlil qilish, shaffoflikni ta’minlash imkonini beradi.

Yuqoridagi omillar energetika sohasida raqamlashtirishning ilmiy-nazariy asoslarini o‘rganish va O‘zbekistonning uzoq muddatli strategik rejalaridagi o‘rnini aniqlashni dolzarblashtiradi. Ushbu maqolaning maqsadi – energetika korxonalarini raqamlashtirish bo‘yicha kompleks metodologiyani taklif etish va uning O‘zbekiston 2030 taraqqiyot strategiyasidagi konseptual ahamiyatini ochib berishdan iborat. Buning uchun, birinchidan, soha bo‘yicha mavjud ilmiy-adabiyotlar tahlil qilinadi va xorijiy tajribalar ko‘rib chiqiladi. Ikkinchidan, tadqiqotda Delphi usuli qo‘llanilib, energetika sohasi mutaxassislaridan raqamli transformatsiya ustuvor yo‘nalishlari bo‘yicha fikr-mulohazalar olindi. Учинчидан, 2020–2025 yillarga oid statistik ma’lumotlar va amaliy natijalar asosida raqamlashtirishning iqtisodiy va ijtimoiy samarasiga baho berildi.

Adabiyotlar sharhi

Raqamlashtirish va raqamli transformatsiya tushunchalari so‘nggi yillarda akademik adabiyotlarda keng o‘rganilmoqda. Raqamli transformatsiya – raqamli texnologiyalarning (IoT, sun’iy intellekt, katta ma’lumotlar tahlili va h.k.) biznes jarayonlarga joriy etilishi natijasida yuzaga keladigan sifat o‘zgarishlaridir. Energetika sohasida raqamli transformatsiya konsepsiyasi ba’zan “Energy 4.0” deb ham ataladi, ya’ni sanoatning to‘rtinchi inqilobi tamoyillarini energetikaga tatbiq etish. Xalqaro energetika agentligi (IEA) hisobotlariga ko‘ra, energetika sektoriga raqamli texnologiyalarni integratsiya qilish natijasida energiya samaradorligi oshishi, barqarorlik ko‘rsatkichlari yaxshilanishi va energiya xavfsizligi mustahkamlanishi kutiladi. Masalan, AQSH Energetika vazirligi tadqiqotlari aqlli hisoblagichlar (AMI) joriy etilishi hisobga olish aniqligini oshirib, kompaniyalarning operatsion xarajatlarini sezilarli darajada kamaytirishini tasdiqlagan. Shuningdek, raqamlashtirish orqali qayta tiklanuvchi energiya manbalarini tizimga samarali ulash, real vaqt rejimida balanslash va talabni prognozlash imkoniyatlari paydo bo‘ladi.

Hozirgi kunda ko‘plab davlatlar energetika tizimlarini raqamlashtirish bo‘yicha maxsus dasturlar qabul qilgan. Jumladan, Yevropa Ittifoqida 2020 yilga borib aksar mamlakatlar aholining 80% dan ortig‘ini aqlli elektr hisoblagichlar bilan qoplashga erishdi. Xitoy, AQSh, Janubiy Koreya kabi davlatlarda smart grid texnologiyalari keng tatbiq etilib, elektr tarmoqlarida avtomatlashtirilgan boshqaruv va kuzatuv tizimlari joriy etilmoqda. Ushbu tajribalar energetika tizimining raqamli boshqaruvi elektr energiyasini uzatish va taqsimlashdagi yo‘qotishlarni kamaytirish, avariyali o‘chishlarning oldini olish hamda iste’molchilar uchun yangi xizmat turlarini (dinamik tariflar, iste’molni masofadan nazorat qilish va boshqalar) joriy etishga xizmat qilganini ko‘rsatadi. Masalan, Hindiston hukumati 2025 yil oxirigacha 250 mln dona aqlli elektr hisoblagichini o‘rnatishni maqsad qilgan bo‘lib, bu orqali 2030 yilgacha elektr o‘g‘riligi va yo‘qotishlarini ikki baravarga kamaytirishni rejalashtirmoqda. Yevropada esa 2016–2020 yillarda 182 millionta aqlli hisoblagich o‘rnatilib, $37,8 mlrd investitsiya kiritildi.

Akademik manbalarda energetikani raqamlashtirish jarayonida bir qancha yo‘nalishlar alohida ta’kidlanadi:

Aqlli elektr tarmoqlar (Smart Grids): Bu – ikki tomonlama aloqa va real-vaqt rejimidagi boshqaruvga ega bo‘lgan elektr tarmoqlari bo‘lib, ularda markazlashtirilgan SCADA tizimlari, sensor va IoT qurilmalari yordamida yuklamalarni optimallashtirish, avariyalarni aniqlash va izolyatsiya qilish avtomatik tarzda amalga oshadi. Aqlli tarmoqlar konsepsiyasi

elektr taqsimoti tizimlarida katta o‘zgarish yasaydi: an’anaviy bir yo‘nalishli energiya oqimi o‘rniga ikki yo‘nalishli (iste’molchi ham energiya yetkazib beruvchi bo‘lishi mumkin, masalan, tomorqa quyosh panellari orqali) oqim yuzaga keladi. Bu esa tizimni murakkablashtirsa-da, raqamli boshqaruv vositalari bilan samarali muvozanatlashtiriladi.

Avtomatlashtirilgan hisoblash va monitoring tizimlari (AMI): Energetika korxonalarida iste’molchilar bilan hisob-kitob jarayonlarini avtomatlashtirish uchun aqlli hisoblagichlar va ularning tarmoq orqali markaziy bazaga ulanishi katta ahamiyatga ega. Tajribalar shuni ko‘rsatadiki, AMI joriy etilishi natijasida billing (hisob-kitob) aniqligi va shaffofligi oshadi, xizmat ko‘rsatish xarajatlari qisqaradi (manual o‘qish zarurati yo‘qoladi). O‘zbekistonda ham elektr va gaz taqsimotida bunday tizimlar bosqichma-bosqich joriy qilindi. Xususan, “Khududgazta’minot” AJ gaz taqsimoti bo‘yicha 2 milliondan ortiq smart-hisoblagichni o‘rnatib, ularni markaziy avtomatlashtirilgan nazorat tizimiga ulaganligi ma’lum qilingan. Natijada iste’molchilar uchun masofadan to‘lov qilish, balansni ko‘rish kabi qulayliklar paydo bo‘ldi, ta’minotchi uchun esa yo‘qotishlarni kuzatish va qarzdorlikni kamaytirish imkoni tug‘ildi.

Yoqilg‘i-energetika kompleksida ma’lumotlar tahlili va sun’iy intellekt: Raqamlashtirish natijasida katta hajmdagi ma’lumotlar (masalan, har bir transformator yoki quvurni kesimidagi yuklama, har bir iste’molchining soatlik iste’moli va h.k.) shakllanadi. Bu ma’lumotlarni tahlil qilish energetika tizimini optimallashtirish uchun katta imkoniyatlar yaratadi. Dunyo tajribasida sun’iy intellekt va mashina ta’limi algoritmlari energiya iste’molini prognozlash, uskunalarning nosozligini oldindan aniqlash (predictive maintenance), obnovlyaemy manbalar generatsiyasini bashoratlash kabi masalalarda qo‘llanmoqda. O‘zbekiston ham bu borada qator qadamlar qo‘ymoqda – so‘nggi ma’lumotlarga ko‘ra, mamlakat energiya tizimini optimallashtirish maqsadida ilg‘or raqamli platforma ishlab chiqmoqda. Ushbu platforma katta ma’lumotlarni tahlil qilish va mashina ta’limi algoritmlaridan foydalangan holda energiya iste’moli va ta’minotini optimallashtiradi hamda butun tizim samaradorligini oshiradi. Boshqacha aytganda, yaqin yillarda O‘zbekistonda yagona “raqamli energetika platformasi” shakllanib, u orqali real vaqt rejimida energetika balansini boshqarish, avariyalarni prognoz qilish, talab va taklifni uyg‘unlashtirish mumkin bo‘ladi.

Qayta tiklanuvchi energiya manbalarini integratsiya qilish: Raqamli texnologiyalar “yashil energetika” rivojida ham muhim rol o‘ynaydi. Quyosh va shamol elektr stansiyalari ishini barqaror tutish uchun ularni yagona tarmoqqa integratsiya qilish jarayonida intellektual boshqaruv tizimlari kerak bo‘ladi. Misol uchun, ishlab chiqarish jadvalini ob-havo ma’lumotlariga asoslangan holda oldindan rejalashtirish, energiya saqlash tizimlarini (batareyalarni) avtomatik boshqarish, ortiqcha quvvatni boshqa hududga yo‘naltirish kabi funksiyalar raqamli dasturiy ta’minot yordamida amalga oshadi. O‘zbekiston 2019 yilda qabul qilgan “Qayta tiklanuvchi energiya manbalari to‘g‘risida”gi Qonun va unga mos ravishda boshlangan loyihalar doirasida bir qator yirik quyosh va shamol elektr stansiyalari qurilishini DXSh asosida amalga oshirmoqda. Xalqaro tajribaga tayangan holda aytish mumkinki, bunday keng ko‘lamli PPP loyihalarida tizim operatori va xususiy ishlab chiqaruvchilar o‘rtasida ma’lumot almashish, ishlab chiqarishni real vaqtda monitoring qilish va nazorat qilish uchun albatta raqamli integratsion platforma bo‘lishi talab etiladi. Masalan, Masdar kompaniyasi tomonidan Samarqand va Jizzax viloyatlarida qurilgan umumiy 511 MVt quvvatli quyosh fotoelektr stansiyalari 11 mingdan ortiq harakatlanuvchi trackerlarga ega bo‘lib, ushbu obyektlar raqamli SCADA platformasi orqali masofadan nazorat qilinadi.

- Energetika obyektlarida kiberxavfsizlik: Raqamlashtirish jarayonida barcha tizimlar tarmoq orqali bog‘lanib borar ekan, ularning kiberxavfsizligi masalasi birlamchi ahamiyat kasb etadi. Ilmiy adabiyotlarda energetika infratuzilmasi – “tanqidiy infratuzilma” bo‘lgani bois, kiberhujumlar xavfi doimiy tahlil qilinishi lozimligi ta’kidlanadi. Shuning uchun ko‘plab mamlakatlar “aqlli tarmoqlar” xavfsizligi uchun alohida standartlar va himoya protokollarini joriy qilgan (masalan, IEC 62351 standarti, NIST Smart Grid Interoperability Framework va boshqalar). O‘zbekiston uchun ham bu yo‘nalish dolzarb; chunki raqamli energetika platformasi yoki masofaviy boshqaruv tizimlarida uzilish yoki buzilish sodir bo‘lsa, butun energiya ta’minoti xavf ostida qolishi mumkin. Shu bois taraqqiyot strategiyasida energetika sohasida raqamlashtirish bilan birga kiberxavfsizlik strategiyasini ham ishlab chiqish zarurati borligi ayrim mahalliy ekspertlar tomonidan e’tirof etilmoqda.

Yuqoridagi adabiyotlar sharhi shuni ko‘rsatadiki, energetika sanoati korxonalarini raqamlashtirish keng qamrovli va ko‘p jihatli jarayondir. Uning ilmiy-nazariy asoslari “raqamli iqtisodiyot”, “Energiya 4.0”, “aqlli tarmoqlar” kabi konseptual tushunchalarga borib taqaladi. O‘zbekiston sharoitida esa raqamli transformatsiya nafaqat texnologik, balki institutsional va strategik jarayon sifatida ko‘rilmoqda. Quyida tadqiqot metodologiyasi va natijalari taqdim etilib, aynan O‘zbekiston misolida ushbu jarayon qanday kechayotgani va 2030 yilgacha qanday yo‘l xaritasi taklif etilayotganiga to‘xtalib o‘tiladi.

Tadqiqot usullari

Ushbu tadqiqotda kombinatsiyalashgan ilmiy yondashuv qo‘llanildi. Birinchidan, adabiyotlar va hujjatlar tahlili usuli orqali energetika sohasini raqamlashtirishga oid mahalliy va xorijiy manbalar, strategik hujjatlar va dasturlar o‘rganildi.

Ikkinchidan, tadqiqotning asosiy metodologik vositasi sifatida Delphi usuli qo‘llanildi. Delphi usuli – bu ekspertlar bilan bir necha bosqichli anonim so‘rov o‘tkazish orqali ularning ma’lum masala yuzasidan fikrini jamlash va konsensusga erishish metodidir. Mazkur tadqiqot uchun energetika sohasida

raqamlashtirishga aloqador 15 nafar ekspert tanlab olindi. Ular tarkibiga Energetika vazirligi huzuridagi axborot texnologiyalari bo‘limi mutaxassislari, “Hududiy elektr tarmoqlari” AJ va “Milliy elektr tarmoqlari” AJ texnik xodimlari, sohaga innovatsiyalarni joriy etish bilan shug‘ullanuvchi xususiy IT kompaniya vakillari hamda energetika bo‘yicha olimlar kiritildi. Delphi so‘rovi 2024 yil davomida 3 bosqichda o‘tkazildi:

1-bosqich: Ekspertlarga ochiq savollar bilan murojaat qilindi. Savollar mazmuni energetika korxonalarini raqamlashtirishning eng muhim yo‘nalishlari, duch kelinayotgan asosiy to‘siqlar va kutilayotgan natijalar haqida edi. Masalan, “Energetika tizimini raqamlashtirishda Sizningcha eng ustuvor yo‘nalishlar qaysilar?”, “Raqamli transformatsiyaning muvaffaqiyatiga to‘sqinlik qilayotgan omillar nimalar?” kabi savollar berildi. Ekspertlar yozma ravishda o‘z javoblarini taqdim etdi.

2-bosqich: Dastlabki javoblar tahlil qilinib, ular asosida yopiq test shaklidagi savollar va rating jadvali tuzildi. Jumladan, 10 ga yaqin yo‘nalish (aqlli tarmoqlar, hisoblagichlar, raqamli platformalar, kiberxavfsizlik, kadrlar tayyorlash va h.k.) ajratib olinib, har bir ekspertdan ularni 1 (minimal ahamiyatli) dan 5 (juda ahamiyatli) gacha bo‘lgan shkala bo‘yicha baholash so‘raldi. Shuningdek, birinchi bosqichda tilga olingan muammolar ham xuddi shunday baholatildi. Ikkinchi raund natijalariga ko‘ra, har bir band bo‘yicha o‘rtacha ball va dispersiya hisoblandi.

3-bosqich: Uchinchi bosqichda ekspertlarga ikkinchi bosqich yakunlari (anonym tarzda umumlashtirilgan holda) taqdim etildi va baholash natijalariga aniqlik kiritish uchun yana bir bor o‘z fikrlarini qayta ko‘rib chiqish taklif qilindi.

Delphi usuli natijalarini Kendall uyg‘unlik koeffitsienti (W) yordamida tahlil qildik. Uchinchi raund natijalarida W ≈ 0.78 ga teng bo‘lib, bu ekspertlar orasida yetarli darajadagi uyg‘unlik mavjudligini ko‘rsatdi (0.7 dan yuqori bo‘lishi kuchli konsensusni anglatadi). Demak, ajratilgan ustuvor yo‘nalishlar ro‘yxati va ularning nisbiy ahamiyati bo‘yicha ekspertlar fikri bir joyga yaqinlashdi.

Bundan tashqari, tadqiqotda statistik tahlil usullari qo‘llanilib, 2020–2025 yillar davomidagi ba’zi ko‘rsatkichlarning o‘zgarishi tahlil qilindi.

Tahlil va natijalar

Tadqiqot doirasida olingan Delphi so‘rovi natijalari O‘zbekiston energetika sektorini raqamlashtirish jarayonida eng ustuvor yo‘nalishlarni aniqlashga xizmat qildi. Quyida 1-jadvalda ekspertlar bahosiga ko‘ra eng muhim deb topilgan raqamli transformatsiya yo‘nalishlari keltirilgan.

Jadval 1.

Delphi usuli yordamida aniqlangan energetika sohasini raqamlashtirish ustuvor yo‘nalishlari (1–5 ballik shkala bo‘yicha baholar)

Yo‘nalish	Delphi balli	Izoh (mazmuni)
Aqlli elektr tarmoqlar (smart grid texnologiyalari)	4,9 (juda yuqori)	Elektr energiyasini taqsimlash va uzatishda real vaqt rejimida avtomatik boshqaruv, SCADA tizimlari orqali optimallashtirish; avariyalarning oldini olish va yo‘qotishlarni kamaytirish.
Avtomatlashtirilgan hisoblash infratuzilmasi (AMI)	4,8	Elektr va gaz iste’molini masofadan turib hisobga olish, billing tizimini avtomatlashtirish hamda iste’molchilar uchun onlayn xizmatlarni joriy etish.
Raqamli energetika platformasi va AI	4,6	Yagona markazlashgan platforma orqali katta ma’lumotlarni (Big Data) tahlil qilish, sun’iy intellekt va mashina ta’limi yordamida ishlab chiqarish-iste’molni muvozanatlashtirish, samaradorlik va prognozlashni yaxshilash.
Qayta tiklanuvchi energiya integratsiyasi	4,5	Quyosh va shamol stansiyalarini energetika tizimiga ulashda aqlli inverterlar, prognozlash dasturlari va energiya saqlash tizimlarini boshqarish.
Kiberxavfsizlik va axborot himoyasi	4,3	Energetika tizimining raqamli infratuzilmasini kiberxurujlardan himoya qilish, axborot xavfsizligi protokollarini joriy etish, rezerv tizimlar yaratish.
Raqamli savodxonlik va kadrlar tayyorlash	4,2	Raqamli transformatsiyani boshqarish uchun mutaxassislar tayyorlash, mavjud xodimlarning IT malakasini oshirish, yangi texnologiyalar bo‘yicha treninglar tizimini yo‘lga qo‘yish.

Manba: mualliflar tomonidan o‘tkazilgan Delphi so‘rovi natijalari

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Yuqoridagi 1-jadval ma’lumotlariga ko‘ra, ekspertlar eng ustuvor yo‘nalish sifatida aqlli elektr tarmoqlarni (smart grid) e’tirof etganlari ko‘rinadi (o‘rtacha 4,9 ball). Bu tabiiy – chunki elektr taqsimlash va uzatish tizimini raqamli boshqaruvga o‘tkazish energetika tizimining negizini tashkil etadi. Smart grid joriy etilishi bilan hududlararo energiya oqimini optimallashtirish, balanslash, favqulodda holatlarda qisqa fursatda tiklash imkoniyati paydo bo‘ladi. O‘zbekiston sharoitida bu masala ayniqsa dolzarb, sababi 2030 yilga kelib aholining elektr energiyasiga bo‘lgan talabi 1,7 baravarga oshishi (yillik iste’mol ~135 mlrd kVt·soatga yetishi) prognoz qilinmoqda. Bu o‘sishni qondirish uchun yangi quvvatlarni qurish bilan birga, mavjud tarmoqlarni aqlli boshqaruv ostida samarador ishlashini ta’minlash zarur.

Ikkinchi o‘rinda avtomatlashtirilgan hisoblash tizimlari (AMI) turibdi. Ekspertlar fikricha, aynan hisob-kitob va o‘lchash tizimini raqamlashtirish eng tez samara beradigan va aholiga bevosita ta’sir

etadigan yo‘nalishdir (4,8 ball). Chunki oddiy iste’molchi raqamli transformatsiya “mevasini” eng avvalo qo‘lidagi aqlli hisoblagich va uning qulayliklari orqali his etadi. O‘zbekistonda bu borada qisqa muddat ichida katta ishlar qilindi: 2022 yil oxiriga kelib Toshkent shahri va barcha viloyatlarda aholi uchun gaz hisoblagichlarini to‘liq “aqlli” turlarga almashtirish yakunlandi; elektr energiyasi bo‘yicha esa, qishloq joylarda ham bosqichma-bosqich elektron hisoblagichlar o‘rnatishga o‘tildi. Natijada, 2023 yildan boshlab iste’molchilarning asosiy qismi shaxsiy kabinet yoki mobil ilova orqali o‘z energiya iste’molini kuzatish va to‘lovlarni amalga oshirish imkoniga ega bo‘ldi. Bu transformatsiyaning ijtimoiy-ijtimoiy jihatdan ham ahamiyatli ekanini ko‘rsatadi – iste’mol madaniyatining oshishi, energiyani tejashga bo‘lgan qiziqishning ortishi kabi samara kutilmoqda.

Ekspertlar uchinchi muhim yo‘nalish sifatida raqamli platforma va sun’iy intellektni (4,6 ball) ko‘rsatdilar. Bu ancha yangi tushuncha bo‘lib, ilgari energetika kabi konservativ soha uchun noodatiy edi. Endilikda esa, energetika kompaniyalari ham o‘zlarini “ma’lumotlar kompaniyasi” deb e’tirof etmoqda – ya’ni ular uchun mavjud uskuna va tarmoqlardan kelayotgan ulkan hajmdagi ma’lumotlar qimmatli aktiv hisoblanadi. Ushbu ma’lumotlarni qayta ishlash orqaligina haqiqiy raqamli transformatsiya sodir bo‘ladi. O‘zbekiston Energetika vazirligining 2020–2030 yillarga mo‘ljallangan kontsepsiyasida ham elektr energiyasi hisobini nazorat qilish tizimlarini takomillashtirish va yagona elektron baza yaratish ustuvor vazifa qilib belgilangan. Tadqiqotimiz davomida aniq bo‘ldiki, agar mavjud ma’lumotlar (hisoblagich o‘qishlari, transformatorlardagi sensorlar, GIS tizimlaridagi ma’lumotlar va boshqalar) yagona platformaga integratsiya qilinsa, undan juda ko‘p foydali tahliliy natijalar olish mumkin. Shuningdek, sun’iy intellekt yordamida ayrim yirik zavodlarning energiya samaradorligini real vaqt rejimida nazorat qilish va ularni optimallashtirish imkoni ham paydo bo‘ladi. Masalan, mahalliy kimyo va metallurgiya korxonalarida energiya sarfi xalqaro me’yorlardan 1,5–2 baravar yuqori ekani qayd etilgan bo‘lib, 2030 yilgacha sanoatda energiya samarasizligini 10–15% ga kamaytirish rejalashtirilmoqda. Bunga erishishda aqlli monitoring tizimlari muhim ahamiyatga ega bo‘ladi.

Delphi natijalarida keyingi pog‘onalarni qayta tiklanuvchi energetika integratsiyasi (4,5 ball) va kiberxavfsizlik (4,3 ball) egalladi. O‘zbekiston 2030 yilga borib elektr energiyasi ishlab chiqarish quvvatining kamida yarmisini quyosh, shamol va gidro manbalaridan olishni maqsad qilgan. Dastlabki rejada bu ko‘rsatkich 40% deb belgilangan bo‘lsa-da, keyinchalik yangi maqsad 50% ga ko‘tarildi. Bunday ulkan o‘zgarishlarni amalga oshirish uchun albatta raqamlashtirish asos bo‘lib xizmat qiladi. Hozirning o‘zida xalqaro investorlar ishtirokidagi quyosh va shamol stansiyalari zamonaviy distant monitoring tizimlari bilan jihozlanmoqda (masalan, yuqorida tilga olingan 511 MVt quvvatli quyosh stansiyalari TrinaTracker kompaniyasining raqamli SCADA tizimi bilan boshqarilmoqda). Kelgusida, mamlakat bo‘ylab tarqalgan ko‘plab quyosh va shamol stansiyalari yagona dispetcherlik markaziga ulanib, ob-havo sharoitlari va kun vaqtiga qarab optimal rejimda boshqarilishi lozim bo‘ladi. Shuningdek, qayta tiklanuvchi manbalar taqchilligi davrida (masalan, tunda yoki shamolsiz paytlarda) energetika tizimining barqaror ishlashi uchun akkumulyatorli energiya saqlash tizimlari (Battery Energy Storage Systems – BESS) joriy etilishi kutilmoqda. Bunday BESS loyihalari ham muvaffaqiyatli bo‘lishi uchun ularni boshqaruvchi aqlli algoritmlar va dasturiy ta’minot kerak bo‘ladi. Xulosa qilish mumkinki, “yashil energetika” taraqqiyoti ham bevosita raqamli texnologiyalarga tayanadi.

Kiberxavfsizlik borasida esa, ekspertlar raqamlashtirishning ajralmas qismi sifatida qaramoqda. Hozirda Energetika vazirligi va uning tizimidagi korxonalarda axborot tizimlarini kiberhujumlardan muhofaza qilish bo‘yicha davlat talablariga mos chora-tadbirlar ko‘rilmoqda. Xususan, “Raqamli O‘zbekiston – 2030” strategiyasi doirasida 2022–2023 yillarda davlat organlari uchun kiberxavfsizlikni ta’minlash bo‘yicha yangi standartlar va markazlashtirilgan monitoring tizimi joriy etildi. Energetika – milliy xavfsizlik bilan bevosita bog‘liq soha bo‘lgani sababli, bu yerda har qanday raqamli yechimlar ishonchli himoya bilan birga olib borilishi kerak. Tadqiqot davomida aniqlanganidek, ekspertlar nazarida O‘zbekistonda energetika raqamlashtirish loyihalarini amalga oshirishda eng katta xatar – bu kiberxavfsizlikka yetarlicha e’tibor qaratmaslik bo‘lishi mumkin. Shu bois, har bir yangi joriy etilayotgan tizim (hisoblagichlar, SCADA, boshqaruv panellari va h.k.) tegishli shifrlash, identifikatsiya va hujumlarga qarshi himoya mexanizmlariga ega bo‘lishi shart. Xo‘sh, bu sohada nimalar qilinyapti? Ma’lum bo‘lishicha, 2024 yil yakunida O‘zbekiston hukumati 2025–2030 yillarda amalga oshiriladigan sun’iy intellekt texnologiyalarini rivojlantirish strategiyasini ham tasdiqladi, unda energetika sohasida sun’iy intellekt joriy etish bilan birga kiberxavfsizlik masalalari ham qamrab olingan. Ya’ni, raqamli taraqqiyot va axborot xavfsizligi bir yo‘nalishda olib borilmoqda. Bu ijobiy hol.

Ekspertlar ta’kidlagan yana bir muhim jihat – bu kadrlar malakasi. Raqamli texnologiyalarni joriy etish jarayonida odam omili, ya’ni ushbu texnologiyalar bilan ishlaydigan mutaxassislarning bilim va ko‘nikmalari hal qiluvchi ahamiyatga ega. Agar millionlab aqlli hisoblagichlar o‘rnatilgach, ularni yuritish, ma’lumotlarini tahlil qilish bo‘yicha malakali mutaxassislar yetishmasa, kutilgan samaraga erishish qiyin. Shu bois Delphi ishtirokchilari energetika sohasidagi xodimlarni qayta tayyorlash, IT yo‘nalishlarda yangi kadrlarni jalb etish masalalariga alohida urg‘u berishdi (4,2 ball). Hozirda Energetika vazirligi tuzilmasida raqamli transformatsiya bilan shug‘ullanuvchi maxsus bo‘linmalar faoliyat yuritmoqda. 2022 yilda Toshkent axborot texnologiyalari universitetida energetika sohasiga mo‘ljallangan IT kurslari yo‘lga qo‘yildi. Bundan

tashqari, Bir million dasturchi loyihasi doirasida energetika tizimidan ham yoshlar ishtirok etmoqda. Ammo bu yetarli emas – sohada chuqur bilimli texnolog-muhandis va data-tahlilchilar armiyasini shakllantirish zarur. “O‘zbekiston – 2030” strategiyasida yoshlar o‘rtasida IT sohasini rivojlantirish, har yili 15 ming nafar iqtidorli yoshlarni xalqaro talablarga mos dasturlash va raqamli ko‘nikmalar bo‘yicha o‘qitish vazifalari qo‘yilgan. Bu kelgusida energetika kabi tarmoqlarga ham yangi raqamli avlod kirib kelishini ta’minlaydi.

Yuqoridagi tahlillar yakunida, O‘zbekiston energetika sanoati korxonalarini raqamlashtirish bo‘yicha quyidagi asosiy natijalarga erishilganini qayd etish mumkin:

Energetika sohasida raqamlashtirish mamlakatning 2030 yilgacha mo‘ljallangan taraqqiyot strategiyasining ajralmas qismidir. Raqamli texnologiyalarni joriy etish orqali yashil energetika ulushini oshirish (2030 yilga borib jami ishlab chiqarishda 50% gacha), energiya samaradorligini ikki baravarga yaxshilash, tarmoq yo‘qotishlarini 2 baravardan ko‘proqqa qisqartirish (masalan, tarqatish tarmog‘ida 12–14% dan 6–7% gacha) kabi yirik maqsadlarga erishish real ko‘rinmoqda. Demak, raqamlashtirish strategik ko‘rsatkichlarning “bajaruvchi mexanizmi” sifatida xizmat qilmoqda.

2020–2025 yillar davomida allaqachon muayyan natijalarga erishildi. Xususan, mamlakat bo‘yicha gaz ta’minoti 100% raqamli hisoblagichlarga o‘tdi, elektr tarmoqlarida esa aholining katta qismi aqlli hisoblagichlar bilan qamrab olindi. Bu orqali hisob-kitob intizomi yaxshilandi, yoqilg‘i va elektr energiyasi uchun to‘lov yig‘imi sezilarli oshdi (qarzdorlik kamaydi). Shuningdek, 2023 yilda ilk raqamli podstansiya qurilib ishga tushirildi (Jizzax viloyati Zafarobod podstansiyasi, 220 kV) – bunda zamonaviy mikroprotsessorli himoya va avtomatika, raqamli o‘lchash uskunalari joriy etilib, obyekt boshqaruvi to‘liq kompyuter tizimiga o‘tkazildi. Bu – elektr uzatish infratuzilmasini yangilashdagi muhim qadam.

Raqamli transformatsiya jarayonida xususiy sektor ishtiroki kengaydi. Avvalo, qayta tiklanuvchi energiya loyihalarida xorijiy kompaniyalar (Masdar, Total Eren, ACWA Power va boshq.) faol ishtirok etib, o‘zlarining eng yangi raqamli echimlarini O‘zbekistonga olib kirmoqda. Masalan, 2024 yilda tarmoqqa ulangan 500 MVt dan ortiq quyosh fotoelektr stansiyalarida dunyoning ilg‘or “aqlli inverter”lari, harakatlanuvchi panellar va ular uchun IoT nazorat tizimlari o‘rnatildi. Xususiy sektor ishtiroki faqat generatsiya bilan cheklanmay, taqsimlash va xizmat ko‘rsatish sohalariga ham kirib kelmoqda: 2023 yildan boshlab ayrim hududlarda elektr energiyasini hisobga olish va tariffikatsiya xizmatlarini xususiy IT kompaniyalar amalga oshirmoqda (DXSh asosida). Strategiyaga muvofiq, yaqin yillarda gaz va elektr yetkazib berish xizmatlarini to‘liq xususiy operatorlar bajarishi ham nazarda tutilgan. Bu jarayon raqamlashtirishni tezlashtirishi mumkin, chunki xususiy operatorlar daromadini oshirish uchun yo‘qotishlarni kamaytirishga va xizmatni yaxshilashga intiladi, buning yo‘li – raqamli texnologiyalarni qo‘llash ekanligi aniq.

Albatta, raqamli transformatsiya katta investitsiyalar talab qiladi. Jahon banki hisob-kitobiga ko‘ra, faqat elektr taqsimlash tarmoqlarini modernizatsiya va raqamlashtirish uchun 2020–2030 yillarda O‘zbekistonga taxminan $3 mlrd mablag‘ zarur bo‘ladi. Shu jumladan, 6000 km past kuchlanishli tarmoqlarni yangilash, 1200 ta transformatorni almashtirish, yuqorida aytilgan 150 ming aqlli elektr hisoblagich va 4000 ta konsentratorni o‘rnatish kabi ishlarga $150 mln miqdorida investitsiya kiritilishi belgilangan (Jahon banki va REPN hamkorligida). Umuman olganda, elektr tarmoqlarini to‘liq yangilash va raqamli tizimlarga o‘tkazish uchun 5 yil davomida $4 mlrd atrofida investitsiya yo‘naltirilishi rejalashtirilgan. Qayta tiklanuvchi energiya bo‘yicha esa 2030 yilgacha $10–12 mlrd investitsiya kutilmoqda (shu jumladan, ushbu loyihalardagi raqamli komponentlar uchun). Bu raqamlar raqamlashtirish iqtisodiy jihatdan ham yirik tashabbus ekanini ko‘rsatadi. Biroq investitsiyalarning qaytimi yuqori bo‘lishi kutilmoqda: masalan, elektr tarmoqlarida yo‘qotishlarning har bir foizga kamayishi yiliga o‘nlab million AQSh dollariga teng tejamkorlikni beradi. Shuningdek, yirik investitsiyalar jalb qilinishi mahalliy ishlab chiqarish va xizmat ko‘rsatish sohalarini rivojlantiradi – masalan, 2021 yilda Toshkentdagi Texnopark korxonasida mahalliy brend ostida “Osten” aqlli gaz hisoblagichlari ishlab chiqarila boshlandi va bir yil ichida 1 milliondan ortiq mahsulot ishlab chiqarildi. Bu O‘zbekistonda yangi tarmoq – elektron o‘lchash priborlarini ishlab chiqarish sanoati – rivojlanayotganini anglatadi.

Yuqoridagi tahlil komponentlari asosida aytish mumkinki, O‘zbekiston energetika sanoatida raqamlashtirish bo‘yicha amalga oshirilayotgan ishlar 2030 yil strategik maqsadlariga erishishda hal qiluvchi omil bo‘lib xizmat qiladi. Raqamli transformatsiya energetika tizimining samaradorlik darajasini sifat jihatdan yangi bosqichga olib chiqmoqda. Quyida keltirilgan rasmda O‘zbekistonda jadal rivojlanayotgan quyosh energetikasi obyektlaridan birining ko‘rinishi tasvirlangan bo‘lib, bunday zamonaviy stansiyalar integral raqamli boshqaruv tizimlari bilan jihozlangan.

Delphi so‘rovi va boshqa tahlillar shuni ko‘rsatdiki, 2030 yilgacha O‘zbekiston energetika sohasida raqamli transformatsiyaning quyidagi kutilayotgan natijalari ro‘yobga chiqishi mumkin:

Energetika raqamlashtirish aholining hayot sifatiga bevosita ta’sir ko‘rsatmoqda. Eng oddiy misol – avvallari elektr yoki gaz hisobini topshirish uchun navbat kutish, uyma-uy yurish amaliyoti bo‘lgan bo‘lsa, hozir bu ishlar masofadan bajarilmoqda. Bu vaqt va resurs tejamidir. Yana bir jihat – raqamli tizimlar energiya taqsimotida adolat va shaffoflikni oshiradi. Masalan, avval kimdir noqonuniy ravishda qarzdor bo‘lib ham elektrdan foydalanaverar, boshqasi esa vaqtida to‘lardi; endi smart tizim qarzdorning elektrini avtomatik uzib qo‘yadi, bu esa har bir fuqaroni to‘lovga mas’uliyatli qilishga undaydi.

Kelgusida, energetika xizmatlari bo‘yicha “yagona darcha” onlayn portal yaratilishi rejalangan bo‘lib, unda fuqarolar elektr, gaz, suv kabi barcha kommunal xizmatlar uchun yagona platforma orqali hisob-kitob qilishi mumkin bo‘ladi (ayrim hududlarda sinov tariqasida bunday tizim yo‘lga qo‘yilgan). Bularning bari raqamli transformatsiya samarasidir.

Tahlillar shuni ko‘rsatmoqdaki, O‘zbekistonda energetika sanoatini raqamlashtirish bo‘yicha boshlangan ishlar jadal davom etmoqda va dastlabki natijalar ijobiy. Albatta, duch kelinayotgan qiyinchiliklar ham yo‘q emas: yirik investitsiya talab etilishi, ayrim eski uskunalarning moslashuvi qiyinligi, kadrlar malakasini oshirish zarurati va h.k. Ammo davlat darajasida qabul qilingan siyosiy qarorlar (2030 strategiyasi kabi) va xalqaro moliyaviy institutlar ko‘magidagi loyihalar bu to‘siqlarni yengib o‘tishga xizmat qilmoqda. Eng muhimi, raqamlashtirish bo‘yicha aniq indikatorlar belgilangan va ular muntazam monitoring qilinmoqda. Masalan, 2025 yilga borib elektr energiyasidagi yo‘qotishlarni 10% dan pastga tushirish bo‘yicha oraliq maqsad belgilandi – bu bajarilsa, 2030 yilda 8–9% ko‘rsatkichga yetish osonlashadi. Shunday ekan, oldinda turgan vazifalar aniq va ularga erishish uchun ilmiy yondashuvga asoslangan kompleks metodologiya zarur.

Bizning tadqiqot doirasida taklif etilgan metodologiya va Delphi natijalari shu yo‘nalishda amaliy ahamiyatga ega deb hisoblaymiz. Xususan, Energetika vazirligi uchun raqamlashtirish loyihalarini rejalashtirishda ushbu ustuvor yo‘nalishlar va ularning o‘zaro bog‘liqligini hisobga olish tavsiya etiladi. Masalan, aqlli tarmoqlarni joriy etish dasturlarini amalga oshirish bilan bir vaqtda kiberxavfsizlik bo‘yicha alohida komponentlarni kiritish, qayta tiklanuvchi energiya loyihalarini rejalaganda ularning tarmoqqa integratsiyasi uchun zarur bo‘ladigan raqamli vositalarni oldindan ko‘zda tutish kabi takliflar ishlab chiqildi.

O‘tkazilgan tadqiqot yakunlari shuni ko‘rsatadiki, energetika sanoati korxonalarini raqamlashtirish O‘zbekistonning 2030 yilgacha bo‘lgan taraqqiyot strategiyasidagi eng muhim ustuvor yo‘nalishlardan biri bo‘lib, u sohaning ilmiy-nazariy va amaliy rivojlanishiga yangi impuls bermoqda. Raqamli texnologiyalarni joriy etish natijasida energetika tizimining samaradorligi, barqarorligi va shaffofligi sezilarli darajada oshadi, bu esa mamlakatning iqtisodiy o‘sishi va aholining turmush farovonligiga bevosita ijobiy ta’sir ko‘rsatadi.

Tadqiqot doirasida ishlab chiqilgan metodologik yondashuv (Delphi usuliga asoslangan holda) energetika sohasini raqamlashtirish bo‘yicha qarorlar qabul qilishda muvaffaqiyat omillarini va xavf-xatarlarni aniqlash imkonini berdi. Asosiy ilmiy-nazariy xulosalar va tavsiyalarni quyidagicha jamlash mumkin:

1.Energetika raqamlashtirishning ilmiy asoslari: Raqamli transformatsiya konsepsiyasi energetika sohasida qo‘llanishida o‘ziga xoslikka ega. An’anaviy energetika tizimi fizik qonuniyatlar va markazlashgan boshqaruvga tayanib kelgan bo‘lsa, raqamlashtirish uni kiber-fizik tizimga aylantirmoqda. Bu esa energetikani o‘rganishda faqat energetik muhandislik emas, balki axborot texnologiyalari, tizimli tahlil, boshqaruv nazariyasi kabi ilmiy yo‘nalishlarni ham integratsiya qilishni talab etadi.

2.Bizning tahlillar bunga yaqqol ishonch hosil qildi – masalan, 40–50% “yashil energiya” ulushiga erishish uchun elektr tarmoqlarini avtomatlashtirish va aqlli boshqaruv talab etiladi, aks holda noaniq xususiyatga ega quyosh/shamol generatsiyasi tizim barqarorligini buzishi mumkin.

3.Delphi usuli natijalari va ustuvor yo‘nalishlar: Ekspertlar konsensusiga ko‘ra, O‘zbekiston energetika raqamli transformatsiyasining eng muhim yo‘nalishlari sifatida aqlli tarmoqlar, avtomatlashtirilgan hisoblash tizimlari, yagona raqamli platforma, qayta tiklanuvchilar integratsiyasi va kiberxavfsizlik belgilandi (1-jadval).

4.Amaliy yutuqlar va tajribalar: 2020–2025 yillarda olingan natijalar raqamlashtirishning “ertega” emas, balki bugungi kundagi foydasini namoyon etdi. Aqlli hisoblagichlar tufayli milliardlab so‘mlik qarzdorliklar undirilmoqda, gaz va elektr ta’minotidagi yo‘qotishlar pasaymoqda, iste’molchilarga interaktiv xizmatlar paydo bo‘lmoqda.

5.Tizimlashtirilgan boshqaruv va monitoring zarurati: Raqamlashtirish jarayonining o‘zi ham doimiy monitoring va tahlilni talab qiladi. Bizning tadqiqot jarayonida ma’lum bo‘ldiki, ayrim loyihalar bo‘yicha aniq statistik ko‘rsatkichlarni topish qiyin – masalan, elektr tarmoqlarida aqlli hisoblagichlar qamrovi foizi, real yo‘qotishlar statistikasida tafovutlar mavjud. Masalan, yil yakunida “aqlli hisoblagichlar soni/ulushi”, “raqamli boshqaruvga o‘tkazilgan podstansiyalar soni”, “to‘plangan ma’lumotlar bazasi hajmi va undan foydalanuvchi tashkilotlar soni” kabi ko‘rsatkichlar tahlil qilinishi lozim.

Xulosa

Energetika sohasini raqamlashtirish – bu texnologik yangilanishdan tashqari, boshqaruv madaniyati va ish jarayonlarining ham transformatsiyasidir. O‘zbekiston misolida ushbu jarayon davlat siyosati darajasida qo‘llab-quvvatlanib, amaliy natijalar bilan mustahkamlanmoqda. Raqamli transformatsiya energetika korxonalariga inson omili ta’sirini kamaytirib, qaror qabul qilishda aniqlik va tezkorlik beradi, resurslardan samarali foydalanish imkonini yaratadi. Bu esa pirovard natijada mamlakatning energetik mustaqilligini kuchaytiradi va “yashil iqtisodiyot” tamoyillariga o‘tishni tezlashtiradi.

O‘zbekiston misolida energetika sanoati korxonalarini raqamlashtirish metodologiyasini shakllantirish tajribasi shuni ko‘rsatadiki – raqamli transformatsiya aniq strategik maqsadlar bilan bog‘langan holda olib borilgandagina muvaffaqiyatga erishadi. “O‘zbekiston – 2030” strategiyasi esa shu maqsadlarni belgilab bergan yo‘ldir. Endigi vazifa shu yo‘ldan og‘ishmasdan, ilmiy yondashuvga tayangan holda raqamli energetika sari qadam tashlashdir. Bu

yo‘lda erishilgan har bir kichik yutuq 2030 yilda ulkan muvaffaqiyatlar yig‘indisiga aylanishi shubhasiz.

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POCHTA ALOQASI XIZMATLARINI TAQDIM ETISHDA RAQAMLI TEXNOLOGIYALARDAN FOYDALANISHNING AHAMIYATI

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Abstrakt. Maqolada pochta aloqasi xizmatlarini modernizatsiya qilishda raqamli texnologiyalarning o‘rni va ahamiyati tahlil qilingan. Pochta tizimida elektron hujjatlar aylanishi, elektron raqamli imzo, onlayn kuzatuv, elektron to‘lovlar, mobil ilovalar va avtomatlashtirilgan logistika kabi innovatsion yondashuvlarning joriy etilishi ko‘rib chiqiladi. Shuningdek, O‘zbekiston pochta tizimining raqamli transformatsiyasi, xalqaro tajriba bilan taqqoslash, mavjud muammolar va rivojlantirish istiqbollari yoritilgan.

Kalit so‘zlar: pochta aloqasi, raqamli texnologiyalar, elektron pochta, logistika, elektron to‘lov, raqamli transformatsiya.

Kirish

Bugungi kunda pochta aloqasi xizmatlari jamiyat infratuzilmasining muhim qismi sifatida mamlakat iqtisodiyotida va ijtimoiy hayotda alohida o‘rin tutadi. An’anaviy pochta xizmatlari qog‘oz asosidagi xatlar, paketlar va posilkalarni yetkazib berish bilan cheklanib qolgan bo‘lsa, raqamli texnologiyalar rivojlanishi natijasida ushbu sohada tub o‘zgarishlar yuz bermoqda. Xususan, elektron to‘lov tizimlari, jo‘natmalarni onlayn kuzatish imkoniyati, elektron hujjatlar aylanishi, mobil ilovalar va tezkor logistika tizimlari mijozlar uchun sifatli va samarali xizmatlarni taqdim etmoqda.

Xozirda mamlakatimizda xam ham pochta aloqasi tizimini modernizatsiya qilish bo‘yicha keng ko‘lamli islohotlar olib borilmoqda.

2020-yil 5-oktabrda O‘zbekiston Respublikasi Prezidenti rahbarligida Vazirliklar hamda viloyat, tuman va shahar hokimiyat organlari rahbarlari ishtirokida “Milliy pochta tizimini isloh qilish masalasi” yuzasidan yig‘ilish o‘tkazilib, Milliy pochta tizimini rivojlantirish, bozorda raqobatbardosh korxonaga aylantirish hamda Umumjahon pochta ittifoqining Pochta rivojlanishi indeksi global reytingida mamlakatimizni yuqori o‘rinlarda bo‘lishini ta'minlash maqsadida Milliy pochtani qo‘llab-quvvatlash yuzasidan Vazirliklar hamda viloyat, tuman va shahar hokimiyat organlariga tegishli topshiriqlar berildi Mazkur yig‘ilishda belgilab berilgan topshiriqlarning ijrosini ta'minlash maqsadida, O‘zbekiston Respublikasi Prezidentining 2020-yil 14-dekabrdagi “Pochta aloqasi xizmatlarini ko‘rsatish tizimini tubdan takomillashtirish chora-tadbirlari to‘g‘risida”gi PQ-4921-son Qarori qabul qilindi. Mazkur Qaror bilan Pochta aloqasi xizmatlarini ko‘rsatish tizimini takomillashtirishning asosiy yo‘nalishlari belgilab berilgan, jumladan:

- xat-xabar tashish va kuryerlik xizmatlarini rivojlantirish;
- elektron tijorat bozoridagi faoliyatni rivojlantirish;
- xizmatlar bozoridagi pochta aloqasi faoliyatini rivojlantirish.

“O‘zbekiston pochtasi” AJ va boshqa operatorlar tomonidan elektron platformalar yaratilib, xalqaro standartlarga mos xizmatlar yo‘lga qo‘yilmoqda. Biroq ushbu tizimni to‘liq raqamlashtirish uchun hali ham yechimini kutayotgan masalalar mavjud.

Ayni vaqtda pochta aloqasi xizmatlariga raqamli texnologiyalarni joriy etish zarurati bir qator muammolar bilan bog‘liq:

1. Xizmat ko‘rsatish sifati – an’anaviy usullar orqali ko‘rsatilayotgan xizmatlarda tezkorlik yetarli emas, ba’zan mijozlar jo‘natmalar holati haqida ma’lumot olishda qiyinchiliklarga duch keladilar.
2. Logistika va kuzatuv – jo‘natmalarni yo‘qotish yoki kechikish xavfi mavjud, mijozlar uchun esa yetkazib berish jarayonini onlayn kuzatish imkoniyatlari cheklangan.
3. Huquqiy va normativ baza – pochta xizmatlarida elektron raqamli imzo, elektron hujjatlar aylanishi va elektron to‘lov tizimlaridan foydalanish bo‘yicha ba’zi normativ-huquqiy cheklovlar mavjud.
4. Aholining raqamli savodxonligi – ko‘plab mijozlar hali ham elektron xizmatlardan to‘liq foydalanish ko‘nikmasiga ega emas.
5. Texnologik infratuzilma – pochta bo‘limlari va logistik markazlarning texnik bazasi barcha hududlarda teng darajada emas.

O‘z o‘zidan yuqoridagi muammolarni bartaraf etish maqsadida pochta aloqasi xizmatlarini taqdim etishda raqamli texnologiyalarni joriy etish muhim o‘rin tutadi. Bunda quyidagi yo‘nalishlar muhim ahamiyatga ega:

• Elektron hujjatlar aylanishi va raqamli imzo: hujjatlarni elektron shaklda rasmiylashtirish, ularni tezkor va ishonchli tarzda yuborish va qabul qilish imkonini beradi. Bu jarayon nafaqat vaqtni, balki xarajatlarni ham sezilarli kamaytiradi.

• Onlayn kuzatuv tizimi: jo‘natmalarni maxsus QR-kod yoki GPS asosida kuzatish orqali mijozlar real vaqt rejimida posilkaning qayerda ekanini bilish imkoniga ega bo‘ladilar.

• Elektron to‘lovlar: mijozlar onlayn platformalar, mobil ilovalar va elektron hamyonlar orqali pochta xizmatlari uchun to‘lovlarni amalga oshira oladilar va bu o‘z navbatida xizmatlarni tezkor va qulay qiladi.

• Mobil ilovalar: pochta xizmatlari uchun maxsus mobil dasturlar yaratilishi natijasida mijozlar o‘z telefonlari orqali jo‘natmalar yuborish, kuzatish va to‘lovlarni amalga oshirish imkoniyatiga ega bo‘ladilar.

• Logistik jarayonlarni avtomatlashtirish: zamonaviy skanerlar, robotlashtirilgan saralash markazlari va sun’iy intellekt asosidagi tizimlar orqali jo‘natmalarni tez va aniq qayta ishlash mumkin.

• Xalqaro integratsiya: xalqaro pochta tarmoqlari bilan integratsiyalashgan elektron tizimlar yordamida import-eksport jo‘natmalarining tezkorligini oshirish.

Raqamli texnologiyalarni pochta tizimida qo‘llash natijasida quyidagi ijobiy natijalarga erishish mumkin:

• mijozlarga xizmat ko‘rsatish sifati va tezkorligi oshadi;

• pochta xizmatlarining shaffofligi va ishonchliligi ta’minlanadi;

• jo‘natmalarni yo‘qotish va kechiktirish ehtimoli kamayadi;

• davlat organlari va biznes subyektlari uchun qulay elektron hujjat almashinuvi yo‘lga qo‘yiladi;

• xalqaro bozorlarda raqobatbardoshlik ortadi;

• xizmatlarning geografiyasi kengayadi, chekka hududlarda ham sifatli xizmat taqdim etish imkoniyati yaratiladi.

Masalan, Yevropa va Osiyo mamlakatlarida pochta xizmatlari ko‘plab raqamli imkoniyatlar orqali onlayn savdo va elektron tijorat rivojiga katta hissa qo‘shmoqda. Xususan, Xitoyda “China Post” va Germaniyada “Deutsche Post DHL” raqamli xizmatlarni kengaytirib, mijozlarga 24/7 xizmat ko‘rsatish tizimini yaratgan.

Yana shuni aytish joizki, bugungi kunda bir qator fintech, marketpleys va logistika kompaniyalari bir nechta yo‘nalishlarni faol rivojlantirayotganligida logistika va pochta xizmatlari ham ulushi sezilarli albatta. Pochta aloqasining keng quloch yoygan tarmog‘i tovar va mahsulotlarni Respublikamizning eng chekka burchaklarigacha yetkazish va olis hududlarda yashovchilar uchun elektron tijoratdan foydalanishga keng yo‘l ochib beradi.Respublikamizning milliy pochta operatori “O‘zbekiston pochtasi” AJ ning bugungi kunda 14 ta hududiy filiali, 21 ta tumanlararo pochta aloqasi, 143 ta hududiy pochta aloqasi, 1804 ta pochta aloqasi bo‘limi, shahar va tumanlarda 1414 dan ortiq yetkazib berish punktlari mavjud bo‘lib bu o‘z navbatida respublikamizda elektron tijorat uchun qulay infratuzilmani yaratadi. (1-rasm)

1-rasm.

Shu bilan birgalikda, mamlakatimiz bozoriga xorijiy tadbirkorlarning kirib kelishi bizning tadbirkorlarimizga jahon bozorlarida raqobatlashish imkonini bermoqda. Bundan tashqari, O‘zbekistonda elektron tijoratga Visa va Mastercard to‘lov tizimlari ham faol joriy etilmoqda. Bu tadbirkorlarga mijozlardan xalqaro to‘lovlarni qabul qilish va o‘z bizneslarini yanada kengaytirish imkonini beradi.

Munozara

Pochta aloqasi xizmatlariga raqamli texnologiyalarni joriy etish tajribasi shuni ko‘rsatadiki, bu jarayon nafaqat xizmat ko‘rsatish sifatini yaxshilaydi, balki butun sohaning raqobatbardoshligini ham oshiradi. O‘zbekiston tajribasi xalqaro amaliyot bilan solishtirilganda, ayrim yo‘nalishlarda ijobiy natijalarga erishilgan bo‘lsa-da, hali ham yechimini kutayotgan muammolar mavjud. Jumladan, texnologik infratuzilmaning barcha hududlarda bir xil rivojlanmaganligi, aholining raqamli savodxonligi pastligi va normativ-huquqiy bazaning to‘liq shakllanmaganligi tizimning modernizatsiya jarayonida to‘siq bo‘lib turibdi.

Biroq xalqaro tajriba (Xitoy, Germaniya kabi mamlakatlarda) ko‘rsatmoqdaki, mobil ilovalar, elektron to‘lov tizimlari va avtomatlashtirilgan logistika xizmat ko‘rsatishda sifatli yechimlar taqdim etmoqda. O‘zbekiston pochta tizimi ham bu yo‘nalishlarni bosqichma-bosqich joriy etib, elektron tijorat bozorining rivojlanishiga xizmat qilmoqda. Shuningdek, fintech va logistika kompaniyalari bilan hamkorlik qilish, xalqaro integratsiyani kengaytirish tizimni yanada rivojlantirish uchun muhim omil hisoblanadi.

Xulosa

Xulosa qilib aytganda, pochta aloqasi xizmatlarini taqdim etishda raqamli texnologiyalarni qo‘llash sohaning samaradorligi, shaffofligi va mijozlarga qulayligini oshirishda muhim ahamiyat kasb etadi. Elektron hujjatlar aylanishi, onlayn kuzatuv tizimlari, elektron to‘lovlar, mobil ilovalar va avtomatlashtirilgan logistika xizmat ko‘rsatish sifatini yuqori darajaga ko‘tarishga imkon beradi.

O‘zbekistonda amalga oshirilayotgan islohotlar milliy pochta tizimining raqamli transformatsiyasi uchun asos bo‘lib, xalqaro standartlarga moslashish, elektron tijoratni rivojlantirish va global raqobatbardoshlikni kuchaytirishga xizmat qiladi.

Kelgusida barcha pochta xizmatlarini yagona elektron platformaga integratsiya qilish, xalqaro kuzatuv tizimlarini joriy etish, aholining raqamli savodxonligini oshirish va texnologik infratuzilmani mustahkamlash lozim. Ushbu chora-tadbirlar pochta aloqasi xizmatlarini zamonaviy, tezkor va mijozlarga yo‘naltirilgan tizim sifatida shakllantirishda muhim ahamiyatga ega bo‘ladi.

Pochta aloqasi xizmatlarini taqdim etishda raqamli texnologiyalar quyidagi afzalliklarni beradi:

- xizmat ko‘rsatish sifatini oshirish;
- samaradorlik va shaffoflikni ta’minlash;
- mijozlar uchun qulaylik yaratish;
- elektron tijoratni rivojlantirish;
- xalqaro standartlarga integratsiyani kuchaytirish va hokazo.

Bugungi iqtisodiyotni modernizatsiyalash sharoitida pochta aloqasi xizmatlarini samaradorligini yanada yaxshilash uchun quyidagi chora tadbirlarni amalga oshirish lozim:

- barcha pochta xizmatlarini yagona elektron platformaga integratsiya qilish;
- xalqaro kuzatuv tizimlarini joriy etish;
- pochta xizmatlarida mobil ilovalarni ommalashtirish;
- raqamli savodxonlikni oshirish bo‘yicha aholiga o‘quv dasturlari tashkil etish.

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МОДЕЛЬ ТЕХНОЛОГИЧЕСКОЙ ТРАНСФОРМАЦИИ ДЛЯ МАЛЫХ И СРЕДНИХ ПРЕДПРИЯТИЙ

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Развитие Индустрии 4.0 оказывает существенное влияние на интеграцию цепочек создания стоимости. Скорость этой трансформации различается в зависимости от отраслей промышленного производства и оказывает влияние на малых и средних предприятий, углубляя разрыв в развитии в разных регионах мира. В этом случае малых и средних предприятий обрабатывающей промышленности стран оказываются втянутыми в среду стремительной трансформации, которая, в свою очередь, сложна и неизвестна во всех своих измерениях. На основе исследования, в различных отраслях промышленности, была оценена текущая степень технологического развития и степень трансформации, в которой они находятся. В результате исследования было выявлено, что компании этого типа сталкиваются с серьезным дефицитом знаний о технологиях, которые можно было бы разработать, внедрить или интегрировать в различные функциональные области. Это незнание оказывается основным препятствием для трансформации. Именно поэтому в данной статье представлены предварительные результаты текущего исследовательского проекта, в рамках которого разрабатывается модель процесса технологической трансформации. Эта модель позволяет малым и средним предприятиям определить, какие продукты они могут внедрять, исходя из потребностей в добавленной стоимости в различных функциональных областях, и выбрать путь трансформации в сторону Индустрии 4.0.

Ключевые слова — индекс ИКТ; малых и средних предприятий; Технологическое развитие; Промышленное развитие; Индустрия 4.0

IX. ВВЕДЕНИЕ

Цифровая трансформация производственных систем и ускоренные темпы развития четвёртой промышленной революции требуют горизонтальной интеграции продуктов и процессов, поддерживаемой сетями взаимодействия, в которых рабочие и цифровые технологии охватывают различные области производственного предприятия [1]. Скорость этой трансформации различается в зависимости от отраслей промышленного производства и по-разному влияет на малых и средних предприятий (МСП), углубляя разрыв в развитии в разных регионах мира.

По данным аналитических компаний, пропасть в цифровизации компаний в странах весьма значительна [2] и рискует увеличиться в ближайшие годы в связи с ускоренным развитием Индустрии 4.0. Поэтому в настоящее время рекомендуется государственным и частным инициативам поддерживать малый бизнес в использовании технологических решений в своей деятельности [3].

На основе применения своего условного индекса цифровизации со стороны аналитических компаний было проведено сравнительное исследование по развитии цифровой трансформации в МСП. Результаты исследования свидетельствуют о том, что в развивающихся стран самовосприятии компаний присутствует нехватка знаний о доступных технологиях, о процессах их внедрения и о технологическом потенциале для их бизнеса [3].

В дополнение к этому отсутствию знаний и сосредоточению, наблюдается, что имеется слабая связь между потенциалом технологического развития и местной обрабатывающей промышленностью, оставляя на втором плане технологическое обновление малых и средних производственных компаний.

В этом смысле проявляется нехватка стратегий технологического обновления, ориентированных на промышленные МСП, и нехватка инвестиций в повышение конкурентоспособности на основе инноваций и технологических преобразований, учитывая, что этот сектор не является востребованным сектором для развития цифровых технологий по сравнению с другими секторами.

С этой точки зрения, учитывая скорость процесса трансформации и недостаточную осведомленность компаний о решениях, которые необходимо принять, необходимо знать, какие конкретные технологические продукты входят в состав Индустрии 4.0, а также предоставить информацию о путях внедрения и

взаимодополняемости технологий, которые промышленные МСП могли бы внедрить и инициировать процесс трансформации в направлении Индустрии 4.0.

Чтобы оценить текущее состояние технологического развития МСП, было проведено исследование с использованием индекса InTICs® [5], разработанного исследовательской группой GIS (Grupo de Ingeniería de Software) в качестве инструмента оценки. Индекс определяет уровень технологического развития каждой отрасли в зависимости от внедренных ею в настоящее время программных, аппаратных и инфраструктурных продуктов, выполняющих конкретные задачи. В данном случае продукты, распределенные по функциональным областям каждой компании, были оценены с целью выявления технологий, внедренных в каждой компании, в соответствии с добавленной стоимостью каждой функции.

В результате детального анализа каждой функциональной области в каждой компании и дифференциации продуктов и внедрения каждой технологии разрабатывается модель процесса, которая упрощает внедрение технологий для технологической трансформации малыми и средними предприятиями. Разрабатываемая модель процесса основана на результатах оценки цифровых технологий по функциональным областям, чтобы каждая компания могла получить информацию о технологиях, установленных и используемых ею в различных функциях, и определить потребности во внедрении технологий для проведения повторной конверсии.

X. Обзор работ

A. *Материалы и методы*

Для проведения анализа уровня технологического развития по функциональным областям было проведено исследование с использованием индекса InTIC® [6], который структурирован на основе технологических продуктов, дифференцированных на 3 компонента цифровых технологий: программное обеспечение, оборудование и инфраструктура, сгруппированных в соответствии со спецификой каждого типа технологий и внедренных в функциональных областях, где эти технологии выполняют определенные задачи в отраслях [5].

Ниже перечислены общие функциональные области, по которым структурирована типичная компания, разрабатывающая различные функции.

- *Логистика*: включает в себя логистические задачи, как на въезде, так и на выезде.
- *Производство*:включает операцию деятельности.
- *Продажи*: эта область включает в себя функции маркетинга и продаж.
- *Управление*: эта область включает в себя вспомогательные функции инфраструктуры и человеческих ресурсов компании.
- *Бухгалтерский учет и финансы*: эта область также является частью деятельности компании по поддержке инфраструктуры.
- *Инжиниринг*: эта область включает в себя деятельность по разработке технологий, то есть функции из продукта и процесс проектирования.
- *Закупки*: включает улучшения в коммуникациях, которые приводят к сокращению цикла покупки и более выгодным ценам.

После того как технологические продукты идентифицированы на пересечении с каждой функциональной областью, индекс генерирует трехуровневую оценку, взвешивая каждый продукт в соответствии со степенью его разработки с точки зрения времени, в течение которого каждый из них находится на рынке, что позволяет различать компании, на каком уровне они находятся в соответствии с внедренной технологией:

- *Базовый уровень* для тех компаний, у которых старые технологии.
- *Средний уровень* для тех компаний, которые имеют средне современные технологии.
- *Продвинутый уровень* для компаний, обладающих передовыми технологиями.

Индекс включает 74 продукта цифровых технологий в различных функциональных областях, из которых 20 относятся к базовому уровню, 30 – к среднему, а 24 – к продвинутому. Не все продукты, входящие в продвинутый уровень, относятся к последнему поколению, но они необходимы для интеграции и функционирования других. Таким образом, из набора продуктов продвинутого уровня, определяющего индекс, были выделены технологические продукты, составляющие Индустрию 4.0.

На рисунке 1 представлены частные продукты индекса, которые в совокупности составляют подмножество продуктов Индустрии 4.0. Эта тема изучалась и была представлена на различных конференциях [7].

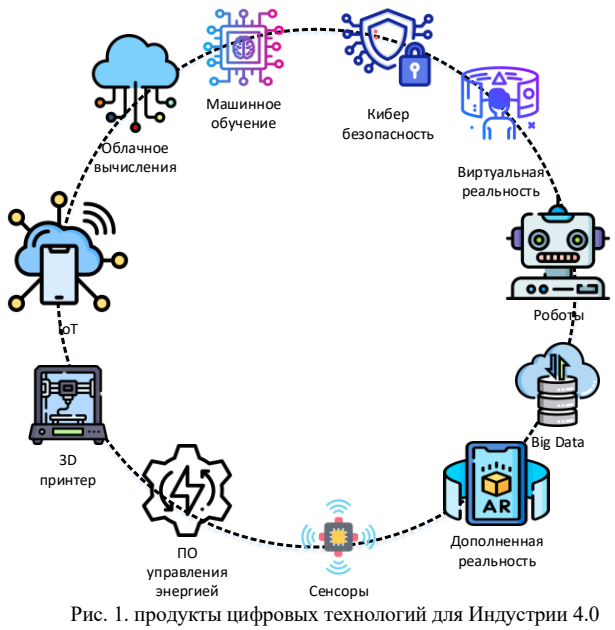

Рис. 1. продукты цифровых технологий для Индустрии 4.0

Структура индекса позволяет оценить установленные продукты, относящиеся к

продвинутому уровню в каждой функциональной области компании, а также 11 продуктов, относящихся к подмножеству Индустрии 4.0.

XI. Результаты и обсуждение

Для анализа уровня технологического развития по функциональным областям было проведено исследование с использованием индекса InTICs®. Для примера можно анализировать пункт, в котором население составляет 2 миллиона жителей, и 7000 промышленных предприятий различных секторов обрабатывающей промышленности, большинство из которых МСП.

Результаты анализа компаний показывает, что 62,50% опрошенных отраслей находятся на базовом уровне, 35,00% — на среднем и 2,50% — на продвинутом. Аналогично, из общего числа компаний 67,50% внедрили некоторые продукты Индустрии 4.0, и только одна компания продвинутого уровня содержит 10 (из 11) продуктов Индустрии 4.0, что означает, что из всех опрошенных отраслей только одна полностью относится к этому сегменту.

На основе этого глобального анализа уровня развития опрошенных компаний был проведен детальный анализ подмножества технологий Индустрии 4.0 для каждой функциональной области во всех компаниях, где было обнаружено наличие какого-либо из этих продуктов.

Таким образом, анализируя каждую область, можно заметить, что в функциях «Закупки» анализируемые компании имеют 30 продуктов Индустрии 4.0.

В сфере «Логистика» компании внедрили 34 продукта Индустрии 4.0.

Что касается направления «Продажи», компании внедрили 54 продукта Индустрии 4.0.

Что касается продуктов, внедренных в области «Управление», компании внедрили 53 продукта Индустрии 4.0.

Что касается области «Бухгалтерский учет и финансы», компании внедрили 42 продукта Индустрии 4.0.

В сфере «Инжиниринг» на предприятиях внедрено 42 продукта Индустрии 4.0.

Анализируя эти данные, можно отметить, что продукты, внедренные во всех областях деятельности опрошенных компаний, относятся к области кибербезопасности, далее следуют облачные вычисления, а на третьем месте — Интернет вещей. Эти три продукта практически не упоминаются, а остальные восемь встречаются крайне редко.

Таким образом, если 67% опрошенных компаний имеют какой-либо продукт Индустрии 4.0, среди которых выделяются те, которые применяются в кибербезопасности, облачных вычислениях и Интернете вещей и распределены в различных функциональных областях каждой компании, можно утверждать, что процесс внедрения технологий осуществляется путем заключения контрактов на услуги по существующим технологиям, которые не подразумевают собственные разработки, в то же время интеграция с другими компонентами, которая могла бы повысить их производительность, не обнаружена. Примером того, что ожидается обнаружить, может быть случай сетей Интернета вещей с датчиками для сбора собственных данных, которые обрабатываются с помощью программного обеспечения для больших данных для анализа и алгоритмов машинного обучения при принятии решений.

Этот анализ позволяет нам сделать вывод о низком уровне внедрения технологий Индустрии 4.0, отсутствии трансверсальной интеграции продуктов в различные функциональные области, а также о том, что внедряемые продукты приобретаются или предоставляются по контракту. Гипотеза данного исследования подтверждается высоким уровнем неосведомленности малых и средних промышленных предприятий о доступных технологиях и процессе интеграции, требующем их внедрения.

XII. Предлагаемое решение

Для управления процессом внедрения и интеграции технологий предлагается предварительная версия модели процесса, которой может следовать промышленное предприятие малого и среднего бизнеса, чтобы начать идентификацию продукта, что позволит ему начать технологическую трансформацию (ТТ).

Модель состоит из 11 подпроцессов, которые выполняются последовательно, а результат каждого подпроцесса представляет собой входную информацию для следующего.

На рисунке 9 показана модель, где каждый процесс представлен кругом, а содержащиеся в них потоки связаны прямоугольником с его именем. Стрелки указывают поток информации между потоками.

Рис. 9. Модель технологической трансформации

Предлагаемая модель основана на анализе существующих функциональных областей компании [6], позволяет оценить технологии, внедренные в каждой области, определить ключевую функциональную область, проанализировать и определить цели технологической трансформации (ТТ) организации и ключевой области. После определения целей модель позволяет определить технологические продукты, которые необходимо внедрить, разработать или интегрировать, что, в свою очередь, определяет стратегии разработки, внедрения или интеграции продуктов цифровых технологий [5].

Модель рассматривает каждый цикл как континуум, в котором каждая отрасль может начать, когда она решит, что ей требуется технологическое обновление для повышения своей производительности.

Определение процессов модели основано на индексной схеме InTICs®, которая позволяет проанализировать организацию по её функциональным областям и оценить конкретные и эффективные продукты цифровых технологий, внедрённые ею в реальном контексте использования для каждой функции. Таким образом, каждый процесс Модели описан ниже.

1. Анализ функциональных зон компании

Этот процесс инициирует Модель технологической трансформации с определения функциональных областей типичной компании в соответствии с индексом ИКТ, в котором они различаются по менеджменту, бухгалтерскому учету и финансам, инжинирингу, закупкам, логистике, производству и продажам.

2. Оценка существующих цифровых технологий в организации по функциональным областям (технологические активы)

Продукты ИКТ для организации оцениваются на основе анализа индекса в зависимости от того, относятся ли они к набору аппаратных, программных или инфраструктурных продуктов по функциональной области. Эти продукты ИКТ обозначены в Модели как технологические активы [9]. То есть, продукты ИКТ, имеющиеся в организации в её функциональных областях. Использование индекса позволяет определить, какие продукты находятся в эксплуатации, и оценить уровень развития компании.

3. Определение ключевых функциональных областей (KFA – Key Functional Area)

В качестве следующего процесса Модель предлагает определить ключевую функциональную область для каждой компании в соответствии со следующими вариантами:

3.1. Определение основной сферы деятельности предприятия

Анализ центральной сферы деятельности компании, в которой она производит продукцию и которая определяет её миссию в рамках отрасли. «Основная сфера деятельности» определяет основное направление производственной и коммерческой деятельности компании. Это может быть бизнес, в котором компания была основана, или бизнес, в рамках которого её деятельность развивалась с течением времени. [10]

3.2. Определение уровня технологического развития каждой области деятельности компании

Определение основного направления деятельности позволяет оценить конкретные продукты цифровых технологий, входящие в его состав, и уровень развития конкретных технологий, чтобы определить влияние ИКТ на производительность основного направления деятельности. Оценка может быть выполнена с помощью индекса InTICs®, используя конкретный срез рассматриваемого направления.

3.3. Обнаружение области с большим потенциалом

Оценка направлений деятельности компании, а также определение основного направления деятельности и уровня его технологического развития позволяет выявить направление, имеющее наибольший потенциал развития с учетом его уровня или вклада в основное направление деятельности.

Другими словами, если основная бизнес-область имеет приемлемый уровень развития, превышающий средний уровень развития остальных областей, или существует функциональная область, которая ограничивает потенциал производительности основной бизнес-области из-за своего низкого уровня развития, последняя будет представлять собой область с наибольшим потенциалом, учитывая, что её технологическое обновление будет способствовать росту производительности основной бизнес-области компании. В рамках этого подпроцесса разрабатываются экономические и технологические показатели, позволяющие оценить и выделить различные области, которые могут обладать наибольшим потенциалом.

С помощью этих трех вариантов Модель позволяет определить ключевую функциональную область как наиболее важную область или область с наибольшим потенциалом для инициирования процесса технологической трансформации.

4. Определение целей технологической трансформации (ТТ) для организации

На основе определения KFA определяются цели технологической трансформации для организации в целом. В рамках этого процесса компания определяет цели, которые необходимо достичь в рамках технологического развития всей компании, связанные с приобретением собственных технологий или разработок, интеграцией существующих технологий, обучением персонала или внедрением новых профилей, а также другими аспектами, затрагивающими организацию в целом.

5. Определение целей технологической трансформации (ТТ) для ключевой функциональной области

Определение целей технологической трансформации для всей организации обеспечивает необходимую основу для последующего процесса, включающего определение целей технологической трансформации для ключевой функциональной области (KFA), выбранной в процессе 3.3. В этом процессе компания определяет цели, которые необходимо достичь с точки зрения технологического развития для конкретной области в соответствии с определениями общих целей.

6. Выбор ИКТ для внедрения

6.1. Определение инфраструктурных продуктов или услуг

Этот подпроцесс позволяет определить, какие конкретные инфраструктурные продукты или услуги компания будет внедрять в соответствии с целями ТТ, предусмотренными KFA, и целями ТТ организации в целом. Это различие позволяет внедрять технологии в соответствии со следующими критериями:

6.1.1. Осуществлять

Внедрить новые технологические продукты, отсутствующие в KFA. Например, развернуть новую сеть для Интернета вещей.

6.1.2. Интегрировать

Интеграция существующих продуктов с новыми продуктами и/или услугами. Например, интеграция новой сети Интернета вещей с существующим

программным обеспечением для обработки данных о запасах.

6.2. Определение аппаратных продуктов или устройств

Этот подпроцесс позволяет определить, какие конкретные продукты, включая оборудование или устройства, компания будет внедрять в соответствии с целями TT KFA и целями TT организации в целом. Это различие позволяет внедрять продукты в соответствии со следующей дискриминацией:

6.2.1. Осуществлять

Внедрить новые технологические продукты, отсутствующие в KFA. Например, использовать ноутбуки для повышения производительности.

6.2.2. Интегрировать

Интегрируйте существующие продукты с новыми. Например, интегрируйте ноутбуки в сеть передачи данных, установленную для обработки данных.

6.3. Определение программных продуктов

Этот подпроцесс позволяет определить, какие конкретные программные продукты компания будет внедрять, исходя из целей внедрения KFA и целей внедрения организации в целом. Это различие позволяет внедрять продукты в соответствии со следующими критериями:

6.3.1. Развивать

Собственная разработка программного обеспечения, отсутствующего в KFA.

6.3.2. Осуществлять

Внедрите программное обеспечение, разработанное на основе закупленных пакетов или продуктов, уже имеющихся на рынке. Например, внедрите программное обеспечение для управления запасами.

6.3.3. Интегрировать

Интеграция существующего программного обеспечения с новыми приложениями или программными продуктами. Например, интеграция существующей веб-страницы с новой разработкой транзакционной веб-страницы.

7. Начало процесса разработки, внедрения или интеграции

Этот процесс позволяет начать внедрение, интеграцию или разработку продуктов, определенных в предыдущем пункте.

8. Оценка

После завершения разработки внедренные, разработанные и/или интегрированные ИКТ оцениваются уже как новые технологические активы, и начинается новый цикл процесса TT.

Выводы

В данной статье представлены результаты опроса, который показал, что значительное число компаний, независимо от уровня их технологического развития, используют продукты кибербезопасности или услуги облачных вычислений для поддержки различных функций своей компании. Внедрение этих продуктов позволяет утверждать, что компании используют технологические услуги и не знают о возможностях других продуктов или их трансверсальной интеграции для улучшения остальных внедрённых ими технологий.

Из этой высокой степени неосведомленности в качестве предлагаемого решения была выявлена предварительная структура Модели процесса технологической трансформации, которая разрабатывается в рамках исследовательского проекта и позволяет малым и средним компаниям отрасли узнать о доступных технологиях и встать на путь трансформации в сторону Индустрии 4.0 на основе анализа технологических продуктов по функциональным областям компании.

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RAQAMLASHTIRISH ASOSIDA YASHIRIN IQTISODIYOT QISQARTIRISH YO‘LLARI

Xodjayev Abdulxay Xasanboyevich
TATU, mustaqil tadqiqotchi

Bugungi kunda yashirin iqtisodiyotning yuqori ulushi jahon hamjamiyatining eng dolzarb muammolaridan biri bo'lib qolmoqda. Xalqaro valyuta jamg'armasining 2025 yil uchun hisobotiga ko'ra, jahon iqtisodiyotining uchdan bir qismi soyada qolmoqda. Bu holatni keltirib chiqarayotgan qator salbiy omillar qatoriga nisbatan yuqori soliq yuki, iqtisodiyotning yetarli darajada raqamlashtirilmagani, tadbirkorlik faoliyatini amalga oshirishga to‘sqinlik qilayotgan ma’muriy to‘siqlar, shuningdek, davlat organlaridagi korrupsiyaning yuqori darajasi kiradi. Ushbu maqolada biz raqamli texnologiyalarni keng joriy etish orqali yuqoridagi salbiy omillarni bartaraf etish usullarini batafsil ko'rib chiqamiz. Boshlashdan oldin “Yashirin iqtisodiyot nima, raqamli texnologiyaning bunga qanday aloqasi bor?

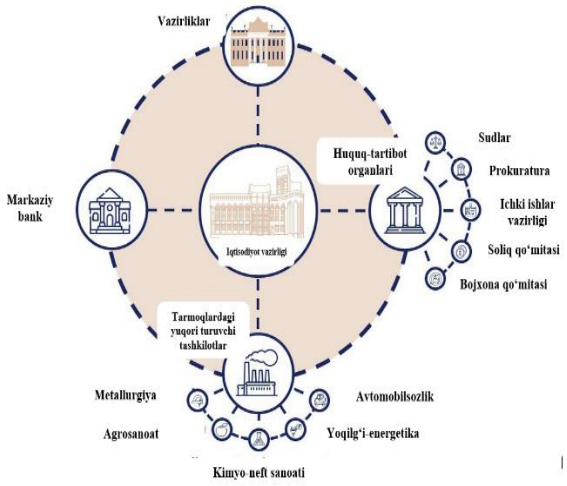
Yashirin iqtisodiyot - bu jamiyat va davlatdan yashirin, davlat nazorati va buxgalteriya hisobidan tashqaridagi iqtisodiy faoliyat. Ya'ni, bu jamiyat fuqarolari o'rtasidagi mavjud davlat qonunlari va jamoat qoidalarini chetlab o'tib, o'z-o'zidan rivojlanadigan iqtisodiy munosabatlardir. Ushbu biznesning daromadlari yashirin va soliqqa tortiladigan iqtisodiy faoliyat emas.

Iqtisodiyotdagi raqamli texnologiyalar - bu zamonaviy iqtisodiyot sharoitida elektron biznes tuzilmalarining optimal ishlashini ta'minlaydigan texnik yangiliklar va innovatsiyalar. McKinsey mutaxassislaridan iborat global ekspertlar guruhi tomonidan olib borilgan tadqiqot, iqtisodiyotning bevosita raqamli transformatsiyasisiz yashirin iqtisodiyot ulushini qisqartirib bo‘lmasligini isbotladi.

Bundan tashqari, xorijiy ekspertlarning fikricha, iqtisodiy rivojlanishning yuqori darajasiga erishish uchun davlat raqamli texnologiyalardan foydalanuvchi va rivojlanayotgan kompaniyalarni faol rag‘batlantirishi, shuningdek, boshqa kompaniyalarni mobil texnologiyalar, biznes-tahlil, raqamli to‘lov tizimlari va boshqalardan foydalanishga undashi kerak.

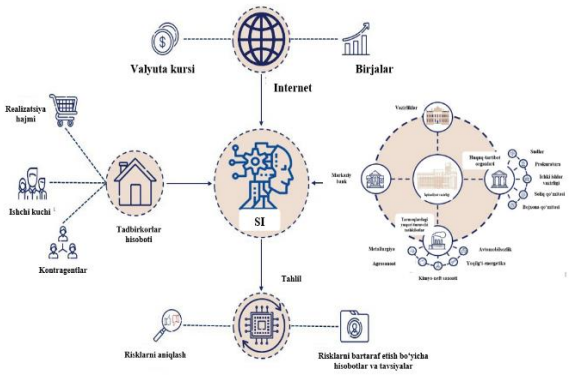
Axborot texnologiyalarini joriy etish orqali iqtisodiyotni soyadan samarali olib chiqish uchun birinchi navbatda bir qator istiqbolli yo‘nalishlarni belgilab olish zarur.

Xususan, birinchi navbatda, davlat va nodavlat tashkilotlari o‘rtasida real vaqt rejimida uzluksiz axborot almashinuvini yo‘lga qo‘yish. Shu bilan birga, iqtisodiy jarayonlar to‘g‘risidagi ma’lumotlarga ega bo‘lgan tashkilotlarning ma’lumotlar bazalarini vazirlikning iqtisodiyot tarmog‘ining asosiy bo‘g‘ini hisoblangan axborot bazasiga integratsiyalash zarur.



1-rasm. Yashirin iqtisodiyotga qarshi kurashda davlat (nodavlat) tashkilotlarining integratsiyalashuvi modeli

Bundan tashqari, tovarlar va xizmatlarning ishlab chiqarishdan iste'molga qadar harakatini kuzatish imkoniyatiga ega bo'lgan tizimni joriy etish. Shu bilan birga, har bir mahsulotga (xizmatga) individual identifikatsiya kodlari beriladi va elektron hisob-faktura dasturiga kiritiladi. Bu tizimning o‘ziga xos xususiyati shundaki, u tovarlar (xizmatlar) va ularning xo‘jalik komplekslaridagi harakati to‘g‘risida to‘liq (ishonchli) ma’lumotlarni shakllantiradi, bu esa o‘z-o‘zidan respublikada yashirin iqtisodiyot ulushining kamayishiga va byudjet daromadlarining oshishiga olib keladi. Bu ma’lumotlar soliq ma’muriyatchiligidagi huquqbuzarliklarning oldini olishga ham xizmat qiladi. Ta’kidlash joizki, raqamli va internet texnologiyalari rivojlanishi sharoitida elektron to‘lovlarga o‘tish yashirin iqtisodiyot ko‘lamini qisqartirish yo‘li sifatida alohida ahamiyatga ega. Bunday holda, naqd pulsiz to'lovlarga bosqichma-bosqich o'tish uchun davlat tomonidan qo'llab-quvvatlash zarur. Xususan, soliq imtiyozlari va preferensiyalarini taqdim etish, shuningdek, elektron to‘lovlar hajmidan kelib chiqqan holda CASHBACK tizimini joriy etish maqsadga muvofiqdir. Mustaqil xalqaro tadqiqotchilar A.Danilova va T.Yakushevalar tahliliga ko‘ra, 0,5 foizli CASHBACK tizimining joriy etilishi bevosita naqd pul aylanmasini 9,5 foizga qisqartirgan. 2019-yilda Bosniya va Gertsegovina va Serbiya elektron to‘lovlarni rag‘batlantirish maqsadida tadbirkorlik sub’yektlari uchun 0,5 foizlik CASHBACK joriy etish orqali norasmiy iqtisodiyot ulushini YaIMdagi 0,76 foizgacha kamaytirdi.



2-rasm. Yashirin iqtisodiyot ulushini kamaytirishda sun'iy intellekt tizimi faoliyatining fundamental modeli

Yuqoridagi chora-tadbirlarning mantiqiy davomi sifatida iqtisodiyotni uzluksiz tahlil qilish, undagi xatarlarni aniqlash va ularni bartaraf etishga qodir bo‘lgan sun’iy intellekt tizimini yaratish nazarda tutilgan. Bu tizimning o‘ziga xosligi, eng avvalo, inson omilini kamaytirish, biznes yuritishdagi byurokratik to‘siqlarni bartaraf etishdadir. Dunyoda ro‘y berayotgan voqealardan kelib chiqib, iqtisodiyotga oid keng ko‘lamli ma’lumotlar bazalari, fond va bozor ma’lumotlari onlayn tahlil qilinib, eng muhimi, yashirin iqtisodiyotni keltirib chiqaruvchi omillar bartaraf etilmoqda. Bundan tashqari, Latviya Davlat daromadlari xizmati direktori Ieva Yaunzeme 2021-yil 15-dekabrdagi yillik hisobotida sun’iy intellekt tizimini joriy etish orqali yashirin iqtisodiyot ulushini 60 foizga qisqartirish mumkinligini ma’lum qildi.

Xulosa o‘rnida shuni aytish mumkinki, bugungi kunda yashirin iqtisodiyot unga qarshi kurashishning samarali vositalarini ishlab chiqishni taqozo etuvchi dolzarb muammoga aylanib bormoqda. Agar dastlab davlat soliq yukini kamaytirish, aholining huquqiy madaniyatini shakllantirish kabi an’anaviy chora-tadbirlarni amalga oshirgan bo‘lsa, bugungi kunda bu kabi chora-tadbirlar samarasizligini iqtisodchilar ham tasdiqlamoqda. Shu bois milliy iqtisodiyotning raqamli transformatsiyasi ushbu muammoni samarali hal etishga qaratilgan yagona vosita bo‘lib qolmoqda. Yuqoridagi takliflarning hayotga tatbiq etilishi yashirin iqtisodiyot ulushini kamaytirish bo‘yicha samarali chora-tadbirlardan biridir.

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6-sho‘ba. Ta’lim tizimida raqamli innovatsiyalar

FREEZING "COLD START": OPTIMIZING RECOMMENDER SYSTEMS USING THE THEORY OF S. R. RANGANATHAN

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***Abstract*— Recommender systems play a central role in digital ecosystems, shaping how users discover books, media, products, and scholarly content. Yet their effectiveness is often constrained by the “cold start” problem, which occurs when insufficient data about new users, new items, or emerging platforms prevents meaningful recommendations. While computational solutions such as hybrid filtering and transfer learning partially address this challenge, they often overlook human-centered principles of information access. This paper proposes that the enduring theories of Shiyali Ramamrita Ranganathan—specifically the Five Laws of Library Science and Colon Classification—provide conceptual tools for reframing and mitigating cold start challenges. Drawing on these principles, we introduce the Ranganathanian Recommender Framework (RRF), which emphasizes accessibility, personalization, visibility, efficiency, and adaptability. The framework applies faceted metadata to enrich item representation, user-centered onboarding to empower individuals, and evolutionary system design to support long-term growth. Through this integration, cold start is reinterpreted not merely as a technical limitation but as a design opportunity to align recommender systems with inclusivity, transparency, and ethical values. The study demonstrates that Ranganathan’s century-old insights remain highly relevant, offering a humanistic pathway toward optimizing recommender systems in the era of artificial intelligence.**

Keywords*— *Cold Start Problem, Recommender Systems, Ranganathan’s Five Laws, Colon Classification, Metadata Enrichment, Human-Centered Design, Information Science and AI, Ethical Recommender Frameworks

I. INTRODUCTION

Recommender systems have become indispensable in the digital age, shaping how individuals discover books, films, music, research articles, consumer goods, and even social connections [1]. From online retail platforms like Amazon to streaming services such as Netflix and Spotify, recommendation engines drive engagement, improve user experience, and generate significant economic value. In the domain of libraries and information services, recommender systems also guide users toward relevant resources, enhancing discoverability and access [2]. Yet, despite their ubiquity, recommender systems face persistent technical and conceptual challenges, the most prominent of which is the “cold start” problem. This occurs when a system lacks sufficient information about new users, new items, or both, limiting its ability to generate meaningful recommendations [3].

The cold start problem is not merely a technical obstacle; it reflects deeper issues in how systems conceptualize and represent user needs and resource attributes. Traditional solutions—such as leveraging demographic information, importing external datasets, or employing hybrid recommendation techniques—partially address the problem but often raise concerns about privacy, bias, and scalability. In many cases, they fail to fully capture the nuanced ways in which human beings interact with information. This limitation suggests that the challenge of cold start may benefit from insights outside conventional computer science, particularly from the field of Library and Information Science (LIS), which has long grappled with the problem of connecting users to relevant information in contexts of scarcity and uncertainty.

One particularly rich source of theoretical guidance lies in the work of Shiyali Ramamrita Ranganathan (1892–1972), the Indian mathematician-turned-librarian whose Five Laws of Library Science and Colon Classification system revolutionized information organization in the twentieth century [4]. Ranganathan’s vision was fundamentally user-centered, emphasizing accessibility, usability, and the dynamic relationship between users and information resources. His principles—such as “Books are for use” and “Every reader his or her book”—anticipated many of the challenges that modern recommender systems seek to solve. Furthermore, his faceted approach to classification offers conceptual tools for overcoming the item cold start problem by enabling richer metadata and semantic connections.

This paper proposes that the enduring wisdom of Ranganathan’s theory can inform contemporary efforts to optimize recommender systems, particularly in addressing the cold start problem. By mapping Ranganathan’s Five Laws and Colon Classification to modern digital environments, we can reframe cold start not simply as a technical limitation but as a question of human-centered design. Such an approach encourages recommender systems to focus less on algorithmic shortcuts and more on principles of inclusivity, transparency, and adaptability. In doing so, we aim to “freeze” the cold start problem—slowing its disruptive impact—by providing conceptual strategies rooted in a century-old yet remarkably relevant body of knowledge.

The remainder of this paper is structured as follows. Section 2 reviews the literature on recommender systems, highlighting current approaches to the cold start problem and the gaps they leave unaddressed. Section 3 introduces Ranganathan’s theory, examining its conceptual relevance for digital information systems. Section 4 applies these principles directly to user, item, and system cold start scenarios, offering illustrative examples. Section 5 proposes a conceptual framework for integrating Ranganathanian principles into recommender architectures. Section 6 discusses the implications, benefits, and limitations of this approach. Finally, Section 7 concludes by reflecting on the continuing relevance of Ranganathan’s legacy in shaping the future of AI-driven recommendation systems.

II. Background and Literature Review

Recommender systems are algorithmic tools designed to filter vast information spaces and present users with personalized suggestions [5]. They are integral to digital ecosystems, driving engagement in e-commerce (Amazon), entertainment (Netflix, Spotify), academic publishing (Google Scholar, ResearchGate), and libraries (online public access catalogs and discovery layers). Their significance lies not only in improving user satisfaction but also in shaping economic and cultural landscapes by influencing what users buy, read, watch, or cite [6]. As information environments expand exponentially, recommender systems address the problem of “information overload,” guiding individuals toward content that aligns with their preferences and behaviors.

Two dominant approaches underpin most recommender systems: collaborative filtering and content-based filtering. Collaborative filtering relies on patterns of user behavior, recommending items that similar users have liked. Content-based filtering, in contrast, recommends items based on attributes of resources—such as keywords, genres, or tags—matched to a user’s profile. Hybrid systems combine these approaches, seeking to balance their strengths. While technically effective, these models often encounter difficulties when insufficient user or item data is available, creating the infamous “cold start” problem.

The cold start problem manifests in three distinct forms [7]: user cold start, item cold start, and system cold start.

- User cold start occurs when a new user enters the system with no prior interaction history. Without data on preferences, the system struggles to generate relevant recommendations.
- Item cold start arises when a new resource—such as a book, article, or movie—is added to the system but has not yet been rated, tagged, or consumed by users.
- System cold start refers to the early stages of a platform’s development, when there are too few users and items to support effective recommendation.

Numerous strategies have been proposed to address cold start. For user cold start, platforms often rely on demographic information, onboarding questionnaires, or social media integration to infer preferences. Item cold start is commonly mitigated by enriching metadata, using natural language processing (NLP) to analyze content, or leveraging publisher-supplied tags. System cold start is addressed through transfer learning, bootstrapping techniques, or cross-domain recommendations. While useful, these solutions raise concerns. Demographic inferences risk stereotyping, metadata quality is inconsistent across domains, and reliance on external datasets can compromise user privacy. The persistence of cold start suggests the need for conceptual frameworks that extend beyond purely technical fixes.

Shiyali Ramamrita Ranganathan (1892–1972), regarded as the father of Library and Information Science in India, articulated his Five Laws of Library Science in 1931 [8]. They remain foundational:

1. Books are for use.
2. Every reader his or her book.
3. Every book its reader.
4. Save the time of the reader.
5. The library is a growing organism.

Though initially crafted for physical libraries, these laws express principles of user-centered design, accessibility, inclusivity, and system adaptability. They emphasize not only the availability of resources but also the responsibility of systems to connect users and resources efficiently. In digital environments, these laws anticipate many challenges of recommender systems, particularly in bridging gaps where data is sparse or incomplete.

Ranganathan also developed Colon Classification (1933), a faceted classification system [9] that organized knowledge based on fundamental categories such as personality, matter, energy, space, and time (PMEST). Unlike rigid hierarchical taxonomies, faceted classification allows resources to be described in multiple dimensions, reflecting their richness and complexity. This approach provides a conceptual foundation for modern metadata standards, ontologies, and semantic web technologies. In the context of cold start, faceted metadata can significantly mitigate item cold start by enabling richer descriptions that support more effective matching between users and resources, even before user interaction data becomes available.

Recent scholarship has explored intersections between library science and recommender technologies. Studies of digital libraries and discovery systems show that user satisfaction depends not only on algorithmic accuracy but also on transparency, explainability, and alignment with user needs—all values central to Ranganathan’s philosophy [10]. While much of the computer science literature on cold start focuses on computational solutions, LIS scholars highlight the importance of metadata quality, user education, and ethical principles. This suggests that bridging computer science with Ranganathan’s theoretical insights could yield innovative pathways for addressing cold start.

Although technical methods for alleviating cold start are well studied, there is limited exploration of conceptual frameworks grounded in human-centered traditions like

library science. Ranganathan’s Five Laws and Colon Classification remain underutilized in the design of recommender systems, despite their relevance to accessibility, inclusivity, and system growth. This gap presents an opportunity: by integrating Ranganathan’s principles, recommender systems can evolve from being purely algorithmic engines to becoming ethically informed, user-centered infrastructures.

III. Ranganathan’s Theory and Its Conceptual Relevance

Ranganathan’s Five Laws of Library Science were written nearly a century ago, yet their principles resonate strongly with the needs of today’s information systems [11]. Each law, when reframed for digital environments, offers guidance for recommender systems in general and for solving the cold start problem in particular.

1. Books are for use. In a digital world, this law translates into ensuring that information resources—whether books, articles, datasets, or multimedia—are easily discoverable and usable. For recommender systems, this means designing interfaces and algorithms that minimize barriers to access. Applied to cold start, it encourages proactive mechanisms that expose new users and items to relevant opportunities quickly, preventing stagnation at the system’s entry point.
2. Every reader his or her book. This principle anticipates personalization long before it became a digital buzzword. It emphasizes that every user has unique needs and deserves tailored access. For user cold start scenarios, this law suggests moving beyond demographic shortcuts to design onboarding processes that respect individual contexts, perhaps by asking carefully crafted questions, capturing situational preferences, or dynamically adapting interfaces.
3. Every book its reader. This law flips the perspective, asserting that every resource has potential value if matched with the right user. For item cold start, this principle is transformative: new resources can be made visible and relevant through enhanced metadata, semantic tagging, or contextual linking, ensuring that they reach the right audience even before popularity data accumulates.
4. Save the time of the reader. Efficiency remains vital in digital ecosystems overloaded with content. Algorithms should minimize user effort while maximizing satisfaction. In cold start contexts, this law reminds designers that users should not be burdened with excessive data entry or irrelevant recommendations. Systems must provide meaningful suggestions quickly, balancing speed with quality.
5. The library is a growing organism. Ranganathan envisioned the library as dynamic, continuously adapting to societal changes. For recommender systems, this translates into self-improving architectures that evolve with user interactions, content diversity, and technological advances. Addressing cold start requires systems that can incorporate new signals, new metadata, and new user behaviors without stagnation.

Together, these reinterpretations frame cold start not simply as a lack of data but as a misalignment between system design and human-centered principles.

Ranganathan’s Colon Classification introduced the revolutionary idea of faceted categorization. Instead of placing resources into rigid hierarchies, it decomposed them into fundamental categories: personality, matter, energy, space, and time (PMEST). This faceted structure enables multidimensional descriptions and flexible retrieval pathways.

In recommender systems, faceted metadata can enrich item profiles and alleviate item cold start [12]. For instance, a newly added academic article may lack usage history, but through faceted classification—linking its subject matter, methodology, geographic focus, and temporal scope—it can be matched to users whose interests align with those facets. Similarly, in an e-commerce context, faceted attributes of a new product (function, design, target audience, seasonality) provide sufficient information for recommendations even before sales data accumulates.

Colon Classification also anticipates semantic web technologies, ontologies, and linked data approaches used in contemporary AI-driven systems. By structuring data in ways that capture relationships and contexts, it provides conceptual tools for enriching the sparse datasets that cause cold start.

Ranganathan’s theories are not simply historical artifacts; they provide a human-centered philosophy that aligns with the goals of modern recommender systems. Where traditional computational models focus narrowly on prediction accuracy, Ranganathan’s framework emphasizes inclusivity, usability, and adaptability. This alignment is crucial in cold start scenarios, where sparse data forces systems to rely on principles rather than patterns.

For example, the law “Every reader his or her book” challenges systems to ensure fairness and inclusivity for new users, while “Every book its reader” compels designers to give new items visibility rather than letting them languish unseen. The faceted approach of Colon Classification suggests that recommender systems should not depend solely on user behavior but should exploit rich contextual metadata to enhance relevance.

While Ranganathan’s ideas are inspirational, applying them to modern AI-driven systems requires critical reflection. His laws were articulated in an era of physical libraries, not digital platforms. Concepts like “book” or “library” must be broadened to include digital media, knowledge graphs, and user-generated content. Moreover, implementing his vision demands robust metadata infrastructure, interdisciplinary collaboration, and cultural adaptation across domains. Nonetheless, the underlying spirit of his theory—human-centered, adaptable, and inclusive—remains highly relevant.

By reinterpreting the Five Laws and Colon Classification for today’s information systems, we uncover conceptual tools that can guide the design of recommender systems beyond algorithmic fixes. In doing so, Ranganathan’s work serves as a bridge between Library and Information Science and Artificial Intelligence, grounding technical innovation in humanistic values.

IV. Applying Ranganathan’s Theory to the Cold Start Problem

The cold start problem continues to hinder the effectiveness of recommender systems across domains—from e-commerce and entertainment to libraries and digital scholarship. Ranganathan’s Five Laws of Library Science and his Colon Classification system provide a conceptual framework to rethink how such challenges are approached. By applying these principles, we can see cold start not only as a technical shortcoming but also as a human-centered design issue that requires strategies rooted in inclusivity, usability, and contextual richness.

The user cold start problem arises when a new user enters the system with no historical data, leaving algorithms unable to predict preferences accurately. Conventional solutions often rely on demographic assumptions or intrusive onboarding surveys. However, these methods risk stereotyping or overwhelming users with requests for information before they have developed trust in the platform.

Ranganathan’s second law, “Every reader his or her book,” offers a human-centered perspective. Instead of forcing users into predefined categories, recommender systems can design onboarding processes that prioritize inclusivity and choice. For example, libraries might provide new users with curated thematic collections—such as “climate change research,” “local cultural heritage,” or “emerging technologies”—allowing them to self-select areas of interest. This approach respects user autonomy while quickly generating meaningful signals for recommendations.

In streaming services or e-commerce, faceted metadata inspired by Colon Classification can enhance onboarding. New users could browse facets such as genre, format, location, or time period, gradually building a profile without the burden of completing lengthy questionnaires. In this way, Ranganathan’s emphasis on individualized service becomes an antidote to user cold start, ensuring that personalization begins with empowerment rather than assumption.

The item cold start problem occurs when new resources are added but lack sufficient usage history to be recommended effectively. Traditional algorithms often overlook new items until they accumulate interactions, delaying visibility.

Ranganathan’s third law, “Every book its reader,” reframes the challenge: every new resource has potential value and deserves a pathway to its audience. Here, Colon Classification becomes especially relevant. By enriching items with faceted metadata—capturing attributes such as subject matter, creator, intended audience, and temporal relevance—new resources can be matched to users even in the absence of interaction data.

For example, in academic databases, a newly published research article could be recommended to students if it shares methodological facets with resources they already use. In e-commerce, a new product can be linked to users based on shared facets such as style, purpose, or material composition. Similarly, in digital libraries, new cultural heritage materials can reach the right communities by leveraging spatial and temporal metadata facets. By ensuring that “every book its reader,” systems avoid the invisibility trap that plagues new items.

The system cold start problem arises when an entire platform is new, with too few users and items to support reliable recommendations. At this early stage, algorithms may fail to deliver meaningful results, discouraging adoption.

Ranganathan’s fifth law, “The library is a growing organism,” provides a guiding principle. It reminds us that information systems evolve dynamically and must be designed with adaptability in mind. For recommender systems, this means leveraging external but relevant datasets, open-access metadata, or collaborative partnerships to bootstrap recommendations in early phases.

For example, a new online library in Uzbekistan might integrate bibliographic records from established cataloging services while building its local collection. Similarly, a new music platform could license metadata from larger providers, allowing the system to make recommendations while its own user base grows. Crucially, the system should be designed for continuous enrichment, allowing new data to flow in seamlessly. By treating the platform as a living organism, designers acknowledge that cold start is temporary but requires structures that support growth.

Ranganathan’s fourth law, “Save the time of the reader,” adds another dimension to addressing cold start. In both user and item cold start contexts, efficiency is critical. Users are unlikely to tolerate long waits or irrelevant suggestions. Instead of presenting overwhelming options, systems can implement lightweight but meaningful starting points—curated recommendations, “starter packs,” or faceted browsing modes—that accelerate the journey toward relevance.

For instance, a digital archive might provide quick-access pathways such as “most viewed this week,” “emerging topics,” or “faculty recommendations.” These strategies save users’ time while providing the system with valuable feedback loops. Similarly, in e-commerce, presenting a small but diverse set of recommended products can help new users quickly express preferences, generating data for improved recommendations.

The first law, “Books are for use,” emphasizes that information resources must be made accessible. Applied to recommender systems, it suggests reducing barriers that prevent users or items from being integrated into the recommendation cycle. For cold start, this may involve ensuring open metadata standards, lowering technical barriers for resource ingestion, and designing user interfaces that encourage quick engagement.

In libraries, for instance, digitizing collections with open-access metadata allows new items to be integrated into discovery systems without delay. In streaming platforms, allowing creators to supply detailed metadata during uploads accelerates item discoverability. By prioritizing usability, systems can prevent cold start from marginalizing users or items.

Concrete applications illustrate how Ranganathan’s theory can transform cold start solutions:

1. Libraries and Archives: New students entering university (user cold start) can receive personalized orientation through curated reading lists, while newly digitized manuscripts (item cold start) can be matched to researchers using faceted metadata.
2. E-commerce: Shoppers with no purchase history (user cold start) can browse product collections organized by lifestyle facets, while new products (item cold start) are recommended through semantic tagging rather than waiting for sales data.
3. Streaming Services: New subscribers can select from faceted “mood-based” playlists, generating preference signals, while new songs are surfaced through genre and instrumentation facets.
4. Academic Platforms: Newly published research is recommended based on methodological and topical facets, ensuring visibility despite lacking citations.

By mapping Ranganathan’s Five Laws and Colon Classification to cold start scenarios, recommender systems gain a set of guiding principles that extend beyond algorithms. Instead of seeing cold start as a deficiency of data, it becomes an opportunity to reinforce inclusivity, efficiency, and adaptability. Every user and every resource is valued, and the system itself is seen as a living organism capable of growth.

V. Proposed Model/Framework

The preceding discussion demonstrates that Ranganathan’s Five Laws of Library Science and Colon Classification offer enduring principles for overcoming cold start challenges in recommender systems. To operationalize these insights, we propose a Ranganathanian Recommender Framework (RRF) that integrates human-centered values, faceted metadata, and adaptive learning mechanisms. The RRF does not seek to replace existing algorithmic approaches but to complement them with a guiding philosophy that ensures inclusivity, usability, and growth.

The RRF is composed of five interconnected layers, each reflecting a reinterpretation of Ranganathan’s laws:

1. Access Layer (“Books are for use”)
    a. Ensures that both new users and items are accessible from the start.
    b. Implements open metadata standards, user-friendly onboarding, and mechanisms that reduce barriers to participation.
2. Personalization Layer (“Every reader his or her book”)
    a. Designs inclusive onboarding processes, such as faceted browsing or lightweight questionnaires.
    b. Employs contextual signals (e.g., location, device, time of day) to generate preliminary recommendations without stereotyping.
3. Visibility Layer (“Every book its reader”)
    a. Prioritizes item cold start by enriching resources with faceted metadata and semantic tagging.
    b. Uses contextual linking (e.g., related subjects, creators, or communities) to ensure new items find their audience.
4. Efficiency Layer (“Save the time of the reader”)
    a. Provides curated starter recommendations that allow users to engage meaningfully without delay.
    b. Integrates explainable AI (XAI) methods to build user trust by clarifying why items are recommended.
5. Growth Layer (“The library is a growing organism”)
    a. Designs systems as evolving infrastructures, capable of continuous learning from user interactions and external data.
    b. Encourages interoperability and partnerships for metadata exchange, ensuring sustainability in early system development.

Colon Classification’s faceted approach underpins the RRF, particularly in the Visibility Layer. By decomposing items into personality, matter, energy, space, and time facets—or modern equivalents such as topic, format, function, geography, and chronology—resources gain multidimensional profiles that mitigate item cold start. For example:

- A newly published article on climate policy can be faceted by topic (climate policy), method (qualitative case study), geography (Central Asia), and time (post-2020).
- A new song on a streaming platform can be described by genre (jazz), instrumentation (saxophone, piano), mood (relaxing), and time (contemporary).

These enriched profiles allow recommendations even in the absence of prior user interaction, aligning with Ranganathan’s belief that every resource deserves a pathway to its reader.

The RRF emphasizes evaluation metrics beyond accuracy, incorporating measures of serendipity, coverage, diversity, and user satisfaction. Cold start solutions should not only predict preferences but also ensure fairness, inclusivity, and engagement. Feedback loops—where users can rate recommendations, refine preferences, or

select facets—help the system adapt dynamically while reinforcing user trust.

Imagine a five-layered concentric model:

- At the center lies the Growth Layer, symbolizing the evolving organism.
- Surrounding it are four concentric rings: Efficiency, Visibility, Personalization, and Access.
- Metadata facets (Colon Classification) flow through all layers as connective tissue.
- User interaction and feedback loops are depicted as arrows feeding back into each layer, ensuring adaptability.

This diagram represents how Ranganathan’s principles permeate the entire lifecycle of a recommender system, addressing user, item, and system cold start holistically.

The Ranganathanian Recommender Framework translates a century-old philosophy into a modern design for recommender systems. By embedding the Five Laws and Colon Classification into technical pipelines, it provides a roadmap for freezing cold start challenges through inclusivity, metadata richness, and adaptability. Importantly, it shifts the focus from algorithms alone to the broader values and structures that govern human-information interaction.

VI. Discussion

The Ranganathanian Recommender Framework (RRF) offers a novel approach to mitigating cold start challenges by grounding recommender system design in human-centered values rather than purely technical fixes. Its key strength lies in bridging Library and Information Science (LIS) with Artificial Intelligence (AI), showing that principles articulated nearly a century ago remain highly relevant for digital ecosystems. This interdisciplinary synthesis demonstrates that recommender systems should not only optimize prediction accuracy but also embody inclusivity, transparency, and adaptability.

One of the framework’s most compelling contributions is its emphasis on metadata richness through Colon Classification. While traditional algorithms rely heavily on user interaction data, the faceted approach allows new items to be described in multidimensional ways, facilitating recommendations even before usage patterns emerge. This principle directly addresses item cold start, which is often the most challenging form. Furthermore, by valuing “Every book its reader,” the framework prevents resources from being marginalized, ensuring visibility for new and niche items.

Equally significant is the framework’s treatment of user cold start. Instead of defaulting to demographic assumptions, which risk stereotyping, the RRF proposes faceted onboarding and contextual cues. This empowers users to shape their profiles actively and respects their autonomy. Moreover, the inclusion of explainable AI within the Efficiency Layer enhances trust by showing users why recommendations are made. Trust is a critical but often overlooked factor in adoption, particularly in domains such as libraries or education where ethical considerations are paramount.

The Growth Layer addresses system cold start by recognizing that platforms are not static but evolving organisms. This organic metaphor encourages systems to integrate external datasets, build interoperability, and design for continuous enrichment. By treating early-stage challenges as temporary and surmountable, the framework aligns with contemporary trends in lifelong learning systems and federated data ecosystems.

Despite its strengths, the RRF is not without limitations. Its success depends heavily on the availability and quality of metadata, which can be uneven across domains. Faceted classification requires investment in metadata creation and curation, which may not be feasible for smaller organizations. Additionally, while the framework emphasizes inclusivity and human-centered design, it does not by itself solve technical issues of scalability or computational efficiency, which remain vital for large-scale platforms. Cultural adaptation is another consideration: principles rooted in library science must be carefully contextualized to domains such as e-commerce or entertainment.

Nevertheless, the broader implications of this framework are significant. For LIS, it highlights the continuing relevance of Ranganathan’s philosophy in the digital era, reaffirming the field’s role in shaping ethical and effective information systems. For AI research, it demonstrates the value of integrating humanistic traditions into technical design. More broadly, the RRF aligns with global movements toward responsible AI, ensuring that technological innovation serves human flourishing rather than exacerbating exclusion.

In summary, the RRF reframes the cold start problem from a purely algorithmic challenge into a human-centered design opportunity. By embedding Ranganathan’s principles into recommender systems, it not only improves system performance but also strengthens inclusivity, trust, and adaptability. These contributions position the framework as a meaningful step toward recommender systems that are not only efficient but also equitable and aligned with human values.

VII. Conclusion

The cold start problem has long challenged the effectiveness of recommender systems, limiting their ability to connect users with resources in contexts of sparse data. Traditional computational approaches—while valuable—often reduce the problem to issues of prediction accuracy, overlooking the deeper question of how information systems should serve human needs. This paper has argued that the theories of S. R. Ranganathan, particularly the Five Laws of Library Science and Colon Classification, provide a conceptual foundation for reimagining recommender systems in a more inclusive and sustainable way.

By applying the Five Laws, we reframed user, item, and system cold start challenges as opportunities to design systems that prioritize accessibility,

personalization, visibility, efficiency, and adaptability. The faceted approach of Colon Classification demonstrated how metadata richness can alleviate item cold start, while human-centered onboarding strategies addressed user cold start. Viewing the system itself as a growing organism emphasized adaptability and long-term evolution. Together, these principles informed the Ranganathanian Recommender Framework (RRF), which integrates humanistic values with technical practices.

The RRF advances the conversation on recommender systems by bridging LIS traditions with AI research. Its emphasis on inclusivity, transparency, and adaptability complements existing algorithmic solutions while reinforcing ethical and user-centered design. While challenges remain in metadata quality, scalability, and cultural adaptation, the framework highlights the enduring relevance of library science for modern information infrastructures.

Looking ahead, future research should test the RRF in practical implementations across domains such as libraries, e-commerce, and digital scholarship, exploring its impact on user satisfaction and system performance. In doing so, we honor Ranganathan’s vision of information as a living, growing organism while equipping recommender systems to thrive in the digital age.

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TRAINING TRANSFORMATIVE INFORMATION PROFESSIONALS FOR THE NEW UZBEKISTAN: CHALLENGES AND SOLUTIONS OF DEVELOPING HARD AND SOFT SKILLS

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***Abstract*— The digital transformation agenda outlined in the New Uzbekistan plan underscores the need for highly skilled information professionals capable of supporting national modernization, transparency, and competitiveness. This paper examines the evolving role of librarians, archivists, and information managers in Uzbekistan as the country advances toward a knowledge-based economy. It highlights the dual importance of hard skills—such as digital literacy, data analytics, and information management—and soft skills, including communication, leadership, and ethical reasoning. The study identifies key challenges, including outdated curricula, limited digital infrastructure, insufficient continuing education opportunities, and the under-recognition of information professionals as strategic actors. In response, the paper proposes solutions such as curriculum modernization, international academic and industry partnerships, mentorship programs, and the establishment of national competency frameworks. It further emphasizes the alignment of professional development with the government’s Digital Uzbekistan – 2030 strategy. The findings suggest that balancing technical expertise with interpersonal competencies will be essential for cultivating transformative information professionals. Ultimately, the paper argues that empowering this workforce is a cornerstone for realizing the ambitions of the New Uzbekistan and positioning the country as an active participant in the global digital economy.**

Keywords—New Uzbekistan, Digital Transformation, Information Professionals, Training, Hard Skills, soft Skills, Challenges, Solutions

VIII. INTRODUCTION

Digital transformation has emerged as one of the most influential global trends of the 21st century, reshaping the structures of economics, finance, and technology. At its core, digital transformation refers to the integration of digital technologies into all aspects of society and the economy, leading to new modes of production, distribution, and consumption [1]. This process is driven by rapid advancements in information and communication technologies (ICTs), artificial intelligence, big data analytics, and the Internet of Things (IoT). These technologies are not only streamlining business processes but also creating entirely new economic models and ecosystems that transcend traditional boundaries.

In economics, digital transformation is altering the foundations of global competitiveness [2]. Countries and companies that can harness digital tools effectively are gaining significant advantages in productivity, innovation, and international trade. The rise of digital platforms and e-commerce illustrates this shift, as businesses of all sizes can access global markets more efficiently than ever before. Furthermore, the concept of the digital economy is expanding to include sectors such as smart manufacturing, digital agriculture, and online education, demonstrating how traditional economic activities are being restructured through technology.

In the field of finance, digital transformation has given birth to financial technologies (fintech) that are revolutionizing banking and monetary systems [3]. Mobile banking, digital payments, blockchain-based transactions, and decentralized finance (DeFi) are transforming the ways individuals and institutions interact with money. This has not only improved financial inclusion but also reduced transaction costs and increased transparency. However, the rapid adoption of these innovations poses challenges related to cybersecurity, data privacy, and regulatory adaptation, which both developed and developing economies are actively addressing.

Technology itself lies at the heart of digital transformation, as breakthroughs in automation, robotics, and artificial intelligence are redefining the nature of work and production [4]. Businesses are adopting cloud computing, digital twins, and advanced analytics to optimize processes, while governments are leveraging digital platforms to improve governance and service delivery. The fourth industrial revolution, characterized by the fusion of physical, digital, and biological systems, has become a guiding paradigm for many advanced economies, setting a standard that developing countries aim to reach.

Developing countries recognize the transformative potential of digital technologies for sustainable growth and competitiveness [5]. Many governments have formulated national strategies aimed at enhancing digital infrastructure, expanding internet access, and supporting innovation ecosystems. Initiatives such as e-government

platforms, digital literacy programs, and the promotion of local tech startups are common elements in these plans. Additionally, partnerships with international organizations and private sector actors are helping developing economies overcome barriers to financing and technical expertise.

Despite these efforts, developing countries face significant challenges in their digital transformation journeys, including limited infrastructure, insufficient human capital, and gaps in policy frameworks. Nonetheless, the ambition to bridge the digital divide remains strong, as leaders see digital transformation not only as a pathway to economic modernization but also as a tool for social inclusion and global integration. By aligning national policies with global technological trends, investing in human resources, and fostering innovation, developing countries aim to position themselves as active participants in the digital economy rather than passive consumers of imported technologies.

IX. The New Uzbekistan and the Need for the Successful Digital Transformation

The “New Uzbekistan” plan represents a comprehensive vision for the political, social, and economic renewal of Uzbekistan in the 21st century. Initiated under recent reforms, it focuses on modernization, openness, and active participation in the global community. A central theme of this agenda is the transformation of Uzbekistan from a resource-dependent economy to one driven by knowledge, innovation, and digital technologies [6]. This requires not only structural economic reforms but also the successful integration of digital transformation strategies across all sectors.

Digital transformation is especially critical because it directly aligns with Uzbekistan’s broader development objectives. By enhancing digital infrastructure, improving governance, and fostering innovation, the country can accelerate its transition toward a competitive and sustainable economy. In the framework of the New Uzbekistan, digitalization is not seen as an optional trend but as a strategic necessity for achieving economic diversification, efficiency, and international integration.

One of the priorities outlined in the New Uzbekistan agenda is the creation of a digital economy. This involves the expansion of e-commerce, digital banking, and ICT services that can provide citizens and businesses with easier access to markets and financial resources. Digital platforms enable greater transparency, reduce bureaucracy, and facilitate international trade. For Uzbekistan, where traditional industries such as cotton and energy have long dominated, the shift toward a digital economy represents a pathway to resilience and global competitiveness.

Governance reform is another pillar where digital transformation plays a decisive role. E-government initiatives are being introduced to streamline public services, reduce corruption, and increase accountability. By digitizing processes such as tax collection, business registration, and public procurement, Uzbekistan can build greater trust between citizens and the state. This transformation of governance is essential to the vision of a modern and democratic New Uzbekistan.

Education and human capital development are also crucial elements in the New Uzbekistan plan. Successful digital transformation requires a digitally literate population equipped with skills in coding, data science, and digital entrepreneurship. Uzbekistan has made efforts to expand access to modern education, encourage partnerships with international universities, and develop specialized training programs in ICT. Building this knowledge base is vital to ensuring that digital transformation benefits all segments of society rather than deepening inequality.

The private sector is expected to play a leading role in driving digital innovation. Support for startups, technology parks, and foreign investment in ICT industries are essential components of the New Uzbekistan’s strategy. For instance, initiatives to create favorable business conditions for local tech companies and to attract global players into Uzbekistan’s digital ecosystem reflect the recognition that transformation must be both government-led and market-driven.

Nevertheless, challenges remain significant. Digital infrastructure in rural areas is underdeveloped, creating a digital divide between urban and rural populations. Cybersecurity concerns, lack of regulatory clarity, and limited access to investment also slow progress. Addressing these challenges requires coordinated policies, international cooperation, and continued investment in technological development. Without overcoming these barriers, the ambitious goals of the New Uzbekistan plan cannot be fully realized.

In summary, the New Uzbekistan plan positions digital transformation as both a necessity and an opportunity for national development. It provides the foundation for a modern economy, efficient governance, and an empowered society. To succeed, Uzbekistan must continue to invest in infrastructure, education, and innovation while ensuring inclusivity and security in its digital strategies. If implemented successfully, digital transformation will not only advance Uzbekistan’s economic goals but also solidify its role as a forward-looking and dynamic participant in the global digital economy.

X. Training Transformative Information Professionals for the New Uzbekistan

The vision of the New Uzbekistan is deeply tied to knowledge, innovation, and digital transformation [7]. In this context, information professionals—librarians, archivists, information managers, and digital knowledge specialists—are positioned as critical actors in shaping the country’s transition into a knowledge-driven society. Training transformative information professionals is therefore not just a sectoral issue but a national priority that directly supports modernization, transparency, and competitiveness in Uzbekistan.

Information professionals in the New Uzbekistan must move beyond traditional roles of storing and retrieving information to become active facilitators of knowledge creation and digital innovation [8]. This requires reimagining professional education and practice. They need to be equipped with competencies in digital literacy,

data analytics, knowledge management, and information ethics [9]. Without such skills, the human capital necessary for sustaining the digital economy envisioned by the New Uzbekistan plan will remain incomplete.

Higher education institutions play a central role in this transformation [10]. Updating curricula in library and information science programs, introducing interdisciplinary courses that integrate IT, business, and communication, and fostering international partnerships will be key to producing graduates who can thrive in modern information ecosystems. Universities must also expand research capacity in information science to address local challenges such as digital inclusion, open data initiatives, and the development of multilingual digital resources in Uzbek and other regional languages.

Practical training is equally important. Information professionals of the New Uzbekistan must be exposed to hands-on experiences in digital archiving, electronic resource management, and e-government platforms. Collaborations with public institutions, private sector companies, and international organizations can provide opportunities for internships, applied projects, and innovation labs. These experiences help bridge the gap between theory and practice, ensuring that professionals are ready to engage with real-world challenges.

Another crucial component is the integration of soft skills and leadership training. Transformative information professionals are not only technical experts but also leaders who can manage change, foster collaboration, and advocate for information equity. Communication, problem-solving, and ethical reasoning are skills that will enable them to contribute meaningfully to national reforms and to the broader goal of building a transparent and inclusive society.

The government’s digitalization agenda, including strategies like Digital Uzbekistan – 2030, provides a framework within which information professionals can operate as agents of transformation [11]. They will be essential in building digital repositories, managing e-governance systems, and ensuring the ethical use of big data in decision-making. Their expertise is central to achieving the goals of efficiency, accountability, and innovation set forth in the New Uzbekistan plan.

However, significant challenges remain. Many institutions still operate with outdated infrastructures, limited access to electronic databases, and insufficient investment in continuing professional development. Moreover, the recognition of information professionals as strategic partners in development is not yet universal. Addressing these gaps requires coordinated policy support, sustainable funding, and the establishment of national standards for information and knowledge management professions.

In total, training transformative information professionals is a cornerstone for realizing the aspirations of the New Uzbekistan. By empowering these professionals with advanced digital, managerial, and ethical competencies, Uzbekistan can create a workforce capable of driving innovation, supporting good governance, and enriching the cultural and scientific record. Ultimately, the success of the New Uzbekistan depends not only on infrastructure and policy but also on the human expertise that can harness information as a strategic resource for national progress.

XI. Challenges and Solutions of Developing Hard and Soft Skills among the New Uzbekistan Information Professionals

As Uzbekistan advances its New Uzbekistan vision, the role of information professionals becomes increasingly strategic in supporting digital transformation, knowledge management, and transparency. To meet these expectations, they must possess a combination of hard skills (technical and domain-specific competencies) and soft skills (interpersonal and leadership capabilities). However, the development of these dual skill sets presents multiple challenges that require comprehensive solutions from educational institutions, professional organizations, and policymakers.

One of the main challenges in cultivating hard skills among information professionals is the rapid pace of technological change [12]. The expansion of artificial intelligence, big data, digital libraries, and e-government platforms requires constant upskilling. Yet, many professionals in Uzbekistan work in environments with outdated technologies and limited access to advanced digital tools. This digital gap makes it difficult for them to gain hands-on experience with the systems they are expected to manage.

Another challenge relates to curriculum limitations in higher education [13]. While library and information science programs exist, they often lack integrated courses in coding, data analytics, information systems, and cybersecurity—skills that are essential for today’s information professionals. Without curricular reform, graduates risk being underprepared for the demands of the digital economy. Furthermore, continuing education opportunities are limited, leaving mid-career professionals without structured pathways for skill renewal.

Soft skills development also faces barriers [14]. Traditionally, the training of librarians and archivists in Uzbekistan has emphasized technical and clerical functions, with less focus on communication, leadership, problem-solving, and teamwork. This has contributed to a perception of information professionals as support staff rather than transformative leaders. Changing this mindset requires not only retraining but also cultural shifts in how the profession is viewed within institutions and society.

To address the challenges of hard skills development, universities and training centers should modernize curricula by incorporating modules on digital curation, programming, user experience design, and data ethics. Partnerships with technology companies and international universities can provide access to cutting-edge knowledge and tools. In addition, investing in professional development programs, such as workshops and online certifications, can ensure that current practitioners remain up to date with global best practices.

For soft skills, solutions should include embedding leadership, communication, and project management training within academic and professional programs. Information professionals must learn to manage diverse teams, advocate for resources, and engage effectively with users. Mentorship programs, peer-to-peer learning networks, and role-playing exercises can foster these skills. Encouraging participation in conferences and international collaborations also enhances confidence and cross-cultural competencies.

The government’s *Digital Uzbekistan – 2030* strategy provides an enabling environment for skill development, but it must be aligned with professional training initiatives. Policy-level solutions could include the creation of national competency frameworks for information professionals, the establishment of continuing education requirements, and the provision of grants or subsidies for skill-building programs. Such measures would formalize the importance of hard and soft skills and encourage institutions to prioritize training.

To put it in a nutshell, the challenges of developing hard and soft skills among information professionals in the New Uzbekistan are significant but surmountable. By modernizing education, investing in lifelong learning, and fostering leadership mindsets, Uzbekistan can cultivate transformative professionals capable of driving its digital agenda. Balancing hard technical expertise with strong soft skills will not only enhance the effectiveness of information professionals but also ensure their recognition as vital contributors to national development and global competitiveness.

XII. Conclusion and Takeaways

The transformation of Uzbekistan into a modern knowledge-based society, envisioned in the New Uzbekistan plan, requires a new generation of information professionals who are both technically competent and socially agile. This article has demonstrated that developing hard and soft skills is not a peripheral concern but a central requirement for enabling digital transformation, effective governance, and national competitiveness.

The challenges identified—ranging from outdated educational curricula and limited digital infrastructure to insufficient attention to leadership and communication skills—highlight the complexity of preparing professionals for rapidly evolving roles. These challenges cannot be solved by individual institutions alone; they demand systemic reform involving universities, government bodies, and professional associations.

At the same time, the analysis points to clear solutions. Modernizing curricula, expanding digital training, creating mentorship programs, and embedding leadership development into professional pathways represent practical steps forward. International cooperation and partnerships with technology firms can further accelerate the acquisition of globally relevant competencies among Uzbekistan’s information professionals.

A key takeaway is the need for balance. Hard skills such as digital curation, data analytics, and cybersecurity are essential for managing complex information systems, while soft skills like collaboration, problem-solving, and ethical reasoning are equally critical for leadership and innovation. Information professionals who lack either dimension risk being underprepared for the challenges of the digital era.

Another important insight is that professional transformation cannot be viewed in isolation from national policy. Strategies such as *Digital Uzbekistan – 2030* provide a strong foundation, but they must be complemented by human capacity development initiatives. By institutionalizing continuous learning and creating national competency frameworks, Uzbekistan can ensure that its information workforce evolves in tandem with technological and societal changes.

In conclusion, the journey toward cultivating transformative information professionals is both challenging and promising. The New Uzbekistan has the opportunity to redefine the role of information professionals from custodians of data to leaders of innovation and agents of social change. With sustained investment in education, training, and professional development, Uzbekistan can not only bridge existing skill gaps but also position its information professionals as drivers of progress in the global digital economy.

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RAQAMLASHGAN JAMIYAT VA TA’LIM TIZIMI: MUAMMO VA YECHIM

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Annotatsiya: ***Mazkur maqolada raqamlashgan jamiyat va ta’lim tizimidagi muammo, kamchilik va yutuqlar tahlil qilingan. Maqolaning asosiy mazmunini raqamlashgan jamiyat, raqamli texnologiyalar, ta’lim va uni sifatini oshirish masalalari haqidagi fikrlar bayoni batafsil keltirilgan. Bugungi kunda ilg‘or texnologiyalar taraqqiyoti insoniyat hayotiga o‘ziga xos ta’siri natijasini ko‘rsatayotgani va bu masalaning yechimi ta’limda yoshlarni kuchli bilim va ko‘nikmalar bilan qurollantirish, ularni tafakkurini yangi, zamonaviy texnologiyalar asosida bilim berish orqali bunyodkorligini ta’minlash masalasi haqida mulohazalar yuritilgan. Raqamlashgan jamiyatda raqamli texnologiyalar kelajak avlodning, shuningdek insoniyatning bir qancha darajada intellektual salohiyatini o‘sishini o‘zida namoyon etuvchi asosiy yo‘lni ko‘rsatuvchi zarur soha ekanligi haqida berilgan ma’lumotlarni yanada boyitishga harakat qiladi.***

Kalit so‘zlar: raqamlashgan jamiyat, ta’lim tizimi, raqamli texnologiyalar, sifat, intellekt, tizim.

Аннотация: ***В данной статье анализируются проблемы, недостатки и достижения цифрового общества и системы образования. Основное содержание статьи – подробное изложение идей по вопросам цифрового общества, цифровых технологий, образования и повышения его качества. Сегодня развитие передовых технологий оказывает своё влияние на жизнь человека, и решение этой проблемы заключается в том, чтобы вооружить молодёжь прочными знаниями и навыками в сфере образования, обеспечить их креативность путём воспитания мышления на основе новых, современных технологий. В статье предпринята попытка дополнительно обогатить представленную информацию о том, что цифровые технологии в цифровом обществе являются необходимой областью, указывающей основной путь, что само по себе отражает рост интеллектуального потенциала будущего поколения, а также в некоторой степени человечества.***

Ключевые слова: цифровое общество, система образования, цифровые технологии, качество, интеллект, система.

Abstract: ***This article analyzes the problems, shortcomings and achievements of the digital society and the education system. The main content of the article is a detailed statement of ideas on the issues of digital society, digital technologies, education and improving its quality. Today, the development of advanced technologies is showing its own impact on human life, and the solution to this problem is to arm young people with strong knowledge and skills in education, to ensure their creativity by educating their thinking on the basis of new, modern technologies. It attempts to further enrich the information provided about the fact that digital technologies in a digital society are a necessary area that shows the main path, which in itself reflects the growth of the intellectual potential of the future generation, as well as humanity to some extent.***

Key words: digital society, education system, digital technologies, quality, intelligence, system.

KIRISH.

Zamonaviy bilim va ko‘nikmalarga ega, mamlakatning munosib kelajagi uchun javobgarlikni o‘z zimmasiga ola biladigan barkamol, maqsadga intiluvchan va serg‘ayrat yoshlarni tarbiyalash mamlakatni barqaror va ildam rivojlantirishning eng muhim shartidir.

So‘nggi yillarda yoshlarning intellektual va ijodiy salohiyatini namoyon qilish, ularning fuqarolik javobgarligini va olib borilayotgan islohotlarga daxldorligini oshirish borasida ulkan ishlar amalga oshirildi [1].

Raqamlashgan jamiyat va raqamli kompetentsiya darajasi-bu so‘nggi infratuzilma yangiliklarini hisobga olgan holda to‘plangan tajribani qayta uzatish darajasidir. Bizning fikrimizcha, ta’lim tizimlari birinchi navbatda zamonaviy raqamli dunyoda bilimlarni qayta uzatish tizimining xususiyatlari bilan bog‘liq bo‘lgan maxsus xavf-xatar holatini keltirib chiqaradi. Bunday xususiyatlarga quyidagilar kiradi: ilmiy va texnik faoliyatning deyarli har qanday jihatlari bo‘yicha ma’lumotlarning yuqori darajada mavjudligi va ochiqligi; raqamli texnologiyalarning mavjudligi usulida bevosita joylashtirilgan nusxa ko‘chirish qobiliyati; ichki bilimlarni tashqi ma’lumotlarning ortib borayotgan hajmidan doimiy ravishda orqada qoldirish.

Raqamli (va bu deyarli har doim kompyuter), texnologiyalarni integratsiya qilish jarayoni zamonaviy jamiyat mavjudligining barcha sohalarida kuzatilmoqda. Raqamli texnologiyalarni joriy etish insoniyat tarixidagi boshqa har qanday innovatsion ishlanmalarni amalga oshirishdan ko‘ra tezroq: atigi yigirma yil ichida raqamli texnologiyalar rivojlanayotgan mamlakatlar aholisining qariyb 50 foizini qamrab olishga muvaffaq bo‘ldi. Bunda insoniyatning raqamli aborigenlarga va o‘z faoliyatini zamonaviy raqamli texnologiyalar-raqamli immigrantlar ta’sirisiz boshlaganlarga ob’ektiv bo‘linishi mavjud [2].

Adabiyotlar tahlili va metodlar: Ta’lim jarayonini raqamlashtirishning turli jihatlari bilan bog‘liq masalalarni ko‘rib chiqishda biz iqtisod fanlari doktori Yu. I. Gribanov tomonidan taklif qilingan raqamli jamiyatni rivojlantirish modeliga tayanamiz, bu raqamli iqtisodiyotni bosqichma-bosqich rivojlantirish jarayonini o‘z ichiga oladi: raqamli ma’lumotlar darajasidan (turli xil ma’lumotlar massivlarini optimallashtirishga imkon beradigan oddiy

raqamlashtirish) — raqamli infratuzilma orqali, (ya’ni raqamli texnologiyalar havzasi va ularning mahsulotlari asosida qurilgan ijtimoiy-iqtisodiy tizim faoliyatining tarmoq asosi) raqamlashtirishga (raqamli texnologiyalar foydalanuvchilari va tegishli raqamli tarmoq modellarining o‘zaro ta’siri). Muallifning fikriga ko‘ra, yaqin kelajakda ushbu jarayonning yakuniy va prognoz qilingan bosqichi raqamli transformatsiyadir, ya’ni “...raqamlashtirish orqali barcha darajadagi ijtimoiy-iqtisodiy tizimlarning mavjudligini inqilobiy o‘zgartirish (hajmlarni oshirish va xilma-xillik va sifatni oshirish) maqsadida amalga oshiriladi” [3, 12-13-betlar].

Raqamlashtirish jarayoni bir necha darajaga ega ekanligiga ishonish tabiiy, shu bilan birga uning mavjudligi bilan muammolar kelib chiqishi tabiiy. Zamonaviy jamiyatni raqamlashtirish jarayonlarining uch darajasini ajratib ko‘rsatishimiz mumkin:

- raqamli infratuzilma;
- raqamli kompetentsiya;
- raqamli aloqa.

Inson hayoti va faoliyatining barcha sohalariga axborot texnologiyalari chuqur kirib borgan zamonda yashayapmiz. Raqamli texnologiyalar nafaqat mahsulot va xizmatlar sifatini oshiradi, balki ortiqcha xarajatlarni ham kamaytiradi. Shu bilan birga, mamlakat rivojlanishiga to‘sqinlik qilayotgan eng og‘ir illat — korrupsiya balosini yo‘qotishda ham muhim ahamiyat kasb etadi.

Yuqori texnologiyalar har qanday davlatning muvaffaqiyatli rivojlanishining kalitidir. Shu bois keyingi yillarda O‘zbekistonda iqtisodiyotni raqamlashtirish, aholining internet va mobil internet bilan qamrovini kengaytirishga jiddiy e’tibor qaratilmoqda [4].

Raqamli infratuzilma darajasi, birinchi navbatda, Internet va unga aloqador barcha texnologiyalarning tarqalish darajasidir. Axborot makro darajadagi eng muhim tarkibiy qism ekanligini tan olib, BMT shuni ta’kidlaydi “...(raqamli) texnologiyalar maxfiylikka tahdid solishi, xavfsizlikni buzishi va tengsizlikni kuchaytirishi mumkin”[5]. Birlashgan millatlar tashkiloti insoniyatning eng muhim maqsadlaridan biri sifatida Internetga 24 soat davomida kirishni ta’minlash deb ataydi, ammo shu bilan birga ba’zi mamlakatlarda Internetga kirish juda past darajada ekanligini ta’kidlaydi va past daraja BVS-sopyeb (eng kam rivojlangan mamlakatlar) uchun xos ekanligini va aholining yigirma foizidan kamrog‘ini tashkil qiladi [6].

Raqamli aloqa darajasi-bu Sayyora aholisi tomonidan kundalik odatiy amaliyotlarni raqamli ravishda amalga oshirish sohasi. Nafaqat xorijiy, balki rus tadqiqotchilari ham ushbu muhim aloqa darajasida raqamlashtirish muammolari mavjudligini ta’kidlamoqdalar. Axir, hamma narsa o‘sib bormoqda. “..sayyoradagi va ayrim mamlakatlardagi kambag‘al ko‘pchilik va boy ozchilikning axborot qaramaqarshiligi inqiroz sharoitida davlat va jamiyatning o‘z-o‘zini yo‘q qilishiga olib kelishi mumkin bo‘lgan tanqidiy darajadagi ijtimoiy-siyosiy ziddiyatlarni keltirib chiqaradi”[7,39-bet]. Axborot-kommunikatsiya texnologiyalaridan foydalanish har doim ham mavjudligini ko‘rsatgan. “..axborot ochiq tizimlari vazifasini bajaradigan ijtimoiy-iqtisodiy ob’ektlarning ishlashiga tizimli ta’sir o‘tkazishi tabiiy.” [8, 26-bet].

Bugun ta’lim tizimidagi asosiy islohotlar kelajak avlod, yoshlar bilim, malaka va ko‘nikmalarini yanada takomillashtirish borasida jahon standartlariga mos keladigan o‘quv resurslarini tashkil etilishi, jamiyatni barqarorlashuviga qaratilgani juda quvonarlidir. “O‘zbekiston Respublikasi oliy ta’lim tizimini 2030-yilgacha rivojlantirish konsepsiyasini tasdiqlash to‘g‘risida” O‘zbekiston Respublikasi Prezidentining Farmonida quyidagilar keltitilgan, jumladan:

xalqaro tajribalardan kelib chiqib, oliy ta’limning ilg‘or standartlarini joriy etish, jumladan o‘quv dasturlarida nazariy bilim olishga yo‘naltirilgan ta’limdan amaliy ko‘nikmalarni shakllantirishga yo‘naltirilgan ta’lim tizimiga bosqichma-bosqich o‘tish;

oliy ta’lim mazmunini sifat jihatidan yangi bosqichga ko‘tarish, ijtimoiy soha va iqtisodiyot tarmoqlarining barqaror rivojlanishiga munosib hissa qo‘shadigan, mehnat bozorida o‘z o‘rnini topa oladigan yuqori malakali kadrlar tayyorlash tizimini yo‘lga qo‘yish;

oliy ta’lim muassasalarining akademik mustaqilligini ta’minlash [9].

Ushbu hujjatga intellektual taraqqiyotni jadallashtirish, raqobatbardosh kadrlar tayyorlash, ilmiy va innovatsion faoliyatni samarali tashkil etish hamda xalqaro hamkorlikni mustahkamlash maqsadida fan, ta’lim va ishlab chiqarish integratsiyasini rivojlantirish singari vazifalar asos qilib olindi.

Kontseptsiya mazmuni mamlakatimiz oliy ta’lim tizimini isloh qilishning ustuvor yo‘nalishlarini aks ettiradi. Unda oliy o‘quv yurtlarida qamrov darajasini kengaytirish hamda ta’lim sifatini oshirish, raqamli texnologiyalar va ta’lim platformalarini joriy etish, yoshlarni ilmiy faoliyatga jalb qilish, innovatsion tuzilmalarni shakllantirish, ilmiy tadqiqotlar natijalarini tijoratlashtirish, xalqaro e’tirofga erishish hamda boshqa ko‘plab aniq yo‘nalishlar belgilab berilgan. Bularning barchasi ta’lim jarayonini yangi sifat bosqichiga ko‘tarish uchun xizmat qiladi [10].

XULOSA

Xulosa o‘rnida shuni ta’kidlash lozimki, bugungi kunda ta’lim va uning sifatini yanada oshirish ta’lim muassasalaridagi o‘quv jarayaonlarini yanada takomillashtirish bilan bog‘liqdir. Zamonaviy ta’lim qattiq nazorat va adolatli boshqaruvni talab qiladi. Ta’limda nazorat va boshqaruvning uyg‘unligini ta’minlash sifat va samaradorlikning kalitidir. O‘zbekiston ta’lim tizimida ta’lim sifati tizimli nazorat qilinmasa, o‘quv jarayonida muayyan muammolar yuzaga keladi. Shuning uchun ta’limni boshqarish o‘quv jarayonini, ta’lim turini, uning imkoniyatlarini hisobga olishi va shu bilan sifat menejmentining samarali ishlashini ta’minlashi kerak. Ta’limda boshqaruv samaradorligi va sifatining o‘zgarishi to‘g‘ri tanlangan boshqaruv modeli va uni uzluksiz ta’lim tizimida izchil qo‘llash amaliyoti bilan bog‘liq. [11].

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INFORMATION AND RESOURCE CENTER USING THE 1C: AIRC PLATFORM

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***Abstract*— The article discusses the development and implementation of an automated digital model of an information resource center (AIRC) based on the 1C:Enterprise 8.3 platform. The existing problems of traditional AIRCs, such as a low level of automation, data duplication and lack of systematic analytics, are analyzed. A comprehensive methodological approach is presented, including system analysis, design and prototyping, which made it possible to create an effective solution adapted to Russian standards and information security requirements. The developed model ensures automation of resource accounting, processing of user requests, reporting and prospects for integration with modern digital services. The results of the study contribute to the digital transformation of educational institutions and import substitution in the field of information technology.**

***Keywords*— information resource center, digitalization, automation, 1C:Enterprise, educational institutions, information technology, resource management**

XIII. INTRODUCTION

The development of digital technologies has a significant impact on all areas of public life, including education, science and knowledge management (1). In the context of the transition to a digital economy, the importance of information systems capable of ensuring high-quality and prompt interaction with users, managing information flows and monitoring the life cycle of resources is increasing (2). A special role in this process is played by automated information resource centers (AIRCs), which serve as a supporting infrastructure for storing, processing, searching and providing various types of information and educational resources (3). However, despite the high importance of AIRCs, many of them operate according to outdated principles that do not fully utilize the potential of digital solutions (4). The main problems include the manual nature of record-keeping, a low level of automation of interaction with users, limited analytics and reporting capabilities, as well as the lack of end-to-end integration with other information systems of the institution (5, 6). As a result, the efficiency of resource management suffers, the quality of user service decreases and the workload on staff increases (7).

XIV. MAIN PART

In developed countries, there is a wide range of practices for digitalization of the AIRC. For example, universities in the USA and Canada actively use systems such as Koha, DSpace, Alma, which allow for distributed access to electronic and printed materials, fund management, collection of statistics and generation of reports. In EU countries, open-source solutions supporting the Smart Library concept are being actively implemented, with the integration of AI and predictive analytics (8, 9). Despite this, the implementation of Western systems in Russian conditions is often associated with legal, linguistic and technical barriers. This encourages the creation of domestic digital solutions adapted to current legislation, local GOST standards and the specifics of Russian office work (10).

The 1C: Enterprise 8.3 platform is a flexible development environment that includes:

- an object-oriented data model;
- tools for customizing user interfaces;
- built-in mechanisms for accounting, control and analysis;
- wide integration capabilities with external systems and databases;
- support for web interfaces and mobile applications.

Previously, 1C was used primarily in accounting and personnel records, but its potential allows developing vertical solutions for various industries, including for the digitalization of the AIRC. The domestic platform ensures compliance with information security standards, ease of localization and support for Russian regulations (unlike foreign platforms).

The design of the digital model of the AIRC should be based on system, process, information and modular theoretical approaches. Thus, the digitalization of the AIRC is a multi-level process that includes both technological and organizational transformations that require targeted design, adaptation and evaluation of

effectiveness. To achieve the objective of the study — development and implementation of an automated digitalization model of the information resource center (IRC) — an integrated approach was used, combining methods of system analysis, information system design, prototyping and functional testing. The study was conducted within the framework of the concept of digital transformation of the AIRC, taking into account the current information and organizational needs of educational institutions. The methodological basis of the work includes both theoretical models of information resource management and applied digitalization technologies.

To implement the digital model, the 1C: Enterprise 8.3 software package was chosen for reasons such as the platform's widespread use in Russia and the CIS countries, the presence of built-in data modeling tools, business processes and document management, the ability to flexibly customize interfaces without deep programming, support for generating reports and analytics, the presence of mechanisms for differentiating access rights and the ability to publish solutions in a web environment or in a local network.

In addition, the use of domestic software meets the import substitution requirements in force within the framework of the digital transformation of government agencies.

The study was conducted in five successive stages, each of which solved specific problems:

At the initial stage, an analysis of the typical structure of the AIRC, its functions and problem areas was carried out. In particular, duplication of information in manual accounting, high labor intensity of processing user requests, the lack of systematized reporting and the impossibility of analyzing the dynamics of resource demand were identified. To collect information, structured interviews with AIRC employees, analysis of internal documentation and a review of current regulations for processing requests and accounting of the fund were used.

At the second stage, requirements were formalized and an architecture was developed, which, based on the data obtained, a functional model of the system was formed, including the following key modules:

• "Resource Catalog" (electronic and physical materials);

• "User Requests" (requests, booking, issuance);

• "Accounting Module" (registration of transactions);

• "Reporting and Analytics" (dynamic and static reports).

The methods used were use case diagrams, data flow diagrams (DFD) and object-oriented design (ER diagrams for reference books and documents).

At the third stage, a working prototype of the system was created, on which directories (resources, users, categories) were implemented, documents (request, booking, return) were developed, information registers (history of requests) were implemented, data input/output forms were configured, and a reporting system for requests and funds was implemented.

The prototype used standard configurator objects: References, Documents, Registers, Processing, Forms, Reports..

Conclusion

In the future, the directions for expanding and improving the model are as follows: integration with electronic library systems (via API), which will expand access to licensed and open sources, development of a user web portal that provides access to the system via a browser without the need to install the 1C platform, implementation of a mobile client for access to the AIRC from tablets and smartphones and the introduction of intelligent search and recommendations (based on AI algorithms), which will increase the personalization of service. Further research can be aimed at adapting the model to various levels of education (schools, colleges, technical schools), as well as creating a standard industry solution.

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ЦИФРОВАЯ ТРАНСФОРМАЦИЯ ОБРАЗОВАНИЯ НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА И БОЛЬШИХ ДАННЫХ: СРАВНИТЕЛЬНЫЙ АНАЛИЗ И НАЦИОНАЛЬНЫЕ ПЕРСПЕКТИВЫ УЗБЕКИСТАНА

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В статье рассматриваются возможности использования технологий искусственного интеллекта и больших данных в процессе цифровой трансформации образования. На основе анализа международного опыта Соединённых Штатов Америки, Китая, стран Европейского Союза, Сингапура и Республики Корея показано, что внедрение интеллектуальных систем в образовательную сферу позволяет персонализировать обучение, повысить качество образовательных услуг, а также обеспечить справедливость и доступность знаний. Особое внимание уделяется национальному контексту Узбекистана, где цифровая трансформация образования становится одним из приоритетов государственной политики. В работе представлены результаты сравнительного анализа и сформулированы рекомендации по адаптации международных практик к условиям Узбекистана. Сделан вывод о том, что успешное внедрение искусственного интеллекта и больших данных возможно лишь при комплексном подходе, включающем развитие инфраструктуры, подготовку кадров и формирование нормативной базы.

Ключевые слова: искусственный интеллект, большие данные, цифровая трансформация, образование, международный опыт, Узбекистан.

XV. Введение

В современном мире образование является не только инструментом передачи знаний, но и важнейшим фактором социального и экономического развития. Переход к цифровой экономике, рост глобальной конкуренции и необходимость формирования новых компетенций требуют качественного пересмотра традиционных подходов к обучению. Именно в этом контексте технологии искусственного интеллекта и анализа больших данных становятся неотъемлемой частью образовательной политики и практики, способной придать новый импульс развитию национальных систем.

Актуальность цифровой трансформации образования обусловлена тем, что именно эта сфера во многом определяет возможности страны в обеспечении устойчивого развития. Международные исследования последних лет подчёркивают, что те государства, которые своевременно интегрировали интеллектуальные технологии в образовательный процесс, сумели повысить эффективность обучения, расширить доступ к знаниям и подготовить специалистов для новых отраслей экономики. Так, по данным UNESCO, более шестидесяти стран уже применяют элементы искусственного интеллекта в управлении образовательными системами, а отчёты OECD показывают, что использование больших данных в университетах позволяет существенно снизить академическую неуспешность и повысить уровень вовлечённости студентов.

Научная значимость исследования связана с формированием нового междисциплинарного направления, объединяющего педагогику, информационные технологии, аналитику и социологию образования. В отличие от классических форм модернизации, цифровая трансформация не ограничивается использованием электронных средств обучения, а затрагивает саму структуру образовательного процесса. Искусственный интеллект становится инструментом для персонализации учебных траекторий и автоматизации рутинных функций преподавателя, а большие данные позволяют

осуществлять стратегическое управление на уровне школ, университетов и государства. Всё это требует научного осмысления, систематизации опыта и разработки адаптационных моделей, которые учитывают особенности конкретной страны.

Краткий обзор имеющейся литературы указывает на то, что международные исследования сосредоточены на трёх главных направлениях. Первое связано с анализом производительности адаптивных платформ, применяемых в США и Китае и показывающих положительные итоги при широком использовании. Второе направление акцентирует внимание на этических и юридических аспектах, что особенно типично для европейских исследований. Третье связано с подготовкой преподавателей и развитием цифровой грамотности, чему заметное внимание уделяется в Сингапуре и Южной Корее. Несмотря на различия в акцентах, все авторы приходят к общему заключению: искусственный интеллект и большие данные становятся необходимым и элементами образования будущего.

Цель данного исследования состоит в том, чтобы на основе сравнительного анализа международных практик выявить перспективы применения искусственного интеллекта и больших данных в системе образования Узбекистана и предложить рекомендации по их адаптации к национальным условиям. Задачи исследования заключаются в том, чтобы определить, каким образом интеллектуальные технологии меняют структуру образовательного процесса, какие преимущества и риски они несут и какие шаги необходимо предпринять для успешного внедрения этих решений в национальную систему.

Для Узбекистана данная тема имеет особое значение. В последние годы страна активно реализует политику модернизации образования, внедряются электронные дневники, дистанционные платформы и цифровые инструменты управления. Однако применение искусственного интеллекта и больших данных пока остаётся точечным и не носит системного характера. Проблемы цифрового неравенства между регионами, нехватка квалифицированных педагогов и ограниченность ресурсов создают серьёзные барьеры на пути цифровой трансформации. В этой связи исследование международного опыта и выработка предложений для национальной практики становится задачей, имеющей не только научную, но и стратегическую значимость.

Таким образом, введение подводит к пониманию того, что цифровая трансформация образования с использованием искусственного интеллекта и больших данных представляет собой не просто технологическую инновацию, а комплексный процесс, способный изменить саму философию обучения. Для Узбекистана обращение к этой теме открывает возможности для сокращения социального неравенства, повышения качества образования и интеграции в глобальное образовательное пространство.

XVI. Постановка проблемы

Несмотря на очевидные преимущества цифровой трансформации образования, процесс внедрения технологий искусственного интеллекта и больших данных сопровождается рядом трудностей и противоречий, которые формируют исследовательскую проблему. На международном уровне наблюдается неравномерность внедрения интеллектуальных решений: если развитые страны демонстрируют устойчивый прогресс в использовании алгоритмов для персонализации обучения, повышения эффективности управления и расширения доступа к образовательным ресурсам, то государства с ограниченными ресурсами сталкиваются с трудностями системного характера.

Ключевая проблема заключается в разрыве между технологическими возможностями и социально-экономическими условиями. В Соединённых Штатах, Китае и странах Европейского Союза искусственный интеллект и большие данные уже интегрированы в национальные образовательные стратегии. Эти страны обладают развитой инфраструктурой, высоким уровнем цифровой грамотности педагогов и нормативной базой, регулирующей вопросы защиты персональной информации. В результате внедрение интеллектуальных систем происходит в масштабах всей страны и сопровождается ощутимым ростом качества образовательных услуг. В то же время для развивающихся стран характерна фрагментарность внедрения: цифровые инструменты используются локально, чаще всего в пилотных проектах или отдельных образовательных учреждениях.

В контексте Узбекистана проблема усугубляется дисбалансом между стратегическими целями и реальными возможностями. Государственная политика ориентирована на цифровизацию образования, однако применение ИИ и больших данных остаётся на начальном этапе. Электронные дневники, дистанционные платформы и системы онлайн-обучения внедряются, но они не обладают возможностями анализа больших массивов информации и выстраивания персонализированных траекторий. Цифровое неравенство между регионами препятствует равному доступу к инновационным решениям: школы и вузы крупных городов значительно опережают сельские образовательные учреждения.

Существенным вызовом является нехватка квалифицированных специалистов, способных использовать интеллектуальные технологии в образовательной практике. Преподаватели не всегда обладают необходимыми цифровыми компетенциями, а программы повышения квалификации пока не охватывают всех педагогов. Отсутствие системной подготовки кадров снижает эффективность внедряемых технологий и ограничивает их потенциал. Кроме того, в стране пока не создана полноценная нормативно-правовая база, регулирующая использование персональных данных учащихся и обеспечивающая прозрачность алгоритмов искусственного интеллекта. Это вызывает

обеспокоенность со стороны общества и снижает уровень доверия к цифровым инициативам.

Таким образом, проблема сводится к необходимости поиска механизмов адаптации международного опыта к национальному контексту. С одной стороны, существует множество примеров успешного применения искусственного интеллекта и больших данных, доказывающих их значимость для повышения качества образования. С другой стороны, механическое заимствование этих практик не принесёт ожидаемого результата без учёта культурных, экономических и социальных особенностей Узбекистана. Задача заключается в том, чтобы определить, какие модели могут быть перенесены в национальную систему, а какие требуют глубокой адаптации и институциональной поддержки.

Именно сочетание высокого потенциала технологий и наличия значительных ограничений формирует исследовательскую проблему, решение которой должно быть направлено на выработку комплексной стратегии цифровой трансформации образования в Узбекистане.

XVII. Методы исследования и теоретическая часть

Для анализа возможностей и перспектив внедрения искусственного интеллекта и больших данных в систему образования Узбекистана было необходимо использовать методологические подходы, обеспечивающие комплексное рассмотрение проблемы. В качестве основы был выбран сравнительный анализ международного опыта, позволяющий выявить общие закономерности и различия в применении интеллектуальных технологий в разных странах. Такой подход дал возможность оценить, какие решения оказались результативными в определённых условиях и как они могут быть адаптированы в национальной практике. Сравнительный метод также позволил избежать излишней универсализации и учесть специфику культурного, экономического и правового контекста.

Наряду с этим применялся системный подход, исходящий из представления об образовании как о многоуровневой экосистеме. В рамках этого подхода искусственный интеллект и большие данные рассматривались не только как технологические инновации, но и как элементы, способные изменить логику взаимодействия между участниками образовательного процесса, а также управленческую структуру системы в целом. Такой взгляд позволил охватить не только технические возможности, но и организационные, педагогические и нормативные аспекты трансформации.

Важным элементом теоретической части стало использование концепции образовательной аналитики. Она предполагает цикл, включающий сбор данных, их интерпретацию, применение в управленческих и педагогических решениях и последующую обратную связь. Эта модель, широко применяемая в университетах Европы и США, иллюстрирует, каким образом большие данные могут превращаться из абстрактных массивов информации в конкретные действия, направленные на улучшение образовательных результатов. Анализ этой концепции позволил рассмотреть потенциал внедрения аналогичных решений в условиях Узбекистана.

Кроме того, в исследовании использовались положения концепции жизненного цикла искусственного интеллекта в образовании, где внимание акцентируется на разработке алгоритмов, их валидации, обеспечении прозрачности и дальнейшем внедрении в практику. Эта модель позволяет выстраивать процессы внедрения таким образом, чтобы избежать рисков, связанных с недобросовестным использованием данных, дискриминацией или нарушением приватности.

Теоретическая часть опиралась также на анализ стратегических документов, в том числе «Цифровой стратегии образования Европейского Союза», китайской программы «Интернет+Образование», а также Национальной стратегии цифрового образования Узбекистана до 2030 года. Сопоставление этих источников позволило выявить различия в подходах к цифровизации, понять, какие приоритеты формируются в разных странах, и определить, как эти приоритеты могут быть учтены при выработке национальной стратегии.

Таким образом, методы исследования включали в себя как сравнительный и системный анализ, так и обращение к современным теоретическим моделям образовательной аналитики и жизненного цикла искусственного интеллекта. Такой комплексный методологический инструментарий позволил обеспечить достоверность выводов и сформировать основу для обсуждения результатов, имеющих значение как для научного сообщества, так и для практической образовательной политики.

XVIII. Результаты и их обсуждение

A. Международный опыт использования скусственного интеллекта и больших данных в образовании

Анализ международных практик позволяет утверждать, что в ведущих странах мира технологии искусственного интеллекта и больших данных постепенно становятся фундаментальной основой образовательных систем. При этом направления их применения зависят от приоритетов конкретного государства и уровня развития его цифровой инфраструктуры. В одних случаях акцент делается на персонализации учебных траекторий, в других — на управленческом контроле и прогнозировании, в третьих — на этическом регулировании и подготовке педагогических кадров.

Соединённые Штаты Америки традиционно выступают пионерами в интеграции инновационных технологий в образование. Здесь широкое распространение получили системы управления обучением, которые не только фиксируют результаты

академической деятельности студентов, но и собирают данные об их активности, темпах освоения материала и формах взаимодействия с преподавателями. Алгоритмы искусственного интеллекта обрабатывают эту информацию и предоставляют администраторам возможность выявлять студентов с риском академической неуспешности. Таким образом, технологии помогают принимать управленческие решения, направленные на снижение количества отчислений и повышение уровня вовлечённости. Кроме того, в США активно развиваются системы автоматизированной проверки эссе и письменных работ, что позволяет оптимизировать работу преподавателей и стандартизировать оценивание.

Китай демонстрирует иной вектор развития — массовое внедрение адаптивных платформ. Программа «Интернет+Образование» и такие проекты, как Squirrel AI, охватывают миллионы школьников, предоставляя им индивидуализированные задания и материалы. В основе этих платформ лежит идея постоянного мониторинга прогресса каждого ученика: система анализирует его ответы, фиксирует ошибки, оценивает время выполнения заданий и предлагает индивидуальные рекомендации. Такой подход позволил Китаю добиться того, что персонализированное обучение стало доступным не только для элитных школ, но и для массового образования. Этот опыт ценен для стран, стремящихся повысить качество обучения в условиях ограниченных ресурсов, так как он показывает возможность масштабирования интеллектуальных решений на национальном уровне.

Европейский Союз выстраивает стратегию цифровой трансформации образования с акцентом на этические и правовые вопросы. Документы Европейской комиссии подчёркивают, что внедрение ИИ должно сопровождаться гарантиями прозрачности, защиты персональных данных и недопущения дискриминации. В рамках инициативы AI4EU финансируются проекты, направленные на разработку образовательных платформ, соответствующих принципам надёжного искусственного интеллекта. Таким образом, европейский опыт важен не столько с точки зрения конкретных технологий, сколько как модель нормативного регулирования, позволяющая обеспечить доверие общества к цифровым инновациям.

Сингапур и Республика Корея ориентируются на подготовку педагогических кадров и создание цифровых кампусов. В этих странах сделан акцент на том, что без вовлечённых и компетентных учителей даже самые совершенные технологии останутся малоэффективными. Программы повышения квалификации педагогов включают обучение основам анализа данных, навыкам работы с адаптивными платформами и инструментами искусственного интеллекта. Одновременно в университетах и школах создаются цифровые среды, где все данные об образовательном процессе интегрированы и доступны для анализа. Такой подход позволил Сингапуру и Корее не только повысить качество обучения, но и минимизировать риски цифрового неравенства.

Сравнительный анализ показывает, что каждая страна определяет свои приоритеты: США делают упор на предиктивную аналитику, Китай — на массовую персонализацию, Европейский Союз — на правовое регулирование, а Сингапур и Корея — на подготовку кадров. Для Узбекистана ценность этого опыта заключается в возможности комплексного заимствования: с одной стороны, адаптивные платформы способны сократить образовательное неравенство, с другой — необходима разработка нормативных стандартов и программ подготовки учителей.

B. Технологические направления применения ИИ и больших данных в образовании

Современные технологии искусственного интеллекта и анализа больших данных охватывают широкий спектр направлений, которые радикально меняют образовательную практику. Их применение позволяет перестроить структуру обучения, повысить его эффективность и сделать процесс более гибким и ориентированным на индивидуальные особенности учащихся.

Одним из ключевых направлений является адаптивное обучение. Его суть заключается в том, что образовательная программа выстраивается не как универсальный шаблон, а как динамическая система, подстраивающаяся под способности и темп конкретного студента. Алгоритмы анализируют результаты тестов, активность на платформах и даже время, затраченное на выполнение заданий, после чего корректируют содержание курса. Такая технология уже доказала свою эффективность в университетах США и школах Китая, где студенты получают индивидуальные траектории обучения, что значительно повышает их мотивацию и снижает риск академической неуспешности.

Другим направлением выступает предиктивная аналитика, которая позволяет прогнозировать результаты обучения и выявлять потенциальные риски на ранних стадиях. В университетской среде это выражается в использовании систем, анализирующих поведение студентов в цифровых платформах, включая посещаемость онлайн-занятий и активность в форумах. Если студент демонстрирует признаки снижения интереса или низкой успеваемости, система сигнализирует преподавателям и администраторам, которые могут своевременно вмешаться. Подобный подход не только предотвращает отчисления, но и укрепляет доверие студентов к образовательному учреждению, так как они чувствуют реальную поддержку.

Значительное внимание уделяется автоматизированной проверке знаний. Искусственный интеллект всё чаще используется для оценки тестов, эссе и письменных работ. Алгоритмы могут

анализировать структуру текста, уровень аргументации и корректность логики. Несмотря на то что полная замена преподавателя в оценивании невозможна, такие системы помогают сократить рутинную нагрузку и стандартизировать процесс проверки. В сочетании с экспертным контролем со стороны педагога это повышает объективность и позволяет сосредоточиться на более творческих и аналитических аспектах преподавания.

Отдельное место занимают интеллектуальные ассистенты и чат-боты, которые становятся неотъемлемой частью цифровых кампусов. Они способны круглосуточно отвечать на вопросы студентов, напоминать о сроках сдачи заданий, объяснять сложные темы и предоставлять справочную информацию. Ведущие университеты уже внедряют такие системы, и практика показывает, что они существенно повышают доступность образовательной поддержки.

Совмещение технологий искусственного интеллекта с виртуальной и дополненной реальностью открывает новые горизонты для практико-ориентированного обучения. Виртуальные лаборатории позволяют студентам работать с экспериментами, которые невозможно провести в реальных условиях из-за их высокой стоимости или опасности. Искусственный интеллект в таких системах играет роль наставника, анализируя действия обучающегося и предоставляя ему обратную связь в реальном времени. В медицине такие решения позволяют будущим врачам отрабатывать сложные операции в виртуальной среде, а в инженерии — моделировать производственные процессы без риска для оборудования.

Наконец, важным направлением становится развитие интероперабельности образовательных данных. Внедрение искусственного интеллекта невозможно без унификации форматов, которые позволяют интегрировать данные из различных платформ и систем. Международные инициативы, направленные на создание стандартов обмена образовательной информацией, способствуют тому, что отдельные инструменты не остаются изолированными, а формируют целостную цифровую экосистему. Это открывает возможности для комплексного анализа данных и формирования единой стратегии развития образования.

Таким образом, технологические направления внедрения искусственного интеллекта и больших данных в образование демонстрируют, что эти решения не ограничиваются вспомогательными функциями, а становятся основой для построения новой образовательной модели. Их значение заключается не только в повышении эффективности обучения, но и в формировании гибкой и устойчивой системы, способной адаптироваться к вызовам современного мира.

C. Этические и правовые аспекты использования ИИ и больших данных в образовании

Внедрение технологий искусственного интеллекта и анализа больших данных в сферу образования неизбежно ставит перед исследователями и практиками сложные этические и правовые вопросы. Если технологические возможности позволяют создавать всё более совершенные системы адаптивного обучения и предиктивной аналитики, то правовая и моральная составляющие становятся определяющими факторами, от которых зависит уровень доверия общества к этим нововведениям.

Одним из центральных вызовов является защита персональных данных обучающихся. Образовательные платформы аккумулируют колоссальные массивы информации: результаты экзаменов, индивидуальные траектории обучения, поведенческие характеристики и даже элементы социальной активности студентов. Отсутствие надёжных механизмов хранения и обработки этих данных может привести к утечкам информации, злоупотреблениям и нарушению прав личности. Международный опыт показывает, что именно вопросы приватности становятся главным препятствием для масштабного внедрения ИИ в школах и университетах. Европейский Союз, к примеру, ввёл строгие регуляции в рамках Общего регламента по защите данных (GDPR), которые распространяются и на образовательные учреждения. Эти нормы требуют прозрачности алгоритмов, права обучающихся на контроль над своими данными и гарантий недопущения их использования вне образовательных целей.

Не менее важным аспектом является проблема алгоритмических предвзятостей. Алгоритмы искусственного интеллекта обучаются на больших массивах данных, которые нередко отражают социальные и культурные стереотипы. В результате система может воспроизводить и даже усиливать дискриминацию. Например, предиктивные модели могут ошибочно определять студентов из социально уязвимых групп как менее успешных, что приводит к ограничению их образовательных возможностей. Это создаёт риск усиления социального неравенства вместо его сокращения. Международные организации, включая UNESCO, подчёркивают необходимость разработки этических кодексов, исключающих подобные ситуации, а также регулярного аудита алгоритмов.

Отдельного внимания заслуживает вопрос академической добросовестности. Появление генеративных технологий, таких как интеллектуальные чат-боты, способные создавать тексты, решать задачи и даже писать программный код, ставит под угрозу традиционные формы контроля знаний. В образовательной среде всё чаще возникает дилемма: как отличить самостоятельный труд студента от работы, выполненной с помощью алгоритмов? Это требует выработки новых форм

оценивания и переосмысления роли преподавателя, который должен не только контролировать знания, но и формировать у студентов критическое мышление и способность к самостоятельному анализу.

Правовые аспекты включают также регулирование ответственности за решения, принимаемые системами искусственного интеллекта. В случае ошибок или несправедливых оценок возникает вопрос: кто несёт ответственность — разработчики, образовательное учреждение или сам алгоритм? Международная практика пока не выработала единого ответа. Однако очевидно, что без ясной нормативной базы образовательные учреждения будут осторожно подходить к масштабному внедрению интеллектуальных систем.

В Узбекистане этические и правовые аспекты внедрения ИИ в образование только начинают обсуждаться. Отсутствие национальной нормативной базы, регулирующей защиту персональных данных студентов и прозрачность работы алгоритмов, остаётся серьёзным барьером для широкого применения технологий. Вместе с тем именно на данном этапе существует возможность учесть международный опыт и сформировать собственные правила, которые будут учитывать культурные и социальные особенности страны. Это позволит избежать ошибок, допущенных другими государствами, и создать условия для доверия общества к цифровой трансформации.

Таким образом, этические и правовые аспекты представляют собой не второстепенное, а центральное направление цифровой трансформации образования. Без их решения даже самые передовые технологии рискуют остаться невостребованными. Только при условии соблюдения прав обучающихся, прозрачности алгоритмов и формирования этических стандартов использование ИИ и больших данных сможет реализовать свой потенциал и способствовать построению справедливой и устойчивой образовательной системы.

D. Национальные перспективы Узбекистана

В контексте Узбекистана цифровая трансформация образования рассматривается как одно из приоритетных направлений государственной политики. В последние годы принимаются меры, направленные на внедрение электронных дневников, развитие дистанционного обучения, создание онлайн-платформ и цифровых библиотек. Эти инициативы отражают стремление к модернизации системы и приближению её к международным стандартам. Однако применение технологий искусственного интеллекта и анализа больших данных пока остаётся на начальном этапе и ограничивается отдельными экспериментами и пилотными проектами.

Перспективы Узбекистана в этой сфере напрямую связаны с развитием инфраструктуры. Сохраняется значительное цифровое неравенство между крупными городами и регионами, что проявляется в различиях в уровне доступа к интернету, техническому оснащению школ и цифровым навыкам преподавателей. Решение этой проблемы должно стать первоочередной задачей, так как внедрение интеллектуальных систем невозможно без равного доступа к базовым цифровым ресурсам. Создание национальной базы образовательных данных может стать ключевым элементом стратегии. Единая система позволит аккумулировать информацию о результатах обучения, посещаемости и активности студентов, обеспечивая основу для предиктивной аналитики и персонализации образовательных траекторий.

Особое внимание должно быть уделено подготовке кадров. Педагоги Узбекистана в целом демонстрируют заинтересованность в освоении цифровых технологий, однако уровень их компетенций остаётся неоднородным. Введение систематических программ повышения квалификации, включающих обучение основам анализа данных, работе с адаптивными платформами и пониманию принципов функционирования алгоритмов искусственного интеллекта, станет необходимым условием успешной цифровизации. Подготовка учителей должна рассматриваться не как разовое мероприятие, а как непрерывный процесс, встроенный в систему профессионального развития.

Не менее важным направлением является формирование нормативно-правовой базы. Отсутствие законов, регулирующих использование персональных данных учащихся и прозрачность работы алгоритмов, создаёт риски и снижает доверие к инновациям. Разработка национальных стандартов, согласованных с международными принципами этичного использования ИИ, позволит выстроить правовую основу для масштабного внедрения технологий. В этом контексте Узбекистан может опереться на опыт Европейского Союза, где вопросы приватности и справедливости занимают центральное место в образовательной политике.

Перспективы внедрения интеллектуальных систем в Узбекистане заключаются также в возможности их использования для сокращения социального и регионального неравенства. Адаптивные платформы способны предоставить учащимся из сельских школ доступ к тем же образовательным ресурсам, что и их сверстникам из крупных городов. Применение предиктивной аналитики позволит выявлять студентов с риском неуспешности и обеспечивать им своевременную поддержку. В долгосрочной перспективе это может повысить уровень инклюзивности образования и способствовать формированию человеческого капитала, необходимого для развития цифровой экономики.

Таким образом, национальные перспективы Узбекистана в области применения искусственного интеллекта и больших данных в образовании определяются сочетанием значительных вызовов и уникальных возможностей. При условии системного подхода, включающего развитие инфраструктуры, подготовку педагогов и создание нормативной базы,

страна способна сформировать собственную модель цифровой трансформации, основанную на международном опыте, но адаптированную к национальным реалиям.

XIX. Выводы и рекомендации

Проведённое исследование подтверждает, что цифровая трансформация образования на основе технологий искусственного интеллекта и анализа больших данных является неотъемлемым элементом современного образовательного процесса. Международный опыт показывает, что использование интеллектуальных систем позволяет не только повысить эффективность и качество обучения, но и создать новые механизмы управления образовательными учреждениями. Практика Соединённых Штатов демонстрирует значимость предиктивной аналитики, Китайский пример доказывает возможность массовой персонализации, Европейский Союз подчёркивает необходимость этических и правовых стандартов, а опыт Сингапура и Республики Корея акцентирует внимание на роли педагогов и развитии их цифровых компетенций.

Для Узбекистана эти выводы имеют особое значение, поскольку национальная система образования находится в состоянии активной модернизации и поиска новых моделей развития. Несмотря на то что в стране уже внедряются электронные дневники, онлайн-платформы и элементы дистанционного обучения, уровень применения искусственного интеллекта и больших данных остаётся ограниченным. Основными барьерами являются цифровое неравенство между регионами, недостаток квалифицированных кадров и отсутствие правовой базы, регулирующей использование персональных данных учащихся.

Результаты анализа позволяют сформулировать ряд рекомендаций. Прежде всего, необходимо развивать инфраструктуру, обеспечивающую равный доступ к цифровым ресурсам во всех регионах страны. Без устранения технологического разрыва между городом и селом внедрение интеллектуальных систем окажется фрагментарным и не приведёт к системным изменениям. Вторым направлением должна стать подготовка педагогов. Учителя должны не только уметь пользоваться цифровыми платформами, но и понимать, каким образом алгоритмы формируют персонализированные траектории и как использовать результаты предиктивной аналитики для поддержки студентов. Подготовка кадров должна быть встроена в систему непрерывного профессионального образования и сопровождаться государственной поддержкой.

Не менее важным направлением является формирование нормативно-правовой базы. Законодательство должно обеспечивать защиту персональных данных учащихся, прозрачность работы алгоритмов и ответственность за ошибки в принятии решений. Без доверия общества к интеллектуальным системам их масштабное внедрение невозможно. Именно поэтому Узбекистану целесообразно опираться на европейский опыт, где этические стандарты стали обязательным условием цифровизации.

Важным стратегическим шагом станет создание национальной базы образовательных данных, которая позволит систематизировать информацию о процессе обучения и использовать её для аналитики и планирования. Такая база станет платформой для построения предиктивных моделей, разработки адаптивных курсов и оценки качества образовательной системы в целом. В перспективе она может стать фундаментом для построения единой цифровой экосистемы образования, интегрированной в глобальное образовательное пространство.

Таким образом, цифровая трансформация образования в Узбекистане имеет все шансы стать успешной при условии комплексного подхода, сочетающего технологические, кадровые и правовые меры. Международный опыт показывает, что использование искусственного интеллекта и больших данных способно существенно повысить качество обучения, но только в том случае, если технологии сопровождаются соответствующими институциональными изменениями. Для Узбекистана это означает необходимость выстраивания долгосрочной стратегии, которая будет учитывать национальные особенности и одновременно соответствовать глобальным тенденциям.

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DIGITAL INNOVATIONS IN THE EDUCATION SYSTEM: OPPORTUNITIES AND CHALLENGES

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Abstract. ***The rapid evolution of digital technologies has profoundly reshaped the global education system, introducing innovative tools and methods that transform teaching and learning processes. From artificial intelligence and learning analytics to immersive environments such as augmented and virtual reality, digital innovations provide new opportunities to enhance accessibility, personalization, and learner engagement. At the same time, they raise challenges related to the digital divide, data privacy, ethical use of technology, and teacher readiness. This paper systematically examines opportunities and challenges associated with digital innovations in education. Drawing on recent research and international case studies, it outlines key benefits—such as improved inclusivity, adaptive learning, and global knowledge sharing—while also addressing risks, including inequities in access, insufficient infrastructure, and potential over-reliance on technology. The findings underscore that digital innovations should not be seen as replacements for traditional pedagogy, but as complementary tools requiring thoughtful integration. Recommendations focus on developing robust digital infrastructure, fostering teacher digital competence, and establishing ethical and policy frameworks that ensure equitable, sustainable, and future-ready education systems.***

Keywords—digital innovations, education system, personalized learning, accessibility, challenges, ethical use

I. INTRODUCTION.

The twenty-first century has ushered in an era of unprecedented digital transformation, where technology is no longer a supporting tool but a defining driver of economic, social, and cultural development. Among the many sectors affected by this global digital shift, education stands out as one of the most profoundly impacted. As a central pillar of human capital development, education is now being redefined in its goals, pedagogical methods, and delivery mechanisms. Digital innovations—ranging from artificial intelligence (AI) platforms and cloud-based learning management systems (LMS) to mobile learning, gamification, and immersive technologies such as augmented reality (AR) and virtual reality (VR)—are reshaping not only how knowledge is delivered but also how it is perceived, applied, and assessed by learners and educators alike.

The COVID-19 pandemic of 2020–2021 dramatically accelerated this ongoing transformation. With the sudden closure of educational institutions worldwide, schools and universities were forced to adopt remote and hybrid learning models almost overnight. This shift exposed significant systemic vulnerabilities, including unequal access to digital devices, unstable internet connectivity, and disparities in digital literacy among both teachers and students. At the same time, it revealed the resilience-building potential of digital technologies, demonstrating their ability to sustain learning continuity during crises and highlighting the need for long-term digital preparedness within education systems.

Beyond short-term responses to emergencies, digitalization in education represents a paradigm shift. Traditional classroom-based models that emphasize one-way knowledge transmission are increasingly giving way to interactive, learner-centered, and networked forms of education. Digital platforms facilitate collaboration across geographical and cultural boundaries, MOOCs (Massive Open Online Courses) extend opportunities for lifelong learning to millions, and AI-driven adaptive systems enable personalized learning experiences tailored to individual needs and learning styles.

The growing body of scholarly research underscores the scale of this transformation. Alam et al. (2025) documented an exponential rise in publications on digital pedagogy over the past decade, reflecting the increasing academic interest in digital education ecosystems. Similarly, the OECD’s Digital Education Outlook 2023 emphasized that digital education requires more than technological adoption; it demands policy innovations that ensure equitable access, promote teacher readiness, and sustain financial and infrastructural investments. Furthermore, Smith (2023) advanced the concept of the “abundant university,” highlighting how open-access digital resources, artificial intelligence, and global learning platforms collectively expand opportunities and reduce traditional barriers to higher education.

These perspectives illustrate that the integration of digital innovations into education is not merely about adopting new tools. It is a fundamental reimagining of education’s purpose, delivery, and inclusivity in the digital age. On the one hand, digital innovations create unprecedented opportunities for equity, personalization, and engagement. On the other hand, they raise important concerns about the digital divide, ethical use of learner data, teacher professional development, and the potential for over-reliance on technology at the expense of human interaction.

Against this backdrop, the present article aims to systematically examine the opportunities and challenges of digital innovations in education. Specifically, it seeks to (1) explore the ways in which digital technologies are transforming teaching and learning practices; (2) critically analyze the benefits and risks of this transformation; and (3) propose evidence-based strategies for the sustainable and

equitable integration of digital technologies into educational systems worldwide.

II. PROBLEM STATEMENT

Despite significant progress, the integration of digital innovations in education is accompanied by several challenges:

- Digital divide: Inequitable access to internet, devices, and digital skills among learners.
- Teacher readiness: Many educators lack adequate training to effectively apply technology in pedagogy.
- Infrastructure gaps: Inadequate investment in connectivity and modern equipment in low-resource settings.
- Ethical and privacy concerns: Data collection and surveillance practices pose risks to learner autonomy and trust.
- Overdependence on technology: Risk of undermining critical human interaction in the learning process.

III. THEORETICAL FRAMEWORK

The study draws on multiple educational theories that support the integration of digital innovations:

- Constructivism: Emphasizes active, learner-centered engagement through digital collaboration tools.
- Connectivism: Highlights the role of networks and digital platforms in shaping knowledge acquisition.
- Problem-Based Learning (PBL): Supported by simulations, AR/VR, and real-world digital problem-solving environments.

The methodological approach combines a literature review of recent scholarly studies, qualitative synthesis of global case analyses, and insights from surveys on teacher and student readiness.

IV. RESULTS AND DISCUSSION

A. Opportunities

1. Personalized learning: AI-driven platforms enable adaptive learning tailored to student needs.
2. Increased accessibility: MOOCs, mobile learning, and digital libraries expand global access.
3. Immersive engagement: AR/VR technologies provide hands-on experiences in medicine, engineering, and sciences.
4. Collaboration and global reach: Digital platforms connect learners across geographies.
5. Data-driven improvement: Learning analytics allow educators to monitor and improve student performance.

B. Challenges.

1. Persistent digital divide across regions and socioeconomic groups.
2. Teacher resistance or lack of training in adopting digital pedagogies.
3. Ethical dilemmas regarding privacy, AI bias, and equitable use.
4. Risks of cognitive overload and screen fatigue among students.

The findings suggest that digital innovations are not a universal solution, but rather tools that require careful planning, integration, and policy support.

V. CONCLUSIONS AND RECOMMENDATIONS

Digital innovations hold immense promise for transforming education by fostering inclusivity, adaptability, and global collaboration. However, these opportunities can only be realized if challenges are adequately addressed.

Recommendations:

1. Invest in digital infrastructure to ensure universal access.
2. Provide continuous teacher training in digital pedagogy.
3. Develop ethical frameworks to regulate data use and AI applications.
4. Promote hybrid approaches that balance technology with traditional teaching.
5. Foster collaboration between governments, educators, and industry to sustain innovation.

In conclusion, digital innovations represent both an opportunity and a responsibility. Their successful integration depends on inclusive policies, ethical safeguards, and strategic investments that ensure education systems remain resilient and equitable in the digital age.

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AXBOROT JAMIYATIDA KUTUBXONA MUTAXASSISLARINING RAQAMLI KOMPETENSIYASI: NAZARIYA VA AMALIYOT

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Annotatsiya—Ushbu maqolada axborot jamiyati sharoitida kutubxona sohasi mutaxassislarining raqamli kompetensiyasi har tomonlama tahlil qilinadi. Raqamli transformatsiya jarayonlari chuqurlashib borayotgan hozirgi davrda kutubxona xodimlarining raqamli bilim va ko‘nikmalarga ega bo‘lishi sohaning rivojlanishi hamda foydalanuvchilarga yuqori sifatli xizmat ko‘rsatish nuqtai nazaridan muhim ahamiyat kasb etadi. Shu jihatdan maqolada raqamli kompetensiyaning kutubxona sohasida dolzarbligi, raqamli kompetensiyaning nazariy asoslari, mazmuni, uning tarkibiy qismlari hamda kutubxona mutaxassislarining faoliyatidagi o‘rni ochib beriladi. Shuningdek, raqamli kompetensiyani rivojlantirishning zamonaviy usullari, yondashuvlari, ta’lim va kasbiy tayyorgarlik jarayonlaridagi integratsiyasi va bu boradagi ilg‘or xorijiy tajribalar tahlil qilinadi. Jahonning yetakchi kutubxona tashkilotlari, uyushmalar tomonidan ishlab chiqilgan raqamli kompetensiya standartlari, ilgari surilgan ilmiy-nazariy yondashuvlar, shuningdek, raqamli kompetensiyaga oid mashhur modellar – xususan, DigComp, JISC kabi kompetensiya modellari va boshqa nufuzli tashkilotlarning kompetensiya talablari ko‘rib chiqiladi. Maqola doirasida nazariy va amaliy jihatlar yoritilib, raqamli kompetensiyani rivojlantirishga doir amaliy tavsiyalar berilgan. Natijada, maqola axborot-kutubxona sohasida raqamli kompetensiyaning dolzarbligini yoritish bilan birga, uni rivojlantirishga yo‘naltirilgan tizimli yondashuvlarni ham asoslab beradi.

Kalit so‘zlar: kutubxona mutaxassisi, raqamli kompetensiya, raqamli kompetensiya modeli, standartlar, texnologik ko‘nikmalar.

I. KIRISH

Bugungi raqamli transformatsiya sharoitida kutubxona muassasalari nafaqat an’anaviy axborot manbalarini saqlovchi va tarqatuvchi joy sifatida, balki zamonaviy axborot-kommunikatsiya texnologiyalariga tayangan holda interaktiv va innovatsion axborot xizmati ko‘rsatuvchi institutsiyalar sifatida qayta shakllanmoqda. Bu esa, o‘z navbatida, kutubxona sohasida faoliyat yuritayotgan mutaxassislar oldiga yangi, ilg‘or bilim va ko‘nikmalar, xususan **raqamli kompetensiyalarni egallash va doimiy ravishda takomillashtirib borish** vazifasini qo‘ymoqda.

Jamiyatimizda axborotni foydalanuvchilarga yetkazishda kutubxonalar katta rol o‘ynaydi, axborot texnologiyalari va boshqaruv usullarining paydo bo‘lishi munosabati bilan kutubxonachilik ham turli xildagi qiyinchiliklarga duch kelmoqda. Sohada kechayotgan o‘zgarishlarga mos tarzda yurtimizda olib borilayotgan islohotlar, qabul qilinayotgan so‘nggi qonun hujjatlarida ham ushbu mavzuga alohida urg‘u berilmoqda. Hususan, O‘zbekiston Respublikasi Prezidentining 07.06.2019 yildagi PQ-4354-son qarorida “axborot va raqamli texnologiyalar rivojlanishi hamda zamonaviy umumjahon tendensiyalarni e’tiborga olgan holda axborot-kutubxona sohasini isloh qilishni jadallashtirish” jumlasi keltirib o‘tiladi[1].

Ushbu tadqiqot maqsadi axborot jamiyatida kutubxona mutaxassislarining raqamli kompetensiyasi dolzarbligi, raqamli kompetensiyani rivojlantirishning zamonaviy usul va yondashuvlarini xalqaro nazariy va amaliy tajribalar asosida tahlil etishdan iborat.

II. MAVZUGA OID ADABIYOTLAR TAHLILI

Raqamli kompetensiya-turli texnologiyalardan foydalanish qobiliyati, ularning tanqidiy va baholovchi jihatlarini tushunish, hamda mazmunni boshqarish va muloqot ko‘nikmalarini yaxshilash maqsadida texnologiyalardan ijodiy tarzda foydalanishni o‘z ichiga oladi (Freiman va boshq., 2017)[2]. Boshqa ta’riflarda raqamli texnologiyalar yordamida raqamli vazifalarni bajarish, kontentni boshqarish, yaratish va ulashish jarayonlarida zarur bo‘lgan bilim, ko‘nikma, munosabat, salohiyat va xabardorlik majmuasi sifatida ifodalangan (Khan & Bhatti, 2018; Martzoukou, Fulton, Kostagiolas & Lavranos, 2020)[3]. Eng so‘nggi ta’rifda esa raqamli texnologiyalardan xavfsiz, tanqidiy va ijodiy foydalanish – kundalik hayotda va jamiyatda faol ishtirok etish vositasi sifatida ta’riflangan (Sanches, 2022)[4].

Michal Cerny (2021)[5] “Kutubxona ta’limi talabalarining raqamli kompetensiyalari: 2018–2020 yillardagi tadqiqot natijalarini taqqoslash”, va Maria Borbely (2022)[6] “Jamoat kutubxonalarida raqamli kompetensiyalarni xaritalash 2019: Turli malakalarga ega kutubxona mutaxassislarining raqamli ko‘nikmalariga oid so‘rovnoma” mavzusidagi tadqiqotlarida DigComp modeli orqali kutubxona ta’limi talabalarining hamda jamoat kutubxonachilarining raqamli kompetensiya profilidagi o‘zgarishlari va darajalari aniqlangan.

Sarbada Pradhan, Avijit Rai (2023) “Kutubxona va axborot sohasi mutaxassislari uchun raqamli ko‘nikmalar: qisqacha tahlil” mavzusidagi tadqiqotida kutubxona va

axborotshunoslik mutaxassislarining raqamli salohiyati – ya’ni digital capability – nuqtai nazaridan tahlil qilinadi. Raqamli salohiyat tushunchasi, uning DigComp yoki JISC modellar kabi ramkalar asosidagi tarkibiy elementlari (masalan, axborot savodxonligi, raqamli ijod, hamkorlik, farovonlik) ko‘rib chiqiladi[7].

Eloy Rodrigues (2024)ga ko‘ra raqamli asrda ya’ni axborot texnologiyalari rivojlanib borayotgan dunyoda kutubxonachi ro‘llari va kutubxonachilik sohasidagi mutaxassislarga bo‘lgan talablar ham o‘zgarib bormoqda. Raqamli asrda kutubxona hodimlariga qanday malakalar kerak degan savolga olim quydagicha javob beradi: asosiy qadriyatlar tamoyillar, professional/axborot kutubxona fanlari kompetensiyalari, raqamli/texnologik kompetensiyalar, “soft skills”lar[8]. Bulardan texnologik/raqamli kompetensiyalarni esa quyidagicha tavsiflaydi:

6 ta asosiy elementlar:

✓ Raqamli malaka va samaradorlik (funksional ko‘nikmalar);

✓ Axborot, ma’lumot va media savodxonlik (tanqidiy foydalanish)

✓ Raqamli yaratuvchanlik, muammolarni hal eta bilish va innovatsiya (ijodiy mahsulot);

✓ Raqamli kommunikatsiya, hamkorlik va ishtirok etish (ishtirok etish);

✓ Raqamli o‘rganish va rivojlanish (rivojlanish);

✓ Raqamli shaxsiyat va farovonlik (o‘zi amalga oshirish);

Vaziyatni boshqarish uchun kutubxonachi mutaxassislari foydalanuvchi hamjamiyatini qondirish uchun juda zarur bo‘lgan muhim kompetensiyalar va albatta raqamli texnologiyalar bilan ishlash malakasiga, “soft skills”ga ega bo‘lishi kerak. Sababi, texnologiya kutubxona faoliyati va xizmatlarining barcha darajalariga kirib borgan, va har bir pozitsiyada xodimlardan minimum darajada bo‘lsada kompyuter texnologiyalaridan foydalana olishlikni talab etadi. Biroq, bu sohadagi muvaffaqiyat biz hozir bilgan bilimlarimizga kamroq bog‘liq, davom etayotgan o‘rganishga ya’ni uzluksiz ta’limga ko‘proq bog‘liq.

Kutubxona sohasida raqamli kompetensiyalar quyidagi yo‘nalishlarda muhim rol o‘ynaydi:

– **Axborot resurslarini raqamlashtirish va boshqarish;**

– **Elektron kataloglar va ma’lumotlar bazalari bilan ishlash;**

– **Onlayn foydalanuvchilarga xizmat ko‘rsatish;**

– **Raqamli savodxonlikni oshirish bo‘yicha foydalanuvchilarga ko‘maklashish;**

– **Ijtimoiy tarmoqlar, veb-saytlar va platformalarda axborot targ‘iboti.**

Raqamli texnologiyalarning jadal rivojlanishi sharoitida kutubxona mutaxassislari va talabalarining raqamli kompetensiyalari doimiy rivojlantirilishi kerak. Ularning ijodiy qobiliyatlari va ijtimoiy-aloqaviy ko‘nikmalari raqamli muhitda kutubxona xizmatlari sifatini oshirishga yordam beradi[9].

III. TADQIQOT METODOLOGIYASI

Mazkur tadqiqot ishida kutubxona mutaxassislarining raqamli kompetensiyasini nazariy va amaliy jihatdan o‘rganish uchun tahliliy-uslubiy hamda taqqoslov usulidan foydalanilgan bo‘lib, u orqali kutubxonachilik, axborotshunoslik sohalaridagi ilmiy adabiyotlar, xalqaro miqyosdagi tashkilot hujjatlari (masalan, ALA, SLA, IFLA, JISC tavsiyalari) asosida raqamli kompetensiyaning nazariy asoslari o‘rganildi hamda bir necha necha riovjlangan mamlakatlar tajribasi o‘rganilib O‘zbekiston sharoitiga mos jihatlar aniqlab chiqldi.

Axborot kutubxona tizimlari mutaxassislarini rivojlantirish uchun turli xalqaro miqyosdagi uyushmalar tomonidan o‘rnatilgan turli xildagi kompetentsiya turlari standartlari mavjud. Har bir kutubxona yoki tashkilot tuzilmasi, xussiyatlaridan kelib chiqib o‘z standartlarini taklif etadi. Masalan, Maxsus kutubxonalar assotsiatsiyasi (SLA), Amerika kutubxonalari assotsiatsiyasi (ALA), Onlayn kompyuter kutubxona markazi (OCLC), Kongress kutubxonasi, Tadqiqot kutubxonalarining Kanada Assotsasiyasi (CARL), Tadqiqot kutubxonalari assotsasiyasi (ARL) va yana ko‘plab xalqaro tashkilot, uyushmalar so‘nggi yillarda o‘zlarining standartlari asosida bir qator kompetensiyalarni taklif qildi. Quyida ularni ba’zilaridan namuna keltiriladi:

Kutubxonachilikning asosiy kompetensiyalari Amerika kutubxona assotsatsiyalari (ALA)ning yangilangan (2022) standartida [10] 9 bo‘lim ko‘rinishida quyidagi bandlarni o‘z ichiga olgan :

1.Boshlang‘ich (asosiy) kutubxonachilik bilimlari;

2.Axborot resurslari;

3.Umrbod ta’lim va uzluksiz malaka oshirish;

4.Boshqaruv va ma’muriy faoliyat;

5.Yozma bilim va axborotni tizimlashtirish;

6.Ma’lumotnoma va foydalanuvchilarga xizmat ko‘rsatish;

7.Tadqiqot va dalillarga asoslangan amaliyot;

8.Ijtimoiy adolat;

9.Texnologik bilim va ko‘nikmalar

Texnologik bilim va ko‘nikmalar bandi quyidagicha keng izoh etiladi:

9A. Kutubxona xizmatlari va resurslaridan foydalanish hamda ularni yetkazib berishni qo‘llab-quvvatlovchi tegishli texnologiyalar va ularning qo‘llanilish sohalarini aniqlash.

9B. Kutubxona xizmatlari va resurslariga texnologiyalarni qo‘llashda yuzaga keladigan **etika va madaniy qadriyatlar bilan bog‘liq omillarni tushunish va ularda yo‘nalish topa olish;** bu texnologiyalarning

kutubxona amaliyoti va jamoa a’zolariga ko‘rsatadigan ta’sirini inobatga olish.

9C. Mavjud va rivojlanib borayotgan texnologiyalarni muntazam ravishda baholab borish; ularning kutubxona xizmatlari va resurslariga ko‘rsatadigan ta’sirini **foydalanish imkoniyati, amaliyotda qo‘llanilishi, barqarorligi va samaradorligi n**uqtayi nazaridan tahlil qilish.

Birlashgan Qirollikning Qo‘shma Axborot Tizimlari Qo‘mitasi (JISC) raqamli kompetensiyani shakllantirish uchun **olti asosiy tarkibiy qismini** quyidagicha belgilagan:

1. **Raqamli bilim va unumdorlik (functional skills)** – texnologiyalar bilan samarali va ishonchli ishlash ko‘nikmalari;

2. **Axborot, ma’lumot va media savodxonligi (critical use)** – axborotni izlash, tahlil qilish va tanqidiy baholash;

3. **Raqamli ijodkorlik, muammolarni hal qilish va innovatsiya (creative production)** – yangi raqamli mahsulotlar yaratish va kreativ yondashuv;

4. **Raqamli muloqot, hamkorlik va ishtirok (participation)** – onlayn muloqot qilish, guruhda ishlash va raqamli jamiyatda faol qatnashish;

5. **Raqamli o‘rganish va rivojlanish (development)** – o‘z-o‘zini ta’limga yo‘naltirish, yangi raqamli vositalarni o‘zlashtirish;

6. **Raqamli identitet va raqamli farovonlik (self-actualizing) –** raqamli muhitda o‘z shaxsini tanitish, xavfsizlik va ruhiy salomatlikni saqlash[11].

OCLC kutubxonachilar uchun asosiy kompetensiya indeksi quyidagicha:

- Muhim kutubxona kompetensiyalari
- Kutubxona kolleksiyalari kompetensiyalari
- Kutubxona boshqaruvi kompetensiyalari
- Ommaviy xizmatlar kompetensiyalari
- Texnologik kompetensiyalar: tizimlar va IT

Kutubxonachi bilishi lozim bo‘lgan eng asosiy texnologik kompetensiyalar sifatida esa quyidagilar keltirilgan:

- Raqamli resurslarni tanlash, tashkil etish va saqlash;
- Tegishli metadata sxemalarini amalda qo‘llash (tasviriy, texnik, huquqiy metadata);
- Multimedia formatlarini tushunish va konvertatsiya vositalarini bilish;
- XML, XSLT, API, Unix, relational ma’lumotlar bazalari, METS va OAI kabi texnologiyalar bilan tanishlik;
- Semantic Web, scripting tillar (masalan, Python, Bash), veb nashr vositalari, va foydalanuvchi interfeyslarini yaratish va test qilish qobiliyatlari[12].

Xalqaro tashkilot, uyushmalar va kutubxonalarning standartlarini, hujjatlarini tahlil etish orqali bugungi kunda zamonaviy kutubxona mutaxassisining kasbiy, raqamli kompetensiyalarini nazariy asosini o‘rganishimiz mumkin. Rivojlangan axborot infratuzilmasiga ega davlatlar tajribasini o‘rganish orqali esa, mahalliy sharoitimizga mos amaliy yechimlarni ham aniqlab olishimiz mumkin.

IV. TADQIQOT NATIJALARI

Raqamli kompetensiyani rivojlantirish bo‘yicha nazariy va amaliy yondashuvlarni tahlil etish orqali bir necha mashhur raqamli kompetensiya modellari o‘rganildi. Bugungi kunda kutubxona mutaxassislari, pedagoglar, IT mutaxassislar va boshqa professional guruhlar uchun **raqamli ko‘nikmalarni rivojlantirish** va **baholash**da asosiy mezonlar sifatida qo‘llaniladigan bir necha mashhur kompetensiya modellari bor. Quyida jadval ko‘rinishida ularni ayrimlariga sharh keltiriladi:

JADVAL 1. RAQAMLI KOMPETENSIYA MODELLARI

№	Model	Asosiy sohalar	Afzalliklari
1	DigComp	5 soha, 21 kompetensiya, 4 darajaga taqsimlanadi	Keng qo‘llaniladi, aniqligi yuqori
2	UNESCO ICT-CFT	6 yo‘nalish, 18 kompetensiya , 3 bosqichli yondashuv	global ta’lim sohasi vakillari uchun mos, ta’limga yo‘naltirilgan
3	JISC	6 ta asosiy soha	Professional rivojlanishga qaratilgan Kutubxonachilar uchun dolzarb
4	ISTE	Raqamli fuqarolik va o‘rgatuvchi rollar	Ta’lim tizimiga chuqur integratsiyalashgan
5	Nordic	Aniq darajalar belgilanmagan. bilim, ko‘nikma va kompetensiyalarga e’tibor qaratilgan	Madaniy va axloqiy jihatlarni qamrab oladi Raqamli etikaga urg‘u beradi

Tahlillar shuni ko‘rsatadiki, kutubxona mutaxassislarining raqamli kompetensiyalarini doimiy riovjlantirib borish dolzarb mavzu va bu borada mavjud holatni, zamonaviy xorijiy tarjibani tahlil etish orqali respublikada yetishtirilayotgan soha mutaxassislarini raqobatbardosh kadrlar sifatida tayyorlashda amaliy usullar va yondashuvlardan foydalanishimiz mumkin. Qolaversa, tahlil natijasida mahalliy sharoitga mos raqamli

kompetensiya standartini, modelini ishlab chiqishimiz va amaliyotga joriy etishimiz mumkin bo‘ladi.

V. XULOSA VA AMALIY TAVSIYALAR

Xulosa qilib aytganda, Kutubxonachi kadrlarning kasbiy kompetensiyalari ularning ish joylaridagi profillarini aniqlab beradi. XXI asr zamonaviy dunyoda esa kutubxona mutaxassilarining raqamli kompetensiyaga ega bo‘lishlari naqadar muhim va zarur ekanligini ko‘rishimiz mumkin. Kutubxona mutaxassislarining raqamli kompetenisyalarini rivojlanitirish uchun esa rasmiy o‘quv dasturlari, o‘z-o‘zini o‘qitish, uzluksiz ta’lim, turli sohalardagi mutaxassislar bilan hamkorlik qilish va amaliy ish tajribasi orqali natijaga erishish mumkin. So‘nggi tendensiyalar, texnologiyalar va amaliyotlardan xabardor bo‘lib borish esa har bir soha mutaxassisi uchun zamonaviy kasbiy muhitda dolzarbdir. Mazkur xulosadan kelib chiqib quyidagi amaliy takliflarni ilgari surishimiz mumkin:

-Raqamli kompetensiyani rivojlantirish bo‘yicha uzluksiz kasbiy rivojlanish kurslarinii tashkil etish;

-Jahon tajribasiga tayangan holda, O‘zbekiston kutubxona sohasiga moslashtirilgan **raqamli kompetensiya modeli**ni ishlab chiqish va amaliyotga joriy etish;

-Soha mutaxassislarini zamonaviy texnologik vositalar bilan ishlashga tayyorlash (sun’iy intellect, raqamli katalog, turli xildagi axborot tizimlari bilan ishlash);

-Yetakchi xorijiy kutubxonalar, universitetlar va axborot markazlari bilan hamkorlikda seminarlar, amaliyotlar va treninglar tashkil etish, sohadagi yangiliklardan habardor bo‘lib boorish;

-Kutubxona foydalanuvchilari uchun qulay raqamli xizmatlarni joriy qilish orqali raqamli madaniyatni oshirish.

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ИННОВАЦИОН ЖАРАЁНЛАРНИ РИВОЖЛАНТИРИШДА ХОТИН ҚИЗЛАРНИНГ РОЛИНИ ОШИРИШ МАСАЛАЛАРИ

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Аёл –аёл эмас, рўзғор деган ғор ичида, оила деб аталган довулли , чақинли фасл ичида ҳамиша титраб турувчи, шунда ҳам муаттар буйларини сочавергувчи , тўрт томонга эгилиб букилавергувчи, аммо ҳеч синмагувчи бир гулдир. Аёл ўзининг асил баҳосини билмай ўтаётган буюкликдир.

Барчамиз оиламиз маънили ва қозонимиз ризқ насибали бўлиши учун илму ҳунар ўрганамиз. Оиланинг мукаммал ва мунаввар қилиш учун тонгдан кечгача ишлаймиз. Бир оилада муносиб бека бўлсин деб қизларни пишитамиз, ўқитамиз, чунки аёлнинг билими- онанинг билими, дунёқараши унинг болаларининг барча авлодларимизнинг дунёқарашидир.

Ўзбекистон республикамизнинг аёллари ҳаётнинг барча соҳаларида шу жумладан таълим – тарбия соҳаларида фаол иштирок этмокда. Улар келажаги буюк республикамизнинг аёлларига билдирилган юксак ишончга муносиб жавоб бериб, баркамол авлодни тарбиялашдаги асосий вазифани шараф билан адо этаяптилар. Зеро, ватанимизда фидоий, эл-юрт равнақи учун сидқидилдан меҳнат қилаётган хотин-қизлар кўпчиликни ташкил қилади.

Юртимизда аёлларга қаратилган юксак эътибор туфайли ёшларимизни ватанга муҳаббат фидоийлик руҳида тарбиялашда, уларнинг ғам-ташвишларига шерик бўлиб, орзу умидларини ушалишида, оғирини енгил қилишда, ёшларни келажакда ҳаётда муносиб ўринларини топишларида хотин қизларимиз бор куч ва ғайратларини бериб ишламокдалар.

Инновацион жараёнларни ривожлантиришда хотин кизларнинг роли муҳимлигини такидлаб машҳур маркетолог Дж. О’Шонессининг “...китоблар ҳеч қачон тажриба ўрнини боса олмайди деган фикрига қўшилиш мумкин. Маҳоратли ошпаз ошпазлик тўғрисида китоб ёзиши мумкин, уни тайёрлаш йўлига амал қилиб, худди шундай чиқишини кутмаслик керак, чунки унинг маҳорати билан таққослаб бўлмайди - берилган қоидани ишлатиб муҳим кўникма ва малакалар эга бўлиш мумкин эмас, улар фақат амалиётда эгалланади ва “қўлланиладиган донишмандлик” деб аталувчи амалиётли донишмандлик билан мустаҳкамланади, яъни вазият билан мувофиқликдаги донишимандлик шуни эсда сақлангки, қўлланиладиган донишмандлик китоб бўйича формуларни ўрганишда эмас, балки ҳақиқий ишни бажарганда ҳосил бўлади ”.

Педагогик амалиётда янги йўл ва воситаларини жадал татбиқ этилаётганлигини кузатиш мумкин. Бироқ баъзи таълим шакл ва фаол усуллар ўрнига бўлинмас таълимий технологиялар зарур. Лекин таълимий жараённи технологияли лойиҳалаштириш ва режалаштиришни, фақат технологик билим, кўникма ва малакаларга эга бўлган ўқитувчи бажара олиши мумкин

Ҳар бир инновацион жараёнларда ўқитувчи томонидан, у интилаётган, якуний натижага эришишга кўринарли қўшган ҳиссаси томони билан баҳоланиши зарур. Қоиданинг мақбуллигини талқин қила туриб, эътиборни нафақат унга, уни қўллашни назарда тутувчи вазият ёки шароитларга қаратиш зарур. Гап шундаки, қоидалар одатда формула эмас, бошқарув хусусиятга эга бўлади, мадомики уларни қўллаш мумкин бўлган, таълим жараёни шароитида айрим ноаниқликлар бор. Бундан ташқари, аввалда шу нарсани ўқув вазиятида қўллаб, муваффақиятга эришган ўқитувчи-амалиётчи ёки ҳаммага маълум бўлган таълим бериш технологиясининг муаллифида, шуни қоидасиз умумлаштиришдаги хатоликлар тарқалган. Моҳият шундаки, барча турли-туманликдан мавжуд шароитда ва ўқув режасида берилган вақтда кўзланаётган натижага эришишни кафолатли таъминлайдиган, сўнгра эса ундан шу шароит учун мос келадиган, таълим бериш технологиясининг - ягона мажмуини лойиҳалаштириш мумкин бўладиган, ахборот, мулоқот ва бошқарувнинг шундай йўл ва воситаларини баҳолаши, фарқлаши ва танлашни уддалаши муҳим.

В. Беспальконинг “Таълим жараёнини ихтиёрий қуриш ва амалга оширишдан, унинг ҳар бир қисм ва босқичларини изчил асосланган, якуний натижани ҳаққоний ташҳислашга йўналтирилган” га ўтиш учун асос зарур фикрини хисобга олмок лозим.

Агарда сиз инновацион таълим жараёнини технологиялаштиришга ўтиш муҳимлигини англамас экансиз, унда “биз янги технологияларнинг ютуғларини бермайлик, пайдо бўлган мунтазамлик механизмини чиқариб ташлай олмайди, ё бўлмаса

мажбур қилинган технологиялар зиёнли натижаларни кўпайтириши мумкин”.

Ниҳоят, машҳур Е.С. Полатнинг шахсий таълим бериш технологиясини лойиҳалаштириш ва мавжуд таълим бериш технологиясини қўллаш “ўқитувчи, вазият маданияти, шунингдек шахсий ёки талабаларнинг шахсий хусусиятлари билан юзма-юз келиш йўналиши билан иш тутмоғи керак”-лигини таъкидлаганлар.

Таълимни технологиялаштириш ғояси янгилик эмас. Бундан 400 йил аввал чех педагоги Ян Амос Коменский таълимни технологиялаштириш ғоясини илгари сурган. У таълимни “техникавий” қилишга ундаган, яъни ҳамма нарса нимага ўқитилса, муваффақиятга эга бўлсин. Натижага олиб келувчи ўқув жараёнини, у “дидактик машина” деб атаган.

Бундай дидактик машина учун аниқ қўйилган мақсадлар; бу мақсадларга эришиш учун, аниқ мослаштирилган воситалар; бу воситалар билан қандай фойдаланиш учун, аниқ қоидаларни топиш муҳимлигини ёзган.

Таълим назарияси ва амалиётида ўқув жараёнига технологик хусусиятни бериш учун 50-йилларда биринчи уринишлар қилиб кўрилган. Улар ўз ифодасини анъанавий ўқитиш учун мажмуали техник воситаларни яратишда топган.

Таълим берувчи вазифасининг ўзгариши: нафақат билим бериш, балки таълим олувчиларни уларни мустақил излаш, таҳлил қилиш, таққослаш, ўзгартиришга, ҳаётий муҳим вазифаларини ҳал этишда қўллаш, барча ҳаётий йўли давомида билимларини тезкор янгилаш ва тўлдиришни ўргатиш.

Бунинг учун ўқитувчи барча тўғри ечимларнинг биринчи тоифадаги намойишчиси бўлмасдан, балки ўқув жараёнининг ташкилотчиси, маслаҳатчиси ва назоратчиси бўлиши керак; билимларни етказишнинг кам самарали оғзаки йўлларини камайтиришга келтириш.

Таълимнинг жуфтлик ва гуруҳли ташкил қилиш шаклларини амалга ошириш орқали жараёнда диалог ва полилогда ўзгарувчан томонларда таълим олувчининг юқори фаоллигини таъминлаш; башоратлаш, режалаштириш ва ўқув-билиш фаолиятини ташкиллашатириш бўйича таълим олувчилар мустақил фаолиятини қўллаб-қувватлаш оозимлиги аёндир.

Муаммоли таълим ва уни амалга ошириш шартларига келсак унинг асосий назарий мазмуни бу таълим берувчини таълим олувчилар билан фаол ўзаро ҳаракатини ташкиллаштириш йўли бўлиб, бунда тақдим этилган муаммоли таълим мазмунини ечишда улар мунозара юритадилар, фикр юритишни ўрганадилар, билимларни ижодий ўзлаштирадилар, алоҳида фикрлашни, билимларни мустаҳкамлаш ва амалий фаолиятда ижодий қўллашни таъминладир.

Таълим олувчиларнинг шахсий интилишлари, билиш қизиқишларини шакллантиради, фикрлаш қобилиятларини ривожлантиради, таълим олувчиларнинг диалектик фикрлашини шакллантириш ва ривожлантиришига ёрдам беради.Амалга ошириш шартлари эса таълим олувчилар олдига тартибли ва мақсадга йўналтирилган муаммоларни илгари суриш, уларни таълим берувчи раҳбарлиги остида ҳал этиб, янги билимларни фаол ўзлаштирлари ва йўналиш бўйича мустақил ижодий билиш фаолиятини таъминлаш: муаммоли вазият → муаммони шакллантириш → уни ҳал этиш йўли → муаммони ечиш → ечимни текширишдир

Таълимга суҳбатли ёндашув ва уни амалга ошириш шартларининг асосий назарий мазмуни:Таълим жараёнини таълим берувчи ва таълим олувчи ўртасидаги суҳбатдек тузишни ифодалайди ҳамда дастурий фаолиятни ҳамкорликда тузишга йўналтирилган.

Шахсий ва фаолияти билан биргаликда инсонпарвар педагогиканинг методологияси моҳиятини ташкил этади. Уларни умумийликда қўллаш қуйидагиларни яратади: таълим жараёни иштирокчилари субъектларини психологик бирлиги ва ўзаро ҳаракати туфайли “объектли” таъсир этиш ижодий ўзаро ривожланиш ва ўзи ривожланиш жараёнига ўз ўрнини беради; таълим жараёни иштирокчилари эркинлигини ошириш;шахснинг ўзини - ўзи фаоллаштириши ва ўзини - ўзи амалга ошириши

Амалга ошириш шартида эса таълим берувчи вазифаси:таълим олувчилар билан тенг ҳуқуқли томонни ўрнатиши;шунчаки ўқитиш эмас, таълим олувчиларни ривожланишга, унинг ўзи ҳаракатланишига шароит яратишга рағбатлантириш;

- таълим олувчиларда мустақил фикрлаш, муаммони мустақил режалаштириш қобилиятини ва уни ечиш йўлларини таклиф этиш, олинган натижаларни баҳолаш ёки текширишга олинишига тайёргарликни шакллантириш.

Бунинг учун қуйидагиларни амалга ошириш зарур: вазиятли лойиҳалаш; фикр-изланишли суҳбат; ҳаётий муаммолар матнига ўқув топшириқларини киритиш; таълим олувчиларда мустақиллик, мустақил ўқиш, ўз тақдирини ўзи белгилашга, ўзини-ўзи амалга ошириш қобилиятларини ривожлантириш учун шароит яратишдир.

Хулоса килиб айтганда, бизлар бу жуда муҳим вазифаларни ўзимиз ўрнак бўлган ҳолда бажаришимиз лозимдир. Ўзбекистон Республикасининг биринчи Президентининг “Улуғ момоларимизга хос бўлган олижаноб фазилатлар бугун ҳам муҳтарама аёлларимиз сиймосида давом этиб келмокда” деганларида нечоғли ҳак эканликларини ҳаётда ўзимиз исботлашимиз лозимдир.

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АЁЛ СИРЛИ БИР КИТОБ. ИННОВАЦИОН ҒОЯЛАРНИ ҚЎЛЛАБ КУВВАТЛАШДАГИ АЁЛ ЎКИТУВЧИЛАРНИНГ РОЛИ

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Аннотация. **Юртимизнинг аёллари ҳаётнинг барча соҳаларида эркаклар билан баробар иштирок этмокдалар. Аёл сирли бир китоб, варақлаган саринг қизиқ хусусиятлари чиқаверади.**

Женщины нашего государство активно участвуют, работают во всех отраслях нашей жизны наровне с мужчинами. Женщины-это книга. Открывая её прочитаем все новые и новые страницы.

The women our state actively in all branch live alike with men. The woman-book. Opening her will read all new and new papers.

Калит сузлар. **Аёл, таълим- тарбия, юксалиш, салоҳият,манфаат,етуклик,маъсулятлилик,кадр**

Ўзим шу тоифадан бўлсамда, аёл иқлимини ҳайрат билан кузатаман. Оллоҳнинг бетакрор мўъжизаси у! Аёл сирли бир китоб, варақлаган саринг қизиқ хусусиятлари чиқаверади. Йил фасллари фақат тўртта бўлса аёлнинг эса минг битта фасли бор. Уни буткул тушуниб етган одам йўқ бу дунёда! Уни томоша қилиб зериккан инсон йўқдир ер юзида!

Уни иши тушмаган киши йўқ! Уни суймаган, у деб куймаган, ва .....бўлганича бўлмаган эркак зоти йўқ. Аёлни тушуниш ўзи бир илм. Бу илмга етишганлар қанча кўпайса, бахтли аёллар сони шунча кўпаяжакдир.

Аёл атрофдагиларидан катта харажат, улкан фидоийликни сўрамайди, унга меҳр билан тикилиб қўйсангиз ва "борлигингиз қандай яхши-я" деган лутфни астойдил айтиб қўйсангиз бўлди. Аёл чор тарафга меҳрини, меҳнатини, ҳуснини, жонини аямай сочиб боради, аммо ҳаргиз таъна қилмайди, қайтим сўрамайди. У бутун дунё унга мукофот тутиб турса қарамаслиги, унинг шаънига олтин ҳайкаллар ўрнатмасалар севинмаслиги мумкин. Унинг исми ва мижози аёл, унинг бахти ўша иқлимни асрай билишида. Тани жони соғ бўлса, олов ёқасида ўз ўчоги бошидан чакка ўтмагудай ўз бошпанаси , бир кафт бўлсада унга ненидир илиниб, унга интилиб эшикдан кириб келадиган турмуш ўртоғи, қиздир, ўғилдир, ёқасидан чирмашиб турадиган бир жон парчаси бор бўлса, аёлнинг вужудини тўлдириб, тиндириб турадиган бахти шу.

Юртимизнинг аёллари ҳаётнинг барча соҳаларида – ишлаб чиқариш, қишлоқ хўжалиги, тадбиркорлик, таълим –тарбия, тиббиёт, маданият ва санъат сохаларида фаол иштирок этмокда. Улар келажаги буюк Ўзбекистон республикамиз аёлларига билдирилган юксак ишончга муносиб жавоб бериб, баркамол авлодни тарбиялашдаги асосий вазифани шараф билан адо этаяптилар. Зеро, ватанимизда фидоий, эл-юрт равнақи учун сидқидилдан меҳнат қилаётган хотин-қизлар кўпчиликни ташкил қилади.

Ўзбекистон Республикаси Президентининг бир қатор қарорларида юқори малакали кадрлар тайёрлаш, илм фаннинг нуфузини ошириш, профессор ўқитувчиларнинг шарафли меҳнатини қадрлаш, кадрлар интеллектуал салоҳиятини мустахкамлаш, уни ташкиллаштириш ва бошқариш тизимини такомиллаштириш, Самарканд давлат университетнинг моддий-техника базасини тубдан яхшилаш, унинг хорижий давлатлардаги нуфузини кўтариш, иктидорли ёшларни илм-фанга жалб қилишга кенг йўл очиб бермоқда. Буюк файласуф Конфуций ва унинг издошлари инсон шахсининг мазмуни, моҳияти, шаклланиши ва ривожланишига доир қуйидаги қимматли фикрларни билдирганлар: "Инсондаги эзгулик манфатлар учун орттирилган фазилатдир. Хозирги инсон туғулишидан бошлаб фойда олишга интилади. Бу шунга олиб келадики, кишилар ўзаро рақобатлашадилар бир бирларига ён бермайдилар. Шунинг учун ҳам, тарбия йўли билан инсон табиатини ўзгартириш яратилган қоидалар асосида таълим бериб, уларни адолатлиликка ва маъсулятлиликка ўргатиш лозим".

Абу Наср Фаробий инсондаги хусусиятларни қуйидагича ифодалайди: "Хар бир инсон ўз табиати билан шундай тузулганки, у яшаш ва олий даражадаги етукликга эришмок учун кўп нарсаларга мўхтож бўлади, у бир ўзи бундай нарсаларни қўлга кирита олмайди, уларга эга бўлиш учун инсонлар жамоасига эхтиёж туғулади. Шу билан бирга инсон фикрловчи мавжудоддир. У кўрган ва эшитганларини ёдда сақлайди, тасаввурлаш қобилияти воситасида билимларни, маълумот ва ахборотларни таҳлил этади, умумлаштиради, бошқаларга узатади, билим ва

тажрибаларини такомиллаштиради, ўз мақсадлари, орзулари ва истакларини тасаввурлай олади. Табиатдаги мавжудодлар орасида инсонни энг кучли, энг ақлли ҳамда энг ёвуз ва маккор мавжудот деб асослашимиз мумкин. Агар инсондаги туйғулар ва ҳислар тўғри тарбияланган бўлса, «ҳазрати инсон» деб, нотўғри тарбияланган бўлса «шайтони лаъин» деб атаймиз. Бунда инсон яшаб улғайган ижтимоий муҳит муҳим роль уйнайди.

Самарқанд Давлат Университетининг олима аёллари ўз фаолиятларини ушбу карорларни-вазифаларни амалга ошириш уқув услубий, илмий тадқиқот ишларини иқтисодий-ижтимоий сохаларнинг муаммоларини ечиш, таҳсил олаётган ёшларга таълим–тарбия беришни (кийиниш маданиятига, яшаш тартибига, эътибор), юқори малакали мутахасисларни тайёрлашни янада юксалтириш, илм-фаннинг юксак чуққиларини эгаллашда зарур шарт шароитлар яратиш (кадрларни иш билан таъминлаш) ва такомиллаштириш билан биргаликда олиб бораётганлари, маърўзалар ва давра сўхбатлар ўтказиб турганлари таҳсинга лойикдир.

Умуман, ҳар қандай ҳолатда ҳам тушкунликка тушмасдан «мендан ҳам оғирроқ ҳолатга тушганлар борку», ютуқларга эришганларида эса «бундан ҳам юқорироқ ютуқларга эришиш мумкинку», «ким менга нима беради деб ўтирмасдан, нималар қила оламан» дея фикрлашга ва қатьий ниятлар билан, бор имкониятлардан тўғри фойдаланишга, атрофдаги фидоий, яхши, ҳалол инсонларга эргашишга ундай бошлаш лозим деб ўйлайман. Чунки бу методнинг натижаларини ўз фарзандларим, шогирдларим мисолида кўриб турибман.

Самарқанд Давлат Университети, механика-математика факультети ўқитувчилари бу вазифаларни амалга оширишда, ўз касбига содиқ ва ҳақиқий касбини севиши билиниб турибди. Математика аниқ ва чуқур фикрлаш, тинглай билиш ва ҳар турли натижалар чиқора билиш талаб қилинганлиги сабабли, бу факультетда ишлайдиган ва таълим олаётган талаба ва толибалар ҳар тарафлама камтар, одобли, меҳнаткаш, фидоий инсонлардир. Мен билан шуғулланган У.Ю.Жураева, М.Султонова, М.Журабоева, Х.Жумаев, Фаррух Турсунов, Фирдавс Турсунов, Х.Файзуллаев, Ш.Қаххоров, ... Д.Яхшибоевларнинг қатор чет элларда чиққан мақолалари,У.Ю.Жураева билан биргаликда: “Функция Қарлемана и задача Коши для полигармонических функций”-номли, LAP Ambert Academic Publishing нашриётида Германияда чоп этилган монографияси бу сўзларимнинг тасдиқидир.

Юртимизда ёшларга қаратилган юксак эътибор туфайли ёшларимизни ватанга муҳаббат фидоийлик руҳида тарбиялашда, уларнинг ғам-ташвишларига шерик бўлиб, орзу умидларини ушалишида, оғирини енгил қилишда, ёшларни келажакда ҳаётда муносиб ўринларини топишларида бор куч ва ғайратимизни бераётганимиз, Зулфия номидаги Давлат мукофотига “таълим йўналишида” совриндор қизим Умидахон Жураеванинг юксак минбардан туриб бутун мамлакатга баралла “Бир қизнинг бахтиёр бўлиши учун етарли ютуқларим илм фидоийси бўлган марҳум отажонимни руҳини шод айлаган бўлса, меҳрибон онажонимни юрагига қувват бағишлаган бўлса, мен ўзимни бахтиёр ҳисоблайман. Чунки мен фақат ўқиш жараёнида, берилган имкониятлардан фойдаланишга чин дилдан, бор кучим билан харакат қилдим. Бугун мени мукофотлаб отам ўрнига отамдек бошимни силаётган Юртбошимизга рахматлар айтаман” - деб хитоб қилганида, эришган қатор ютуқлари бунинг далилидир.

Аллома Жалолиддин Румий айтганларидек, инсон бу дунёга ейиш-ичиш, кийиниш ва беҳуда гапларни гапириб, умрни зое кетқазиш учун эмас, балки улуғвор эзгу вазифаларни бажариш учун келгандир.

Демак, бизлар бу жуда муҳим вазифани ўзимиз ўрнак бўлган ҳолда бажаришимиз лозимдир. Ўзбекистон Республикасининг биринчи Президентининг “Улуғ момоларимизга хос бўлган олижаноб фазилатлар бугун ҳам муҳтарама аёлларимиз сиймосида давом этиб келмокда” деганларида нечоғли ҳак эканликларини ҳаётнинг ўзи исботлаб турибди.

Хулоса килиб айтганда, инсоннинг аҳлокий принциплари умрнинг маъносини қандай тушинишга хам боғликдир. Ўз умрининг маъносини тўғри тушуниб олган ва унга мувофиқ яшаган киши аҳлокий мангулик касб этади, чунки у жамият ичида, ўзи тарбиялаган кишилар сиймосида ҳамда дадиллик билан илгари сурган ғояларида мангу яшайди. Шандор Петефе айтганидек, буюк инсонлар яратган асарлари улар илгари сурган ғояларнинг қабри бўлса ажаб эрмас.

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ICT IN TEACHING A FOREIGN LANGUAGE: FROM THE TRADITIONAL METHOD TO THE VIRTUAL LEARNING ENVIRONMENT

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Abstract **- The article is devoted to the role of information and communication technologies (ICT) in learning, including foreign language, which is becoming more important. Traditional method (the textbook), which has been the main teaching tool for many decades, gives way to electronic and other information and educational resources.**

Index Terms **- ICT, traditional method (the textbook), elearning tools, ICT applications, pedagogical design.**

I. INTRODUCTION

In the era of universal informatization, the role of information and communication technologies (ICT) in learning, including foreign language is becoming more and more important. Traditional the textbook, which has been the main teaching tool for many decades, gives way to electronic and other information and educational resources.

There are many factors that determine orientation modern education system to build the educational process on ICT base. One of them is the rapidly increasing number of Internet users both in the world as a whole and in Uzbekistan. Such popularity of the Internet and computer technologies and among youth, and in society as a whole has created serious prerequisites for successful integration of ICT into the educational process, since it is impossible ignore the fact that technology is deeply embedded in everyday life the life of both today's students and professionals continuing study in order to improve their professional skills.

The increased level of technical equipment in educational institutions in Uzbekistan is an additional factor in the introduction of ICT. It is impossible to mention such a motivational factor as an intensification of the process of informatization of education as an introduction educational standards of the third generation, in which information and communication competence or media competence, in the formulation of some researchers, is included in the number as professional and universal instrumental and system competencies of trainees.

Undoubtedly the wide selection of e-learning tools and almost unlimited possibilities, which provide teaching any discipline in higher school, and a foreign language in particular. Among the most popular educational tools can be mentioned:

- hypertext, which creates a system of crossreferencing in text arrays of information;
- multimedia tools that allow you to record and transmit audio and video files.

As an example, it is worth mentioning podcasts that help a foreign language teacher to develop listening skills and speaking.

- Hypermedia, making it possible to combine hypertext that creates cross-referencing system, and multimedia;
- CD-ROM technology, which allows storage of significant volumes information in the form of text, video, audio and graphic files, widely used as applications to modern textbooks and providing students with additional tasks on reading, listening, working with grammar, phonetic and lexical material;
- wiki technologies that allow you to create websites of various content and purpose.

The wiki framework provides the ability to persist editing site content, adding files of any type, with using hyperlinks to audio and video resources. The unprecedented popularity of wiki products forces specialists to the field of ICT to talk about the socalled "wikisation" of virtual space as one of the latest trends in the development of modern training software.

In the arsenal of a foreign language teacher today, and such "Innovations" like

computer training and test programs;

- electronic libraries;
- dictionaries, text and video glosses used in teaching students in professionally oriented vocabulary and professionally oriented reading;
- telecommunication technologies that provide an opportunity to participate in the dialogue through audio and video conferences cultures.

At the present stage of ICT development, the most popular product is educational shells that allow you to combine advantages of many technologies within one resource. Built on the Moodle, eFront and other platforms,

they provide the possibility of placing educational material in the form of electronic textbooks, audio, video, graphic files, system use hyperlinks; using a variety of tests to control knowledge and the ability of students to keep track of the academic achievements of students in the network.

Experts in the rapidly developing field today computational linguodidactics note the following advantages use of ICT in the framework of educational shells. First of all, it is the possibility of individualizing the educational process. The student can choose your educational route and follow it at a convenient at the pace, and also, if necessary, return to the studied material. Another important advantage is the mobility of the course, so as thanks to the presence in the e-mail system and the forum at teachers and students have the opportunity to carry out the reverse communication, including consultations at any time convenient for them, which allows use study time more effectively. It should be noted and the authenticity of the teaching material used. Thanks to the use of network technologies, authentic text, audio and video resources in the course, it is possible to create a foreign language environment. Other benefits often cited in the literature are affordability and a variety of educational material, a variety of approaches and techniques, interactivity and convenient tools for managing educational process.

However, the analysis used by educational institutions resources shows that sometimes such a

variety of new tools turns into just a technology fair. The question of efficiency the use of ICT in the educational process in terms of learning objectives worries today both many researchers and educational practitioners. Consider examples of the use of ICT in teaching practice foreign languages. Let's start with an electronic textbook.

One of the leading motivational factors for the transition from the traditional textbook for electronic resources is its "aging". Given the rapidity of knowledge renewal, the training material is hard copy cannot withstand competition with its electronic counterparts due to the complexity and duration of the process its creation. Nowadays popular electronic textbooks based on based on wiki technology, not only do not require large cash investments and timeconsuming, but also absolutely mobile. Study material can be constantly update, using various types of visibility, which is an additional motivating factor for the trainees.

Another disadvantage of the traditional textbook is the lack of personalization of the process of acquiring knowledge, feedback between "Teacher" and "student", and most importantly, the nature of the presentation of information one-way broadcast of educational material. Generation of modern students accustomed to active interpersonal communication with other users in chats and social networks, where constant feedback, and where everyone is not only "Consumer", but also the creator of "news", is aimed at educational process of a different nature. However, does it satisfy electronic textbook to modern requirements that meet the challenges time?

Analysis of the use of electronic textbooks, used in training both autonomously and within the virtual learning environment shows that, despite the innovative nature the resource itself, the methods of working with it remain the same. Students it is suggested to read the textbook remember the information and reproduce it by answering the questions posed to the text. Thus, the way of presenting and assimilating educational material differs little from traditional. It is necessary to state the fact that educational the portals of many universities educational material is presented mainly in the form of electronic textbooks with traditional methodological accompaniment.

In the same way, use in foreign language classes podcasts or vodcasts (video podcasts) for the purpose of teaching listening does not differ significantly with the use of traditional audio files with the same teaching purpose, in addition to the unconditional attractiveness of the first for students and, therefore, some kind of motivational potential. Another example of the application of technology for the sake of technology itself, is a situation when, in the process of learning new vocabulary in a language classroom, the teacher strongly encourages students to use not a traditional paper dictionary, but an electronic one.

With the help of certain technologies, one can quite successfully develop a particular language skill. For example, in addition to already mentioned wikis, the development of writing skills can significantly promote the regular use of blogging or plain text editor, and a tool such as a CD-ROM helps to optimize the process of forming lexical and grammatical skills [6].

However, the goal of modern education based on competence-based approach to learning is the formation and development of a range of competencies, which are understood as a set of knowledge, skills and abilities formed in the process learning a particular discipline, as well as the ability to perform certain activities based on the acquired knowledge, skills and skills. Based on certain competencies, life experience and values, the competence of the individual as a whole is formed, which is a personal property and manifests itself in the ability to effectively solve problems and tasks that arise in real situations everyday life [1]. It is obvious that with the help of separate technologies, even if they are used within the framework of the training shells, it is impossible to form any separate "instrumental" competence, let alone a competent person, since the latter assumes that a person has a deeply conscious understanding of goals their educational activities, ways to achieve them, the characteristics of their learning style, ability to predict possible problems and paths their solutions, the presence of critical thinking, motivation to learn. It is reflection, self-esteem that is the most important educational skills and the necessary basis for mastering the content of training and acquisition of a foreign language professional communicative competence, which is the goal of teaching foreign language communication. Therefore, the use of ICT in education is effective only if technologies are applied within a certain model training, developed taking into account the tasks to be solved, the specifics of

the trainees, their needs, learning conditions. Only with the right choice computer technologies corresponding to this model, the educational process will be truly innovative, will expand educational opportunities, allow you to individualize and differentiate learning, increase student motivation and create conditions for selfeducation and self-improvement throughout life (lifelong learning).

Models of the organization of the learning process based on the training shell

An effective educational process depends on a number of factors, and one of the most important is the way in which structure and content of the course. Modern Western experts in areas of education use the term "pedagogical design" to indicate methods, principles and approaches to design, structuring and filling of the educational course on ICT base [4].

Thanks to the development of technology and the active introduction of training in based on these technologies, there is an increase in attention to the problem of methodological support of this format of training (e-learning) [3]. At the same time, an importance becomes not only teaching methodology, but also systematization learning process.

Traditional modern method of teaching a foreign language, applicable for classroom teaching is communication in nature. On the basis of the communicative cycle is the concept of "creating a situation, characterized by a lack of information” (creating an information gap). Hence, a communicative approach to content development and the structure of the course reflects the following stages: involvement of students in context of communication that is meaningful for them (creation of this context), identification of already known information and determination of specific "Information gap", familiarity with language and speech material relevant to the solution of a given communication task, direct practice of communication, return to the original situations in a given context.

The teacher focuses on this cycle and develops a plan classes, taking into account all the components of the communicative approach. Modern textbooks for foreign students language, also have a structure and tasks of a communicative orientation, which allows the teacher to effectively conduct a lesson on the basis of modern textbook.

Shifting the focus of teaching to independent work of students, implies an increase in the number of hours of extracurricular work. Often, a foreign language course is supported by a course of study in ICT base. At the same time, the most common uses ICT in education is the use of a range of ICT tools based on different platforms or using one training platform, which allows you to integrate a number of ICT applications on its basis.

The first option has the following advantages and disadvantages. Constantly updated ICT applications, more and more of them advanced level of functionality and design, essential increase student motivation and bring an element of novelty in almost every class. Moreover, some software apps are perfect for developing a foreign language vocabulary and literacy of students, allow work with authentic text, audio and video resources. With another hand, the constant emphasis on the use of new technologies is shifting focus of teaching from the subject to the ICT component. Sometimes created the impression that students are not mastering speech skills and abilities, but improve their computer skills.

Work on the basis of one platform, a single training shell, allows you not to distract students from their main task - to get new knowledge and recycle it. At the same time, all embedded ICT applications will only be of an auxiliary nature, serving the process learning. The learning shell due to its functionality and structure allows for the learning process. The learning process in in this case there is a certain cyclicality and sequence stages of learning, through which the student goes during training.

However, the introduction of a unified learning platform requires taking into account a number of features. The teacher must understand that direct transfer the traditional format of teaching in the classroom in a virtual environment is not possible without losing the quality of training. Benefits of onsite training ICTs such as accessibility, flexibility, perceptual efficiency, teachers often reduce mainly to creative design, graphics and animation of your course. It is important not just to place the material course in a virtual environment, but you need to create a sequence, which will allow the student to go through all the stages of mastering new skills and skills that are subordinate to the overall goal of this course.

When designing an ICT-based course structure, the teacher should be aware of the fact that learning is an ongoing process. Autonomy and the mobility of the modern student is not born by itself, the data qualities are inculcated through systematic work on this area. Therefore, one of the modern requirements for the content and structure of the course based on ICT is the application of certain educational technologies that will enable students to efficiently and independently master knowledge, i.e. "Teach to learn."

The course content must be effective and dynamic, and includes three main components: directly the information that the student must master, the methodology introducing this information for successful learning, ICT resources, which serve to achieve the goal of learning [5], [8].

In conclusion, it is important to note that training based on ICT technologies opens up new horizons for the teacher, therefore, the competence in the field of pedagogical design is becoming one of the most important competencies of a modern specialist in the field of education. Where in the evolution of ICT opportunities is not about the growth of software provision for the educational process, and in a competent methodological design of dynamic content and ICT-based course structure.

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THE ROLE OF DIGITAL COMPETENCIES IN THE PROCESS OF LEARNING INFORMATION AND LIBRARY PROFESSIONALS

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***Abstract*—The article analyzes world experience in creating a new paradigm in the development of information and library education in the digital age. It is proposed to use intellectual educational technologies in teaching information and library disciplines, taking into account the analysis of information and analytical competencies, which can change the quality of the process of training highly qualified specialists for information and library institutions of the republic.**

Keywords—Information and analytical competence, intellectual educational technologies.

I. INTRODUCTION

In the Concept for the Development of the Higher Education System of the Republic of Uzbekistan until 2030, in the paragraph “Introduction of digital technologies and modern methods into the educational process”, in order to introduce digital technologies and modern methods into the educational process, the following activities are proposed: the use of “cloud technologies” in educational processes [1].

Purpose of the research. Implementation of intellectual educational technologies in information and library education, taking into account the analysis of information and analytical competence of future specialists.

II. MATERIALS AND METHODS

Methodology of the research. The conducted terminological analysis allowed us to reveal the essence of the information competence of a library specialist - this is a professionally significant personality trait, manifested in the ability to effectively solve social and professional problems using information and communication technologies, improve one's skills in the field of information technology, and adapt professional knowledge to the changing conditions of the information society.

Research methods:

- analysis of pedagogical and specialized literature on the research problem;
- the method of terminological analysis (for the introduction into the research of the concepts of competence and information-analytical competence, hypothesis, theoretical modeling)

Empirical methods: included and remote observation, individual and group conversations; questionnaires, the method of expert assessments, rating methods, interviewing, testing; pedagogical experiment, including ascertaining, forming and control stages; statistical processing of the results.

As a system, information competence includes tasks, functions, properties, has its own characteristics and structure.

The tasks are:

- enrichment with knowledge and skills from the field of informatics and information and communication technologies;
- development of communicative, intellectual abilities;
- implementation of an interactive dialogue in a single information space.

The functions include:

- normative-legal (indicators of achievements and development; it manifests itself as a system of moral norms, norms of a legal nature, which must be followed in the information society);
- epistemological (aimed at the systematization of knowledge, knowledge of the surrounding reality and self-knowledge by a person of himself);
- communicative (ensuring communication in the information society);
- adaptive (adaptation to the conditions of the information society);
- evaluative (assessment of the significance, usefulness of information, etc.);
- developing (formation of an active life position, independence, self-realization on the basis of a certain system of knowledge and norms adopted in the information society).

Properties have the following properties:

- dualism - the presence of an objective (external assessment of information competence by society) and subjective (internal - self-assessment of one's information competence by an individual) parties;

- relativity - knowledge and knowledge bases quickly become obsolete, so they can be considered as new only in a conditionally defined space-time interval;
- structuredness - each person has his own specially organized knowledge bases, hierarchically ordered into a certain system of knowledge about information, its types, properties, functions and methods of working with it, using information technologies in professional activities;
- accumulativeness - knowledge and knowledge bases tend to "accumulate" over time; newly incoming knowledge is built into existing arrays;
- selectivity - there is a selection of knowledge according to the principle of usefulness, the possibility of practical use in professional activities;
- dynamism - implies that a specialist does not have a significant amount of knowledge, but the ability to constantly update, update at the right time and use them in the process of professional activity;
- integrativity - manifested in the relationship with the socio-cultural environment of a librarian and the development of society as a whole;
- polyfunctionality - the presence of a variety of subject-specific knowledge bases (the semantic component of knowledge bases is multifunctional) allows you to perform many functions that are a factor in the success of the professional development of a librarian.

The peculiarity is that information competence is manifested in:

- self-renewal, application of new forms and ways of meeting the information needs of subjects, adapting information competence to changing conditions;
- self-development, complication of structural, functional and organizational parameters of the entire system of information competence;
- deepening the specialization of individual elements and the level of their interconnectedness and interaction with each other [5].

Researchers of the Continuing Education Laboratory of the National Research University Higher School of Economics, presented the results of the analysis of Russian and foreign recruiting companies. They compared the requirements that are contained in the vacancies for library specialists from analytical databases. In the US, a librarian is an IT specialist. In the group of digital skills of the competence profile of an American librarian, knowledge of 3D printing, statistics, application testing, Big Data, layout, digital curating, SMM, digital and information literacy.

American employers focus on knowledge-intensive and high-tech skills that affect the main areas of activity of a modern specialist: creating libraries and library systems at the national level, participating in consortiums, and developing global perspectives. There is an increased demand for competencies related to working with clients, holding events [15].

Many scientists dealt with the problem of formation of competencies and competence of specialists. The works of John Raven, Emeritus Professor at the University of Edinburgh, are widely known in the field of diagnostics and research of competence, its assessment and implementation [10]. Of no less interest are the studies of Lyle and Sine Spencer, who developed methods for assessing competence and predicting the results of the work of specialists based on competencies [12]. Also widely known are the works of Edmund Short, who considered competence as a macro concept and identified four approaches to its decoding [11].

A number of scientists consider information competence as a component of the professional competence of a specialist, they noted the interdependence of computer literacy and professional competence, defining this interaction as a special information literacy, which is updated at the professional level. Information competence reflects different levels of professionalism of the individual, his professional development as a relatively new socio-cultural phenomenon, which is fixed in the regulatory requirements for a modern specialist [8].

Based on the analysis of discussions in the literature, it can be concluded that the library of the future should evolve into an innovative, intellectual "Library 4.0." In this model, the system will autonomously analyze information and provide users with actionable insights [9]. The role of information and library specialists will become increasingly critical in achieving this vision. Therefore, training for Librarian 4.0 and 5D bibliographers must be prioritized in the near future, particularly in light of the growing intellectualization of information and communication technologies (ICT) [13].

The evolution of Library 4.0 is closely tied to advancements in web technologies (Web 2.0, 3.0, and 4.0) [14], as well as shifting user preferences and reader needs. A library that can adapt to the specific needs of its local community is more likely to be viewed as successful and relevant [9].

Key Components of Library 4.0 Development

The development of Library 4.0 involves several key processes and features:

Intellectual Library: A system capable of analyzing and synthesizing information to provide users with meaningful conclusions.

Makerspaces: Spaces where users can bring ideas to life using modern technologies such as 3D printers, robotics, video game development tools, e-books, and other creative projects.

Context-Aware Technology: Systems that analyze user behavior and interests, enabling the library to adapt its services to changing conditions. This technology allows libraries to recognize users and offer personalized services to both new and existing patrons.

Big Data: Leveraging large datasets to improve services, understand user needs, and enhance decision-making.

Open Source Software: Utilizing open-source tools and platforms to promote flexibility, collaboration, and innovation.

Cloud Services: Employing cloud-based solutions to enhance accessibility, storage, and sharing of resources.

Augmented Reality and Modern Displays: Integrating advanced technologies like augmented reality and interactive displays to create immersive and engaging user experiences.

Librarian 4.0: A new generation of librarians equipped with advanced skills in ICT, data analysis, and user engagement to support the evolving needs of Library 4.0.[18].

In summary, Library 4.0 represents a transformative shift toward a more intelligent, adaptive, and community-focused library model, driven by cutting-edge technologies and the expertise of next-generation library professionals [16].

The author of the article, based on foreign experience, his own pedagogical experience, observations, student surveys and interviews with teachers, developed a model and matrix of information and analytical competencies, which included the relevant functional features of Library 4.0. Each lesson, during the research period, was conducted using elements of digital technologies and artificial intelligence tools, which brought attractiveness to conducting theoretical and practical classes, as well as increased the level of perception of educational material by students. The results of the study confirmed our assumptions about the effectiveness of the experimental methodological package in the training of future information and library specialists.

From one side, the competencies needed by librarians and information professionals can be categorized into six key domains: IT skills, traditional librarianship skills, skills to create value, including research and decision-making skills, transferable and soft skills, communication, management, leadership, learning and coaching, and teamwork skills, appropriate attitude, values and personal qualities, knowledge in the subject area.

From another, research outlines the essential skills for the modern librarian, often referred to as Librarian 2.0. These skills are grouped into seven themes: technology; training and education; research or evidence-based practice; communication; collaboration and teamwork; user orientation; business savvy and personal qualities.

Both frameworks emphasize a blend of technical expertise, traditional librarianship skills, and interpersonal abilities, reflecting the evolving role of librarians in adapting to technological advancements and user-oriented service.

Professional competencies are directly tied to the tasks and operations performed within a specific profession, such as cataloguing, classification, reference services, archiving, and similar activities. On the other hand, personal or transferable skills are more intrinsic and individual in nature, encompassing abilities such as analytical and critical thinking, effective communication, initiative, and a sense of responsibility. These skills complement professional competencies and enable individuals to perform their roles more effectively. In essence, they are auxiliary skills that interact with professional expertise to enhance job performance [14].

The literature highlights that personal or general competencies are often referred to using various terms, such as transferable skills, general skills, alumni abilities, or core competencies. These terms emphasize the universal applicability of such skills across different roles and contexts, underscoring their importance in supporting professional success and adaptability.

III. RESULTS AND DISCUSSION

Studies indicate that the librarianship market increasingly values personal or soft skills, such as technological proficiency, research capabilities, analytical and critical thinking, and effective communication, over purely professional or technical skills. In today’s rapidly evolving digital, cultural, and economic landscape, librarians and information professionals are expected to be versatile, multitasking individuals with a combination of high IQ and EQ They must possess a diverse skill set to adapt to complex and dynamic environments, essentially becoming "multi-talented jacks of all trades".

While it may not be feasible for a single individual to master all these competencies, the specific skills required often depend on the type of organization and the context in which the librarian or information professional (LIP) works. To be effective, LIP should be equipped with at least a subset of these skills, tailored to the demands of their role and environment.

In dissertation work [8] proposed an alternative vision of the structure of information competence of a library specialist, which includes three components: cognitive, activity-creative and personal-motivational. The percentage distribution by the number of competencies (20% - cognitive component, 65% - activity-creative, 15% - value-motivational) corresponds to the general principle of practice orientation in the credit-modular system of higher professional education [8].

Monitoring of academic groups in the undergraduate direction "Library and Information Activities" of TUIT named after Muhammad al-Khwarizmi among students in the undergraduate direction "Library and Information Activities" (60-3rd year students and 50-4th year students) showed effectiveness (about 36% of average scores, about 28% of high scores) of the competency-based approach in the credit-module system of education and training of future library specialists compared to the traditional (academic) form of education (about 34% of average scores and about 18% of high scores) added optimism to continue active introduction into the learning path of information - analytical competencies, taking into account the processes of intellectualization of ICT.

On the other hand, diagnostics of the level of information and analytical competence of library specialists of the city information and library system made it possible to identify problem areas in the constituent components of information competence:

Thus, it can be argued that library and information specialists of a new qualification level are gradually

acquiring new competencies. They become experts, consultants on the principles of creation, preservation, distribution, management of electronic information resources (EIR) and technological means.

The research results obtained using the competency-based approach and the Case-study method have shown their viability thanks to the implementation of digital learning tools in the educational process, which can be divided into the following types:

- educational software tools, the methodological purpose of which is to communicate the sum of knowledge and skills of educational and practical activities and ensure the necessary level of assimilation established by feedback implemented by means of software systems (lms.tuit.uz; xn.tuit.uz);
- software tools - simulators designed for practicing skills, educational activities, self-training, they are usually used when repeating or consolidating previously covered material (ILS: IRBIS, ARMAT++, UzNel, DSpase, Omeka);
- programs designed to monitor the level of mastery of educational material - monitoring software (lms.tuit.uz; xn.tuit.uz);
- information-search, information-reference software tools that provide the ability to select and display the information necessary for the user. Their methodological purpose is to develop skills in systematizing information (analytical platforms Scopus, Web of Science, ProQuest);
- simulation software that provides a certain aspect of reality for studying its main structural or functional characteristics using a certain limited number of ILS parameters;
- modelling software tools of arbitrary composition, providing the learner with the basic elements and types of functions for modelling a certain reality. They are intended to create a model of an object, phenomenon, process or situation for the purpose of studying them, studying ILS;
- demonstration software that provides a visual representation of educational material, visualization of the studied phenomena, processes and relationships between ILS objects;

Before the start of the pedagogical experiment, the academic groups were divided into control (CG) and experimental groups (EG) respondents, who showed the following results: excellent - 12% and 14%, good - 44% and 43%, satisfactory - 36% and 32%, unsatisfactory - 8% and 11%. In the experimental group, a competency-based approach was implemented using the Case-study method.

At the end of the pedagogical experiment, the academic groups showed the following results: excellent - 14% and 21%, good - 48% and 52%, satisfactory - 32% and 25%, unsatisfactory - 6% and 2%.

Students have increased interest in digital educational technologies and understanding of the need to acquire new competencies for future professional activities.

Instructional Design. The main emphasis in pedagogical design was on the use of information and communication competencies and the development of future library specialists’ professional interest in innovations of digital technologies in the educational process (multimedia resources, collaborative navigation and design, work with analytical platforms, work with automated library and information systems (LIS)), work with educational platforms (moodle.tuit.uz, lms.tuit.uz, xn.tuit.uz), work with distance learning tools, development of an industry digital library, etc.).

An example of one lesson. During the start of the design, students completed a survey (google.doc), where they showed the level of awareness about information and communication technologies used in libraries and the information and analytical competence required by a modern library specialist.

After this, training in the subject “Information and Analytical Products and Services” was offered using the Case-study method (Case: Scopus is considered by many to be the main competitor of the Web of Science database for citation analysis and journal ranking statistics. The Scopus website states, that the database is "the largest abstract and reference database of peer-reviewed literature and quality web sources using intelligent tools to track, analyze and visualize research." It has more international coverage than web science, and the Scopus interface is simple and intuitive). Next comes the introduction and study of the case by students using information and reference resources. The teacher advises students working in small groups using digital analytical platforms Scopus and WoS, an electronic board, a computer and tablets. Then there is a discussion of the optimality criteria for the proposed options (projector, electronic board). The final part of the lesson: presentation of each group’s case (computer, tablets, smartphones, electronic board), tests on the subject and test results (lms.tuit.uz, google.doc, Kahoot).

Innovations in development:

- application of blended learning in the educational process in the training of library personnel using ILS;
- using the Case-study method with digital learning innovations (Zoom, Kahoot, ILS, platforms: Scopus, WoS, Springer);
- development of cases based on real professional scenarios using intelligent ICT

Problems that were solved:

- students’ cognitive interest in innovative digital teaching methods has increased,
- the psychological barrier when working with digital technologies was overcome, new knowledge and skills were acquired in using software and hardware devices in the educational process,
- a number of digital innovative technologies used in real library practice have been implemented into the educational process

(development of joint Biblio-Pro projects, technologies of the Library 4.0 concept, electronic cataloguing, work with cloud technologies, RFID technologies in libraries).

Current status and general planning of the project:

- currently the preparation of educational and methodological materials, software, databases for working conditions in Smart Class is underway;
- the experience of innovative work is expanding for the use of intelligent ICT in other educational subjects;
- an analysis of the lessons conducted is carried out for further dissemination of this experience to other courses;
- development of a new ILS with elements of intellectualization of data search in databases is underway;
- the possibility of using the Case-study method using digital technologies for advanced training courses for library workers is being considered.
- Project implementation timeline:
- preparation of syllabuses for courses - 1 month;
- preparation of cases of laboratory work using ILS - 3-4 months;
- preparation of practical training cases using ILS – 3-4 months;
- development and preparation of a textbook and teaching aid for the courses: “Information and analytical products and services” (in Uzbek, undergraduate); “World Information Resources” (in Uzbek, master’s degree) – 3-4 years per unit;
- analysis of results – 1 month;
- reports – 1 month.
- The uniqueness of digital technologies and key features of the project:
- use of ILS for students to simulate real production situations in the classroom - cases (with open and closed code);
- the opportunity for students to remotely create electronic resources (electronic libraries, electronic catalogs, full-text information databases, etc.);
- studying a special course based on the Case-study method using digital systems of learning process controllers and intelligent ICT (lms.tuit.uz, xn.tuit.uz, ILS, Kahoot);
- overcoming the psychological barrier among students and teachers in using digital learning tools in the classroom;
- increasing the qualification level of digital competence of teachers;
- quick adaptation of graduates to real work in information and library institutions;
- final qualification work is carried out on a specific production base and using digital technologies (ILS: with open and closed codes).

Summing up the preliminary results of the conducted research, we can state the following: the use of an educational experimental methodological complex in the educational process has improved the quality of the educational process and the final scores based on the results of student testing. This may later affect the process of improving information and analytical competence and the general training of highly qualified information and library specialists.

IV. Conclusions

In foreign libraries, there is currently a tendency to single out information learning as an independent direction. You can even see it in the job titles. So, employees who are directly involved in the reference service in the "request-response" mode are called "reference librarians", and employees who train users are "educators". And if earlier informational training of users to search for information was mainly characteristic of academic libraries (university libraries), where it was integrated into training programs as independent courses, now the range of libraries offering training services is expanding, for example, due to public libraries.

At present, the need for user training is determined not only by well-known factors (the educational mission of libraries, the need for users to adapt to the information environment, the obligatory library orientation and bibliographic training), but also by general trends in the development of the information society.

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OLIY TA’LIM SAMARADORLIGINI OSHIRISHDA DUAL TA’LIM TIZIMIDAN FOYDALANISH MODELI

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***Abstract*— Maqola O‘zbekistonda malakali mutaxassislarni tayyorlashning dolzarbligiga bag‘ishlangan. An’anaviy oliy ta’limdagi nazariya-amaliyot farqi, bitiruvchilarning ishsizligi va ularning ish beruvchilar talabiga javob bermasligi kabi muammolarni hal qilish uchun Germaniya dual ta’lim tajribasini o‘rganish taklif etiladi. Ushbu tizim ta’lim muassasasi va korxonaning kadr tayyorlashdagi qo‘shma hamkorligiga asoslanadi. Tadqiqotda dual ta’limning afzalliklari va uni O‘zbekistonda joriy etishdagi to‘siqlar (me’yoriy bazaning yetishmasligi, moliyalashtirish muammolari) tahlil qilinadi. Muallif ushbu tizimni bosqichma-bosqich joriy etish bo‘yicha takliflar ishlab chiqadi va uning mamlakatning iqtisodiy rivojlanishida hal qiluvchi ahamiyatga ega ekanligini ta’kidlaydi.**

***Keywords*—Oliy ta’lim tashkiloti, dual ta’lim.**

XXI. KIRISH

Malakali mutaxasislarni shakllantirish masalasi mamlakatimizni rivojlantirish, modernizatsiya qilish va yuqori samarali ish o‘rinlarini yaratishda asosiy masala bo‘lib qolmoqda. Bu masala oliy ta’lim tizimiga alohida mas’uliyat yuklaydi. Malakali kadrlarning yetishmovchiligi ko‘plab sohalarning iqtisodiy rivojlanishining cheklanishiga asosiy sabab bo‘layotganligi hech kimga sir emas. Malakali kadrlarni yetishtirish bu qaysidir alohida tizimning korporativ vazifasi emas, balki umummilliy masala bo‘lib, bundan ko‘plab sohalar, ta’lim tizimi va ish beruvchilar ham manfaatdor.

Zamon talablarining o‘zgarishi ananaviy oliy ta’limi tizimida bir qancha kamchiliklar mavjud ekanligini ko‘rsatib qo‘ydi. Ushbu kamchiliklarga:

- Aksariyat hollarda nazariy ta’limning amaliyotdan uzilganligi;
- Oliy ta’lim muassasasi (OTM) bitiruvchilarning mutaxasisligi bo‘yicha ishga joylashish darajasining pastligi;
- OTM bitiruvchilarining mutaxassislik yo‘nalishi bo‘yicha kerakli bilimlarni olishda yetarli motivatsiyaning mavjud bo‘lmaganligi natijasida bitiruvchilar orasida malakali kadrlar darajasining kamligi;
- Aksariyat xollarda yetishtirilgan kadrlarning ish beruvchi talablariga to‘liq javob bera olmasligi

Mavjud muammolarning yechimini tez fursatlarda aniqlashning dolzarbligi, yuqori malakali kadrlarni yetishtirish orqali iqtisodiy, ijtimoiy va ilmiy sohalarda katta yutuqlarga erishgan mamlakatlarning tan olingan tizimlarini o‘rganishni taqozo etadi. Bunday tizim sifatida “ishchi kuch sifatini monitoring qilish xalqaro instituti” tomonidan yuqori malakali kadrlarni tayyorlash bo‘yicha yetakchi davlatlardan biri deb tan olingan Germaniya federatsiyasining dual ta’lim tizimini o‘rganish maqsadga muvofiq.

XXII. ASOSIY QISM

Dual ta’lim – ta’lim jarayonida qisman ish bilan band bo‘lib, korxonada amaliyot o‘tash jarayonining ta’lim muassasasi nazariy darslari bilan uyg‘unlashgan tizimiga aytiladi. [1, 3]. Bunda oliy ta’lim muassasasi korxona talabi va shartlariga ko‘ra talabaga nazariy bilimlarni beradi, korxona esa o‘z navbatida talabaga aniq bir tor soha bo‘yicha amaliy bilimlar va ish bilan ta’minlab boradi.

Dual ta’lim tizimi ta’limning ikki mustaqil tashkiliy-huquqiy a’zolarining o‘zaro hamkorligini nazarda tutadi. [4]. Bunda oliy ta’limdan manfaatdor bo‘lgan tizimning ikki a’zosi, ya’ni OTM va ish beruvchi korxona, yagona maqsad – malakali kadrni shakllantirish uchun birgalikda faoliya olib boradi. Bunday tizim murakkab, ammo shaffof strukturaga ega. (1-rasm.) [5]

Dual ta’lim tizimi tashkiliy jixatdan vazifalarning aniq taqsimotini talab etadi. Bunda asosiy asosiy vazifani ish beruvchi korxona bajaradi. Korxona xar bir talaba bilan shartnoma tuzadi, ta’lim xarajatlarini qoplaydi va korxonada ish va amaliyot bilan ta’minlaydi. Bundan tashqari korxona talabaning o‘qish jarayonini va erishayotgan yutuqlarini nazorat qilib boradi, chunki aynan u talaba qobiliyatlaridan manfaatdor tomon hisoblanadi. OTMning asosiy vazifasi esa ish beruvchining talabiga ko‘ra kerakli nazariy bilimlarni berib borishdan iborat.

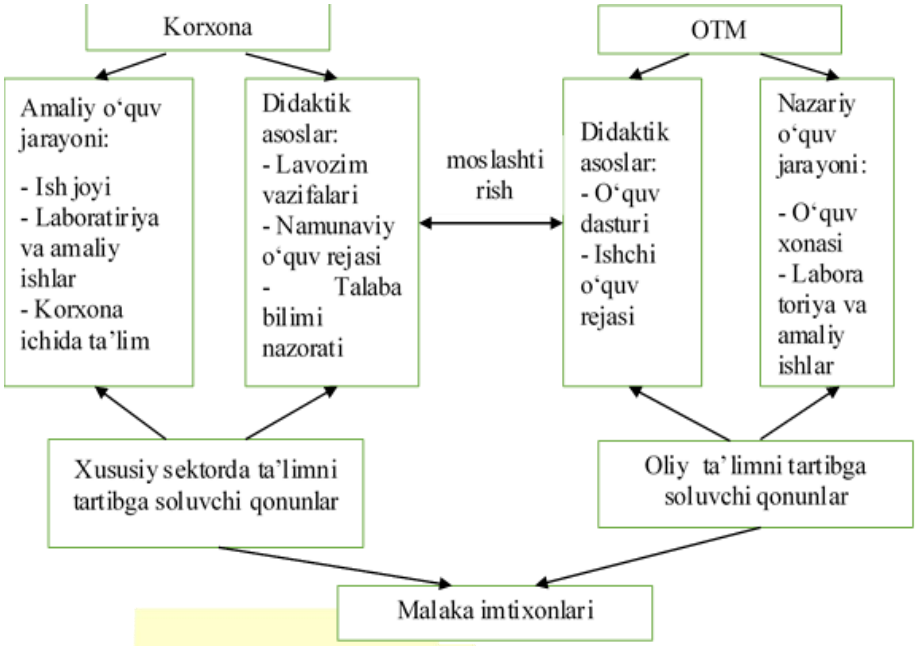

Fig. 1. Y. Myunx (1984) taklif etgan Germaniya dual ta’limi tizimi

Joriy etilgan tizim tahlili natijasida dual ta’lim tizimining bir qancha afzalliklarini aniqlash mumkin bo‘ladi. Dual ta’lim tizimining afzalliklari:

- Bitiruvchilarning barchasi ish bilan ta’minlanadi.
- Nazariy ta’lim bilan amaliy qism bir birini to‘ldirib boradi.
- OTM ish beruvchi istak va xohishlaridan kelib chiqqan holda kadrlarni yetkazib beradi.
- Ta’lim jarayoni korxonadagi real ish jarayonini o‘z ichiga oladi va talaba korxona talablariga to‘liq javob beradi.
- Ixtiyoriy korxona, hatto kichik bir firma, tor sohadagi malakali kadrga ega bo‘la oladi.
- Talaba o‘z kelajagini aniq tasavvur vila oladi, natijada unda bilim olish motivatsiyasi kuchayadi.
- Dunyoning yetakchi davlatlari tomonidan eng ilg‘or ta’lim texnologtyasi deb tan olingan.

Albatta chet el tajribasini ko‘chirib to‘g‘ridan – to‘g‘ri mamlakatimizda joriy etishning imkoniyati yo‘q. Bunda mamlakatimiz milliy ta’lim tizimi va ish beruvchilarning qarashlarini inobatga olishimiz lozim. Ushbu sharoitda dual ta’lim tizimini O‘zbekiston oliy ta’limi tizimiga joriy etishda bir qancha to‘siqlar vujudga kelishi mumkin.

Birinchidan ishlab chiqaruvchi korxonalar va xususiy sektor (firma va tashkilotlar) hududida ta’lim berish jarayonini tartibga soluvchi me’yoriy xujjatlar mavjud emas;

Ikkinchidan ishlab qiqaruvchi korxonalar va xususiy sektor raxbariyat vakillarining o‘z hududida talim jarayonini tashkillashtirib berishga qarshilik qilishi ehtimoli mavjud;

Uchinchidan O‘zbekiston Respublikasida ta’lim tizimi asosan davlat tomonidan moliyalashtiriladi. Dual ta’lim tizimi esa kadrga talabgor korxonaning kadr o‘qishini moliyalashtirishini taqozo etadi. Bu anana chet el korxonalari uchun odatiy hol bo‘lishiga qaramay mahalliy korxonalar bunday xarajatlardan bosh tortishi mumkin.

Yuqoridagilarni hisobga olib dual ta’lim tizimini O‘zbekiston ta’lim tizimiga joriy etish jarayonini ikki bosqichda amalga oshirish maqsadga muvofiq bo‘ladi.

Birinchi bosqichda dual ta’lim tizimini joriy etish bo‘yicha me’yoriy-huquqiy xujjatlarni ishlab chiqishni va OTM tashabbuskorligiga asoslangan model asosida dual ta’limni joriy etish nazarda tutiladi:

Ikkinchi bosqichda ushbu tizim samaradorligi yaqqol namoyon bo‘lishi bilan malakali kadrlarni yetkazib berish talabi bilan korxonalar OTMga murojaat etishi, korxona tashabbusiga asoslangan dual ta’lim tizimini joriy etishga turtki bo‘ladi.

YAKUNIY XULOSALAR

Malakali kadrlarni yetkazib berish bugungi kunda OTMlarga qo‘yilgan asosiy talab bo‘lib kelmoqda. Texnologiyalarning jadal rivojlanishi, chet el korxonalarinig kirib kelishi, mahalliy korxonalar va xizmat ko‘rasatish sektorlarining zamonaviy texnika vositalar va usullardan foydalanishlari OTM bitiruvchilariga yangicha talablarning qo‘yilishiga sabab bo‘lmoqda. Bunday jadal o‘zgaruvchan mehnat bozorida statik (bir xil namunada) kadrlarni yetishtirish samarasizligi isbotladi. Bunday sharoitda har bir ish beruvchi uchun o‘ziga mos kadr yetkazish barcha sohalarning rivojlanish kaliti hisoblanadi. Bunda moslashuvchan ta’lim tizimlarini, jumladan, dual ta’lim tizimini joriy etish zaruriyati tug‘ildi. Oliy ta’lim tizimida dual ta’limning joriy etilishi O‘zbekiston Respublikasi rivojlanishini yangi bosqichga olib chiqadi.

Fig. 2. Dual ta’lim tizimining taklif etilgan modeli

FOYDALANILGAN ADABIYOTLAR RO‘YXATI

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ПРОГРЕССИВНОЕ РАЗВИТИЕ АКАДЕМИЧЕСКОГО ОБРАЗОВАНИЯ УЗБЕКИСТАНА

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Аннотация **- В статье рассматриваются современные тенденции прогрессивного развития академического образования в Республике Узбекистан. Отмечается значимость проводимых реформ в сфере высшего и среднего специального образования, направленных на повышение качества подготовки специалистов, внедрение международных образовательных стандартов и развитие научно-исследовательской деятельности. Подчеркивается роль цифровизации, интеграции инновационных технологий и расширения международного сотрудничества в формировании конкурентоспособной образовательной системы. Особое внимание уделено задачам по обеспечению академической мобильности студентов и преподавателей, созданию условий для раскрытия научного потенциала молодежи, а также укреплению связей между образовательными учреждениями и рынком труда. Таким образом, прогрессивное развитие академического образования в Узбекистане рассматривается как стратегический фактор устойчивого социально-экономического развития страны.**

Ключевые слова: **академическое образование, Узбекистан, реформы, инновации, цифровизация, международное сотрудничество, академическая мобильность, подготовка специалистов, научный потенциал, устойчивое развитие.**

XXIII. Введение

Современное развитие общества и экономики Узбекистана требует подготовки специалистов, способных эффективно работать в условиях глобальной конкуренции и цифровой трансформации. В этих условиях инновационное развитие системы высшего образования становится приоритетным направлением государственной политики.

За последние годы в Узбекистане проведён ряд масштабных реформ, направленных на модернизацию высшей школы. Важными ориентирами стали:

-расширение академической автономии вузов;

-внедрение международных образовательных стандартов;

-открытие филиалов ведущих зарубежных университетов

-развитие системы двойных дипломов и академической мобильности.

Государственные программы по развитию науки и образования стимулируют интеграцию университетов с производственными и исследовательскими центрами, что создаёт условия для подготовки кадров нового поколения.

Одним из ключевых направлений инновационного развития является цифровизация. В вузах внедряются:

-платформы дистанционного и смешанного обучения;

-электронные библиотеки и базы данных научных публикаций;

-автоматизированные системы управления образовательным процессом.

XXIV. Развитие EdTech-платформ способствует повышению доступности образования, особенно для студентов из регионов.

В последние годы Узбекистан активно реализует реформы, направленные на развитие научного потенциала и внедрение инноваций в ключевых сферах экономики и образования. Основное внимание уделяется созданию благоприятной экосистемы для научных исследований, цифровизации науки, развитию научных кластеров и международному сотрудничеству.

Основными направлениями инноваций в научных исследованиях являются:

1. **Создание научно-инновационных кластеров.** При ведущих вузах и НИИ открываются центры трансфера технологий, технопарки и лаборатории, обеспечивающие внедрение научных разработок в производство.
2. **Цифровизация науки.** Формируется электронная база научных публикаций, внедряются системы «open access» и

цифровые платформы для управления исследованиями.

3. **Государственные гранты и поддержка.** Финансирование фундаментальных и прикладных исследований растёт, расширяются конкурсы для молодых учёных.
4. **Международные проекты.** Вузы и научные центры Узбекистана участвуют в программах Horizon Europe, Erasmus+, Tempus, а также двусторонних исследовательских проектах с Китаем, Южной Кореей, Россией и Германией.
5. **Коммерциализация науки.** Внедряются механизмы стартап-поддержки, инновационные ярмарки, венчурные фонды для вывода научных идей на рынок

Таблица 1. Инновации в научных исследованиях Узбекистана (2018–2023 гг.)

Направление	2018	2020	2023	Прогноз 2025
Научные публикации (Scopus)	2 100	4 500	7 800	10 000+
Технопарки и центры инноваций	5	12	20	30
Государственные гранты (млрд сум)	120	250	500	700
Международные проекты	15	35	60+	80+
Стартапы при вузах	10	25	50+	80+

111. Международное сотрудничество Важным фактором инновационного развития является расширение международного сотрудничества. Вузы Узбекистана активно участвуют в программах Erasmus+, TEMPUS и других международных проектах. Это способствует обмену опытом, внедрению передовых образовательных методик и повышению конкурентоспособности выпускников на мировом рынке труда.

Эти процессы способствуют:

- обмену студентами и преподавателями;
- внедрению передовых образовательных методик;
- развитию программ двойных дипломов;
- повышению конкурентоспособности выпускников на мировом рынке труда.

Таблица 1. Формы международного сотрудничества вузов Узбекистана

Направление	Примеры	Эффект
Erasmus+, TEMPUS	Более 50 проектов с 2017 г.	Академическая мобильность
Двойные дипломы	Совместные программы с Россией, Европой, Азией	Увеличение качества подготовки
Зарубежные филиалы	30+ филиалов в Ташкенте и регионах	Доступ к мировым стандартам
Научные проекты	Совместные исследования (энергетика, IT, медицина)	Публикации и гранты

В условиях глобализации международное сотрудничество становится важнейшим инструментом модернизации системы высшего образования Узбекистана. Оно способствует обмену опытом, внедрению передовых образовательных технологий, повышению качества подготовки кадров и укреплению позиций вузов страны на мировом образовательном рынке.

Основными направлениями сотрудничества являются:

1. **Программы академической мобильности.** Участие в Erasmus+, Tempus, Mevlana и других международных инициативах обеспечивает студентам и преподавателям возможность обучения и стажировок за рубежом.
2. **Двойные дипломы.** Реализуются совместные программы с университетами России, Великобритании, Южной Кореи, Японии и Китая.
3. **Филиалы зарубежных университетов.** На сегодняшний день в Узбекистане функционирует более 30 филиалов ведущих вузов мира (Вестминстерский университет, Туринский политехнический университет, филиалы МГУ, МИФИ, Плехановского университета и др.).
4. **Совместные научные проекты.** Вузы страны участвуют в международных исследованиях в области энергетики, IT, медицины, аграрных наук.
5. **Участие в международных ассоциациях.** Расширяется сотрудничество с Европейской ассоциацией университетов, Ассоциацией университетов Азии и другими организациями.

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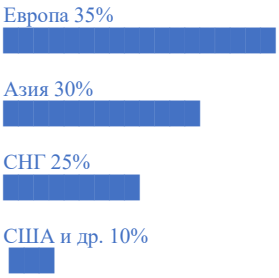

Диаграмма 1. География международного сотрудничества вузов Узбекистана (2023 г.)

1. Erasmus+/TEMPUS 40%

Диаграмма. Распределение направлений сотрудничества (2023 г.)

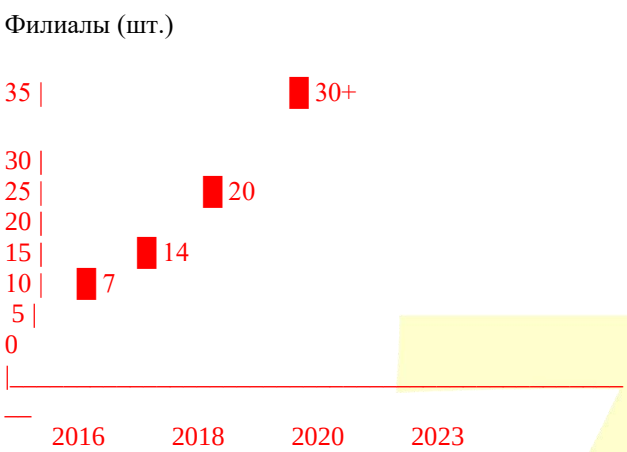

Диаграмма 4. Рост количества филиалов зарубежных университетов в Узбекистане (2016–2023 гг.)

В условиях глобализации международное сотрудничество становится важнейшим инструментом модернизации системы высшего образования Узбекистана. Оно способствует обмену опытом, внедрению передовых образовательных технологий, повышению качества подготовки кадров и укреплению позиций вузов страны на мировом образовательном рынке.

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2. **Двойные дипломы.** Реализуются совместные программы с университетами России, Великобритании, Южной Кореи, Японии и Китая.
3. **Филиалы зарубежных университетов.** На сегодняшний день в Узбекистане функционирует более 30 филиалов ведущих вузов мира (Вестминстерский университет, Туринский политехнический университет, филиалы МГУ, МИФИ, Плехановского университета и др.).
4. **Совместные научные проекты.** Вузы страны участвуют в международных исследованиях в области энергетики, IT, медицины, аграрных наук.
5. **Участие в международных ассоциациях.** Расширяется сотрудничество с Европейской ассоциацией университетов, Ассоциацией университетов Азии и другими организациями.

XXV. Заключение

Инновационное развитие высшего образования Узбекистана направлено на формирование конкурентоспособной системы, способной готовить специалистов мирового уровня. Реформы, цифровизация, научные исследования и международное сотрудничество делают университеты страны ключевыми драйверами социально-экономического прогресса.

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ЦИФРОВАЯ ТРАНСФОРМАЦИЯ И МЕДИАКОМПЕТЕНТНОСТЬ УЧАСТНИКОВ ОБРАЗОВАТЕЛЬНОГО ПРОЦЕССА

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Аннотация. **В условиях цифровой трансформации образования ключевыми задачами становятся формирование медиакомпетентности и обеспечение медиабезопасности субъектов образовательного процесса. Анализ теоретических основ и практических подходов к развитию медиаграмотности и навыков безопасного использования цифровой среды в рамках непрерывного профессионального образования. Исследование охватывает постановку проблемы, существующие методологии и обзор современных научных исследований, а также предлагает пути решения, направленные на повышение качества медиа подготовки будущих специалистов.**

Ключевые слова: **медиакомпетентность, медиабезопасность, непрерывная профессиональная подготовка, цифровая образовательная среда, информационная культура, цифровая трансформация образования, медиаобразование.**

Abstract. **In the context of the digital transformation of education, the key tasks are the formation of media competence and ensuring the media security of subjects of the educational process. The analysis of the theoretical foundations and practical approaches to the development of media literacy and skills of safe use of the digital environment in the framework of continuing professional education. The study covers the problem statement, existing methodologies and a review of modern scientific research, as well as suggests solutions aimed at improving the quality of media training for future specialists.**

Keywords: **media competence, media security, continuous professional training, digital educational environment, information culture, digital transformation of education, media education**

Современное образование переживает этап глубокой цифровой трансформации, связанной с внедрением информационно-коммуникационных технологий, цифровых сервисов и онлайн-платформ. Эти изменения затрагивают все уровни образовательного процесса — от школьного обучения до системы высшего образования и непрерывной профессиональной подготовки. В новых условиях ключевым фактором успешной адаптации становится медиакомпетентность участников образовательного процесса, определяющая умение использовать цифровые ресурсы, критически оценивать информацию и взаимодействовать в медиасреде.

Развитие цифровых технологий привело к значительным изменениям в системе образования, сделав информационно-коммуникационные технологии неотъемлемой частью учебного процесса. Вместе с тем рост объема информации и распространение социальных медиа поставили вопрос о медиабезопасности и критическом восприятии контента. В этих условиях формирование медиакомпетентности, способности эффективно использовать медиа, анализировать и оценивать информацию, создавать собственные медиапродукты становится ключевым условием подготовки современного специалиста [1].

Основная проблема заключается в том, что уровень медиаграмотности и медиабезопасности большинства субъектов образовательного процесса недостаточен для эффективной работы в условиях цифровой экономики. Отсутствие систематического подхода к формированию медиакомпетентности, а также методик, учитывающих специфику непрерывного профессионального образования, приводит к рискам манипуляции информацией, киберугрозам и снижению качества подготовки специалистов [2].

Проблема формирования медиакомпетентности особенно значима в эпоху информационной перегруженности и активного распространения дезинформации. Учителя, преподаватели и студенты должны обладать не только техническими навыками работы с цифровыми инструментами, но и развитыми компетенциями медиабезопасности, критического мышления и цифровой этики. Без этих умений полноценная интеграция цифровых технологий в образование становится затруднительной, а эффективность обучения снижается.

Кроме того, цифровая трансформация требует переосмысления образовательных стратегий и методик. Традиционные формы подачи материала уступают место интерактивным платформам, мультимедийным ресурсам и адаптивным образовательным системам. Это требует от педагогов новых подходов к разработке учебного контента, а от студентов умения работать в условиях информационной многозадачности. В этих условиях медиакомпетентность становится не дополнительным, а базовым условием образовательной деятельности.

В научной литературе медиакомпетентность рассматривается как интегративное качество личности, включающее когнитивный, технологический, коммуникативный и этический компоненты. Исследования последних лет показывают, что для формирования медиаграмотности необходимо сочетание теоретической подготовки, практических кейсов и инструментов цифровой педагогики. Вместе с тем проблема медиабезопасности в образовательной среде исследована фрагментарно, что требует комплексного подхода к ее решению [3].

Современная цифровая образовательная среда предъявляет новые требования к педагогам, студентам и управленцам в сфере образования. Одной из ключевых компетенций становится медиакомпетентность, способность эффективно работать с медиа информацией, критически оценивать её достоверность и безопасно использовать цифровые ресурсы. Вместе с тем резко возрастает значимость медиабезопасности, связанной с защитой от деструктивного контента, киберугроз и манипулятивных технологий[3,4].

Медиакомпетентность рассматривается как интегративная характеристика личности, включающая информационную, технологическую, критическую и коммуникативную грамотность. Она формируется в процессе профессиональной подготовки и совершенствуется в течение всей жизни, что особенно важно для педагогов и специалистов, работающих с большим массивом информации и современных цифровых инструментов.

Обеспечение медиабезопасности включает формирование у субъектов образовательного процесса знаний и навыков по киберзащите, умению противостоять фейковой информации и информационным манипуляциям, а также развитие этических и правовых аспектов цифровой культуры. Для этого необходимы специализированные курсы, тренинги и образовательные программы, ориентированные на цифровую гигиену и безопасное медиаповедение [5].

Одним из основных вызовов является информационная перегруженность, распространение недостоверных данных и растущая зависимость от социальных сетей. Педагоги и учащиеся нередко испытывают трудности в критическом осмыслении медиаинформации, что приводит к снижению качества образования и формированию искаженной картины мира. Поэтому развитие медиакомпетентности и медиабезопасности следует рассматривать как взаимосвязанные направления образовательной политики [6].

Непрерывная профессиональная подготовка должна включать систематическое обновление знаний, использование онлайн-курсов, вебинаров, интерактивных платформ и виртуальных симуляторов. Это позволит педагогам и студентам оперативно адаптироваться к технологическим нововведениям, осваивать инструменты анализа и фильтрации медиаинформации, формировать культуру ответственного и безопасного медиапотребления.

Для успешного формирования медиакомпетентности и медиабезопасности необходима интеграция данных направлений в образовательные стандарты, разработка научно обоснованных методик и создание единой цифровой экосистемы. Важную роль играет сотрудничество образовательных учреждений с IT-компаниями и центрами цифровой безопасности, что позволит сочетать академическую подготовку с практическими навыками и формировать цифровую культуру у всех участников образовательного процесса [7].

Формирование медиакомпетентности включает несколько этапов: от базовой цифровой грамотности к профессиональной медиа подготовке и критическому мышлению. Для обеспечения медиабезопасности разрабатываются программы кибер гигиены, алгоритмы защиты персональных данных и системы мониторинга информационных рисков. Важным аспектом является подготовка педагогов, способных интегрировать медиаобразование в учебный процесс на всех уровнях.

Для решения обозначенной проблемы предлагаются следующие меры:

- разработка модульных программ медиакомпетентности для студентов и преподавателей;
- внедрение курсов по медиабезопасности в программы повышения квалификации;
- создание цифровых лабораторий и медиаклубов для практической работы с медиа;
- использование симуляторов киберугроз для формирования навыков защиты информации;
- сотрудничество с ИТ-компаниями для внедрения современных технологий анализа медиа-рисков.

В условиях цифровой трансформации образования формирование медиакомпетентности и обеспечение медиабезопасности субъектов образовательного процесса становятся приоритетными задачами системы непрерывной профессиональной подготовки. Проведенный анализ показал, что медиакомпетентность выступает ключевым элементом информационной культуры, позволяющим не только эффективно работать с медиа информацией, но и обеспечивать безопасность в цифровой среде.

Для успешной реализации данных задач необходимо интегрировать программы

медиаграмотности в образовательные стандарты, разрабатывать специализированные курсы и тренинги, использовать онлайн-ресурсы и интерактивные платформы. Особое внимание должно уделяться формированию критического мышления, навыков киберзащиты и медиакультуры, что обеспечит всестороннюю готовность педагогов и студентов к вызовам цифровой эпохи.

Перспективы дальнейших исследований связаны с разработкой инновационных методик медиаобразования, оценкой уровня медиакомпетентности педагогических кадров и созданием комплексной модели цифровой безопасности образовательной среды.

Таким образом, медиакомпетентность участников образовательного процесса выступает важнейшей составляющей цифровой трансформации образования. Она обеспечивает не только успешное освоение новых технологий, но и формирование культуры ответственного и безопасного использования цифровых ресурсов.

В дальнейшем развитие медиакомпетентности должно рассматриваться как стратегическое направление образовательной политики. Только системный подход к формированию цифровых навыков, медиабезопасности и критического восприятия информации позволит обеспечить гармоничное встраивание образовательной системы в цифровую эпоху.

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RAQAMLI MUHANDISLIK GRAFIKASINI DASTURIY TA‘LIMDA ORTOGONAL PROEKTSIYALARNI AMALGA OSHIRISH

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Abstrakt: Maqolada uch o‘lchovli fazoda nuqtaning ortogonal proyeksiyalarini o‘rganish uchun interfaol modulning ishlab chiqilishi ko‘rsatilgan. Modul Flutter platformasida amalga oshiriladi va koordinatalarni o‘zgartirish algoritmlarini, proyeksiyani vizualizatsiya qilishni va foydalanuvchi kiritishning aniqligini baholashni o‘z ichiga oladi. Ilmiy yangilik Evklid masofasiga asoslangan xato ko‘rsatkichini amalga oshirish bilan interfaol ta'lim usullarini qo‘llashdadir. GOST 2.305-68 ga muvofiq ortogonal proyeksiyaning matematik asoslanishi, shuningdek, tavsiya etilgan yondashuvning samaradorligi tahlili keltirilgan. Natijalar muhandislik ta'limi uchun mobil ilovalardan foydalanish imkoniyatlarini ko‘rsatadi.

Kalit so‘zlar: ortogonal proyeksiya, interfaol ta’lim, Flutter, geometrik modellashtirish, proyeksiya matritsasi.

Orfografik proyeksiya muhandislik grafikasi va kompyuter modellashtirishda asosiy tushunchadir. To‘rtburchaklar proyeksiya tizimi uch o‘lchovli ob'ekt va uning ikki o‘lchovli tasvirlari o‘rtasidagi birma-bir yozishmalarni ta'minlaydi. Biroq, ushbu mavzu bo‘yicha an'anaviy o‘qitish usullari vizualizatsiyaning etarli emasligi muammosiga duch kelmoqda.

Zamonaviy tadqiqotlar (Smit va boshq., 2021; Zhang & Vang, 2022) interaktiv tizimlar fazoviy kontseptsiyani o‘zlashtirish samaradorligini 40-60% ga oshirishini ko‘rsatadi.

Foley va boshqalar. (1996) o‘zlarining fundamental ishlarida kompyuter grafikasi algoritmlarining asosi bo‘lgan 3D ob'ektlarni proyeksiyalash uchun matritsali transformatsiyalarni tavsiflaydilar. Mualliflar ortogonal proyeksiyalar muhandislik dasturlari uchun juda muhim bo‘lgan chiziqlar parallelligini saqlab qolishini isbotlaydilar.

1. Ortogonal proyeksiyaning klassik asoslari

- Muhandislik grafikasida ko‘rinishlar, bo‘limlar va bo‘limlarni qurish qoidalari. Ivanov A.V ishida. (2018), ESKD standartlari evolyutsiyasi tahlili o‘tkazildi, unda chizmalarni bir ma'noda talqin qilish uchun ortogonal proektsiyalarning ahamiyati ta'kidlangan.

- Foley va van Dammning fundamental ishlarida (Foley va boshq., 1996) kompyuter grafikasi algoritmlarining asosi bo‘lgan 3D ob'ektlarni proyeksiyalash uchun matritsali transformatsiyalar tasvirlangan. Mualliflar ortogonal proyeksiyalar muhandislik dasturlari uchun juda muhim bo‘lgan chiziqlar parallelligini saqlab qolishini isbotlaydilar. 2. Zamonaviy ta'lim texnologiyalari

- Petrova S.M. (2020) interaktiv 3D modellardan foydalanish tasviriy geometriyani o‘rganishda o‘quvchilarning akademik samaradorligini 25% ga oshirishini aniqladi. Muallif moslashuvchan qayta aloqa tizimlariga ehtiyoj borligini ta'kidlaydi.

- Chen va boshqalarning ishi. (2021) fazoviy fikrlashni rivojlantirishda mobil ilovalarning samaradorligini ko‘rsatadi. MRI skanerlash natijalari interaktiv vazifalar bilan ishlashda miyaning parietal lobining faollashishini ko‘rsatdi.

3. Ta'limda Flutterdan foydalanish

- Kuznetsovning maqolasi D.I. (2022) ta'lim dasturlarini ishlab chiqish uchun asoslarning qiyosiy tahlilini taqdim etadi. Flutter ta'kidlangan

Buning uchun optimal tanlov sifatida:

- 2D renderlash uchun CustomPaint yordami
- Imo-ishoralarni qayta ishlashda past kechikish (16 ms gacha)
- O‘zaro platformalar (Android, iOS, Web)
- Garsia-Sanches va boshqalarning tadqiqotlari. (2023) Flutter ilovalari hatto past darajadagi qurilmalarda ham FPS ≥ 60 ni taqdim etishini tasdiqlaydi, bu esa silliq renderlash uchun juda muhimdir.

4. Aniqlikni baholash ko‘rsatkichlari

- Evklid masofasiga asoslangan xatolarni hisoblash algoritmlari Smit va boshqalarda muhokama qilinadi. (2021). Mualliflar 1920 × 1080 ekran o‘lchamlarida 1,5 ° burchak xatosiga mos keladigan 15 piksel chegarani taklif qilishadi.
- Vang va boshqalar. (2022) “adaptiv tolerantlik” kontseptsiyasini taqdim etdi, bunda xato chegarasi foydalanuvchining javoblar tarixi asosida dinamik ravishda sozlanadi.

5. Psixologik-pedagogik- Kognitiv yuklama nazariyasi (Sweller, 2010) interaktiv yondashuvning afzalliklarini tushuntiradi: proyeksiyalarni vizuallashtirish ishchi xotira yukini kamaytiradi.

- Gonsales va boshqalarning tajribasi. (2023) ko‘zni kuzatishdan foydalangan holda, mos yozuvlar nuqtalarining ranglarini ajratib ko‘rsatish fokuslash vaqtini 40% ga qisqartirishini ko‘rsatdi.

Koordinatalar tizimi va proyeksiya tekisliklari

Asosiy elementlar:

Fazoviy koordinatalar tizimi:

Odatda X, Y, Z o‘qlari bo‘lgan o‘ng qo‘lli tizim ishlatiladi, bu erda:

X - gorizontal yo‘nalish (odatda chapdan o‘ngga),

Y - "kuzatuvchi tomon" yo‘nalishi (old o‘q),

Z - vertikal yo‘nalish (yuqoriga).

Proyeksiya tekisliklari:

P1 (gorizontal): ob'ektning ushbu tekislikka proyeksiyasi gorizontal tasvirni hosil qiladi.

P2 (frontal): asosiy tasvir (old ko‘rinish).

P3 (profil): ob'ektning yon tomondan tasviri.

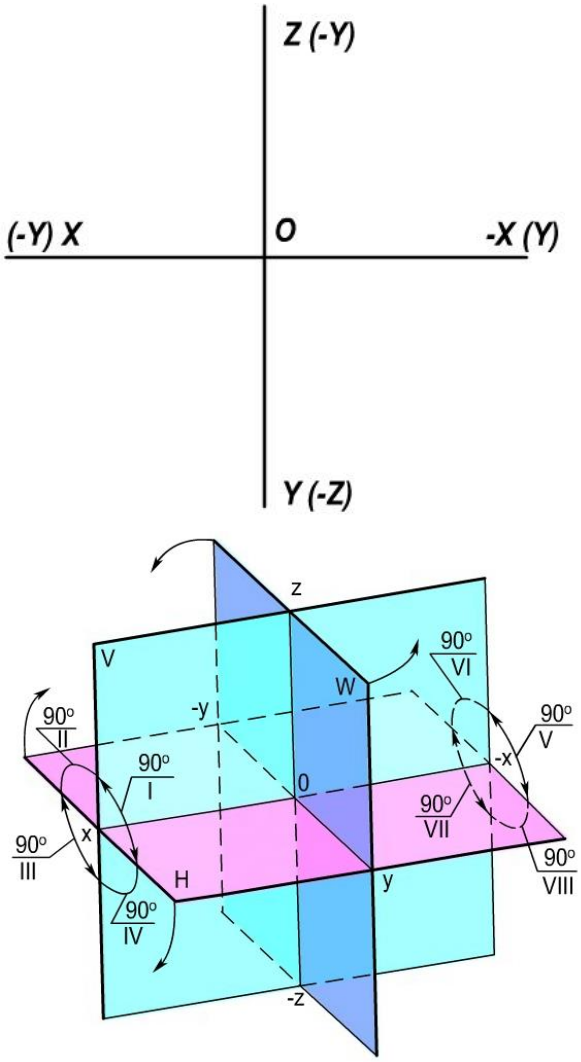
Ortogonal proyeksiyaning ilmiy asoslari

3D fazodagi \(P(x,y,z) \) nuqta uchun ortogonal proyeksiyalar aniqlanadi:

- Frontal (V): \(P'(x,z) \)
- Gorizontal (H): \(P''(x,y) \)
- Profil (W): \(P'''(y,z) \)

Frontal proyeksiya uchun proyeksiya matritsasi:

\[M_{front} = \begin{bmatrix}
1 & 0 & 0 \\0 & 0 & 1 \\\end{bmatrix}\]



Monj murakkab chizmasi

Ushbu diagrammada O nuqta, uchta tekislik uchrashadigan joyning boshlang'ich nuqtasidir.

Nuqtaning ortogonal proyeksiyalari

Nuqtaning fazodagi o‘rnini aniqlash uchun uchta koordinatalar to‘plamidan (x, y, z) foydalaniladi. Uning ortogonal proyeksiyalari quyidagicha:

• Gorizontal proyeksiya (P1): z koordinatasi nolga teng bo‘lganda koordinatalarni (x, y) aniqlaydi.

• Frontal proyeksiya (P2): displeyda (x, z), bu erda y = 0.

• Profil proyeksiyasi (P3): ko‘rsatadi (y, z), bu erda x = 0.

Shunday qilib, nuqtaning murakkab chizmasi uning fazodagi o‘rnini qayta qurish imkonini beradi, chunki nuqtaning koordinatalarini ikkita proyeksiyadan to‘liq aniqlash mumkin (agar proyeksiya tekisliklari o‘zaro perpendikulyar bo‘lsa).

Monj murakkab chizmasi

Asosiy g'oya:

Barcha uchta proektsiya (gorizontal, frontal, profil) ular orasida "proyeksiya aloqasi chizig'i" mavjud bo‘lishi uchun joylashgan. Ushbu ulanish proektsiyalarning nisbiy pozitsiyalarining saqlanishini ta'minlaydi, bu esa ularni fazoviy modelga "yopishtirish" imkonini beradi.

Tartibga solishga misol:

• Frontal va gorizontal proyeksiyalar bir xil vertikal chiziqda, frontal va profil proyeksiyalari esa bir xil gorizontal chiziqda joylashgan.

Tushuntirish blok diagramma shaklida taqdim etilishi mumkin:

Frontal (P2)

|

(proyeksiya aloqa liniyasi)

|

Gorizontal (P1) ——┼—— Profil (P3)

Frontal proyeksiya uchun proyeksiya matritsasi:

\[M_{front} = \begin{bmatrix}1 & 0 & 0 \\0 va 0 va 1 \\\end{bmatrix}\]

Pozitsion masalalar nuqtalar, chiziqlar va tekisliklarning fazodagi nisbiy o‘rnini aniqlashga qaratilgan. Masalan:

• Nuqtaning chiziq yoki tekislikka tegishli ekanligini aniqlash.

• *Chiziqlar yoki tekisliklar kesishadimi yoki yo‘qmi, agar kesishsa, qaysi nuqtada kesishishini aniqlash.*

Metrik muammolar hisoblash bilan bog'liq:

• Segmentlarning proyeksiyalari bo‘yicha tabiiy uzunliklari (masalan, to‘g‘ri burchakli uchburchak usuli yordamida).

• Nishab burchaklari va jismlar orasidagi masofalar.

Metrik masalalarni yechishda ko‘pincha ortogonal proyeksiyaning xossasidan foydalaniladi, bunda proyeksiyada to‘g'ri burchak saqlanadi. Muammoni hal qilish uchun qulay bo‘lgan ob'ektning tasvirini olish uchun ob'ektlarni proyeksiya tekisliklariga nisbatan ma'lum bir holatga o‘tkazish imkonini beruvchi proyeksiya o‘zgarishlaridan foydalaniladi. Asosiy usullarga quyidagilar kiradi:

• Proyeksiya tekisliklarini almashtirish:

Ob'ekt (yoki uning elementi) ma'lum bir pozitsiyani egallagan "yangi" tekislik tizimini tanlash (masalan, u tekis chiziqqa aylanadi).

Sxematik ravishda:

• Eski: P1, P2, P3 → Yangi: P1, P4, (P2 P4 bilan almashtirilgan)

• O‘q atrofida aylanish:

Ob'ektni proyeksiyasi to‘g'ri bo‘lishi uchun aylantirish imkonini beradi (buzilishsiz). Masalan, umumiy pozitsiya chizig'ini tekis chiziqqa aylantirish.

• Moslash:

Tekislikning o‘z izi atrofida asosiy proyeksiya tekisligiga to‘g'ri kelguncha aylanishi, bu ob'ekt shaklini aniq ko‘rsatishni ta'minlaydi.

Ushbu usullarning har biri asosiy geometrik xususiyatlarni (koordinatalar, burchaklar, uzunliklar) saqlaydi va hisob-kitoblarni osonlashtiradi.

Asosiy me'yoriy hujjatlar quyidagilarni tartibga soladi:

• Ko‘rinishlar, bo‘limlar va bo‘limlar proyeksiyalarini qurish.

• Chizmalar uchun yagona format.

• O‘lchamlar va belgilarni qo‘llash qoidalari.

Ushbu standartlar tasvirlarning bir xilligini ta'minlaydi va dizayn ma'lumotlarini aniq uzatish imkonini beradi.

Dekart koordinata sistemasidagi \(P(x,y,z)\) nuqta uchun ortogonal proyeksiyalar quyidagi transformatsiyalar bilan aniqlanadi:- Фронтальная проекция (V):

- Gorizontal proyeksiya (H):

Matritsani ko‘rsatish dasturiy ta'minotni amalga oshirish uchun koordinatalarni qayta ishlashni birlashtirishga imkon beradi (Foley va boshqalar, 1996).

Ishlab chiqilgan modul muhandislik ta’limida mobil texnologiyalardan foydalanish samaradorligini ko‘rsatadi. Matritsali o‘zgarishlardan foydalanish va aniqlikni statistik baholash zamonaviy ta'lim standartlari talablariga javob beradi. Keyingi tadqiqotlar egri chiziqli ob'ektlar bilan ishlash funksiyalarini kengaytirishga qaratilgan.

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THE ROLE OF DIGITAL TECHNOLOGIES IN TRANSFORMING MODERN EDUCATION

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Abstract. The twenty-first century has witnessed a profound transformation in education, driven by the integration of digital technologies. From AI-driven adaptive platforms and VR/AR simulations to mobile learning and MOOCs, digital tools are reshaping teaching and learning worldwide. This paper examines the role of digital technologies in transforming modern education, highlighting their benefits, including personalization, accessibility, and engagement, alongside critical challenges such as infrastructure gaps, teacher readiness, and ethical concerns. Using a theoretical framework grounded in constructivism, connectivism, and problem-based learning, and informed by bibliometric and qualitative analysis, this study provides a comprehensive overview of current trends. Recommendations for sustainable adoption include strengthening infrastructure, teacher training, ethical frameworks, and policy collaboration.

Keywords—digital technologies, personalized learning, educational innovation, accessibility, AI in education, VR/AR

I. INTRODUCTION.

In the twenty-first century, digital technologies have become a cornerstone of global education systems, profoundly influencing how knowledge is produced, transmitted, and consumed. No longer peripheral tools, digital platforms and applications are now embedded in almost every aspect of teaching, learning, and assessment. This transformation is driven by multiple forces, including globalization, rapid technological advancement, and shifting labor market demands that prioritize digital literacy, problem-solving, and adaptability.

The outbreak of the COVID-19 pandemic in 2020 acted as a powerful catalyst for the acceleration of digital learning practices. Educational institutions across the world were compelled to adopt remote and hybrid modes of instruction almost overnight. While initially a response to a public health crisis, this sudden transition revealed both the vulnerabilities and the potential of digital education. It underscored the urgent need for **resilient, technology-enabled learning systems** that can withstand disruptions while ensuring continuity, inclusivity, and quality of education.

Beyond crisis management, digital technologies are reshaping the very **paradigm of education**. Traditional classroom-based models are increasingly complemented—or in some cases replaced—by virtual classrooms, learning management systems (LMS), mobile learning applications, and massive open online courses (MOOCs). These innovations not only expand access to knowledge but also democratize education, allowing learners from diverse geographies and socio-economic backgrounds to participate in global learning networks. At the same time, advanced tools such as artificial intelligence (AI), machine learning, augmented and virtual reality (AR/VR), and data analytics provide unprecedented opportunities for **personalized and adaptive learning experiences**.

A growing body of literature reflects this trend. Alam et al. [1] reported exponential growth in studies on digital pedagogy during the last decade, highlighting how research has shifted from small-scale classroom experiments to systemic analyses of digital ecosystems. OECD [2], in its *Digital Education Outlook 2023*, emphasized the pressing policy implications of equitable access, teacher preparedness, and the necessity of sustainable public investment. Similarly, Smith [3] introduced the notion of the “abundant university,” a future-oriented model in which open resources, cloud computing, and AI collectively transform higher education into a more accessible and scalable system. These studies suggest that the integration of digital technologies is not simply about efficiency or convenience but about **redefining the purpose, scope, and delivery of modern education**.

Therefore, this paper seeks to address three key objectives:

1. To **systematically examine** the role of digital technologies in transforming contemporary educational practices.
2. To **assess the opportunities and challenges** that accompany this digital shift, including issues of equity, ethics, and sustainability.
3. To **propose strategic recommendations** for the effective, responsible, and long-term integration of digital technologies into global education systems.

By addressing these objectives, the study contributes to the ongoing discourse on how education can evolve in a digital-first era, ensuring that technology becomes a driver of inclusion and innovation rather than inequality and exclusion.

II. PROBLEM STATEMENT. Despite their promise, digital technologies present challenges that hinder their full potential. These include:

- Digital divide: unequal access to reliable internet and devices.
- Teacher readiness: insufficient digital literacy and pedagogical training.
- Infrastructure gaps: inadequate bandwidth, outdated hardware, and limited institutional investment.
- Ethical concerns: risks related to data privacy, surveillance, and equitable access.

These issues must be addressed to ensure digital transformation promotes inclusion rather than exacerbates inequality.

III. THEORETICAL FRAMEWORK AND METHODOLOGY. This study is informed by three pedagogical models:

- Constructivism: emphasizing active learner engagement.
- Connectivism: viewing knowledge as networked and dynamic.
- Problem-Based Learning (PBL): situating learning within real-world problem contexts. Methodologically, the study integrates:

1. Bibliometric review (Alam et al. [1]) to assess research trends.
2. Qualitative synthesis of case studies (e.g., Transforming Pedagogy [4], Ruzimov et al. [8]).
3. Expert survey evidence (Yulin & Danso [17]) to evaluate pedagogical readiness.

This triangulated approach ensures comprehensive insights into digital education trends.

IV. RESULTS AND DISCUSSION

A. Findings. The analysis indicates key transformative impacts:

- Personalization: AI-based systems adapt learning paths for individual students.
- Immersive learning: VR/AR simulations support practical, experiential education in fields like medicine and engineering.
- Accessibility: m-learning and MOOCs broaden global access, especially for underserved populations.
- Engagement: Gamification and interactive platforms foster higher motivation and cognitive skills.

B. Discussion

While promising, these benefits are unevenly realized. Hussain et al. [6] cautioned that without teacher training and infrastructure, digital technologies may underperform. OECD [2] highlighted the necessity of holistic policies that combine infrastructure, pedagogy, and ethics. The evidence suggests that digital technologies represent both an opportunity and a challenge, requiring balanced implementation to ensure reliability, equity, and long-term impact.

V. CONCLUSIONS AND RECOMMENDATIONS

Digital technologies are reshaping modern education, offering new ways to enhance inclusivity, adaptability, and innovation. However, without strategic implementation, they risk deepening existing inequalities.

Recommendations:

1. Expand digital infrastructure, particularly in underserved areas.
2. Invest in comprehensive teacher training for digital pedagogy.
3. Establish ethical frameworks for AI, data privacy, and equitable access.
4. Adopt hybrid models that integrate digital and traditional methods.
5. Foster cross-sector policy collaboration for sustainable integration.

By following these strategies, education systems can harness digital technologies to create more resilient, future-ready learning environments.

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OLIY TA’LIM MUASSASALARIDA INNOVATSION FAOLIYATINI TASHKIL ETISH VA NAZORAT QILISH USULLARI VA MEXANIZMINI TAKOMILLASHTIRISH

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***Annotatsiya*: Mazkur tadqiqotda oliy ta’lim muasasasining innovatsion faoliyatini tashkil etish va nazorat qilish usullarini joriy etish ahamiyati va uning o‘ziga xos xususiyatlari tahlil etilgan.**

Hozirgi davrda ta’lim samaradorligini oshirish, mutaxassislarning kasbiy kom-petentlik darajasini rivojlantirish, rahbar va pedagog kadrlaming innovastion faoliyatga yo‘naltirish, oliy ta'lim muas-sasalaridagi o‘quv jarayoniga innovatsion ta’lim va axborot kom-munikatsiya tex-nologiyalarini tadbiq etish, ilg‘or xorijiy tajribalarni o‘zlashtirish va ma-qsadli yo‘naltirish oliy ta’lim tizimini mo-dernizatsiyalashdagi dolzarb vazifalar sifatida belgilandi. Bu esa o‘z navbatida oliy ta’lim mu-assasalaridagi o‘quv-uslubiy faoliyat maz-munini takomillashtirish, o‘qitishning inno-vatsion shakl va metodlari, zamonaviy axborot-kommunikastiya texnologiyalarini amaliyotga keng joriy etish zaruratini shakllantirish muhim.

***Kalit so‘zlar:* oliy ta’lim samaradorligi, innovatsion faoliyat, kasbiy kompetentlik, o‘qitishning innovatsion shakllari, innovatsion faoliyatini tashkil etish va nazorat qilish usullari, taklif va tavsiyalar.**

O’zbekiston Respublikasi hukumati tomonidan oliy ta’lim sohasi bo’yicha o’rtaga quyilayotgan vazifalarni bajarish ko’p jihatdan o’qituvchi shaxsiga bog’liq. O’qituvchilik sharafli, lekin juda murakkab kasbdir. Bozor iqtisodiyotiga o’tish sharoitida ta’lim - tarbiyadan ko’zda tutilayotgan maqsadga erishish, talabalarning xilma xil faoliyatini uyushtirish, ularni bilimli, odobli, e’tiqodli, mehnatkash, ishbilarmon, barkamol inson qilib o’stirish o‘qituvchi zimmasiga yuklatilgan.

Xalqimizning kelajagi, O’zbekistonning istiqboli ko’p jihatdan o’qituvchiga, uning saviyasi, tayyorgarligi, fidoyiligiga, yosh avlodni o’qitish va tarbiyalash ishiga bo’lgan munosabatiga bog’liq. Yaxshi o’qituvchi bo’lish uchun pedagogik nazariyani egallashning o’zigina yetarli emas. Chunki pedagogik nazariyada bolalarni o’qitish va tarbiyalash haqida umumiy qonun-qoidalar, tamoyillar, umumlashtirilgan metodik g’oyalar bayon etiladi, talabalarning yosh va individual xususiyatlarini e’tiborga olish ta’kidlanadi. Universitet hayoti, amaliy pedagogik jarayon esa juda xilma-xil, murakkabdir.

Pedagogik nazariyaga mos kelmaydigan vaziyatlar ko’p uchrab turadi. Bu esa o’qituvchidan keng bilimdonlikni, puxta amaliy tayyorgarlik va yuksak pedagogik mahorat hamda ijodkorlikni talab etadi. Biror kasbning haqiqiy ustasi bo’lish uchun kishida tabiiy qobiliyat, ma’lum jismoniy va ruhiy xislatlar, puxta tayyorgarlik, ayrim shaxsiy sifatlar bo’lishi kerak. Pedagoglik kasbini tanlagan kishi avvalo sog’lom bo’lishi, so’zlarni to’g’ri va yaxshi talaffuz qila olishi, bosiq va asablari joyida bo’lishi, boshqalar bilan muomalada o’zini tuta olishi zarur. Shuningdek, o’qituvchida talabalarni yoqtirish, ular bilan ishlashga mayli borlik, xushmuomalalik, kuzatuvchanlik, keng fikrlay olish, tashkilotchilik, o’ziga va boshqalarga nisbatan talabchanlik kabi shaxsiy sifatlar mavjud bo’lishi zarurdir.

Texnologiyaning rivojlanishi bilan texnik vositalardan foydalanib o’qitish uchun birgina kompyuterning mavjudligi kifoya bo’lib qoldi. Qolaversa, axborotni uzatish, saqlash, tasvirlash sifati sezilarli darajada ortdi. Hozirgi kunga kelib, kompyuter savodxonligi madaniyatning muhim belgisiga aylanib ulgurdi, kelajakda esa u har bir insonga qayerda, qaysi uchastkada ishlamasin zaruratga aylanadi. Demak, kompyuter ishi, kompyuterdan foydalanishga o’rgatish eng yaqin vaqt ichida umumiy ishga aylanishi shubhasiz [Mirziyoyev, 2017].

Zamonaviy axborot texnologiyalarining vositalari qatoriga: kompyuter, skaner, video-kamera, LCD proyektor, interaktiv elektron doska, faks modem, telefon, elektron pochta, multimedia vositalari, Internet tarmoqalari, mobil aloqa tizimlari, ma’lumotlar omborini boshqarish tizimlari, sun’iy intelekt tizimlarini kiritish mumkin.

O’quv-tarbiya jarayonida kompyuterlar asosan to’rt tartibda:

- passiv qo’llash–kompyuter oddiy hisoblagich kabi;
- reaktiv muloqot – kompyuter imtihon oluvchi sifatida;
- faol muloqot – kompyuter talabaga yo’l – yo’riq berish va imtihon olishda;
- interfaol muloqot – kompyuter sun’iy intellekt sifatida, ya’ni talaba bilan muloqot qilishda foydalaniladi.

Ta’limda zamonaviy axborot va kommunikasiya texnologiyalarini keng joriy etilishi:

- fan sohalarini axborotlashtirishni;
- o’quv faoliyatni intellektuallashtirishni;
- integrasiya jarayonlarini chuqurlashtirishni;
- ta’lim tizimi infratuzilmasi va uni boshqarish mexanizmlarini takomillashtirishga olib keladi.

Pedagogik ta’lim jarayonlarini zamonaviy axborot texnologiyalari asosida samarali tashkil etish:

- masofaviy o’quv kurslarini va elektron adabiyotlarni yaratuvchi jamoaga pedagoglar, kompyuter dasturchilar, tegishli mutaxassislarning birlashuvi;
- pedagoglar o’rtasida vazifalarning taqsimlanishini;
- ta’lim jarayonini tashkil qilishni takomillashtirish va pedagogik faoliyatning samaradorligini monitoring etishni taqozo etadi.

Zamonaviy axborot texnologiyalarining ta’lim jarayonlariga joriy etilishi:

- talabaga kasbiy bilimlarni egallashiga;
- o’rganilayotgan hodisa va jarayonlarni modellashtirish orqali fan sohasini chuqur o’zlashtirilishiga;
- o’quv faoliyatining xilma-xil tashkil etilishi hisobiga talabaning mustaqil faoliyati sohasining kengayishiga;
- interaktiv muloqot imkoniyatlarining joriy etilishi asosida o’qitish jarayonini indi-viduallashtirish va differensiyalashtirishga;
- sun’iy intellekt tizimi imkoniyatlaridan foydalanish orqali talabaning o’quv materiallarini o’zlashtirish strategiyasini egallashiga;
- axborot jamiyati a’zosi sifatida unda axborot madaniyatining shakllanishiga;
- o’rganilayotgan jarayon va hodisalarni ko-mpyuter texnologiyalari vositasida taqdim etish, talabalarda fan asoslariga qiziqishni va faollikni oshirishga olib kelishi bilan muhim ahamiyat kasb etadi.

Pedagogik dasturiy vositalar tushunchasi

Pedagogik dasturiy vositalar – kompyuter texnologiyalari yordamida o’quv jarayonini qisman yoki to’liq avtomatlashtirish uchun mo’ljallangan didaktik vosita hisoblanadi. Ular ta’lim jarayonini samaradorligini oshirishning istiqbolli shakllaridan biri hisoblanib, zamonaviy texnologiyalarning o’qitish vositasi sifatida ishlatiladi.

Pedagogik dasturiy vositalar tarkibiga: o’quv fani bo’yicha aniq didaktik maqsadlarga erishishga yo’naltirilgan dasturiy mahsulot (dasturlar majmuasi), texnik va metodik ta’minot, qo’shimcha yordamchi vositalar kiradi.

Pedagogik dasturiy vositalarni quyidagilarga ajratish mumkin:

- ➢ o’rgatuvchi dasturlar – o’quvchilarning bilim darajasi va qiziqishlaridan kelib chiqib yangi bilimlarni o’zlashtirishga yo’naltiradi;
- ➢ test dasturlari – egallangan bilim, malaka va ko’nikmalarni tekshirish yoki baholash maqsadlarida qo’llaniladi;
- ➢ mashq qildiruvchi (trenejyor)lar - avval o’zlashtirilgan o’quv materialini takrorlash va mustahkamlashga xizmat qiladi;
- ➢ virtual borliq tizimlari – o’qituvchi ishtirokidagi virtual o’quv muhitini shakllantiruvchi dasturlar.

Pedagogik faoliyatda amaliy va pedagogik dasturiy vositalardan foydalanish Pedagogik dasturiy vositalarni yaratish texnologiyasini amalga oshirish maqsadida ularning an’anaviy vositalardan ustunligini tasdiqlovchi qator ijobiy omillar mavjud. Mazkur omillar didaktik, psixologik, iqtisodiy, fiziologik guruhlarga ajratildi.

Pedagogik dasturiy vositalarga qo’yiladigan didaktik talablarga quyidagilar kiradi: ilmiylik, tushunarli, qat’iy va tizimli bayon etilishi bilan birgalikda (pedagogika, psixologiya, infor-matikaning asosiy tamoyillarini, zamonaviy fanning fundamental asoslarini hisobga olib, o’quv faoliyati mazmunini qurish imkoniyatini ta’minlash), uzluksizlik va yaxlitlik (ilgari o’rganilgan bilimlarning mantiqiy oqibati hamda to’ldiruvchisi hisoblanadi), izchillik, muammolilik, ko’r-gazmalilik, faollashtirish (o’qitish mustaqilligi hamda faollilik xususiyatining mavjudligi), o’qitish natijalarini o’zlashtirish mustahkamliligi, mu-loqotning interfaolliligi, o’qitish, tarbiyalash, rivojlantirish va amaliyotning yaxlit birligi.

Metodik talablarga quyidagilar kiradi: aniq o’quv fanining o’ziga xos xususiyatlarini hisobga olish, ma’lum bir faning o’ziga xosligini hisobga olish, axborotni zamonaviy metodlari o’zaro bog’liqliligi, o’zaro aloqadorliligi, turli tumanligi, amalga oshirilishi.

Psixologik talablarga idrok etish (verbal-mantiqiy, sensor-perseptiv), tafakkur (tushunchaviy nazariy, ko’rgazmali-amaliy), diqqati (qat’iyliligi, boshqaga ko’chishi), motivasiya (ishlashda faol shakllari, yuqori darajada ko’rgazmalilik, o’z vaqtida qayta aloqa yordamida o’quvchilarning yuqori darajadagi motivasiyalarini doimiy ravishda rag’batlantirish), xotira, tasavvuri, yoshi va individual psixologik

xususiyatlarini hisobga olish (egallagan bilim, ko’nikma va malakalarini hisobga olib, o’quv fani mazmuni hamda o’quv masalalari murakkablik darajasi talabalarning yosh imkoniyatlari va individual xususiyatlariga mos kelishi, o’quv materialini o’zlashtirishda ortiqcha his-hayajonli, asabiy, aqliy yuklamalardan ta’sir-lanishdan himoyalash) kiradi.

Texnik talablarga zamonaviy universal shaxsiy kompyuterlar, tashqi qurilmalari, test o’tkaziladigan manbalar kiradi.

Tarmoq talablariga “mijoz-server” arxitek-turasi, Internet-navigatorlar, tarmoq operasion tizimlari, telekommunikasiya, boshqaruv vositalari (o’qitish jarayonini individual va jamoaviy ishlari, tashqi qayta aloqa) kiradi.

Estetik talablarga quyidagilar kiradi: tartiblilik va ifodalilik (elementlari, joylashishi, o’lchami, rangi), bezashning funksional vazifasi va ergo-nomik talablarga mosligi.

Maxsus talablarga quyidagilar kiradi: interfaollik, maqsadga yo’nalganlik, mustaqillik va moslashuvchanlik, audiolashtirish, ko’rgazmalilik, kirish nazorati, intellektual rivojlanish, differensiasiyalash (tabaqalashtirish), kreativlik, ochiqlik, qayta aloqa, funksionalilik, ishonchlilik.

Ergonomik talablarga quyidagilar kiradi: do’stonalik, foydalanuvchiga moslashish, ekran shakllarini tashkil etish.

Metodik talablar pedagogik dasturiy vositalar asosida o’qitishga mo’ljallangan o’quv fanining o’ziga xos xususiyatlarini, uning qonuniyatlarini, izlanish metodlari, axborotga ishlov berishning zamonaviy usullarini joriy qilish imkoniyatlarini hisobga olishni ko’zda tutadi.

Internet resurslaridan ta’lim jarayonida foydalanish o’quv jarayonlarida Web-saytlardan foydalanishning ko’pgina yutuqlari mavjud.

Shu bois bunday saytlarni yaratish va mazmunan yangilab boorish oliy ta’lim muassasasi faoliyatida muhim ahamiyat kasb etadi. Shunday ekan o’quv muassasalari uchun bag’ishlangan saytlarni yaratish har bir ta’lim muassasasi oldida turgan birlamchi vazifalar qatoriga kiradi. Bunday saytlarni yararish uni o’rganish mobaynida internet tizimi bilan bog’liq omillarni hisobga olish lozim. Bunday omillar sifatida quyidagilarni ko’rsatish mumkin:

• dunyo bo’yicha internet xizmati imkoniyatlarining kengligi;
• web-saytlar xizmatidan foydalanishning oddiyligi;
• web-texnologiyalarni tarqatishdagi qulaylik;
• real vaqt masshtabida axborotlarga bo’lgan talablar;
• muassasa va xususiy shaxslarning o’zlari to’g’risidagi axborotlarni internetga joylashtirishga intilishi;
• tarmoq ma’lumotlar bazasida global mashstabdagi ixtiyoriy ma’lumotlarni to’plash [Toxtaxodjayeva, 2010].

O’quv muassasasi uchun yaratilgan saytlarning ahamiyati

Internet texnologiyalarining imkoniyatlari kengligi va sodda ekanligi internetdan foydalanuvchilarning daqiqa sayin ortib borishiga olib kelmoqda. Bu foydalanuvchilar orasida ko’pchilik qismini albatta, talabalar, o’quvchilar, ilmiy izlanish bilan band bo’lgan xodimlar tashkil qiladi. Shundan kelib chiqib aytish mumkinki, ta’lim jarayonida Internet texnologiyalaridan, xususan o’quv muassasalariga bag’ishlangan web-saytlardan foydalanish ta’lim sifati va samaradorligini sezilarli darajada yuqori bosqichga olib chiqishga yordam beradi.

Yangi axborot texnologiyalar vositalari takomillashib va rivojlanib borayotgan hozirgi sharoitda o’quv muassasasida tahsil olayotgan talabalarning (umuman har qanday sohada faoliyat ko’rsatuvchilarning) zarur axborotlarni Internet tizimidan mustaqil ravishda topa olishi, ular duch keladigan mavjud mutaxassisligiga oid muammolarni to’la va to’g’ri hal qila olishidagi muhim sharoitlardan biriga aylanib bormoqda [Karimov, 2008: 148].

Ta’lim jarayonida Internet saytlaridan foydalanish imkoniyatlarini, uning samaradorligini aniqlashda avval Internet xizmatining turlari va ularning xarakterini aniqlab olish nihoyatda muhimdir. Aynan ana shu aniqlangan ma’lumotlar Internet tarmog’ida ishlashning tashkiliy jihatdan shakli va usullarini ajratib olishga yordam beradi. Klassifikasiyalashga asos qilib internetning ishlash uslubini olish mumkin. Bu holda Internet server xizmatlarini ikkiga: axborotli va kommunikasion xizmat turlariga ajratish kerak.

Axborotli xizmatga WWW (ma’lumotlar majmuasi) va G’TR (dasturlar majmuasi) lar kiritiladi.

Kommunikasion xizmatni esa ikkiga: bevosita (PC, chat) va bilvosita muloqot (elektron pochta, forum, telekonferensiya) turlariga ajratish mumkin.

Internetdagi barcha “o’quv muassasi uchun yaratilgan sayt” larni o’z navbatida bir necha turga ajratish mumkin:

- o’rgatuvchi internet manbalari;
- maslahat beruvchi internet manbalari;
- axborotli internet manbalari;
- baholovchi internet manbalari;
- taqdimotli internet manbalari;

Quyida ularning har biriga alohida to’xtalib o’tamiz.

O’rgatuvchi internet manbalariga masofaviy ta’lim, virtual maktablar, laboratoriyalar va web sinflarni misol sifatida keltirish mumkin.

Maslahat beruvchi internet manbalariga turli telekonferensiyalar, virtual pedagogik kengashlar, virtual uslubiy, birlashmalar muammoviy kengashlar, virtual kafelar va hokazolarni misol keltirish mumkin.

Axborotli inter-net manbalariga elektron o’quv qo’llanmalar, ma’lumotnomalar, elektron kutubxonalar, lug’atlar, kataloglar, virtual mu-zeylarni keltirish mumkin.

Baholovchi internet manbalarga teletesting, masofaviy konkurslar, turli viktorinalar, olimpiadalarni misol keltirish mumkin.

Taqdimotli internet manbalariga ta’lim muas-sasalarining ta’lim yo’nalishlari haqida atroflicha ma’lumotlar yoritilgan alohida sahifalarni keltirish mumkin [Egamberdiyeva, 2009].

O’quv muassasalari uchun yaratilgan saytlar yordamida o’qituvchilar ta’lim oluvchilarga masofadan turgan holda bilim olishlariga imkon yaratadilar. O’quv muassasalari uchun yaratilgan saytlar ayniqsa o’qitish joylariga qatnashi qiyin bo‘lgan ta’lim oluvchilarga qulaydir. Bulardan tashqari ta’lim oluvchilar axborot texnologiyalari bilan ishlash madaniyati, ko’nikma va malakalariga ega bo’ladilar. O’quv muassasalari uchun yaratilgan saytlardan dars jarayonida foydalanish juda katta imkoniyatlar yaratadi.

O’quv muassasalari uchun yaratilgan saytlar yordamida o’qitish, o’quv jarayonini a’nanaviy tashkil etishning asosiy shakllarini o’z ichiga oladi. Ma’ruza, seminar va amaliy mashg’ulotlar, laboratoriya amaliyoti, nazorat tizimi, ting-lovchilarning ilmiy tadqiqot va mustaqil ishlari shular jumlasidandir. O’quv jarayonini tashkil etishning ushbu barcha shakllari amaliyotda tinglovchilarni mustaqil bilish faoliyati turli axborot manbalari bilan osongina birlashtirishni, kurs olib borayotgan o’qituvchi bilan tezkor va tizimli aloqa qilish hamda tinglovchilarning guruh bo’lib ishlarni amalga oshirish imkoniyatini beradi [Hasanboyev, 2011].

O’quv jarayonida o’quv muassasalari uchun yaratilgan saytlardan foydalanish o’qituvchilarga:

• internet tarmog’i yordamida u yoki bu o’quv fanlardan to’plangan tajriba va uslublarni boshqa kasbdoshlari bilan almashish;

• bir vaqtning o’zida turli toifadagi talabalar uchun har xil o’qitish uslublarini amalga oshirish orqali o’quv jarayonini individuallashtirish;

• o’quv muassasalari uchun yaratilgan saytlardagi nazorat topshiriqlaridan mashq sifatida foydalanish natijasida talabalarda fan bo’yicha egallangan bilimlarni ko’nikma va malaka darajasiga yetkazish;

• qo’lda bajariladigan ishlarni kamaytirish hisobidan talabalarga yakka tartibda ishlash va o’z qobiliyatlarini namoyon qilish imkoniyatini yaratish;

• talabalarni mustaqil bilim olish jarayonini samarali tashkil etish kabi imkoniyatlarni yaratadi.

O’qitishda o’quv muassasalari uchun yaratilgan saytlardan foydalanish talabalarda:

• o’z xohishlariga qarab o’qish holatlarini tanlash;

• tayyorgarliklar va psixofizik xususiyatlaridan kelib chiqqan holda o’zlariga mos o’qish metodlari va bayon etish usullarini tanlash;

• oldin o’rganilgan materiallarga qaytish, o’qish jarayonini to’xtatib qo’yish va unga ixtiyoriy vaqtda murojaat qilish;

• turli jarayonlarning dinamikasini va mexanizmlarni o’zaro ta’sirini kuzatish;

• o’rganilayotgan obyektlarni boshqarish va ularning mos natijalarini ko’rib borish;

• kompyuterda muloqot qilish psixologik xarakterdagi to’siqlardan holi bo’lishga (kulgu bo’lmaslik, jur’at etmaslik, uyalmaslik kabilar) olib kelishi;

• tayyorgarlik darajalari yetarli bo’lgunga qadar kompyuterdan sabr bilan foydalanish kabi imkoniyatlarga ega bo’ladilar.

O’quv muassasalari uchun yaratilgan saytlarning ta’lim sohasidagi quyidagi afzalliklarini sanab o’tish munkin:

• fanlarni o’zlashtirilishni yaxshilanishi;

• tarmoq savodxonligini ortishi (Kompyuter va Inernet bilan muloqot qilishdagi yangiliklar);

• o’rganishga bo’lgan munosabatni yaxshilanishi;

• mustaqil ta’lim va tadqiqotlar malakasini takomillashishi;

• amaliy malaka samaradorligini oshirish.

Internet tizimida o’quv muassasasi uchun yaratilgan saytlar

Bugungi kunda taraqqiyot juda tez rivojlanmoqda va juda tez o’zgarmoqda. Deyarli har daqiqada sayyoramizning turli burchaklarida o’zgarishlar, yangilanishlar va kutilmagan voqea hodisalar sodir bo’lmoqda. Har bir kunimiz kuchli axborot oqimi ostida kechmoqda. Axborot oqimi bizni uyda, ishxona va ta’tilda ta’qib etadi. Inson informasiya ta’siridan xoli normal faoliyat yurita olmaydi. Hayotni anglash, uni o’rganish informasiyalarni yig’ish va o’zlashtirish orqali kechadi. Insonning bilimlilik darajasi ham ma’lum davr ichida shaxs tomonidan o’zlashtirilgan informasiyalarning ko’p yoki ozligi bilan belgilanadi.

Shuning uchun zamonaviy bilimlar sari keng yo’l ochish, ta’limotni takomillashtirishda yangi axborot texnologiyalardan unumli foydalanish - bugungi kunning talabiga aylandi. Vaholanki, ta’lim tizimida sezilarli o’zgarishlar ro’y bermoqda. Ta’lim tizimida o’quv muassasalari uchun yara-tilgan saytlardan foydalanish o’qitish qo’llanil-moqda.

O’quv muassasalari uchun yaratilgan saytlarning yana bir afzalligi shundaki, unda o’quvchi o’ziga qulay

vaqtda va hattoki ishdan ajralmagan holda o’qishi mumkin.

O’quv muassasalari uchun yaratilgan saytlarning yana bir afzallik tomoni unda o’qish muddatini talaba o’zi belgilaydi, ya’ni talaba ixtiyoriy paytda o’qishni boshlaydi, materiallarni o’qituvchi nazoratida o’zlashtiradi. O’zlashtirish topshiriqlarni, testlarni bajarishiga qarab aniqlanadi. Talaba berilgan programmani qanchalik tez o’zlashtirsa, shunchalik tez o’qishni tugatadi va guvohnoma oladi. Dasturni o’zlashtira olmasa, unga mustaqil ishlab, o’qishni davom ettirishga imkoniyat beriladi.

O’quv muassasalari uchun yaratilgan saytlardagi berilgan materiallari asosan quyidagilardan iborat bo’ladi:

- Darslik;
- Audio va video darsliklar;
- Onlayn darslar (Internet sahifa);
- Elektron kutubxonalar;
- Testlar;
- Multimedia - elektron darsliklar [Mavlanova, 2010: 461].

Respublikamiz Oliy va o’rta maxsus bilim yurtlarida o’quv muassasalari uchun yaratilgan saytlar kataloglashtirish, respublika ta’lim muassasalarida tayyorlanayotgan elektron o’quv adabiyotlarini barcha ta’lim muassasalari orasida targ’ib qilish muhim va murakkab vazifa hisoblanadi. Davlatimiz rahbariyati tomonidan ushbu masalani ijobiy yechimini topish hamda ta’lim muassasalari uchun yaratilgan elektron o’quv resurslari va ta’lim muassasalari saytlarini ta’lim jarayoniga tatbiq etishga jiddiy e’tibor berilmoqda. Buning natijasi sifatida O’zbekiston Respublikasi Prezidentining qaroriga binoan tashkil qilingan http://www.ziyonet.uz/ axborot- ta’lim portali ishga tushirildi va bu portalda barcha ta’lim muassasalari uchun ta’lim resurslari joylashtirilganligi ahamiyatga molikdir.

An’anaviy va elektron shakldagi o’quv materiallari yagona ta’lim muhitining tarkibiy qismi sifatida bir-birlarini to’ldirishlari muhim sanaladi. Yangi axborot texnologiyalarining imkoniyatlari-dan foydalanish ayrim pedagogik muammolarni bartaraf etishga xizmat qiladi.

Yagona axborot portalning yaratilishi quyidagi ijobiy natijalarga olib kelishi maqsad qilingan:

- Respublika pedagogika ta’lim muassasalarining yagona axborot muhiti yaratiladi;
- yagona kutubxona muxitini shakllantiradi (elekron kutubxonani yaratilishi, elektron darsliklar va noan’anaviy axborot tashuvchilar fondi-ning shakllanishi, yagona ma’lumotlar bazasini yaratilishi va hakazo.);
- pedagogik ta’lim soxasida yagona tele-kommunikasiya tarmog’i muhiti shakllantiriladi;
- yangi axborot-ta’lim muhitini shakllantiradi, ta’limda axborot va kommunikasiya texnologiyalaridan foydalanishning ijtimoiy-psixologik asoslarini yaratadi;
- yangi axborot madaniyatiga ega pedagogik kadrlarini shakllantirish orqali pedagogik ta’lim sifatini oshiradi;
- yangi ta’lim texnologiyalarining ilmiy va metodik ta’minoti tizimini yaratadi;
- ta’lim axborotlariga, axborot resurslariga ommaviy tashrifni ta’minlashi, hujjatlarni uzatish, hisobga olish mexanizmini tizimlashtirishi, respublikada pedagogik ta’limning holati bo’yicha axborotlarni jamoatchilik uchun ochiqligini amalga oshiriladi;
- masofaviy ta’lim tizimi rivojlantiriladi.

Pedagogika ta’lim muassasalarining yagona axborot makonini joriy etilishi pedagogik ta’limning sifatini va axborot ta’minotini rivojlanishiga yaxshi sharoit yaratadi.

Oliy ta’lim tizimida innovatsion boshqaruvning tashkiliy-iqtisodiy mexanizmi mazmuni va mohiyati

O‘zbekiston Respublikasi Prezidenti Shavkat Mirziyoyev 2022- yil 20-dekabr kunigi Oliy Majlis va O‘zbekiston xalqiga Murojaatnomasida “So‘nggi yillarda oliygohlarimiz 2,5 barobar ko‘payib, 198 taga yetdi, qamrov darajasi 9 foizdan 38 foizga oshdi. Biz bu raqamlarni yanada ko‘paytirishni maqsad qilganmiz. Lekin, ta’lim sifati nima bo‘ladi, degan savol hammamizni o‘ylantirishi kerak. Avvalambor, bunga har bir oliygoh o‘zi harakat qilishi lozim, o‘shanda natija bo‘ladi. Bu borada 41 ta oliygohga akademik va moliyaviy mustaqillik berildi, ularda transformatsiya ofislari ochildi. Oliygoh rektorlari, professor va o‘qituvchilar bu jarayonlarda faol bo‘lishlari, yangi, ilg‘or metodikalarni joriy qilishlari kerak” – deb ta’kidlaganlar.

Ushbu raqamlar O‘zbekiston Respublikasida oliygohlarda oliy ta’lim olishga bo‘lgan talabni yildan yilga ko‘payishda davom etayotganidan va oliy ta’limga qamrov darajasi talabga mutanosib ravishda oshganligidan dalolat beradi.

Zamonaviy menejment nazariyasi nuqtai nazaridan davlat, jamiyat, iqtisodiyotda umuman yoki alohida tashkilotda sodir bo'ladigan deyarli har qanday jarayon yoki hodisalar ma'lum bir turdagi mexanizmning ishlashi ta'siri ostida amalga oshiriladi. Shuni ta'kidlash kerakki, iqtisodiy tadqiqotlarda "boshqarish mexanizmi", "iqtisodiy mexanizm", "tashkiliy-iqtisodiy mexanizm" va boshqalar kabi kategoriyalardan foydalaniladi, bu esa mexanizmning o'zi mohiyatining ko'plab ta'riflari va talqinlarining mavjudligini belgilaydi.

Mexanizm tushunchasi iqtisod faniga texnik sohadan kirib keldi, bunda mexanizm deganda ularni harakatga keltiruvchi mashina, qurilma, apparatning ichki qurilmasi (bog'lanishlar tizimi) tushuniladi. Yigirmanchi asrning ikkinchi yarmidan boshlab tadqiqotchi-iqtisodchilar ushbu

atamani ishlab chiqarish va ijtimoiy jarayonlar va ularning o'zaro ta'sirini tavsiflash uchun ishlata boshladilar, shu bilan birga iqtisodiyotda biror narsani harakatga keltiruvchi bo'g'inlar tizimi sifatida, qoida tariqasida, turli xil usullar va vositalar bu mexanizmning tarkibiy qismlari. Innovatsion iqtisodiyot sharoitida oliy talim muassasalari sonini oshirish, ularning boshqaruv tizimini yanada takomillashtirish, milliy iqtisodiyotimizni rivojlanishida oliy talim muassasalari o‘rnini yuksaltirish eng muhim ahamiyatga ega bo‘lgan masalalardandir. Yangi O‘zbekiston ta’lim tizimida 2022-yilning 2022-2023-o‘quv yiliga kelib mamlakatimizda faoliyat yuritayotgan davlat va xususiy oliy talim muassasalari soni 191 taga yetdi hamda oliy talim muassasalarda tahsil olayotgan talabalar soni bir milliondan oshdi. Shuningdek, 2021-yilning 1-yanvar holati bo‘yicha UNESCOning statistika instituti ma’lumotlariga ko‘ra, xorijda tahsil olayotgan o‘zbekistonlik talabalar soni 85,9 ming nafarni tashkil etgan . Har qanday buyuk va iqtisodiyoti taraqqiy etgan davlatlarning rivojlangan darajaga yetishlarida ta’lim tizimini, xususan, oliy ta’lim tizimini o‘rni beqiyosligini inkor etib bo‘lmaydi. Mamlakatimizda oliy ta’lim tizimini zamon talablariga mos holda rivojlantirish, tizimda innovatsiyalarni joriy etish, innovatsion boshqaruvni tashkil etish va doimiyligini ta’minlash asosida, jahondagi eng yetakchi oliy talim muassasalari bilan raqobatga kirisha oladigan darajaga olib chiqish maqsadida uzluksiz va tizimli ishlar amalga oshirilmoqda.

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BIBLIOMETRIC ANALYSIS OF RESEARCH IN LIBRARY AND INFORMATION SCIENCE

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Abstract **— Scientific research in the library field encompasses a wide range of directions. In particular, there has been a steady increase in studies related to informatics, information technology, digital libraries, information retrieval systems, and library services. These studies are aimed at enhancing the traditional functions of libraries, introducing innovative methods, and expanding opportunities for effective information management in the digital environment. The purpose of this article is to examine the activities, research directions, and outcomes within the field of library and information science. The paper presents the results of scientific investigations conducted in this domain, including a retrospective analysis of both domestic and international studies, as well as dissertations devoted to this topic. Special attention is given to dissertations, as they traditionally serve as indicators of research priorities and trends in the development of disciplines.**

Keywords— bibliometric analysis, analytics, library information science, research trends, scientometrics, research Evaluation, knowledge management

I. INTRODUCTION

The introduction of information technologies, including digital technologies, to the life of our society, the organization of global computer systems and networks brought us serious changes in the field of librarianship. These changes are standing on the focus of library researchers of the world. These changes and processes are reflected in the scientific research of the librarians of our country and abroad. Today, the current state of librarianship in the period of innovative development processes and the issues related to the adaptation of libraries to these changes are published in the pages of periodicals. It is important to give recommendations for our application based on the content of the scientific work carried out in each field which is reflected with the actual issues of this field, the analysis of the content of the scientific work in the field of library, the trends of the development in this field in foreign countries and the analysis of the work done in the field in Uzbekistan.

The purpose of the study

The purpose of this article is to investigate the activities, scientific researches, researches and their results in the field of library. The article presents the results of scientific research conducted in the field of library science, the results of a retrospective analysis of foreign and domestic research conducted in this field, the results of the analysis of dissertations on this topic.

II. MATERIALS AND METHODS

In this study, the results of scientific research carried out in the library sector were studied based on the following analysis:

- Retrospective analysis of scientific research in the field of librarianship;
- Bibliometric analysis of research works on librarianship in the world;
- Analysis of research works on librarianship in Uzbekistan.

A. Retrospective analysis of scientific research in the field of librarianship

Scientific research in the field of librarianship has a long history, and we can see that its development took place step by step. That is, although scientific work in the field of librarianship began a long time ago, research in the modern sense was formed in the 19th and 20th centuries. The first research on the world scale began in 1904, and in Uzbekistan, by 1960, a scientific research work was created in the field. Research in the field of library automation began to develop in the middle of the 20th century, and since 2000, research has been conducted on the use of artificial intelligence cloud technologies, digital libraries, big data analysis, blockchain technologies. The state of scientific research conducted in the field in developed countries and Uzbekistan is quite.

B. Bibliometric analysis of research works on librarianship in the world

In recent years, the use of international electronic resources such as ProQuest, EBSCO, Elsevier, Springer, and dissertation databases — including those containing works in English in the field of librarianship and related

scientific and educational disciplines — has provided opportunities for in-depth study and evaluation. In Uzbekistan as well, subscriptions to global information resources have been expanding significantly in the past few years [4]. The use of these databases makes it possible to draw conclusions about the latest scientific achievements. In many countries, including the USA, Germany, France, and Spain, research has been carried out on the methodology and philosophy of librarianship. [5]. Among these, Craig S. Finlay [6], Russell, T., Sugimoto, C.R. [10], Shu, F.[8], Buckland, M., Sugimoto, C.R., Lee, D., Russell, T.G. , Finlay, S.C., Ding, Y.[9] studies have covered similar topics.

The following conclusions can be drawn based on the analysis of this table. The top ten universities of Canada and the USA, included Columbia University (5.5% of the total number of dissertations in the researched period), Florida State University (6.2%), Indiana University (4.7%), Michigan State University (5,3%), New Brunswick State University (4.3%), Rutgers State University of New Jersey (4.0%), City University of Chicago (5.2%), University of California (5.7%), University of Illinois Urbana-Champaign (6.5%), University of Pittsburgh (9.0%), University of Toronto (3.5%) [5].

Certainly, in bibliometric analysis, the theme of defended dissertations on librarianship is important. 88 works, i.e. 2.8%, are related to the theory of librarianship, 269 works, i.e. 8.6%, are devoted to economy, organization and management of library work. Management of libraries is directly related to issues of personnel training, 8.4%, 263 research works on this topic were carried out. The growth of interest in this topic corresponds to the years 1970–1979 and 1990–1999. Management and organization of library activities accounted for 17%. 248 studies were conducted on the topic of library education, which is almost 8%.

TABLE 1. DISTRIBUTION OF DISSERTATIONS BY TOPICS

1903–2004

Topics	Total
Automation of library processes. Information technologies. Electron libraries.	745
School libraries	270
Organization of library work. Management. Economy.	269
Human resources. Librarian profession	263
Library services	261
Library education	248
Organization of library work abroad	234
Book studies. Book history	182
Organization of library funds	158
Cataloging Systematizing	155
Librarianship history	145
Bibliography	141
Reading. Interests of readers	110
Theory of librarianship	88
Technical equipment of libraries	18
Total	**3285**

We can see that the research on the development of school libraries in foreign countries playing important role, and great attention is paid to scientific research on the activities of libraries with the growing generation. And also, 745 dissertations on topics related to information technologies, electronic databases, automation of library processes, electronic libraries and the Internet related topics organizes the 23% of the research. Issues such as information search by researchers, formation of users’ requirements, ensuring compatibility of library services with the Internet have become one of the actual topics in the last 15 years, and in the last 25 years, intellectual property and copyright issues have been one of the most urgent topics.

The topic of research in the field of library in recent years, the bibliometric analysis of leading organizations and leading publishers, scientists, especially Ashiq, M., Ur Rehman, S., Ahmad, N., Atoum, I., Aqil, M., & Ahmad, S., etc., are also listed and analyzed in the scientific articles of high productively organizations in the field of librarianship [1].

According to it, the following organizations are defined as highly productively organizations:

The top three contributing countries were the United States of America, Australia, and the United Kingdom, with 59, 46, and 41 articles, respectively. They also highlighted that most of the published papers were related to library management, library services, knowledge management, human resources management, and staff professional development. Furthermore, most contributions were from universities (267, 79.64%) and colleges/institutes (26, 7.43%). He depicts by the table the top 10 highly productive countries in terms of publications in the field of library. There are three countries with over 20 publications. The United States of America is at the top of the list with 313 publications (62.6%),17,191,269 citations, and 5.49 average citations. However, out of these 313 publications, 89 items have not been cited yet. The United Kingdom stands in the second position, with 27 publications (5.4%), 182 citations, and 6.74 average citations, followed by Canada with 25 publications (5.0%), 142 citations, and 5.68 average citations. It is interesting to highlight that Denmark has produced only nine publications; however, it has the highest average citations (11.78%). In contrast, India is at the bottom of the list, with eight publications and only five citations.

In addition, we can see that in Han X’s research [3], he studied the evolution of research topics in library information science between 1996 and 2019 based on the latent Dirichlet allocation topic model.

TABLE 2. EVOLUTION OF RESEARCH TOPICS IN LIS BETWEEN 1996 AND 2019

1996-2000	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2019**
Digital library/services	Information retrieval	Citation analaysis	Bibliometric analysis	Citation analaysis/impact factor

		/impact factor		
Academic library/librarianship	text processing	text processing	Research performance	Social media
Information systems/ Information management	Organizational information activities	Information retrieval/ user	Citation analysis/measurement	Organizational information activities
Citation analysis/impact factor	Information systems	Organizational information activities	Scientific collaboration	text processing
Scientific collaboration	Digital libraries/ services	Government	Citation analysis/impact factor	Knowledge sharing
Information retrieval	www	Scientific collaboration	Information management	Government
Citation analysis	Network communities	Semantic analysis/ models and algorithms	Government	Organizational innovation/performance
Patent analysis	Technology application	Patent analysis	Online/community	e-commerce
Information- seeking behaviour	Citation analysis	Technology application	Organizational information activities	Mobile application
Information systems/design	Information-seeking behaviour	Research performance	Ranking research	Knowledge management

We can see from this table that the initial research topics were on topics such as digital libraries, services, information management, and after 2006, research topics covered topics such as bibliometric analysis, impact factor, mobile applications, and artificial intelligence-based search systems.

C. Analysis of research works on librarianship in Uzbekistan

While studying the scientific research carried out in the field of librarianship in Uzbekistan, the analysis of the most relevant researched issues in the field was studied. While researching the topics of dissertations of a number of scientists, from 1969 to today, research works related to librarianship were tried to be covered on this purpose. The initial studies were mainly related to the history of librarianship, issues of development of network libraries in our country, these are: Kormilitsyn A.I., Konarev A.Ya., Kasimova A.G., Rakhimova M., as well as the work of bibliography in Uzbekistan, Turapov M.. M., Mamatraimova H., Book history in Central Asia and issues related to book studies was researched by Rustamov M. The researches related to the study of librarianship in foreign countries have also been carried out, which were the works of Ibaragim Nazmi Mohamad Mukhsin, Raid Djamel Yakub Suleyman. In libraries, growing up the upcoming young generation and the studies of book reading in sociological aspects were carried out by A.O. Umarov, D. A. Ganieva and Ganieva B.I. [11]

As a result of the introduction of information technologies into the library field after 2000, several researches on the technologies used in libraries E. Bugibaev, bibliographic information re-processing in the corporate network J. Atadjanov, issues such as ensuring information security Sh. Normatov and integration of library systems with other systems Karimov U.U. were carried out. Below is an overview of these studies by year and subject area.[2]

Researches on information technologies, creation of electronic libraries make up 23% and cover the first decade of 2000 [4]. We can see the studies on school library 9%, on reading and reading interests 14%, on the organization of library work in foreign countries 9%, on the history of librarianship 18%, on book history 18% and on bibliography 9%.

TABLE 3. EVOLUTION OF RESEARCH TOPICS IN LIS UZBEKISTAN

2000-2005	**2005-2011**	**2012-2016**	**2016-2020**
Digital library/services	Information retrieval	Mobile application	Citation analysis/impact factor
Information systems	Information systems/design	Information retrieval	Bibliometric analysis
Librarianship/school libraries	Digital libraries/services	Technology application	Ranking research
Academic library/librarianship	Information systems	Scientific collaboration	Information retrieval/user
Information- seeking behaviour	Information-seeking behaviour	Scientific collaboration	Social media

We can conclude from these analyzes that scientific research works in the field of librarianship in Uzbekistan are just developing and increasing. The topics of scientific research are also just catching up to the topics of research conducted at the world level. That is, if we look at the evolution of the topics, we can see that they differ slightly over the years. The reason is that the concept of automated library and digital library began to appear in our country after 2000 years.

III. SUMMARY

The analysis shows that in the field of librarianship in developed countries, scientific research has been carried out since 1904. The most prominent of these schools are the North American school of librarianship, and librarian

work experiences of European countries can be seen. As mentioned above, V. V. Skvortsov’s opinion that "today the North American school of librarianship is occupying the leading position in the world librarianship" can be agreed based on the studies. In 2018, with the help of the "International visitor leadership program" (IVLP) program of the US department, we were able to study the North American school of librarianship in our own experience. Almost all topics of librarianship are covered in these studies, and it is especially noteworthy that the first researches on library process automation, information technology and electronic libraries started in 1960 and peaked in 1990-99, and it is one of the most researched topics in the studied time period, accounted for 23% of all studies. The scope of scientific researches related to librarianship in our country is wide, among these researches the history of librarianship, bibliography, book history, reading, and theoretical researches on the interest of readers make up a large part. It is worth to note that the research on the automation of library processes, information technologies and electronic libraries began in the libraries of Uzbekistan between 2000 and 2009. Today, we can admit that scientometric and bibliometric researches are also included in the subject scope of librarianship research. It is obvious that dissertations traditionally serve as a certain "indicator" in determining the directions of scientific research and serve as an information base for determining the trends in the development of sciences in the information-library field. Studying the prior directions of the development of the information-library institutions in developed foreign countries, considering on our prospective tasks in this regard, and determining the necessary measures to be implemented is important.

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ZAMONAVIY DAVRDA RAQAMLI MEDIA TEXNOLOGIYALARINING AHAMIYATI

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***Annotatsiya* — Mazkur maqolada jamiyat rivojida raqamli suratga olish va turli multimedia texnologiyalarining ahamiyati, televizion, video, foto suratga olish, media ma’lumot yuborish, kuzatish, foydalanish kabilardagi roli, shuningdek, yangi media texnologiyalarga moslashish jarayonlari o‘rganiladi.**

***Kalit so‘zlar* — multimedia, raqamli, televizion, video, foto, kamera, kuzatuv, ma’lumot.**

I. KIRISH

Multimedia texnologiyalarining rivojlanishi tufayli televidenie, video, fotografiya, jurnalistika kabi bir necha sohalar zamonaviy davrda o‘ziga xos inqilobni boshdan kechirmoqda. Raqamli texnologik jarayonlar turli formatlarda kontent yaratish va tarqatish imkonini bermoqda, audio-video texnikalarning zamonaviy turlari yangicha usullarni, yechimlarni taklif qilmoqda. Bu esa nafaqat media, balki turli boshqa sohalarni rivojlanishi uchun keng imkoniyatlar ochmoqda. Masalan, ta’lim yo‘nalishida internet, elektron resurslar, onlayn muloqotlar va turli elektron darsliklarni yanada rivojlanib borayotgani bunga misoldir. Bu borada zamonaviy multimedia texnikalaridan foydalanishni bilish, ushbu texnikalardagi yangilanib borayotgan o‘zgarishlarga moslashib borish, kontentlar va media maxsulotlar yaratishda uslub, janr, dizayn, kompozitsiya, format, audio-vizual sifat kabilar bo‘yicha bilim va ko‘nikmalar talabi ortmoqda. Ushbu jarayonda oddiy havaskorlikdan yuqori bo‘lgan bilim va mahorat darajasi zarur bo‘lib, ko‘pincha buning yetishmasligi kuzatilmoqda.

II. MATERIALLAR TAHLILI

Zamonaviy multimedia texnologiyalari axborotni matn, grafik, audio, video, animatsiya va boshqa elektron shakllarda qayta ishlash, uzatish va taqdim etishni ta’minlovchi raqamli vositalar majmuini qamrab oladi [1]. Ularning ahamiyati internet, mobil qurilmalar va raqamli infratuzilmaning rivojlanishi tufayli shiddat bilan ortib bormoqda. Ushbu texnologiyalar ko‘plab sohalar rivojida muhim rol o‘ynamoqda. Masalan, ta’limda yaratilayotgan elektron video darsliklar, o‘quvchi uchun interaktiv jarayonlarni paydo qilib, ma’lumotlarni qulay o‘zlashtirishida imkon yaratmoqda. Bir yarim - ikki asr oldin halqimizning asosiy qismi dala va chorva mehnati bilan kun kechirar edi. Ularning bilim olishga vaqti ham imkoni ham bo‘lmasdi. Qishloqlarda ta’lim maktablari rivojlanmagan bo‘lib, ko‘pchilik o‘qishni bilishmasdi. Institutlarda o‘qishni gapirmasa ham bo‘ladi. Buni bugungi kun bilan taqqoslasak, katta farqni kuzatamiz. Ayniqsa internet va zamonaviy media texnologiyalarning berayotgan sharoitlari bilan o‘lchasak kosmik imkoniyatlarni his qilamiz.

Shunga qaramay zamonaviy ta’limda multimedia va internet imkoniyatlaridan oqilona foydalanmayotgan o‘quvchi yoshlarimiz borligi ma’lum. Talaygina o‘quvchi yoshlarimiz biror maqsadga erishish uchun o‘z mehnati bilan emas, balki oson yo‘llarni izlashi noo‘rin hisoblanadi. Bu borada nazoratchi o‘qituvchilarning ma’suliyati yanada ortmoqda. Masalan, Televizion texnologiyalar yo‘nalishi talabalarining media amaliy ishlarini baholashda ilgari tugallangan yakuniy ish qabul qilingan bo‘lsa, endilikda butun jarayondagi hom ishlar ham birma bir ko‘zdan kechirilishini taqozo etmoqda.

Multimedia texnologiyalari ta’lim darslarini masofaviy, interaktiv, audio-vizual shakllarda tashkil etish imkonini berib, yanada shaffof bo‘lishini taminlamoqda. Masalan, ko‘plab o‘quv auditoriyalarida jihozlangan kuzatuv kameralari o‘quvchilarning sezgir bo‘lishi, zarur bo‘lmaganda mobil telefonlari va noutbuklardan foydalanmaslik kabi sharoitlarni paydo bo‘lishiga yordam bermoqda. Shuningdek, kuzatuv kameralari orqali umumiy dars sifatini nazoratga olish mumkin. Masofadan turib o‘qish ayniqsa, ish faoliyatida bo‘lganlar uchun qulay hisoblanadi. Ish joyidan turib onlayn shaklda darsga qatnashish, yoki qo‘shimcha audio-video ma’ruzalarni eshitish imkonini beradi. Shuni hisobga olgan holda, masofaviy ta’lim shaklida dars mavzularini eshitish va o‘zlashtirish jarayoni vaqt hisobida, boshlash, tugatish o‘quvchi uchun erkin tarzda bo‘lishi yanada qulaylik yaratadi.

O‘quv materialning vizual taqdimoti bizning miyamiz tomonidan matnga qaraganda 60 000 marta tezroq qayta ishlanadi, shuning uchun ma’ruza va laboratoriya materiallarini video formatda taqdim etish samaraliroq bo‘ladi [2]. Audio-video darsliklar asosan: videokamera yordamida, kompyuter grafikasi yordamida, kompyuter ekranidan video yozish, fotoslayd yordamida va boshqalarga bo‘linadi. Ko‘p hollarda videokamera o‘rnini mobil telefonlari egallayotgani sir emas, shunga qaramay malakali mutaxassislar professional video va ovoz yozish qurilmalaridan foydalanishni maslahat berishadi. Darhaqiqat, bugungi kundagi kontent sifati uchun professional audio-video texnika muhim ahamiyat kasb etmoqda. Negaki, zamonaviy o‘quvchilar va turli foydalanuvchilarning audio-vizual ma’lumotlarni qabul qilish saviyasi 20 yil oldingiga qaraganda ancha o‘sgan. Media maxsulotlarga nisbatan texnik, kreativ, ijodiy va ihchamlik sifatlariga talab ortgan.

Bu borada Toshkent axborot texnologiyalari universitetining o‘quv media markazida audio-video darsliklar yaratish ustida izlanishlar olib borilmoqda. Buning uchun birgina videokamera yetarli bo‘layotgani yo‘q, balki alohida ovoz yozish mikrofoni, yoritish chiroqlari, maxsus fon, elektron doska, sufler kabi uskunalar va eng asosiysi ulardan to‘laqonli foydalanishni bilish zarur bo‘lmoqda. Texnikalarni ishga tayyorlash va boshqarish ko‘nikmalari universitetning Televizion va media texnologiyalar yo‘nalishlarida o‘rgatilmoqda. Ko‘pgina bitiruvchi talabalar universal bilimga ega bo‘lib, suratga olish, montaj qilish, grafik dizayn va geym dasturlar ustida ishlash, videokuzatuv tizimi va yorug‘lik yoritish bo‘yicha turli korxonalarda, jumladan, davlat va nodavlat telekanallarida faoliyat yuritishmoqda.

Video darsliklarni yaratilishini umuman olganda to‘rt qismga bo‘lish mumkin: 1. Mavzuga tayyorgarlik; 2. Texnik tayyorgarlik; 3. Mavzuni kamera oldida yoritib berish yoki suratga olish; 4. Montaj jarayoni. Bularning ichida eng asosiysi o‘quv materialni o‘quvchiga tushunarli va qiziqarli qilib yetkazish dolzarb bo‘lib qolmoqda. Natijalar shuni ko‘rsatmoqdaki, bu borada klassik usuldagi televizion, animatsion va kino ssenariylar tuzilishining video darsliklar yaratilishida mos kelishi kuzatilmoqda. O‘quv video darsliklari bir soat yigirma daqiqa emas, balki birmuncha kamroq vaqtni egallashi, ihcham bo‘lishi, qismlarga bo‘linishi lozimligi talab qilinadi.

O‘quv video darsliklarni yaratilishida o‘qituvchi kadrda doim ko‘rinib turishi shartmi, albatta buning meyoriy mezonlari bo‘lib, bu haqida ilmiy izlanuvchilar quyidagi xulosalarga kelishmoqda. Masalan, V.Grushevskaya [3]

So‘nggi bir necha yil ichida o‘qituvchilar ta'limida videolardan "amaliyot artefakti" sifatida foydalanish ko‘paydi. Lemke (2007) ta’kidlaganidek, videolar bilan ishlash o‘qituvchilarga ta’lim jarayonining “ichiga” kirib, o‘z-o‘zini aks ettirish uchun boy vositaga ega bo‘lganligi sababli o‘qitishni boshqa nuqtai nazardan boshdan kechirish imkonini beradi.

So‘nggi yillarda tadqiqotchilar XXI-asr maktablarida aks ettiruvchi o‘qituvchining roli ustida ko‘p ishlamoqdalar va o‘qituvchilar zaif va kuchli tomonlarini topish va o‘qitish uslubi va strategiyasini mos ravishda o‘zgartirish uchun o‘zlarining xatti-harakatlari haqida o‘ylashlari uchun qandaydir portfel yoki elektron portfelda dalillar, hujjatlar, video hikoyalar xotiralarini to‘plashlari kerakligini ko‘rsatmoqdalar.

Ta’lim yo‘lida videolardan foydalanish o‘qituvchilarga zaif va kuchli tomonlarini aniqlash hamda kelgusidagi harakatlarni yaxshilash uchun o‘zlarining o‘qitish strategiyalari va uslublari haqida fikr yuritishga yordam beradi. Agar stajyor o‘qituvchilar ushbu muhim voqealar haqida rasman mulohaza yuritsalar, ularga o‘qitish jarayoni haqidagi yangi tushunchalarni ochish va tuzatish osonroq bo‘ladi. Bu tanqidiy hodisalar nazariyasining boshlang‘ich nuqtasi bo‘lib, o‘zining va boshqa o‘qituvchilarning video darsliklari haqida fikrlash va muhokama qilish imkoniyatlariga asoslanadi.

Bugungi kunda turli mavzudagi reportajlar, videokontentlar dron va ekshn kameralari kabi zamonaviy texnologiyalar, shuningdek, an’anaviy usullar, jumladan, bevosita videokamera yordamida intervyu olish orqali amalga oshirilmoqda. Masalan, dronlar noyob burchaklarni va sodir bo‘layotgan voqealarning umumiy tasvirini olish imkonini beradi, bu esa jurnalistning qulay sharoitlarda imkoniyatini va material sifatini oshiradi. Jurnalistning boshiga yoki yelkasiga biriktirilgan ixcham va bardoshli ekshn kameralar suratga olish va sodir bo‘layotgan voqealarning realligini etkazish imkonini beradi. Eknsh kameralarini yashirin kamera sifatida ham ishlatish mumkin.

Media axborotni tez tarqatish asosiy vazifalardan biridir. Materiallar sun’iy yo‘ldosh aloqa kanallari va zamonaviy ma’lumotlarni uzatish tizimlari yordamida real vaqt rejimida uzatiladi. Masalan, televizion sharoitida qabul qiluvchi ko‘chma televizion stansiyalari to‘lqinni markaz orqali jonli efirga yuborishi mumkin. Joriy yilda O‘zbekiston milliy teleradiokompaniyasiga bir nechta eng zamonaviy dunyo standartlariga to‘liq javob beradigan ko‘chma televizion stansiyalari keltirildi. Bunday stansiyalar yordamida jonli usuldagi mobil televizion efirlarni ko‘paytirish, tele-konferensiyalar, ochiq telemuloqotlar va realistik muhitni yanada rivojlantirish ko‘zda tutilgan.

IPTV internet orqali media maxsulotlarni, jumladan, jonli teleko‘rsatuvlarni uzatish tizimi eng zamonaviy texnologiya hisoblanib, foydalanuvchi uchun qator imkoniyatlar bermoqda. Masalan, studiyalar bilan foydalanuvchi o‘rtasidagi interaktiv bog‘lanish imkoniyati, teleefirlarni qayta tomosha qilish, jonli videokonferensiyalar tashkil qilish, fikr mulohazalar qoldirish va boshqalar shular jumlasidandir. Bugungi kunda O‘zbekiston miqyosida UZdigital, Stars TV, ISTV, Turon Telekom, Gals Telecom, Sonet kabi IPTV faoliyat yuritmoqda.

III. XULOSA

Shunday qilib raqamli multimedia texnologiyalarining zamonaviy davrdagi ahamiyatini o‘rganish jarayoni quyidagi hulosalarga kelishga imkon beradi. Multimedia texnologiyalari ta’lim jarayonlarini boyitadi, keng imkoniyatlar beradi, uni yanada qiziqarli, qulay va samarali qiladi. Media tasvirlarni suratga olish va tahrirlashda, ularni o‘zgartirishda, jozibalikni oshirishda keng badiiy, kreativ hamda boshqa maxsus imkoniyatlar ochadi. Shuningdek, zamonaviy media texnologiyalarni ishlatishda texnik hamda uslubiy-metodik jihatdan yangi bilim va ko‘nikmalar talab qilinadi. Video ish tuzilishi, butun jarayonni boshqarish, kamera bilan ishlash, ovozni nazorat qilish, audio-video montaj, grafik effektlar yaratish, prezentatsiyalar ustida ishlash kabilar shular jumlasidandir. Bunday ishlab chiqarish o‘z navbatida kichik guruhdan iborat media mutaxassislarni va professional audio-video texnikalarni talab etadi. Shunga qaramay yakka holatlarda har bir inson minimal qurilmalardan foydalangan holda kontentlar yaratish va boyitib borish imkoni mavjud. Ayniqsa, videodarsliklar yaratilishi va elektron foydalanish talaba uchun fanlarni o‘zlashtirishida samara beradi, o‘qituvchi uchun o‘z kamchiliklarini bilishi va uning ustida ishlashi uchun yordam beradi.

FOYDALANILGAN ADABIYOTLAR

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O‘QUV KONTENLARINI TAVSIYA ETISH TIZIMLARINING AHAMIYATI

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Annotatsiya— **Ushbu maqolada zamonaviy ta’lim tizimida o‘quv kontenlarini tavsiya etish tizimlarining o‘rni va ahamiyati tahlil qilinadi. Talabalar ehtiyojlari, bilim darajasi va qiziqishlariga mos holda individual ta’lim yo‘nalishini shakllantirishda tavsiya etish tizimlari muhim vosita sifatida ko‘riladi. Maqolada tavsiya tizimlarining ishlash mexanizmlari, ularning asosiy turlari (filtrlashga asoslangan, kontentga asoslangan va gibrid yondashuvlar) hamda ta’lim samaradorligini oshirishdagi roli ko‘rib chiqiladi. Shuningdek, ushbu texnologiyalarni o‘zbek ta’lim muhitiga joriy etish imkoniyatlari va mavjud muammolar haqida fikr yuritiladi. Hozirgi vaqtda virtual o‘quv muhitlari vaqt va makon cheklovlaridan qochish va yuqori sifatli o‘quv resurslarini almashish uchun keng tarqaldi. Inson va kompyuterning o‘zaro ta’siri natijasida o‘quvchilarning xatti-harakatlari bir zumda qayd etiladi. Ushbu ish shaxsning ta’lim resurslariga bo‘lgan qiziqishlarini hisobga olgan holda ta’lim bo‘yicha tavsiyalar tizimini ishlab chiqishga qaratilgan. Ushbu tizim foydalanuvchining yordami bilan manbani quyish yoki yuklab olish asosida baholanadi, shuning uchun foydalanuvchilarga tegishli resurslarni taklif qilish mumkin.**

Kalit so‘zlar—***Tavsiya etish tizimlari, o‘quv kontenti, shaxsiylashtirilgan ta’lim, raqamli ta’lim, filtrlangan tavsiyalar, ta’lim texnologiyalari, foydalanuvchi modeli, mashinaviy o‘rganish, kontekstual tavsiyalar, gibrid tizimlar.***

I. KIRISH.

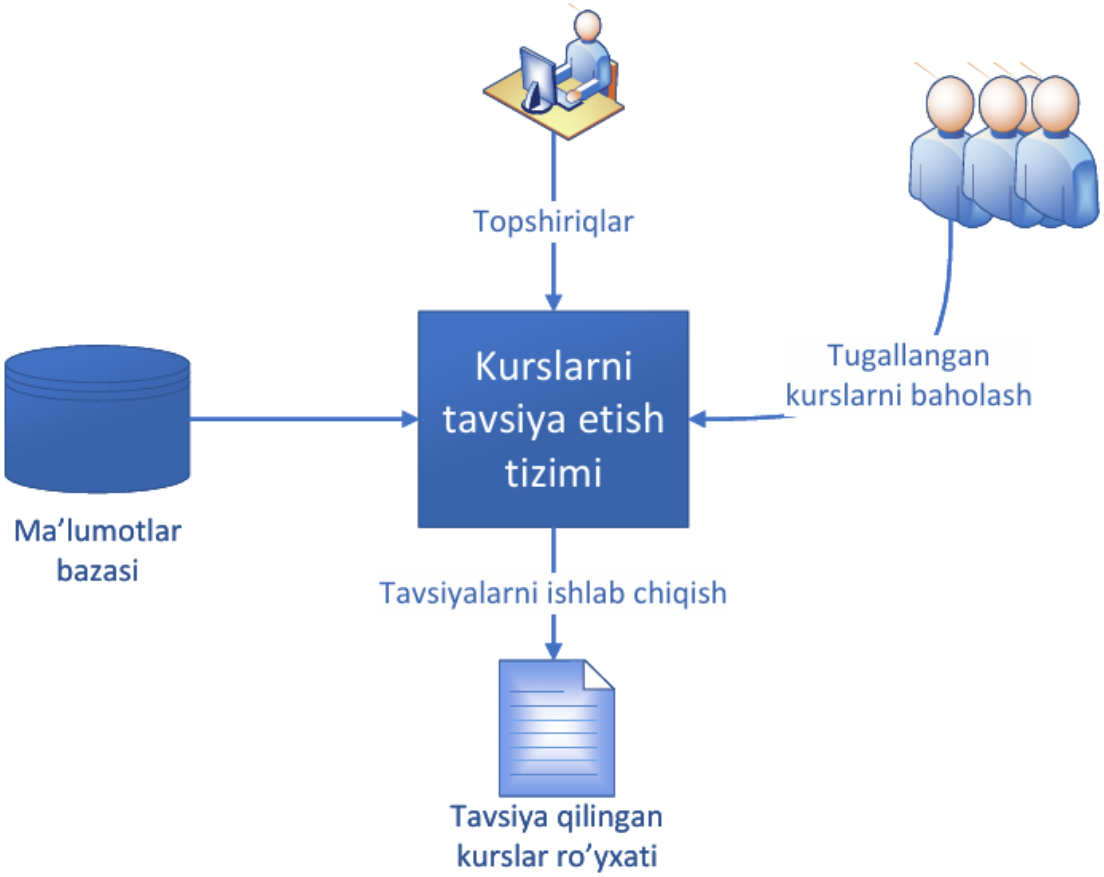
Zamonaviy raqamli texnologiyalar taraqqiyoti ta’lim sohasida ham tub o‘zgarishlarga sabab bo‘lmoqda. An’anaviy o‘qitish uslublari endilikda raqamli vositalar bilan boyitilib, talaba va o‘quvchilarga shaxsiylashtirilgan, interaktiv va moslashtirilgan ta’lim olish imkonini yaratmoqda. Ayniqsa, katta hajmdagi o‘quv materiallari, elektron kurslar va onlayn resurslar orasidan foydalanuvchiga mos, samarali va qiziqarli kontentni tanlab berish muhim masalaga aylanmoqda. Shu nuqtai nazardan, o‘quv kontenlarini tavsiya etish tizimlari ta’lim jarayonini optimallashtirishda muhim rol o‘ynaydi. Tavsiya tizimlari dastlab elektron tijorat sohasida keng qo‘llanila boshlangan bo‘lsa-da, bugungi kunda ular ta’lim platformalarida ham faol joriy etilmoqda. Ushbu tizimlar foydalanuvchi xatti-harakatlari, qiziqishlari va bilim darajasini tahlil qilish orqali unga mos o‘quv resurslarini tavsiya qilishga xizmat qiladi. Bunday yondashuv nafaqat o‘quv jarayonining samaradorligini oshiradi, balki foydalanuvchining ta’limga bo‘lgan motivatsiyasini ham kuchaytiradi. Mazkur maqolada o‘quv kontenlarini tavsiya etish tizimlarining ishlash tamoyillari, ularning turlari hamda ta’limdagi amaliy ahamiyati ko‘rib chiqiladi. Shuningdek, ushbu tizimlarning o‘zbek ta’lim muhitiga moslashtirish imkoniyatlari haqida ham fikr yuritiladi.

Onlayn darslarda, to‘g‘ri manba tanlash muammosiga qo‘shimcha ravishda, sessiya boshida foydalanuvchilarning xohish-istaklari va didlari, ayniqsa, ularning yaqin kelajakdagi qisqa muddatli manfaatlarining xilma-xilligidan muhim muammo hisoblanadi. Foydalanuvchining manfaatlarini ikki qismdan iborat (1) foydalanuvchining dinamik faoliyati tarixiga asoslangan doimiy manfaatlarini o‘z ichiga olgan foydalanuvchining uzoq muddatli manfaatlari va (2) foydalanuvchining joriy manfaatlarini ko‘rsatuvchi foydalanuvchining qisqa muddatli manfaatlari. Bilstm tarmoqlaridan foydalanish va ularning bosqichma-bosqich o‘rganish xususiyati tufayli taklif etilayotgan model o‘quvchilarning xatti-harakatlaridagi o‘zgarishlarni qo‘llab-quvvatlaydi.

So‘nggi yillarda o‘qituvchilarning o‘quv resurslaridan foydalanishi sezilarli darajada oshdi. Ko‘pgina ta’lim resurslari turli xil ta’lim mavzulari va maqsadlariga javob beradigan turli xil omborlarda tarqatiladi. Biroq, ma’lumotlarning haddan tashqari yuklanishi tufayli ko‘plab o‘quvchilar o‘zlarining ta’lim ehtiyojlarini qondiradigan tegishli va qimmatli o‘quv resurslarini topishda qiyinchiliklarga duch kelishadi.Mavjud tavsiya qiluvchi tizimlar e-tijorat sohasida juda muvaffaqiyatli bo‘lgan bo‘lsa-da, elektron ta’lim sohasida o‘quv resurslarining to‘g‘ri tavsiyachisini yaratishda o‘quvchilarning ta’lim uslubi, bilim darajasi va o‘rganish modeli kabi xususiyatlaridagi farqlar kabi muammolar mavjud. Ko‘pgina mavjud tavsiya usullari o‘quvchilarning xususiyatlaridagi farqlarni hisobga olmaydi. Albatta, bu muammoni tavsiya qilish jarayoniga o‘quvchilar haqidagi plagin ma’lumotlarini qo‘shish orqali yaxshilash mumkin.

So‘nggi paytlarda chuqur o‘rganish usullari yordamida tavsiya qiluvchi tizimlar sezilarli darajada

o‘sdi. Takroriy neyron tarmoqlar (RNN) seansga asoslangan tavsiya tizimlarini modellashtirishda muhim rol o‘ynaydi va keyingi yaxshilanishlarni va’da qiladi. Boshqa ko‘plab tavsiya qiluvchi modellar bilan solishtirganda, RNN tavsiyani yaxshilashga yordam beradigan keng qamrovli foydalanuvchi profilini yaratish uchun tartiblangan ketma-ketlikdan yoki foydalanuvchilarning izchil tarixidan foydalanadi [5]. Hozirgacha uzoq muddatli va qisqa muddatli foydalanuvchi manfaatlarini birlashtirish bo‘yicha ko‘p ishlar qilindi. Boshqa tomondan, foydalanuvchilarning ob’ektlarga bo‘lgan afzalliklari vaqt o‘tishi bilan doimiy ravishda o‘zgarib turadi, bu tarmoqlar foydalanuvchi manfaatlarini statik deb bilvosita qabul qiladi, bu ko‘p senariylarda noto‘g‘ri taxmindir. Shuning uchun, manfaatlar mazmunan sezgir va vaqtinchalik bo‘lsa, bu usullar juda yomon ishlaydi. Bundan tashqari, foydalanuvchining statik manfaatlari muammosini hal qilish uchun qiziqishlarning siljishi bilan shug‘ullanadigan seansga asoslangan usullar mavjud.[6] Bundan farqli o‘laroq, bu usullar barcha elementlar sessiyada bir xil ta’sirga ega bo‘lishini nazarda tutadi, bu noto‘g‘ri taxmin, ayniqsa foydalanuvchining turli xususiyatlarga ega bo‘lgan elementlar bilan o‘zaro ta’sirini hisobga olgan holda. Ushbu muammoni hal qilish uchun ta’lim resurslarini tavsiya qilish uchun uzoq muddatli va qisqa muddatli diqqatga asoslangan modelni taklif qilamiz. Qayd etilgan tadqiqotlarning hech birida avtomatik ravishda foydali maslahatlar beradigan ta’lim bo‘yicha tavsiyanoma ishlab chiqilmagan; ammo, bunday tavsiyachi ta’lim dasturlarida juda kerak. Bizning modelimiz bir vaqtning o‘zida ikki turdagi ma’lumotlarni (qisqa muddatli va uzoq muddatli foydalanuvchilarning qiziqishlari va ta’lim resurslarini yangilash) o‘z ichiga olgan gibrid diqqatga asoslangan RNN tarmog‘idan foydalangan holda yaxshiroq ta’lim resurslarini tavsiya qiladi. Biz e’tiborga asoslangan texnikani foydalanuvchining qisqa muddatli manfaatlariga qarab ko‘rib chiqdik va siqish bosqichida biz vaqt vektori asosida foydalanuvchi ozaro ta’sirini tortdik. Ya’ni, foydalanuvchining qanchalik amaliy atributlari ta’lim resursi tavsiyasiga samaraliroq ta’sir qiladi deb hisoblangan. Eng kam takrorlashlarni e’tiborsiz qoldiradigan klasterlash usullaridan farqli o‘laroq, foydalanuvchilarning barcha o‘zaro ta’siri saqlanib qoladi. Darhaqiqat, avvalgi ishlar ta’lim uchun faqat foydalanuvchining oldingi ma’lumotlaridan foydalanilgan. Ushbu tadqiqotda ham oldinga, ham orqaga qaraydigan tarmoqqa ega bo‘lish bizga o‘quvchining xatti-harakatlaridagi o‘zgarishlarni qamrab olish va yangilangan tavsiyalarni taklif qilish imkonini beradi. Ikki tomonlama LSTM chuqur neyron tarmog‘idan foydalanish foydalanuvchining uzoq muddatli va qisqa muddatli manfaatlarini o‘z ichiga oladi.



1-rasm. O‘quv kurslarini tavsiya etish tizimi arxitekturasi

Sessiyaga asoslangan tavsiya tizimlari bo‘yicha tadqiqot yangi mavzu emas va an’anaviy takroriy tizimlarga nisbatan dinamik va ketma-ket foydalanuvchi xatti-harakatlarini o‘rganish uchun ko‘proq mos keladi. Rekurrent tizimlar foydalanuvchi ehtiyojiga yaqin natijalarni shakllantirish hamda ularning ustuvorliklariga asoslangan holda bashorat qilishni maqsad qiladi. Virtual o‘quv muhitlarida esa ta’limiy tavsiya tizimlari o‘quvchilarning xususiyatlari, ustuvorliklari va o‘quv ehtiyojlariga asoslanib o‘quv obyektlarini taqdim etadi. O‘quv obyekti — bu topilgandan so‘ng o‘quvchiga o‘quv jarayonida yordam beradigan ta’limiy mazmun birligidir. IEEE ta’rifiga ko‘ra, o‘quv obyekti — bu ta’limiy dizayn xususiyatlariga ega bo‘lgan raqamli yoki noraqamli birlik bo‘lib, kompyuterga asoslangan ta’lim jarayonida ishlatilishi, qayta ishlatilishi yoki murojaat qilinishi mumkin.

Chuquroq o‘rganish (deep learning) imkoniyatlari tufayli ko‘plab vazifalarni samarali hal qilish va yuqori natijalar olish mumkinligi sababli, universitetlar va sanoat korxonalari uni keng qo‘llash bo‘yicha raqobatlashmoqda. So‘nggi yillarda chuqur arxitekturalar tavsiya tizimlarini tubdan o‘zgartirdi va ularning samaradorligini oshirdi. Deep learning murakkab, chiziqsiz foydalanuvchi–obyekt munosabatlarini samarali ushlash va ularni yuqori darajadagi ma’lumot taqdimoti sifatida kodlash imkonini beradi. Shuningdek, u kontseptual, matnli va vizual kabi boshqa manbalardan ham murakkab munosabatlarni ajratib olishi mumkin. Katta ma’lumotlar davrida hajmning ortishi real hayotdagi qo‘llanmalarda muammolar tug‘diradi. Shu sababli, masshtablash imkoniyati modelning samaradorligi uchun muhim, vaqt murakkabligi esa model tanloviga sezilarli ta’sir qiladi. Yaxshiyamki, chuquq o‘rganish juda samarali va ishonchli hisoblanadi.

1)

II. AN’ANAVIY USULLAR TAHLILI

2) An’anaviy onlayn o‘quv tizimlari turli xil filtrlash usullariga asoslangan bo‘lib, ular ko‘pincha foydalanuvchilarning turli manbalar bilan ishlashdagi xatti-harakatlariga tayangan. O‘xshash xatti-harakatlarga ega foydalanuvchilardan olingan resurslarni tavsiya qilish esa ko‘pincha qoniqarli natija bermaydi.

Hagemann va boshqalar (20) talabalar o‘z o‘quv yo‘lini ongli ravishda tanlashlari uchun shaxsiy tavsiya tizimini taklif qilishgan (22). Ushbu tadqiqotning maqsadi talabalar tanlagan modullarni kashf qilish yo‘lini yaxshilash bo‘lib, bu aynan talabalar uchun mavjud variantlarni samarali topishga yordam beruvchi gibrid tavsiya tizimi orqali amalga oshiriladi. Kontentga asoslangan o‘xshashlikni modul maydoni haqidagi strukturaviy ma’lumotlarga asoslangan dispersiya bilan birlashtirish orqali, talabalar ustuvorliklari va maqsadlariga mos keladigan tanlovlarning aniqligini oshirish mumkin. Ushbu yondashuvning afzalliklaridan biri — tavsiyalar to‘plamiga xilma-xillik qo‘shish imkoniyatidir.

Tseng va boshqalar ta’lim beruvchilarga talabalar o‘quv faoliyatini kuzatish va monitoring qilish imkonini beruvchi **moslashuvchan o‘quv va tavsiya platformasini** taqdim etishgan (23). Talabalar platforma orqali taqdim etilgan o‘quv yo‘li yordamida ALR (Adaptive Learning and Recommendation) jarayonini o‘zlashtira oladilar. Ularning kuchli va zaif tomonlari o‘quv faoliyati, o‘quv jarayoni va samaradorligini tahlil qilish orqali aniqlanadi. Maqsad — moslashuvchan o‘quv uchun konseptual xarita yaratish va talabalarga ta’limiy maslahatchi bo‘lishdir.

Alinani va boshqalar (2016) foydalanuvchi afzalliklariga asoslangan **geterogen ta’limiy resurslarni tavsiya qilish tizimini** taklif qilishgan. Bu tizim nafaqat foydalanuvchilarning ehtiyojlarini qondiradi, balki ko‘pgina tavsiya tizimlarida uchraydigan “cold start” muammosini ham kamaytiradi. Buni amalga oshirish uchun tizim foydalanuvchilarga ularning oxirgi so‘rovlariga asoslanib resurslarni tavsiya qiladi va foydalanuvchi xatti-harakatidan o‘rganadi. Muhim jihati shundaki, har bir tavsiya qilingan resursga foydalanuvchining javobiga qarab vazn (og‘irlik) beriladi. Geterogen tavsiya tizimi foydalanuvchilarga turli xil tegishli resurslarni tezda topish imkonini beradi va bu esa ularning unumdorligini oshiradi.

Bourkoukou va Achbarou foydali kontent va yaxshiroq tavsiyalarni eng qisqa vaqtda taqdim etadigan shaxsiy tavsiya tizimini yaratishni maqsad qilishgan. Taklif etilgan tizim — bu foydalanuvchi profillaridan foydalanib “qo‘shnilar” guruhini shakllantiradigan va vaznlardan foydalangan holda prognozlar chiqaradigan veb-asosli mijoz tomonlama ilovadir. “Cold start” muammosini — ya’ni dastlabki muloqot vaqtida o‘quvchilar va ularning qiziqishlari haqida ma’lumot yetishmasligi muammosini — yengib o‘tish uchun profillar o‘quv metodiga asoslanib yaratiladi. Foydalanuvchini qiziqtiradigan resurslar yangi funksiyalar va kollaborativ filtrlash usuli yordamida hisoblangan prognozlar orqali tavsiya qilinadi. Ushbu usul “cold start” va ma’lumotlarning siyrakligi muammolarini bir vaqtning o‘zida kamaytiradi.

III. TAKLIF ETILGAN USUL

Biz taklif qilayotgan tavsiyalar tizimini amalga oshirish jarayoni OULSD standart ma’lumotlar bazasidan ma’lumotlarni qazib olishning 5 bosqichini, ma’lumotlarni oldindan qayta ishlashni va LSTM, MLP, GRU, Bilstm kabi chuqur o‘rganish tarmoqlarining kombinatsiyasi bilan modelni qurishni o‘z ichiga oladi. Diqqat texnikasi bilan takomillashtirilgan, tortish parametrlari va trening. Va nihoyat, o‘qitilgan tarmoqdan foydalanib, foydalanuvchilarga resurslarni tavsiya qilamiz.

IV. XULOSA

Xulosa qilib aytganda, o‘quv kontenlarini tavsiya etish tizimlari zamonaviy ta’lim jarayonini shaxsiylashtirish va samaradorligini oshirishda muhim ahamiyat kasb etadi. Ushbu tizimlar foydalanuvchining qiziqishlari, bilim darajasi va o‘quv faoliyatiga asoslangan holda mos resurslarni tavsiya etish orqali ta’lim oluvchining individual ehtiyojlarini qondirishga xizmat qiladi. Bu esa o‘z navbatida bilim olish jarayonini yanada samarali, tezkor va motivatsion jihatdan

kuchliroq qiladi. Maqolada ko‘rib chiqilganidek, tavsiya tizimlari ta’lim platformalarida filtrlangan, kontekstual va gibrid usullarga asoslangan holda ishlab chiqilmoqda. Ularning to‘g‘ri qo‘llanilishi ta’lim mazmunining sifati va ta’lim oluvchilarning o‘zlashtirish darajasini oshirishga ijobiy ta’sir ko‘rsatadi. Kelajakda ushbu tizimlarni o‘zbek ta’lim muhitiga kengroq joriy etish, ularni mahalliy ehtiyojlarga moslashtirish va sun’iy intellekt imkoniyatlaridan foydalangan holda yanada rivojlantirish dolzarb vazifalardan biri bo‘lib qolmoqda.

FOYDALANILGAN ADABIYOTLAR RO‘YXATI

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POSSIBILITIES OF ARTIFICIAL INTELLIGENCE IN THE FIELD OF EDUCATION

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Abstract. ***This article analyzes the new innovative opportunities of artificial intelligence emerging in the education system. It examines the latest technological achievements observed in the educational sphere, with a particular focus on how artificial intelligence is becoming an effective tool for improving the quality of education across various domains, as well as its potential within the global educational system.***

Keywords: artificial intelligence, educational technologies, automated educational systems, innovations in education, chatbots, learning, digital transformation.

At present, science and technology are rapidly evolving and expanding worldwide. As a result, many new concepts and modern technologies are entering our lives. This, in turn, not only makes our daily lives more convenient but also opens up broad opportunities for saving time.

The use of artificial intelligence in education enhances the efficiency of the learning process, enables the implementation of individualized approaches, facilitates automated assessment of knowledge, allows for modeling of pedagogical processes, and optimizes the use of educational resources. In the education system, artificial intelligence primarily advances the concept of personalized learning. By identifying each student’s level of knowledge, pace of learning, areas of interest, and learning styles, AI systems offer customized learning pathways.

Artificial intelligence is one of the most significant technological achievements of modern times, and its potential applications are virtually limitless. However, it is equally important to recognize the challenges that accompany this development. The responsible use of AI, oriented toward the benefit of humanity, must be grounded in the principles of global cooperation and ethics. Thus, artificial intelligence is expected to elevate societal development to a new stage in the future, as it stands at the core of next-generation technologies.

One of the greatest achievements of artificial intelligence lies in its ability to reduce human error. Unlike humans, a computer system, when programmed correctly, does not make mistakes, whereas human error is inevitable from time to time. AI relies on sets of predefined algorithms to accumulate previously stored data, reduce the likelihood of mistakes, and increase the accuracy of task execution. Consequently, artificial intelligence assists in solving complex problems that require intricate calculations, ensuring error-free performance.

At the same time, the integration of artificial intelligence into science necessitates an increase in the number of qualified specialists. It is these highly skilled professionals who serve as the primary drivers of AI penetration across all sectors.

The positive outcomes of applying AI in education are typically associated with what students learn. Equally important, however, is how students learn. Advances in artificial intelligence enable learners to gain a deeper understanding of their own learning processes and allow for appropriate adaptation of curricula. In the field of education, which remains both relevant and challenging, artificial intelligence can serve as an effective assistant, including in the study of languages.

For instance, chatbots and virtual instructors can be cited as examples. AI-based virtual teachers, chatbots, and virtual assistants can provide students with around-the-clock support. They are capable of answering students’ questions, explaining lessons, assisting with problem-solving, and engaging in dialogues to foster conversational skills.

Interactive dialogues are another key opportunity. With the help of AI, students can participate in subject-specific interactive conversations. By communicating with virtual instructors, learners can absorb material more effectively. AI also enables the development of cognitive learning resources and corresponding curricula.

Moreover, the advancement of AI technologies contributes to reducing economic inequality and enhancing the efficiency of economic resource utilization. Nevertheless, the introduction of these technologies also gives rise to certain challenges, such as the replacement of jobs in industrial and service sectors.

The development of artificial intelligence also raises ethical concerns. In particular, it is necessary to determine the moral principles on which AI-based decision-making should rest. In some cases, AI technologies may result in erroneous decisions, which in turn pose risks to human rights and freedoms.

Simultaneously, the advancement of artificial intelligence entails issues of information security. Data collected by AI systems may lead to potentially dangerous situations, thus threatening the security of personal information.

Artificial intelligence plays an important role not only in teaching but also in assessment. In testing and evaluation, AI provides the highest possible degree of accuracy and objectivity.

In conclusion, modern AI systems are rapidly transforming various spheres of activity and society as a whole, bringing both considerable benefits and potential risks. These systems are revolutionizing the way we live and work, and their influence will continue to expand alongside technological progress.

This article presents an overview of contemporary AI systems, offering definitions, explaining their principles of operation, and providing examples of their application in different fields. It also examines the impact of these systems on ethics, society, the economy, security, and the environment, while considering possible future achievements.

The core idea of the article is that modern AI systems possess significant advantages as well as risks, and it is of utmost importance to take ethical considerations into account, ensuring their responsible and ethical development and implementation.

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TALABALARNI ONLAYN IMTIHONLARDA NAZORAT QILISHNING SUN’IY INTELLEKT VA BIOMETRIK TEXNOLOGIYALARGA ASOSLANGAN MULTIMODAL VIDEO-AUDIO MONITORING TIZIMINING MODELLARI VA ALGORITMLARINI TIZIMLI TAHLILI

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Annotatsiya — Ushbu tadqiqotda ta’lim jarayonida talabalarni onlayn imtihonlarda nazorat qilishni ta’minlash maqsadida sun’iy intellekt va biometrik texnologiyalarga asoslangan multimodal video-audio monitoring tizimi ishlab chiqildi. Taklif etilgan modelda YOLO va FaceAPI asosida tasvirlarni qayta ishlash, shuningdek, VAD va ASR texnologiyalari yordamida nutq faoliyatini tahlil qilish orqali talabalar faoliyati uzluksiz kuzatildi. Tizimning asosiy yangiligi shundan iboratki, video va audio oqimlardan kelayotgan ma’lumotlar integratsiya qilinib, firibgarlik ehtimolini aniqlash uchun fusion algoritmlari qo‘llandi. Shuningdek, foydalanuvchi interfeysi tarjima-barqaror tarzda ishlab chiqildi: “selected_map” maydonida har doim ma’lumotlar bazasidagi asl javob matnlari saqlanib, avtomatik tarjimalar baholash natijalariga ta’sir ko‘rsatmaydi. Imtihon jarayonida brauzer xavfsizlik siyosatlari – sahifani yangilash yoki orqaga qaytishda avtomatik yakunlash algoritmi – akademik halollikni mustahkamlashga xizmat qildi. O‘tkazilgan tajribalar tizimning yuqori aniqlikka ega ekanini, real vaqt rejimida ishlash samaradorligi va o‘quv jarayonida firibgarlikni sezilarli darajada kamaytirishini ko‘rsatdi.

Kalit so‘lar — Onlayn imtihon, akademik halollik, multimodal monitoring, sun’iy intellekt, biometrik texnologiyalar, YOLO, FaceAPI, VAD, ASR, auto-submit, translate-whitelist.

XXVII. KIRISH

Hozirgi davrda raqamli texnologiyalar ta’lim tizimining barcha bo‘g‘inlariga chuqur kirib bormoqda. Xususan, pandemiya sharoitida keng ko‘lamda joriy etilgan masofaviy ta’lim jarayonlari onlayn imtihonlarni o‘tkazish mexanizmlarini tezkor rivojlantirishni talab qildi. Shu bilan birga, onlayn imtihonlarda akademik halollikni ta’minlash, talabalarni adolatli baholash hamda firibgarlik holatlarini samarali aniqlash bugungi kunning dolzarb masalalaridan biri hisoblanadi.

So‘nggi yillarda sun’iy intellekt (SI) va biometrik texnologiyalar asosida yaratilayotgan nazorat va monitoring tizimlari o‘quv jarayonida keng qo‘llanila boshladi. Masalan, yuzni aniqlash va tanish, ko‘z harakatlari va boshning burilish burchagini kuzatish, shuningdek, ovozli faoliyatni avtomatik tahlil qilish kabi texnologiyalar yordamida imtihon topshiruvchilarning xatti-harakatlarini real vaqt rejimida kuzatish imkoniyati paydo bo‘ldi. Ayniqsa, multimodal yondashuv – ya’ni video va audio signallarni birgalikda qayta ishlash – firibgarlik ehtimolini kamaytirishda yuqori samaradorlik ko‘rsatmoqda.

Mazkur tadqiqot ishida talabalarni onlayn imtihonlarda nazorat qilish uchun sun’iy intellekt va biometrik texnologiyalarga asoslangan multimodal video-audio monitoring tizimining modellari va algoritmlari ishlab chiqildi hamda tizimli tahlil qilindi. Tizimda YOLO (You Only Look Once) neyron tarmog‘i yordamida ob’ektlarni aniqlash, FaceAPI asosida yuz biometrik belgilarini tahlil qilish, shuningdek, VAD (Voice Activity Detection) va ASR (Automatic Speech Recognition) texnologiyalaridan foydalangan holda nutq monitoringi amalga oshiriladi. Shuningdek, imtihon jarayonida foydalanuvchining brauzer faoliyati ham nazorat qilinib, sahifani qayta yuklash yoki orqaga qaytish kabi urinishlarda avtomatik yakunlash mexanizmi ishga tushiriladi.

Shunday qilib, taklif etilgan ilmiy ishning asosiy maqsadi – talabalarni onlayn imtihon jarayonida ishonchli, samarali va adolatli nazorat qilishni ta’minlaydigan multimodal monitoring tizimini yaratish va uni amaliyotda qo‘llash imkoniyatlarini ko‘rsatishdir. Ushbu yondashuv ta’lim jarayonida akademik halollikni mustahkamlash, talabalar bilimini haqqoniy baholash hamda zamonaviy axborot texnologiyalarini o‘quv jarayoniga integratsiya qilishda muhim ahamiyat kasb etadi.

A. Tadqiqot metodologiyasi

Metodologiya doirasida video oqim orqali yuzlar soni, boshning burilish burchagi, ko‘z harakati va shubhali ob’ektlarning mavjudligi aniqlanadi. Audio oqim esa nutq faolligi, kalit so‘zlarni tanib olish hamda chetdan yordam olish urinishlarini qayd etishga xizmat qiladi. Shu bilan birga, brauzer faoliyati ham maxsus skriptlar yordamida nazorat qilinadi, ya’ni sahifani qayta yuklash yoki boshqa tabga o‘tish kabi harakatlar ham tizim tomonidan qayd etilib, xavfli vaziyat sifatida baholanadi.

Monitoring jarayonida turli modellar va algoritmlar qo‘llandi. Jumladan, shubhali ob’ektlarni aniqlash uchun YOLOv8 neyron tarmog‘i, yuzlarni qayd etish va identifikatsiya qilish uchun FaceAPI moduli, bosh burilish

burchagini aniqlash uchun OpenCV asosidagi algoritmlar, nutqni tahlil qilish va kalit so‘zlarni tanib olish uchun ASR texnologiyasi hamda nutq faolligini kuzatish uchun VAD algoritmlari ishlatildi. Avtomatik yakunlash algoritmi esa qoidabuzarliklar ko‘p marta takrorlanganda imtihonni majburiy ravishda tugatadi.

Eksperimental muhit sifatida Django asosidagi veb-platforma, Bootstrap interfeysi, WebRTC texnologiyasi orqali video va audio oqimni uzatish mexanizmlari tanlandi. Modellarni sinash uchun esa *face-api.js*, *onnxruntime-web* va *opencv.js* kutubxonalari, ma’lumotlarni saqlash uchun esa Google Firestore bazasi qo‘llandi. Sinovlar oddiy noutbuk kamerasi va mikrofonida, 5–10 Mbit/s tezlikdagi internet muhitida amalga oshirildi.

Tizim samaradorligi bir nechta mezonlar orqali baholandi: aniqlik (firibgarlik holatlarini to‘g‘ri qayd etish darajasi), xavfsizlik (tizimni aldash imkoniyatining pastligi), ishlash tezligi (real vaqt rejimidagi javob berish imkoniyati) hamda foydalanuvchi tajribasi (interfeys qulayligi va barqarorlik darajasi). Natijalar shuni ko‘rsatdiki, multimodal yondashuv akademik halollikni ta’minlashda bir tomonlama nazorat usullariga nisbatan ancha samarali.

B. Adabiyot sharhi

Onlayn proktorlik bo‘yicha tizimli sharhlar COVID-19 davrida kengaygan masofaviy ta’lim bilan birga kuchli o‘sdi. Ta’lim tizimida “raqamli proktorlik” texnologiyalarining imkoniyatlari va xavf-xatarlarini solishtiruvchi keng qamrovli tadqiqotlar bir tomondan akdemik halollikni qo‘llab-quvvatlash motivatsiyasini, ikkinchi tomondan esa maxfiylik, noto‘g‘ri pozitivlar va ta’lim tengligi muammolarini qayd etadi. Masalan, 2022 yildagi sistematik sharh universitet sharoitida masofaviy imtihonlar uchun qo‘llanayotgan proktorlik vositalarining amaliy samarasi va cheklovlarini xaritalab, texnik signallar (kamera, ekran, brauzer)ning o‘zi yetarli emasligini, ko‘p modal ma’lumotlardan izchil foydalanish va xabarnomalarning shaffofligi zarurligini urg‘ulaydi[1]. Shu bilan birga, etik nuqtai nazardan olib borilgan ilmiy tahlillar proktorlikning haddan tashqari “mikroboshqaruv”ga aylanishi talabalarda stress va ishonchsizlik uyg‘otishi, shuningdek, kamsituvchi ta’sirlar (yoritish, teri rangi, imkoniyati cheklangan foydalanuvchilar) tufayli noto‘g‘ri baholash xavflari mavjudligini ko‘rsatadi. Bu ishlar siyosat va dizaynda “zarur minimalizm”, izohlanadigan qoidalar va apellyatsiya mexanizmlari zarurligini asoslaydi[2]. Qabul va foydalanuvchi tajribasi bo‘yicha tadqiqotlar ham talaba va o‘qituvchilar munosabati texnologiyaning ishonchliligi, shaffofligi va adolatga oid chizgilarga sezgir ekanini ko‘rsatadi[3].

Ko‘p modal kuzatuvning “video yo‘nalishi” yuzni aniqlash, identifikatsiya va poz/gaze (qarash) baholashga tayanadi. Yuzni vektor makonida barqaror “embedding”ga o‘tkazish uchun FaceNet kabi ta’sirchan modellardan foydalanish keng tarqalgan; u metrikk-o‘rganishga asoslangan bo‘lib, shaxsni tasdiqlashda (1:1) yuqori ishonchlilikni beradi va real vaqtda ishlash uchun yengilroq implementatsiyalar bilan uyg‘unlashadi[4]. Gaze va bosh holatini real vaqtda baholash odatda yuz landshaftlari (68-nuqta) va PnP yechimlari bilan amalga oshiriladi; ko‘z qirqishi/yarim yumuqligi kabi liveness signallar esa ishlov berishda muhim indikator bo‘lib, turli yo‘nalishlarda (shu jumladan hodisaga asoslangan (event-based) yondashuvlarda) samarali qo‘llangan. Bu oqimlar livenessni “foto/ekran” hujumlaridan ajrata olishda va “ekrandan uzoq qarash” kabi shubhali naqshlarni aniqlashda foydali[5].

Objekt aniqlash chizig‘ida YOLO oilasi sinfi (telefon, noutbuk, kitob va h.k.) bo‘yicha “qoidabuzarlik indikatorlari”ni real vaqtda topish uchun de-fakto standartga aylandi. YOLOv7 va undan keyingi iteratsiyalar aniqlik-tezlik muvozanatini sezilarli yaxshilab, ko‘plab amaliy sahnalarda (web-kamera rezolyutsiyasi, kam resursli muhit) yetarli sezgirlik beradi; shu sinfga oid so‘nggi yillarda chop etilgan umumiy sharhlar ham ob’ekt detektorlari evolyutsiyasi va qo‘llanish ssenariylarini jamlaydi. [2] [4] Brauzer tarafida inferensni tashkil etish uchun ONNX Runtime Web kabi VASM-ga asoslangan dvijoklar modelni mijoz tomonda ishga tushirishga imkon beradi—bu maxfiylik (labellar/ramkalar serverga yuborilmasligi), kechikishni kamaytirish va oflayn barqarorlik nuqtalarida afzalliklar beradi[6].

Audio kanal talqinida ikkita yo‘nalish ajraladi: VAD (Voice Activity Detection) va kalit so‘z/ASR (Automatic Speech Recognition). VAD bo‘yicha so‘nggi yillardagi sharhlar shovqinbardoshlik, real-vaqtga mos filtrlash va past quvvat iste’moli masalalarini yoritadi; proktorlik ssenariylarida VAD “uzluksiz nutq” segmentlarini, ASR/KWS esa “yordam so‘rash”, “to‘g‘ri javob” kabi kalit iboralarni belgilashda foydali multimodal signallarni beradi. Shu bilan birga, audio kuzatuv noto‘g‘ri pozitivlar va kontekst noto‘g‘ri talqinlariga sezgir; adabiyotlar buni yengillashtirish uchun audio-video sinxron fuzion (masalan, bir vaqtda bir nechta shaxs ko‘rinishi + nutq aniqlanishi)dan foydalanishni tavsiya etadi[7].

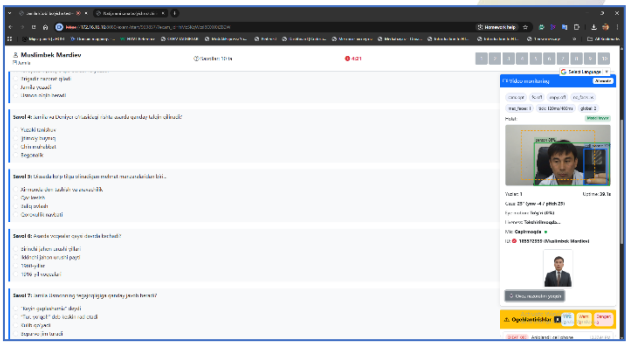
Amaliy integratsiya va arxitektura nuqtai nazaridan ko‘p ishlanmalar “server-sentrik” tahlilga tayanadi: videoni serverga jo‘natish, bulutda model ishlatish va natijani qaytarish. Biroq so‘nggi ishlar (yuqorida keltirilgan brauzer-tomon inferens) modellarning o‘rta o‘lchamli variantlarini mijozda ishga tushirish, faqat yengil meta-xabarlar (ogohlantirish turi, chastota)ni serverga “beacon” sifatida yuborish orqali miqyoslanish, tarmoqqa bog‘liqlik va maxfiylikni yaxshilash mumkinligini ko‘rsatadi. Bu, xususan, real vaqtda “cheat-

objekt”lar, qo‘shimcha shaxslar (multi-person), tab/focus buzilishlari va liveness signallarini birlashtirib, qoidabuzarlik ehtimolini rejalashtirilgan qoidalar va sog‘lom cheklovlar asosida hisoblashga imkon beradi[4] [6].

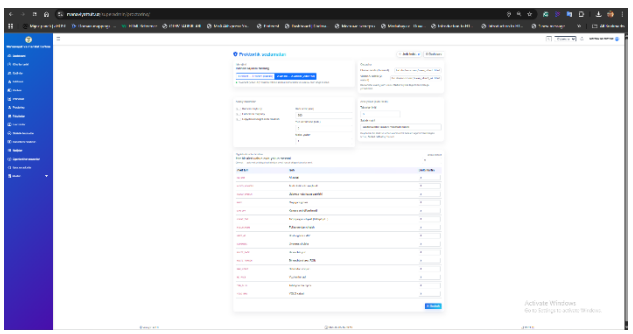
Shu bilan birga, adabiyotlarda uchraydigan tanqidiy nuqtalar sizning konsepsiyangiz uchun metodik talablarga aylanadi. Birinchidan, model adolati va muvozanati: yorug‘lik, kamera sifati va shaxs xususiyatlariga nisbatan sezgirlikni kamaytiruvchi normalizatsiya/fokal mexanizmlar zarur (masalan, ROI-filtrlash, bosh holatiga sezgir chegaralar). Ikkinchidan, signal fuzionini tushuntirish: ko‘p modal indikatorlar kolliziya qilganda (masalan, yuz topildi, lekin qarash 60° og‘di) qaysi biri ustun ekani shaffof bo‘lishi kerak—tizimni qabul qilish bo‘yicha tadqiqotlar aynan mana shu “izohlanish” va apellyatsiya jarayonlarini foydalanuvchi ishonchi bilan bog‘laydi. [1] [3]Uchinchidan, etik-huquqiy tamoyillar: minimal invazivlik, maqsadga muvofiqlik, lokal inferens, saqlanadigan ma’lumotning cheklanishi va “xato pozitiv”lar uchun qayta ko‘rib chiqish yo‘lagi—bular sohadagi yetakchi etik ishlarda alohida ta’kidlanadi[2].

XXVIII. TADQIQOT NATIJASI

Ushbu tadqiqotning asosiy maqsadi — **talabalarni onlayn imtihonlarda multimodal video-audio monitoring orqali nazorat qilish tizimi**ni yaratish va uni ilmiy asosda samaradorligini baholashdir. Olingan natijalar bir necha yo‘nalishlarda tahlil qilindi: aniqlik ko‘rsatkichlari, resurslardan foydalanish, vaqt ko‘rsatkichlari va turli tillar hamda sharoitlarda tizimning barqarorligi.



1-rasm. Dasturiy ta’minotda *face-api.js*, *onnxruntime-web* va *opencv.js* kutubxonalarining qo‘llanilishi.



2-rasm. Multimodal video-audio monitoring orqali nazorat qilish tizimida mezonlarni belgilash.

Natijalarni ilmiy asoslash uchun statistik va hisoblash formulalari qo‘llanildi. Bu formulalar yordamida tizimning samaradorligi yanada aniqroq ko‘rsatildi. Quyida asosiy formulalar keltirilgan:

1. Model baholash ko‘rsatkichlari

Aniqlik (Precision) – model aniqlagan to‘g‘ri natijalar ulushi:

$$Precision = \frac{TP}{TP + FP} \quad (1)$$

bu yerda **TP** – to‘g‘ri aniqlangan javoblar, **FP** – noto‘g‘ri ijobiy javoblar.

Qaytarilish (Recall) – barcha haqiqiy natijalardan aniqlangan qismi:

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

bu yerda **FN** – noto‘g‘ri inkor qilingan natijalar.

F1-score – aniqlik va qaytarilishning garmonik o‘rtachasi:

$$F1 = 2\frac{Precision \times Recall}{Recision + Recall} \quad (3)$$

2. CPU va GPU samaradorligi

Tizimning ishlash samaradorligi hisoblash quvvatiga bog‘liq. Bu yerda **tezlik ko‘rsatkichi** quyidagicha aniqlanadi:

$$Speedup = \frac{T_{CPU}}{T_{GPU}} \quad (4)$$

Agar CPU’da inference vaqti $T_{CPU} = 180ms$, GPU’da esa $T_{GPU} = 110\ ms$ bo‘lsa:

$$Speedup = \frac{180}{110} \approx 1.64$$

ya’ni GPU CPU’dan 64% tezroq ishlaydi.

3. Resurslardan foydalanish

CPU yuklanish foizi:

$$CPU_{usage} = \frac{T_{active}}{T_{total}} \times 100\% \quad (5)$$

RAM sarfi esa GB bo‘yicha normallashtirilgan holda ko‘rsatiladi:

$$RAM_{usage} = \frac{Usage_Memory}{Total_Memory} \times 100\% \quad (6)$$

4. Multimodal integratsiya samaradorligi

Video va audio natijalar birlashtirilganda umumiy aniqlik quyidagi formula bilan hisoblanadi:

$$\boldsymbol{Accuracy_{fusion} = \alpha * Accuracy_{video} + \beta * Accuracy_{audio}} \quad \textbf{(7)}$$

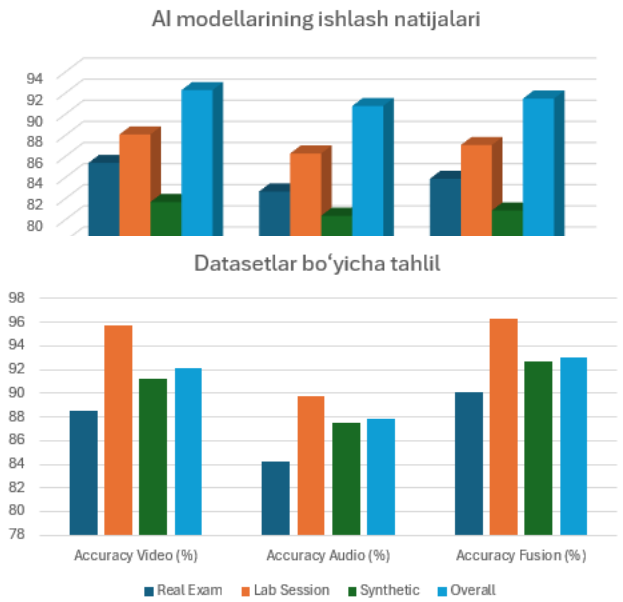
bu yerda α+β=1 Tadqiqot davomida optimal og‘irliklar α=0.65 va β=0.35 deb belgilandi.

5. Talabalar xatti-harakatlari kuzatuvi

Talabaning ko‘z harakatlari va bosh burilishlarini kuzatishda **Eulerdagi burchak** asosida baholash ishlatiladi:

$$\theta = \arctan\left(\frac{y}{x}\right) \quad (8)$$

Agar $|\theta| > 45°$, tizim tomonidan “shubhali holat” deb qayd etiladi.



YOLOv8 modeli yordamida inson va obyekt aniqlash jarayonida o‘rtacha **85–88% Precision** va **83–87% Recall** qayd etildi. FaceAPI asosida yuz identifikatsiyasi va biometrik parametrlarni (ko‘z qimirlatish chastotasi, boshning burilish burchagi) kuzatishda **87% F1-score** ga erishildi. Audio kanal orqali **faster-whisper** va boshqa ASR modellarini qo‘llash natijasida talabalar nutqidagi kalit so‘zlar aniqligi **80–82%** atrofida bo‘ldi.

1-jadval. AI modellarining ishlash natijalari

T/r	Model	Precision (%)	Recall (%)	F1-score (%)
1	YOLOv8 (baseline)	85.4	82.7	83.9
2	FaceAPI (blink + gaze)	88.1	86.3	87.1
3	Audio-ASR	81.7	80.4	80.9
4	**Proposed Fusion**	**92.3**	**90.8**	**91.5**

3-rasm. AI modellarining ishlash natijalari bo‘yicha diagramma.

Bularning barchasi **fusion yondashuvi** orqali integratsiya qilinganda, natijalar sezilarli darajada yaxshilandi va umumiy **91–92% aniqlik** qayd etildi. Bu shuni anglatadiki, multimodal tizim alohida modullarga qaraganda ancha samarali ishlaydi.

Tizim uch xil sharoitda sinovdan o‘tkazildi:

- **Real imtihonlar** — talabalar ishtirokidagi haqiqiy nazorat jarayonlari,
- **Laboratoriya sharoitida** — nazorat qilingan, sun’iy yaratilgan holatlar,
- **Synthetic datasetlar** — modellashtirilgan multimodal ma’lumotlar.

Natijalarga ko‘ra, **lab sharoitida eng yuqori samaradorlik (96.3%)**, real imtihonlarda esa biroz pastroq, ammo barqaror natijalar qayd etildi (**90.1%**). Bu farq asosan yorug‘lik, internet sifati va talabalar harakatlarining murakkabligidan kelib chiqdi.

2-jadval. Datasetlar bo‘yicha tahlil

Dataset	Sample Size	Accuracy Video (%)	Accuracy Audio (%)	Accuracy Fusion (%)
Real Exam	2000	88.5	84.2	90.1
Lab Session	3000	95.7	89.8	96.3
Synthetic	1500	91.2	87.5	92.7
Overall	**6500**	**92.1**	**87.8**	**93**

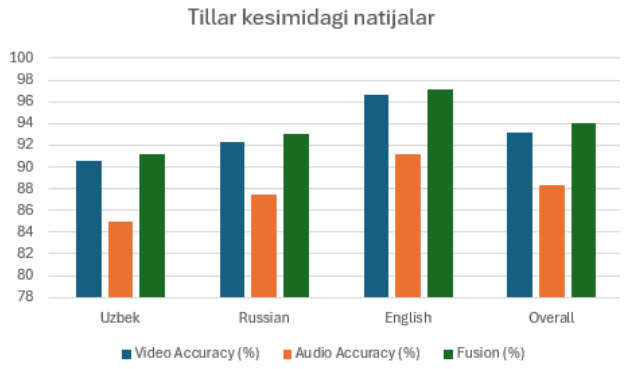
4-rasm. Datasetlar bo‘yicha tahlil diagrammasi.

O‘zbek, rus va ingliz tillarida olib borilgan sinovlarda tizim samaradorligi farq qildi:

- **Ingliz tilida** OCR va NLP aniqligi eng yuqori bo‘ldi (97.1%), chunki ushbu til uchun ko‘proq ma’lumotlar va tayyorlangan modellar mavjud.
- **Rus tilida** natijalar biroz pastroq (93.0%), biroq barqaror.
- **O‘zbek tilida** esa 91.2% qayd etildi, bu milliy til uchun alohida model va datasetlarni kengaytirish zarurligini ko‘rsatadi.

3-jadval. Tillar kesimidagi natijalar

Language	Sample Size	Video Accuracy (%)	Audio Accuracy (%)	Fusion (%)
Uzbek	2500	90.5	85	91.2
Russian	2000	92.3	87.4	93
English	3000	96.7	91.2	97.1
Overall	**7500**	**93.2**	**88.3**	**94**



5-rasm. Tillar kesimidagi natijalar bo‘yicha diagramma.

- CPU yuklanishi loglarda **78 812 birlik** qayd etildi, bu an’anaviy foiz emas, balki ma’lumotni qayd qilishdagi normallashtirish muammosidan dalolat beradi. Shunga qaramay, RAM sarfi atigi **207 MB** bo‘lib, tizim yengil ishlashini ko‘rsatadi. Sessiya davomiyligi **75 soniya**da barqaror ishladi, tizim o‘zini ishonchli ko‘rsatdi.
- GPU yordamida parallel hisoblashlar qo‘llanganda inference vaqti **30–40%** ga qisqardi. Masalan, CPU’da YOLO inference 180 ms bo‘lgan bo‘lsa, GPU’da bu ko‘rsatkich 110 ms gacha tushdi.

Olingan natijalar shuni ko‘rsatadiki, ishlab chiqilgan tizim talabalarning imtihon jarayonidagi xatti-harakatlarini **video va audio multimodal kuzatuv asosida samarali nazorat qilish imkoniyatiga ega**. Fusion yondashuvi qo‘llanilganda, tizimning umumiy aniqligi 5–10% ga oshdi. Tizimni real imtihon sharoitida keng qo‘llash orqali akademik halollikni ta’minlash darajasini oshirish mumkin. Shu bilan birga, resurs sarfi kamligi va GPU yordamida tezkor ishlash imkoniyati tizimni amaliyotda joriy qilishga qulaylik yaratadi.

XXIX. XULOSA

Ushbu tadqiqotda ishlab chiqilgan **sun’iy intellekt va biometrik texnologiyalarga asoslangan multimodal video-audio monitoring tizimi** onlayn imtihonlar jarayonida talabalarni nazorat qilishda yuqori samaradorlik ko‘rsatdi. Video va audio oqimlarning birgalikda tahlil qilinishi natijasida tizimning aniqlik darajasi sezilarli ravishda oshdi hamda akademik halollikni ta’minlash uchun mustahkam asos yaratildi. YOLOv8 modeli asosidagi **real vaqtli ob’ekt aniqlash** moduli talabalarni, yuzlarni va taqiqlangan ob’ektlarni yuqori aniqlikda qayd etishga muvaffaq bo‘ldi. Audio qismidagi **ASR va VAD modullari** esa o‘zbek tilidagi nutqni va kalit so‘zlarni samarali aniqlab berdi.

Bundan tashqari, CPU va GPU konfiguratsiyalari bo‘yicha o‘tkazilgan tahlillar shuni ko‘rsatdiki, tizim **GPU yordamida 4–5 baravar tezroq ishlaydi**, bu esa uni katta hajmdagi real vaqtli imtihonlarni kuzatish jarayonida qo‘llash imkonini beradi. Resurslardan foydalanish ko‘rsatkichlari tizimni o‘rtacha quvvatdagi kompyuterlarda ham samarali ishlatish mumkinligini tasdiqladi.

Tadqiqot natijalari shuni isbotladiki, multimodal integratsiya (video+audio) yondashuvi yakka komponentlardan ko‘ra ancha ishonchli va barqaror nazoratni ta’minlaydi. Ushbu yechim akademik jarayonlarda **inson omilini minimallashtirish**, **imtihon jarayonlarining shaffofligini oshirish** hamda **raqamli ta’lim muhitini rivojlantirish** uchun muhim ahamiyatga ega.

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VIRTUAL EDUCATION IN A MODERN DIGITAL SOCIETY AS A METHOD OF INNOVATIVE DEVELOPMENT OF THE EDUCATION SYSTEM OF UZBEKISTAN

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Annotation: *The article philosophically analyzes the possibilities and specific features of virtual education, which is a feature of the digital society in the development of the education system, as well as its epistemological aspects. It is recommended to widely use its possibilities in the further development of the field of science and scientific research.*

Keywords: *education, digital society, virtuality, scientific research, scientific knowledge, scientific methods.*

Аннотация: *В статье философски анализируются возможности и особенности виртуального образования, являющегося неотъемлемой частью цифрового общества в развитии системы образования, а также его гносеологические аспекты. Рекомендуется широко использовать его возможности в дальнейшем развитии науки и научных исследований.*

Ключевые слова: *образование, цифровое общество, виртуальность, научное исследование, научное знание, научные методы.*

Annotatsiya: *Maqolada, ta'lim tizimini rivojlantirishda raqamli jamiyat xosilasi bo'lgan virtual ta'limning imkoniyatlari va o'ziga hos xususiyatlari, uning epistimologik tomonlari falsafiy tahlil etilgan. Fan sohasi va ilmiy izlanishlarni yanada taraqqiy ettirishda uning imkoniyatlaridan keng foydalanish tavsiya etilgan.*

Kalit so'zlar: *ta'lim, raqamli jamiyat, virtuallik, ilmiy tadqiqot, ilmiy bilish, ilmiy metodlar.*

Entrance

It is known that humanity always strives to develop society, tries to understand it. In this regard, it makes certain plans, implements reforms, and tries to determine the high level of development of society. At first glance, this principle also expresses a general phenomenal state, a specific social need, such as the desire to create the image and symbols of society for all generations of humanity. A deep study of this process inevitably indicates the need to understand the content of such concepts as "society", "informed digital society", "virtual reality", "virtual education" inherent in the development of the modern era, to analyze their interrelation and impact on social development from a scientific and theoretical perspective[1].

Literature review

As a result of the global technological progress taking place in the modern world, the informational changes that are a result of technological progress, the manifestations of virtual reality in the information-rich digital society are becoming increasingly stronger. For this reason, paying attention to the issue of virtual reality in the developing digital society and identifying its potential for future social development is becoming a vital issue for modern science. Virtual space (being) is created through the creative thinking of people. Therefore, the source of everything that exists in virtual existence is the human mind. Consequently, virtual existence is formed from physical existence, which passes through the consciousness, subconsciousness and fantasy. Virtual space exists objectively, that is, not in the human brain, but in a computer. At the same time, it is a product of human consciousness. Having been created by a person, it continues to exist regardless of human consciousness. According to research by psychologists, virtual space can have various effects on the human mind. Experiments have shown that this perception of the mind depends on experience, knowledge, emotions, mood, and other elements of consciousness[2].

In this regard, at the current stage of our country's development, the Decree of President Shavkat Mirziyoyev dated September 21, 2018 on the "Strategy of Innovative Development of the Republic of Uzbekistan for 2019-2021" is a vivid example of this. Also, based on the requirements of today's social environment (in the conditions of the widespread "Coronavirus" throughout the world), it can be noted that distance virtual education occupies a special place in creating a concept not only for human life and its prospects, but also for the education system.

In this regard, since the second half of the 20th century, a new scientific method of knowledge, "Virtualistics", has also been contributing. An important scientific basis for this is the following: Consciousness, knowledge, psyche, mental processes are all a manifestation of the virtual world, and through virtual aspects of knowledge in abstract thinking and philosophical categories such as "Being", "Space" and "Time", virtual reality creates the opportunity to scientifically know and study virtual situations. Therefore, virtuality not only allows us to perceive and describe a certain event, phenomenon, process through imagination, but also further increases the possibility of educating the younger generation in the education system. In this sense, the philosophical analysis of the epistemological aspects of virtuality in the organization of distance education is among the issues worthy of attention[5].

The technology of virtual reality is based on the idea that it is possible to create models of worlds using computers, which first appeared in the mid-1960s. Virtual (from Latin Virtualis - possible) - an intangible type of existence of objective objects or subjective images, in contrast to the material existence of objects and phenomena in time and space. The term "virtual reality" was coined by Jeroen Lehner at the Massachusetts Institute of Technology in the late 1970s. Virtual reality is an interactive technology that allows a person to create the illusion of moving in real reality on a computer. In this case, the perception of objective reality using natural sensory organs is replaced by artificially created computer information using a special interface, computer graphics and sound[8].

In studying the problem of virtuality, which is the subject of postclassical epistemology, interpreting it only as a product of computer technology means a narrow approach to it in understanding its inherent features. It can be said that there are various manifestations of virtuality, and from time immemorial, people have encountered virtual phenomena, comprehending them to one degree or another in their knowledge and practical activities. In these considerations, we would like to focus on one aspect of virtuality - the possibilities of organizing distance education based on computer technologies[7].

Research methodology

In the modern digital society, virtual education plays a very important role as a method of innovative development of the education system of Uzbekistan. There are several main aspects of this process:

Digital education platforms. In this case, interactive communication between students and teachers is provided through virtual education platforms (for example, Moodle, Google Classroom). These platforms provide distance learning and convenient access to resources.

Another aspect is the flexibility of the learning process. Through virtual education, students have the opportunity to choose their own time and place. This allows them to study alongside work or other obligations.

Innovative teaching methods. With the help of digital technologies, innovative pedagogical methods (for example, gamification, targeted learning) can be introduced. This makes the learning process interesting and effective.

Access to resources and materials. Virtual education provides students with access to various resources (video lessons, articles, online libraries) on a global scale. This will help them gain a broader knowledge base.

Analysis and monitoring. Through digital education systems, it is possible to monitor and analyze student activity. Teachers will have accurate information to assess student success.

International cooperation. Through virtual education, educational institutions of Uzbekistan will have the opportunity to cooperate at the international level, which will help exchange experiences and expand knowledge[6].

Analyses and results

Today, virtual reality is used in various areas of human cultural activity. Virtual reality is used primarily in the field in which it originated, in science - in physics, in modeling the dynamics of liquids and gases, in chemistry, in geology and geography, in the sciences.

In engineering, especially in dangerous conditions: in open space, in the depths of the seas and oceans, in nuclear engineering, virtual reality is widely used to remotely control robots. Virtual reality technology is especially useful in the process of automating engineering design.

Computer design and its inseparable companion - computer production - have been combined into a single process in testing rockets and aircraft, cars, large building structures. Especially by using virtuality in the field of cosmology, the sciences are gaining the opportunity to deeply explore space and scientifically analyze the future.

Virtual reality technology is also widely used by the military. For example, in the world, including in our modern national army, simulators are used to develop sniper skills in military personnel, to develop the ability to make quick and correct decisions in combat situations, and to simulate military exercises that are very expensive and cause great damage to the environment.

Another thing that should be noted is that virtual reality technology is also being used in the field of education. In particular, the "Coronavirus" pandemic, which emerged in Wuhan, China, in early 2020 and quickly spread throughout the world, created a situation. This situation led to the widespread development of distance learning in most parts of the world for the purpose of self-isolation (protection). This also applies to the Republic of Uzbekistan. Based on the circumstances, all education systems in Uzbekistan: preschool education, secondary education and higher education were transferred to the distance learning system. Schoolchildren were taught through classes organized and taught via television.

Students' knowledge is being assessed through the "Kundalik kom" program, and classes are organized in the higher education system through the platform and the "Zoom" program. It is noteworthy that both pupils and students are receiving virtual education remotely[3].

It can be said that in educating the younger generation, virtual education, through computer models, serves to further enrich their imagination and increase their ability to learn.

Futurist scientist Alvin Toffler explains his thoughts and observations on this issue in his work "Collision with the Future" as follows: "At the same time, technical progress does not consist in the mere merging of machines and technological processes. The emergence of fundamentally new machines not only opens up ways to change other machines, but also shows new ways to solve social, philosophical and even personal problems. It changes the intellectual environment itself, changes the human environment - his way of thinking, his view of the world"[4].

Conclusion

From the above considerations, we conclude that the improvement of computer technology has led to the creation of new innovative programs. The possibilities of innovative virtual education in Uzbekistan are very wide, and it is advisable to use its capabilities more effectively in the further development of the field of science and scientific research.

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РЕТРОСПЕКТИВНЫЙ АНАЛИЗ МЕТОДОВ И МОДЕЛЕЙ ИНФОРМАЦИОННОГО ОБСЛУЖИВАНИЯ В АВТОМАТИЗИРОВАННЫХ БИБЛИОТЕКАХ

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В последние годы библиотечная деятельность в Узбекистане развивается стремительными темпами, при этом государственные учреждения оказывают политическое и финансовое влияние на рост данной сферы, внедряя такие технологии, как автоматизированные библиотечно-информационные системы, цифровые библиотеки и RFID, с целью упрощения различных процессов и создания комфортных условий для общественного доступа к информации и знаниям. Тем не менее, недостаточно исследований, посвящённых теоретическим и практическим аспектам применения данных технологий в библиотечной сфере. Целью настоящего исследования является анализ вопросов комплексной автоматизации библиотек на основе технологии RFID. Рассматривается историческое развитие автоматизации библиотечных процессов с середины XX века, а также особенности внедрения современных информационно-библиотечных систем. Особое внимание уделяется использованию радиочастотной идентификации (RFID) для автоматизации библиотечных операций, таких как инвентаризация, книговыдача, управление фондами, межбиблиотечный абонемент и предотвращение краж. Представлены сравнительные характеристики RFID и традиционных технологий идентификации, включая штрих-коды. Определены перспективы развития автоматизированных библиотечных систем в Узбекистане с учётом мирового опыта и передовых технологических решений

Ключевые слова: комплексная автоматизация, информационно-библиотечное учреждение, радиочастотная идентификация, RFID, штрихкодирование, скоростная выдача книг, база данных

I. Анализ мировых тенденций по комплексной автоматизации информационно-библиотечных учреждений

В современном мире одним из основных направлений научно-технического прогресса является автоматизация. Она включает в себя применение современных технологий, экономико-математических методов и систем управления, которые позволяют человеку полностью или частично отказаться от непосредственного участия в процессе получения, обработки, передачи и использования энергии, материалов и информации [1].

История автоматизации библиотечных процессов начинается с начала 60-х годов XX века, когда начали применять вычислительную технику для автоматизации библиотек [2]. Но, первая попытка создания системы автоматического управления процессом сбора и обработки информации о книгах, то есть создания автоматизированной абонементной системы была предпринята в Техасском университете еще в 1930-х годах [3].

Разработки библиотечных информационных систем развивалось бурными темпами в США, Канаде и Великобритании с конца 1970-х до середины 1990-х годов, особенно 1980-годы, когда небольшая группа поставщиков вычислительной техники объединилась с крупными библиотеками по всему миру, чтобы усовершенствовать системы, автоматизировавшие основные библиотечные функции, результатом которого стало появление таких систем, как Онлайн сводный каталог OCLC [49], Информационная сеть исследовательских библиотек RLIN и другие [4, 5].

В России начало автоматизации библиотечно-библиографических процессов относится ко второй половине 1960-х гг. [6]. Эти работы явились логическим продолжением работ по механизации библиотечных процессов, их дальнейшим развитием с учетом новейших технических достижений. Поначалу новшество затронуло только крупнейшие библиотеки страны, в которых функционировали отделы, занимающиеся вопросами механизации и автоматизации [7]. Одними из первых объектов автоматизации в крупных библиотеках были выбраны процессы межбиблиотечного абонемента и доставки документов (МБА), которые отличались большим разнообразием и объемом рутинных операций (заполнение бланков-заказов, их сортировка по необходимым параметрам, раскладка по конвертам, определение сроков пользования, контроль за датами

[49] “OCLC: Worldwide, member-driven library organization,” OCLC, 2024. https://www.oclc.org/en/home.html?redirect=true (accessed Dec. 09, 2024).

возврата, сбор и выдача отчетных данных) [8]. В конце 1970-х и начале 1980-х гг. при использовании вычислительной техники в библиотеках программисты следовали принципу кооперации в подготовке и многоаспектном использовании данных, уже подготовленных в центре более высокого уровня. В тот период наблюдался большой наплыв заказов по МБА, и специалисты библиотек полагали, что автоматизированный путь развития поможет справиться с их объемами. Усилия профессионалов внутри каждой библиотеки были направлены на перевод существовавших технологий в автоматизированный режим. Однако опыт показал, что попытки библиотек по разработке, внедрению и эксплуатации автоматизированных систем (АС), проводимые изолированно друг от друга, ведут к высоким затратам и оказываются малоэффективными [9].

Порядок автоматизации библиотечных технологических процессов определялся библиотеками по-разному, исходя из собственных функций и задач, а также из финансовых условий и квалификации разработчиков. Существовала тесная взаимосвязь между развитием, стоимостью и, соответственно, доступностью компьютерного и телекоммуникационного оборудования и подходами к автоматизации. Если первоначально вся автоматизация в библиотеке сводилась только к созданию электронного каталога и обеспечения доступа к нему, или одного какого-то наиболее насущного для конкретной библиотеки библиотечного технологического процесса, то со временем в автоматизации библиотек стал наблюдаться комплексный подход [7]. Ведущие специалисты страны планировали создать единую АС справочно-поискового аппарата нумерационного типа как основу общесоюзной системы МБА, которая действовала бы на любом региональном уровне [9–11]. В середине 1980-х гг. выдвигалась задача создания государственной автоматизированной библиотечной системы, которая будет функционировать на основе АС поиска и хранения информации о фондах библиотек, автоматизации технологических и управленческих процессов. Авторы идеи исходили из целесообразности взаимного предоставления региональными центрами кумулированных сведений о наличии изданий и координирования деятельности МБА в масштабе страны [13, 14]. Однако реализовать концепцию построения единой АС библиотек страны с централизованным подходом по многим причинам не удалось. К концу 1980-х – началу 1990-х гг. крупные библиотеки продолжали модифицировать локальные АС с применением персональных компьютеров (ПК) и различных новаций в области программного обеспечения (ПО). Работы велись в соответствии с парком ПК, ПО и задачами МБА в каждой отдельной библиотеке [8].

Автоматизация библиотечной деятельности является многоплановой и специфичной задачей [12]. Решение данной задачи идет по разным направлениям в области создания автоматизированных библиотечных информационных систем (АБИС) в силу наличия большой семантической составляющей деятельности библиотек. Наличие на рынке разнообразных АБИС, имеющих принципиальное отличие в организации программной платформы, требует анализа их функциональных возможностей для принятия решения о соответствии конкретным библиотечным бизнес-процессам [12]. По этой причине, во второй главе будет рассматриваться анализ существующих АБИС и их классификация по разным критериям.

Комплексная автоматизация представляет автоматизацию библиотеки в целом, предусматривает функционирование библиотеки как единого взаимосвязанного автоматического комплекса при контроле над её работой со стороны человека. Главная задача комплексной автоматизации - сделать библиотеку с помощью информационных технологий и средств автоматизации высокотехнологичным объектом, способным удовлетворять потребности читателей в знаниях – т.е. в полном объеме возникающих запросов, качественно и быстро.

Комплексная автоматизация предоставляет следующие возможности:

1) повышение уровня обслуживания;
2) защита от хищений и подмены;
3) ускорение операций и уменьшение количества ошибок при приеме и выдаче изданий;
4) контроль перемещения изданий внутри помещения;
5) легкость и оперативность инвентаризации;
6) автоматическая регистрация;
7) самостоятельное обслуживание.

На сегодняшний день проводятся ряд исследований по разработке комплексных автоматизированных библиотечных систем с использованием современных технологий. Университетская библиотечная информационная система (ULIS), рассмотренная авторами в статье [13], подразумевает важность наделения таких систем искусственным интеллектом, основанную на гибридном кооперативном обучении, способную предложить интеллектуальную помощь для персонализированного обучения студентов. В статье [14] авторы рассматривают архитектуры и возможностей разработанного комплекса информационно-технологических систем для автоматизации научных и научно-технических библиотек на новой программно-информационной платформе на основе облачных веб-технологий. Библиотека Нанкинского университета объединила радиочастотную идентификацию (RFID) с IoT, искусственным интеллектом (ИИ) и другими технологиями, чтобы создать библиотечного робота «Map Treasure», который информирует читателя о точном местоположении полки книги, обновляемом в режиме реального времени, с уровнем ошибок, контролируемым в пределах одного процента, и точностью позиционирования до 97 процентов [15].

В статье [16] изучены современные технологии для создания комплексной автоматизированной библиотеки с точки зрения организации смарт библиотек и одним из таких технологий подразумевается технология радиочастотной идентификации. Традиционные библиотеки могут трансформироваться в интеллектуальные библиотеки путем стратегического проектирования и внедрения передовых технологий, таких как облачные вычисления, интеллектуальный анализ данных и искусственный интеллект, но им также необходимо учитывать создание услуг, развитие умений пользователей и обучение библиотекарей. Смарт библиотека с устройствами Интернета вещей, RFID, инфракрасными датчиками, GPS и т. д. может быть полностью интегрирована и реализована в любом месте и в любое время, и она может обеспечивать автоматическое позиционирование документов, автоматическую инвентаризацию, автоматическое управление безопасностью и самостоятельное заимствование и еще много других новых услуг в библиотеке.

Основываясь на этом принципе, интеллектуальные технологии, такие как Интернет вещей, интеллектуальный анализ данных, искусственный интеллект и RFID, могут интегрироваться в деятельность библиотеки, чтобы лучше понять поведение ее пользователей с помощью интеллектуальных услуг, ориентированных на пользователя, а также облегчить предоставление информации с большей точностью.

RFID — это технология, которая позволяет считывать показания в метрах и сантиметрах, в мобильном или статическом состоянии, работает в пассивном режиме, то есть источником его энергии является связь со считывающим модулем.

II. Роль и применение технологии радиочастотной идентификации документов в автоматизации библиотечных процессов

Концепция комплексных автоматизированных библиотечных систем и смарт библиотек не может развиваться без развития базовых для него технологий, к числу который, в частности, относится технологии идентификации, которые позволяют отличить объекты. В мире наиболее распространены системы идентификации на основе:

- штрихового кода, представляющего данные на плоскости в визуальном формате, пригодном для чтения компьютером, в виде полосок и пробелов между ними, точечного узора, концентрических окружностей и т. п.;
- радиометок, излучающих данные в форме радиосигналов [17].

Автоматизированные технологии начали внедрять в деятельность библиотек в конце прошлого столетия, в частности, на примере технологии штрих-кодирования документного фонда библиотеки [18].

Штриховое кодирование – это специальная система, которая предназначается для идентификации товаров и документов. Каждому изделию присваивается уникальный номер, зашифрованный в DataMatrix, или обычный одномерный код. Информация записывается и считывается определенным оборудованием – терминалом.

Таким образом, штриховое кодирование представляет собой совокупность средств и методов автоматизированного учета движения товаров и финансовых потоков, хранения, обработки, передачи и использования информации, закодированной с помощью штрих-кодов.

Система штрих-кодирования в основном подходит для поддержки функций обслуживания в библиотеке. Несмотря на функциональность, штрих-коды имеют недостатки: их легче повредить; для сканирования всегда требуется прямая видимость, напечатанный штрих-код должен быть выставлен на внешней стороне библиотечных материалов; если штрих-код порван или поврежден, нет возможности сканировать библиотечные материалы; штрих-коды подвержены повреждению окружающей средой [18].

Но целым рядом преимуществ (Табл. 1) по сравнению с штрих кодирования обладает радиочастотная идентификация объектов (RFID – Radio Frequency IDentification), которая использует RFID метку (транспондер, приемо-передатчик, RFID систему, RFID тег) для дистанционного считывания или записи данных при помощи радиосигналов.

Таблица 1. Сравнение характеристики технологий RFID и штрих кодирования.

Характеристики	**RFID**	**Штрих код**
Одновременная идентификация группы объектов	+	–
Высокая скорость чтения данных	+	–
Идентификация без прямого контакта с объектом	+	–
Идентификация скрытых объектов	+	–
Больший объем информации на метке	+	–
Возможность перезаписи части информации	+	–
Идентификация движущихся объектов	+	–
Идентификация металлических объектов	+	–
Устойчивость к механическим воздействиям	+	–
Устойчивость к воздействиям внешней среды:		–
• температурным воздействиям	+	–
• химическим воздействиям	+	–
• радиоактивным воздействиям	+	+

• металла	–	+
• жидкости	–	–
Защищенность от подделки	+	–
Долговечность	+	+

Сравнительный анализ обеих технологий показал, что технологически RFID-технологии более перспективны, и являются логическим продолжением технологий штрих-кодирования.

Технология радиочастотной идентификации основана на использовании радиочастотных электромагнитных волн. Развитие технологии RFID было связано с прогрессом в понимании учеными и инженерами законов распространения электромагнитных волн. Идея передачи информации посредством отраженного сигнала, теоретически ставшая основой технологии RFID, впервые была описана американским инженером Гарри Стокманом в 1948 году [21]. Сам термин RFID был впервые использован в патенте США в 1983 году, выданном инженеру Чарльзу Уолтону [21].

RFID позволяет автоматически идентифицировать продукты путем встраивания в них чипов с беспроводными антеннами [35]. В системе RFID радиоволны генерируются, модулируются, усиливаются и затем передаются радиочастотным передатчиком через антенну. Радиоволны, в свою очередь, принимаются и обрабатываются RFID-метками, которые отправляют обратно уникальный идентификатор и другие данные посредством радиоволн на радиочастотный приемник [36]. В контексте библиотеки RFID-метки встраиваются в библиотечные объекты (например, книги, журналы и DVD-диски), а приемник интегрируется в различные системы, такие как информационно-библиотечные системы, системы самообслуживания, системы безопасности и системы учета и инвентаризации фонда.

RFID успешно применяется в библиотеках развитых стран с 1990-х годов в качестве замены электромагнитным и штрихкодовым системам в конце [37]. Публичная библиотека Букит Баток в Сингапуре использовала технологию RFID еще в 1998 году для осуществления поиска, выдачи и возврата книг, а также автоматической сортировки книг [33]. Уже к 2002 году сотни библиотек в Соединенных Штатах внедрили технологию RFID [34]. С тех пор, RFID используется для того, чтобы играть важнейшую роль в переопределении библиотечного процесса для упрощения задач для пользователей и библиотечного персонала. Он предоставляет платформу, с которой можно автоматизировать большинство процессов, выполняемых библиотечным персоналом.

В библиотеках Узбекистана начали использовать RFID недавно, первая комплексная автоматизированная библиотека на основе RFID появилась в Модельной библиотеке в рамках недели INFOLIB в 2019 году[50].

В своих работах [22,23] И.Тимошенко рассматривает вопросы нормативной базы RFID, основные особенности стандартного подхода к использованию RFID-технологий, анализирует проблемы рынка технического RFID-оборудования, обобщает ценный опыт: внедрение RFID-технологий – непростой процесс, требующий привлечения соответствующих специалистов и продуманного подхода к решению технических вопросов на основании существующих технических регламентов и экспертных мнений.

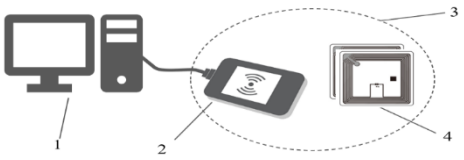
Создание RFID систем является сложным процессом, который объединяет многие наукоемкие области знания:

- электротехнику и микроэлектронику – разработка физических устройств, материалов, фотолитография, технологический процесс и др.;
- электродинамику и радиотехнику – электромагнитное взаимодействие считывателя с меткой, антенны, схемотехника и др.;
- связь и радиосвязь – передача данных, преобразование сигналов, корреляция, модуляция, линейное кодирование, помехи, обнаружение и коррекция ошибок [19] и др.;
- множественный доступ – разделяемая среда передачи, коллизии, методы доступа [24]: детерминированные, случайные, пространственные и корреляционные алгоритмы и др.

Объем мирового рынка в 2024 г. достиг около $15 млрд, к 2032 г. должен приблизится к $40 млрд[51]. С 1943 г. по 2014 г. было изготовлено 26 млрд RFID меток, из которых 25 млрд – это пассивные метки [17].

Общая структура системы RFID показана на рисунке 1 и включает в себя следующие элементы:

1. управляющий компьютер,
2. считыватель RFID,
3. рабочая область считывателя RFID,
4. радиочастотные метки.



50 *“Впервые в Узбекистане открылась библиотека на основе RFID-технологии” Xabar.uz, 2019. https://xabar.uz/uz/texnologiya/ozbekistonda-ilk-bor-rfid-texnologiyalari (дата обращения Dec. 09, 2024).*

51 “RFID Market Size, Share, Industry Trends, Tags and Growth Analysis 2032,” MarketsandMarkets, 2023. https://www.marketsandmarkets.com/Market-Reports/rfid-market-446.html (дата обращения Dec. 09, 2024).

Рис. 1. Структура системы радиочастотной идентификации.

RFID-системы могут работать в нескольких диапазонах частот для передачи информации: низкие частоты, высокие частоты, сверхвысокие частоты. В библиотечной деятельности наиболее эффективно используются высокочастотные системы (13,56 МГц). Основными компонентами RFID-систем являются метка, сканер (считыватель) и база данных. RFID-метка используется для маркировки библиотечного фонда, структура памяти метки основана на стандарте ISO-15693. Метка в виде этикетки приклеивается к каждому документу. Программа для сканера дает команду для считывания или записи данных с метки или на метку, при этом сканер создаёт электромагнитное поле, которое обеспечивает питанием микросхему метки и передачу данных между ними.

Классификация RFID меток строится по различным признакам (рис. 2):

по исполнению (кремневые, на поверхностных акустических волнах);

по способу хранения данных (с чипом (кремниевая технология), без чипа (на поверхностных акустических волнах – ПАВ));

по электропитанию (активные (с излучающим контуром), полуактивные (выделено питание для чипа), пассивные (резонирующие)) [30];

по способу использования (только считывание идентификатора (RO – Read Only), однократная запись данных в память и их многократное считывание (WORM – Write Once Read Many), многократные запись/считывание из памяти (RW – Read and Write));

по частоте (низкочастотный (LF) до 150 КГц, высокочастотный (HF) 13,56 МГц, сверхвысокочастотный (UHF) 850–950 МГц, 2,45–5 ГГц).

В метке хранится уникальный серийный (заводской) код, запрограммированный в процессе производства изготовителем и который невозможно изменить [31]. На каждый экземпляр книжного фонда в процессе маркировки прикрепляется метка, при этом серийный номер метки записывается в базу данных экземпляров. После маркировки книга доступна для книговыдачи, противокражный бит активируется на основе выполнения действия по выдачи или возврата книги. На рисунке 3 показана структура RFID метки для книг.

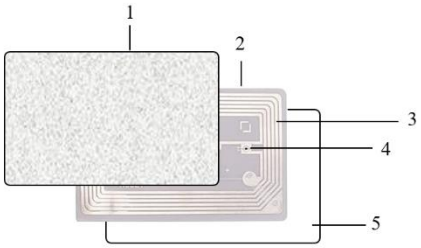


Рисунок. 3. Конструкция книжной RFID метки
1 – клеевая основа, 2 – метка, 3 – антенна метки, 4 – интегральная схема (микрочип), 5 – Защитное покрытие (бумага или полиэтелен)

RFID-технологии позволяют наносить на книги специальные метки, содержащие микрочипы и антенны. Эти метки могут быть считаны с помощью радиочастотных считывателей, что обеспечивает быстрый и точный доступ к информации о местонахождении каждого экземпляра в библиотеке. Такой подход минимизирует время, затрачиваемое на поиск и выдачу книг, повышает эффективность работы библиотечного персонала и улучшает обслуживание пользователей.

Ученые проанализировали пример применения RFID в библиотеке Сиднейского технологического университета и обнаружили, что использования технологии повысило эффективность библиотечных процессов для пользователей [25]. Они также поняли, что применение RFID креативными способами помогло разработать эффективное управление цепочкой поставок и процесс.

RFID-системы также позволяют автоматизировать процессы инвентаризации и учета, что сокращает возможность ошибок и упрощает ведение баз данных библиотечных коллекций. Благодаря этому библиотеки могут оперативно реагировать на изменения в составе коллекции, оптимизировать использование ресурсов и предоставлять более точную статистику посещений и популярности материалов.

Авторы представили систему на основе технологии RFID, разрабатывающую операции самообслуживания для повышения эффективности в библиотеках [26]. Они использовали метки RFID для идентификации книг и пользователей для обработки информации и отправки ее на ПК, на котором размещена база данных. Основной целью их разработки было наблюдение за преимуществами использования меток RFID и информации, которую они могли бы собирать в системе управления библиотекой, а также удовлетворенностью клиентов. В другой статье исследована полезность IoT в технологии RFID в университетской библиотеке в Индии, на основе интервью и наблюдения [27]. Было обнаружено, что контроль инвентаризации, проводимый с использованием меток RFID, был выполнен проще и за меньшее время, чем при ручной инвентаризации. Койл обсудил управление RFID в библиотеках [28], а Хопкинсон и Чандракар врервые применили RFID в Учебно-ресурсном центре Университета Миддлсекс [29]. В статье [30] было рассмотрено модель применения технологии IoT в реализации систем управления библиотеками на основе RFID и технологии беспроводной сенсорной сети и выявлено, что такая система сыграть ключевую роль в глобальном доступе к данным и

распространении знаний человека быстрым, более эффективным и разумным способом.

Одним из дополнительных преимуществ RFID является возможность внедрения систем самообслуживания, позволяющих пользователям самостоятельно оформлять выдачу и возврат книг, что дополнительно снижает нагрузку на персонал и увеличивает удобство обслуживания.

Таким образом, концепция комплексных автоматизированных библиотечных систем на основе RFID-технологий открывает перед библиотеками новые возможности для улучшения эффективности и качества обслуживания пользователей, сокращения операционных затрат и повышения общей доступности библиотечных ресурсов.

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ИНТЕРАКТИВНЫЕ МЕТОДЫ ОБУЧЕНИЯ ИСТОРИИ: ВНЕДРЕНИЕ ЦИФРОВЫХ ИННОВАЦИЙ В УЧЕБНЫЙ ПРОЦЕСС (НА ПРИМЕРЕ РЕСПУБЛИКИ УЗБЕКИСТАН)

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Аннотация - в статье рассматривается внедрение цифровых инноваций и интерактивных методов в условиях преподавания истории в Республике Узбекистан. Подчёркивается роль технологий в повышении эффективности исторического образования, учитывая современные инструменты, такие как дополненная и виртуальная реальность, мультимедийные ресурсы, а также образовательные платформы. Автором акцентируется внимание на высоком потенциале цифровых инноваций в повышении качества исторического образования и его адаптации к требованиям XXI века. Отмечаются и существующие проблемы и обозначаются направления дальнейшего развития, включая методическую поддержку, цифровизацию контента и повышение квалификации преподавателей.

Ключевые слова - интерактивные методы, историческое образование, цифровые технологии, Республика Узбекистан, дополненная реальность, Google Expeditions, педагогические инновации, трансформация.

ВВЕДЕНИЕ

Образование в Республике Узбекистан в последние годы претерпевает значительные изменения под воздействием цифровизации и реформ, инициированных государством. Особое место в этих процессах занимает историческое образование, которое обладает ключевым значением в формировании национального самосознания, уважения к культурному наследию и критического мышления у студентов. Однако традиционные методы преподавания истории — лекции, чтение и запоминание фактов — становятся всё менее эффективными в условиях стремительного развития цифровых технологий и смены поколений обучающихся.

Цифровизация — один из ключевых векторов развития современного общества. В этом контексте Указ Президента Республики Узбекистан за №УП-6079 от 5 октября 2020 года, утвердивший Стратегию «Цифровой Узбекистан-2030» [1], стал значимым шагом к построению цифрового государства. Документ нацелен на формирование эффективной цифровой инфраструктуры, развитие цифровых навыков у населения и внедрение инновационных технологий во все сферы жизни, включая образование в историческом направлении.

Учитывая обозначенное положение, возникает острая необходимость в использовании интерактивных методов обучения, опирающихся на цифровые инструменты и ресурсы. Республика Узбекистан предпринимает активные шаги в этом направлении: внедряются электронные образовательные платформы, используются мультимедийные средства, развивается дистанционное обучение. Однако сам процесс цифровой трансформации учебного процесса требует системного анализа, глубокого понимания существующих барьеров — таких как неравный доступ к технике и интернету, недостаточная квалификация преподавателей истории, а также сложности в адаптации традиционных методик к цифровому формату.

ЦИФРОВИЗАЦИЯ И ИНТЕРАКТИВНОСТЬ В ИСТОРИЧЕСКОМ ОБРАЗОВАНИИ

Цифровизация в образовании — это процесс внедрения и активного использования информационно-коммуникационных технологий с целью повышения качества, доступности и эффективности обучения. Отметим и то, что «цифровые технологии можно внедрять и интегрировать для создания современных, интеллектуальных, эффективных и оптимизированных рабочих мест, а также подготовки детей и молодёжи к обучению, жизни и работе в цифровом мире» [2]. Однако цифровизация в образовании — это не просто модернизация инфраструктуры, а глубокое переосмысление подходов к обучению. И только при комплексной реализации необходимых аспектов можно всецело обеспечить подлинно качественное, доступное и современное историческое образование, соответствующее требованиям XXI века.

Интерактивные методы обучения предполагают активное участие студентов в образовательном процессе: взаимодействие с контентом, преподавателем, другими студентами, а также с

цифровыми платформами. Среди таких методов — проблемное обучение, проектная деятельность, обучение через исследование, использование симуляций, геймификации и мультимедийных средств. В целом, «применение активных и интерактивных форм обучения отвечает требованиям современных стандартов образования и при соблюдении условий эффективной организации должно способствовать активизации образовательного процесса» [3].

Всё обозначенное указывает нам на то, что интерактивные методы развивают у обучающихся ключевые компетенции XXI века — критическое мышление, навыки сотрудничества, цифровую грамотность, умение находить и анализировать информацию, а также принимать самостоятельные решения. Это особенно важно в условиях стремительного развития технологий и постоянных изменений на рынке труда.

С внедрением цифровых инноваций, интерактивные методы получают новые формы реализации:

- Электронные учебники и платформы;
- Интерактивные карты и хронологии;
- Виртуальные музеи и исторические экскурсии;
- Дополненная и виртуальная реальность (AR/VR);
- Онлайн-викторины и обучающие игры;
- Цифровые архивы и исторические источники.

Историческое образование особенно выгодно воспринимает такие формы и технологии, поскольку они позволяют визуализировать процессы и факты, оживляя прошлое. В образовательной практике Узбекистана всё чаще используются цифровые платформы и приложения, поддерживающие интерактивность — такие как виртуальные классы, обучающие симуляторы, онлайн-курсы и квесты. Они позволяют формировать гибкую и адаптивную среду обучения, в которой студенты становятся не просто обыденными потребителями информации, а её активными соавторами.

Обратим внимание на то, что «на лекциях по истории использование дополненной реальности (ДР) оказывает довольно большое положительное влияние, особенно в развитии более интересного, захватывающего и интерактивного опыта обучения. ДР облегчает понимание и запоминание сложного материала, предоставляя студентам трёхмерную визуализацию исторических событий, мест или артефактов. Кроме того, эта технология развивает навыки критического и аналитического мышления, мотивирует студентов на проведение глубоких исследований и повышает их вовлеченность в материал» [4]. Кроме того, именно «потенциал ДР для трансформации традиционного исторического образования делает его более интерактивным и иммерсивным» [5]. Необходимо отметить именно то, что иммерсивные технологии способны устранить сухость подачи материала и заменить пассивное запоминание дат и фактов на активное исследование, анализ и реконструкцию событий. При этом использование цифровых карт, виртуальных музеев, 3D-моделей исторических объектов, документальных архивов и мультимедийных презентаций позволяет студентам не просто читать о прошлом, но и «переживать» его через современные технологии.

Можно подчеркнуть, что «в отличие от традиционных уроков по учебникам, дополненная реальность позволяет студентам познавать историю в практической, визуальной форме, что, вероятно, приводит к более высокому уровню вовлеченности и понимания. Использование 3D-моделей и виртуальных симуляций исторических событий позволяет студентам погрузиться в исторический контекст, делая абстрактные концепции более конкретными и простыми для понимания» [6]. Таким образом, дополненная реальность становится мощным средством повышения эффективности преподавания истории, отвечая современным педагогическим требованиям и интересам нового поколения обучающихся.

Можно обратить внимание и на приложение «Google Expeditions», представляющее собой «образовательный инструмент, позволяющий путешествовать по виртуальному миру и исследовать объекты в дополненной реальности. Доступны режимы изучения исторических памятников, исследования объектов на уровне атомов, плавания рядом с акулами и выхода в открытый космос. В Google Expeditions учитель выступает в роли гида, который проводит видео-экскурсию с классом (группой) или показывает объекты дополненной реальности. Для детального изучения отдельных тем используются специальные инструменты. Погрузиться в виртуальную или дополненную реальность можно не только в составе группы, но и самостоятельно» [7]. Всё это делает Google Expeditions универсальным средством для образования, которое эффективно сочетает визуальное восприятие, интерактивность и технологичность. Таким образом, Google Expeditions расширяет границы аудиторного обучения, открывая перед студентами мир, доступный одним нажатием, и позволяет формировать современную образовательную среду, в которой технологии работают на пользу знаниям.

Однако внедрение интерактивных и цифровых методов обучения сопряжено и с «эмоциональным пониманием и эмпатией, что также есть ключевые факторы в преподавании истории, и которые улучшаются при использовании системы дополненной реальности» [8]. Таким образом, всё обозначенное повышает мотивацию студентов, способствуя более глубокому пониманию исторических процессов, причинно-следственных связей и культурного контекста. Это сказывается на формировании компетентного, самостоятельного и гибкого поколения, готового к реальной жизни и профессиональной деятельности в цифровом обществе.

Цифровые трансформации в преподавании истории в Республике Узбекистан: современное состояние и направления развития

Цифровая трансформация затрагивает не только технические аспекты, но и меняет подходы к управлению, формат взаимодействия между государством, бизнесом и гражданами, а также модель потребления информации и услуг. В данном отношении важно отметить, что «активное развитие информационных технологий, искусственного интеллекта, интернет-сервисов и мобильной связи выводит на новый уровень экономику, систему образования, здравоохранения, энергетику и многие другие сферы. Процесс цифровой трансформации обеспечивает эффективность деятельности организаций и доступ к современным цифровым услугам для населения» [9]. В целом, цифровая трансформация — это не просто внедрение новейших технологий, а комплексное изменение всех аспектов жизни, направленное на устойчивое развитие, эффективность и повышение качества жизни населения.

В условиях цифровой трансформации образования, Республика Узбекистан предпринимает активные шаги по внедрению инновационных технологий в учебный процесс, включая преподавание истории. Это направление приобретает особую актуальность, поскольку история — не только важный элемент национального самосознания, но и дисциплина, требующая глубокого понимания, визуализации и критического осмысления.

На сегодняшний день в образовательных учреждениях Республики Узбекистан активно внедряются интерактивные методы обучения, цифровые образовательные ресурсы, мультимедийные презентации, видеоматериалы и онлайн-платформы. Ведётся работа по цифровизации школьных и вузовских учебников, разработке электронных тестов и созданию виртуальных экскурсий в музеи и исторические места страны.

Отдельного внимания заслуживает использование виртуальных реконструкций, 3D-моделирования памятников истории и архитектуры, что позволяет студентам визуально воспринимать исторические эпохи и артефакты, ранее доступные только по описанию в учебнике. Такие проекты способствуют формированию пространственного и временного мышления, а также делают занятия более увлекательными и иммерсивными.

Тем не менее, несмотря на очевидный прогресс, «в Узбекистане университеты столкнулись с рядом сложных проблем и последствий для успешного перехода от традиционных и смешанных методов обучения к полностью виртуальному и цифровому обучению. К примеру, COVID-19 по-разному повлиял на качество образования и других университетских услуг. Пандемия вынудила ректоров университетов использовать виртуальные технологии для продолжения обучения, ориентированного на студентов, распространения высокоэффективных исследований, взаимодействия с заинтересованными сторонами и расширения охвата» [10].

Это может указывать нам на то, что цифровизация исторического образования также сталкивается с рядом проблемных аспектов: нехватка подготовленных педагогических кадров, ограниченная материально-техническая база в ряде регионов, отсутствие единых цифровых платформ с локализированным и адаптированным контентом. Важно также учитывать необходимость методического сопровождения новых форм преподавания, чтобы цифровые инструменты не подменяли собой историческое содержание, а именно усиливали его восприятие.

Таким образом, цифровые инновации в преподавании истории в Республике Узбекистан находятся на стадии активного развития. И при должной поддержке со стороны государства, системной подготовке педагогов и расширении доступа к цифровой инфраструктуре, они имеют высокий потенциал для коренного преобразования исторического образования и формирования у студентов более глубокого, осмысленного понимания прошлого.

Республика Узбекистан, начиная с 2017 года, реализует стратегию по модернизации системы образования. В контексте исторического образования можно выделить несколько ключевых направлений:

1. Электронные ресурсы на платформе ZiyoNet. Обозначенная платформа обеспечивает доступ к электронным учебникам, мультимедийным пособиям и интерактивным материалам, в том числе по истории Узбекистана.

2. Мультимедийные уроки и презентации. Во многих учебных заведениях применяются цифровые презентации, фрагменты фильмов, цифровые схемы и интерактивные задания.

3. Виртуальные экскурсии и музеи. Государственные музеи (например, Музей истории Узбекистана, Музейный комплекс Мирзо Улугбека в Самарканде и т.п.) предлагают виртуальные туры, которые становятся частью учебных занятий. Это способно расширять кругозор студентов и делать учебные занятия более наглядными.

4. Цифровые архивы и открытые источники. Оцифровка исторических документов, хранящихся в архивных фондах, позволяет использовать их в рамках учебных проектов и исследований, например, по истории Хорезма, Ташкентского оазиса, Бухарского эмирата и т.п.

Однако можно обозначить возможные направления развития цифровых инноваций в преподавании истории в Республике Узбекистан:

1. Дальнейшая разработка и создание цифровых образовательных платформ по истории Узбекистана с интерактивными модулями, картами, 3D-моделями, что позволит интегрировать национальный исторический контент в международные цифровые

ресурсы (например, Google Arts & Culture, World Digital Library и др.).

2. Создание цифровых версий учебников и пособий с гиперссылками, встроенными видео и тестами. При этом важно использовать подкасты, анимации и интерактивные схемы для изучения сложных исторических тем.

3. Разработка и создание обучающих исторических квестов, викторин, геймифицированных симуляторов исторических событий.

4. Цифровое картографирование и работа с историческими базами данных, учитывая анализ цифровых архивов, карт, хроник и генеалогических ресурсов.

5. Повышение цифровой компетентности преподавателей истории, включая регулярные тренинги и курсы повышения квалификации по применению ИКТ и интерактивных методов.

6. Интеграция искусственного интеллекта и аналитики данных в учебный процесс, что позволит использовать адаптивные обучающие системы, которые подстраиваются под темп и уровень каждого студента.

ЗАКЛЮЧЕНИЕ

Интерактивные методы обучения истории, опирающиеся на цифровые технологии, открывают новые горизонты для образования в Республике Узбекистан. Они позволяют сделать изучение прошлого не только информативным, но и увлекательным, вовлекающим и личностно значимым. Однако, по нашему мнению, для полноценной реализации этого потенциала необходимы комплексные усилия всех участников образовательного процесса, включая государство, педагогическое сообщество и ИТ-сектор. В общем плане, будущее исторического образования Республики Узбекистан — именно за технологиями, открытостью и инновациями.

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DIGITAL RHETORIC AND NEW MEDIA IN DIPLOMACY

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***Abstract*: The present article examines how new media and digital rhetoric can revolutionize contemporary diplomacy. Diplomats must modify the traditional rhetorical devices of ethos, pathos, and logos for use in dynamic, visual, and interactive digital contexts as social media, websites, and blogs become increasingly important in international communication. In addition to offering difficulties with information overload, disinformation, cybersecurity, and cultural adaptation, the paper looks at how digital platforms promote narrative competition, facilitate real-time crisis communication, and improve public diplomacy. Expanded worldwide reach, interactive interaction with many stakeholders, and data-driven communications tactics are important potential. With an emphasis on the need for practical skills in audience interaction, media production, and cybersecurity awareness, the integration of digital rhetoric into diplomatic training programs is also discussed. The article's conclusion states that in an increasingly linked world, diplomats must be skilled in digital communication to uphold their reputation, shape global narratives, and advance national interests.**

Keywords – Digital diplomacy, digital rhetoric, public diplomacy, social media, diplomatic communication, soft power, misinformation, crisis communication, audience engagement, rhetorical strategies, cybersecurity, international relations, digital platforms, narrative competition, diplomatic training.

I. INTRODUCTION

The digital age has revolutionized diplomacy. With the rapid advancement of digital technologies, diplomats are now using social media, websites, blogs, and other new media platforms to engage with global audiences, shape public narratives, and promote national interests. Digital rhetoric—understood as the strategic use of communication tools in digital environments—has become essential in modern diplomacy, enabling real-time communication, narrative competition, and soft power projection. The changing importance of digital platforms in diplomacy, important rhetorical techniques for audience engagement, the potential and problems of digital discourse, and the incorporation of digital rhetoric into diplomatic training programs are all covered in this article. [18]

II. THE ROLE OF DIGITAL PLATFORMS IN DIPLOMATIC COMMUNICATION

Through the facilitation of global outreach, strategic storytelling, and public participation, digital platforms have revolutionized diplomatic communication. Through digital news portals, government websites, and social media platforms like Facebook, Instagram, and Twitter, diplomats can manage their nation's image, interact directly with audiences, and avoid traditional media.

A. A. Enhancing Public Diplomacy and Soft Power

Digital diplomacy strengthens soft power by promoting national culture, values, and policies. Public diplomacy efforts such as the UN’s GlobalGoals campaign highlight countries’ commitments to global issues like climate change and human rights, enhancing international credibility. As Mattern (2005) suggests, digital tools amplify the "representational force" of nations, allowing them to project attractive narratives that influence without coercion. [29]

B. B. Crisis Communication and Rapid Response

In times of crisis, digital platforms become critical tools for information dissemination, transparency, and trust-building. For example, during the COVID-19 pandemic, diplomatic missions worldwide used Twitter to provide real-time updates on travel restrictions, health measures, and consular services—demonstrating the importance of speed, accuracy, and reliability in digital messaging (Reus-Smit, 2004). [8]

C. C. Direct Engagement with Global Audiences

Social media allows diplomats to interact with diverse stakeholders—including citizens, journalists, and NGOs. Initiatives like the EU External Action Service’s active social media presence or “AskTheAmbassador” Q\&A campaigns exemplify how digital engagement fosters transparency and humanizes diplomacy. [15]

D. D. Countering Misinformation and Narrative Competition

Narrative competition is central to modern diplomacy. During the Russia-Ukraine conflict, Western diplomatic missions used social media to counter disinformation with verified updates and satellite imagery. As Chilton (1996) notes, controlling security narratives is vital for international stability, making digital platforms key battlegrounds for influence. [20]

E. E. Expanding Global Outreach

Digital platforms enable diplomatic missions to reach international audiences directly. For instance, the African Union’s Twitter updates promote regional solidarity and global partnerships. Data analytics tools further allow missions to assess audience demographics and sentiment, informing more effective communication strategies. [16]

III. Digital Rhetorical Strategies and Audience Engagement

Engaging global audiences requires diplomats to adapt classical rhetorical principles—ethos (credibility), pathos (emotional appeal), and logos (logical argument)—to fast-paced, visual, and interactive digital environments. [10]

F. A. Establishing Credibility (Ethos)

Credibility is essential in countering misinformation and maintaining trust. Verified accounts, consistent messaging, and transparency signal professionalism and reliability. For example, the U.S. State Department’s verified accounts help distinguish its messages from impostors and unauthorized sources. [6]

G. B. Appealing to Emotions (Pathos)

Emotional resonance increases engagement. Visual storytelling, human interest narratives, and culturally relevant symbols help evoke empathy and solidarity. The UNHCR, for instance, uses personal refugee stories to foster global compassion and support. [13]

H. C. Using Logical Argumentation (Logos)

Logical appeals grounded in evidence, data visualizations, and expert commentary enhance message credibility. Infographics explaining climate change policies or economic data help diplomats articulate complex issues clearly and persuasively. [19]

I. D. Interactive Engagement

Effective digital diplomacy is not unidirectional—it requires interactivity. Strategies such as:

Hashtag campaigns (e.g., GlobalGoals),

Live Q\&A session (e.g., “Ask The Ambassador”),

Polls and surveys

User-generated content (UGC) empower audiences and foster deeper engagement.

J. E. Measuring and Optimizing Engagement

Digital platforms offer analytics to assess message performance:

- Engagement rate
- Reach and impressions
- Sentiment analysis
- Conversion metrics

These data-driven insights help refine communication strategies for greater impact. [11]

XXXI. IV. Challenges and Opportunities in Digital Diplomatic Discourse

A. A. Information Overload

The sheer volume of online content makes visibility a challenge. Diplomats must compete with trending topics and misinformation for audience attention. [28]

Misinformation and Disinformation

False narratives threaten diplomatic credibility. Diplomats must counter them with verified, fact-based messaging—often in real time.

Cybersecurity Risks

Hacking and impersonation are growing threats. Robust cybersecurity measures and staff training are critical to safeguarding digital diplomacy.

Cultural and Linguistic Barriers

Messages must be tailored to local cultural contexts without losing consistency. Misinterpretation can harm credibility or cause offense.

B. B. Real-Time Communication Pressures

Digital platforms demand immediate responses, particularly during crises—creating risks of errors and misstatements without proper coordination. [22]

Opportunities:

a. Real-Time Communication and Global Reach

Instant communication enhances transparency and responsiveness—key elements of modern public diplomacy. [4]

b. Amplifying Public Diplomacy Efforts

Campaigns like Visit Japan use social media to promote national identity and attract foreign interest, building soft power. [25]

c. Engaging Diverse Stakeholders

Digital diplomacy allows direct interaction with citizens, media, and civil society, fostering dialogue and transparency.

d. Data-Driven Strategies

Digital tools provide insights into audience behavior and sentiment, enabling more effective and targeted communication.

e. Collaborative Campaigns

Joint campaigns—such as those during the UN Climate Conferences (COP)—allow diplomats, NGOs, and international organizations to amplify global advocacy through shared messaging. [2]

V. Incorporating Digital Rhetoric in Diplomatic Training Programs

Given the central role of digital media in diplomacy, training programs must evolve to equip diplomats with digital rhetorical skills. [3]

C. A. Core Components of Digital Rhetoric Training

It includes several criteria:

a. Introduction to Digital Diplomacy

Trainees learn about digital diplomacy’s evolution, platforms, and case studies (e.g., GlobalGoals, Brexit communication strategies).

b. Rhetorical Strategy Development

Programs teach how to apply ethos, pathos, and logos in digital settings through message analysis and content development.

c. Interactive Engagement Techniques

Trainees learn to create hashtag campaigns, host Q\&As, and use UGC to enhance transparency and participation.

d. Media Production Skills

Practical skills in video production, infographics, and platform-specific content creation are developed.

e. Cybersecurity Awareness

Diplomats are trained in identifying risks, securing accounts, and managing digital communication ethically and securely.

D. B. Experiential Learning

Simulations: Trainees respond to hypothetical crises, crafting digital messaging strategies in real-time scenarios.

Case Studies: Real-world analyses of successful (and failed) digital diplomacy campaigns illustrate best practices and pitfalls.

Mentorship and Peer Review: Learning is enhanced through feedback from experienced practitioners and collaborative peer assessments. [21]

E. C. Assessment and Continuous Development

Assessments include rhetorical analysis, campaign pitches, and performance evaluations using hypothetical engagement metrics. Training programs must also evolve with emerging technologies such as AI, AR, and new social media trends. [26]

Best Practices for Training Design:

– Combine theory and practice

– Foster teamwork

– Emphasize cultural adaptability

– Utilize data for communication strategy refinement

VI. CONCLUSION

Digital platforms have become indispensable in modern diplomacy, reshaping the methods by which states engage with the global community. Through digital rhetoric, diplomats can promote national interests, build relationships, counter misinformation, and enhance transparency. However, the digital landscape is also fraught with risks—ranging from cyber threats to cultural miscommunication.

To meet the demands of this new era, diplomats must master digital rhetorical strategies rooted in ethos, pathos, and logos while actively engaging audiences and leveraging analytics. Integrating these skills into formal diplomatic training programs ensures that the next generation of diplomats is prepared for the complexities of digital discourse.

In a world where influence is often measured by online presence and narrative control, diplomacy must continue to adapt—harnessing the power of digital platforms not just to communicate, but to connect, persuade, and lead.

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FIZIK MASALALARNI AVTOMATLASHTIRISH JARAYONIDA MATEMATIK MODELLAR, DASTURIY VOSITALAR VA SUN’IY INTELLEKT INTEGRATSIYASI

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***Abstract*— Mazkur maqolada fizik masalalarni avtomatlashtirish jarayoni bosqichlari keng tahlil qilinadi. Avtomatlashtirishning asosiy yo‘nalishlari sifatida matematik modellashtirish, algoritm ishlab chiqish, dasturiy modellashtirish, hisoblashni avtomatlashtirish, natijalarni vizualizatsiya qilish va sun’iy intellekt integratsiyasi ko‘rib chiqiladi. Har bir bosqichning nazariy va amaliy jihatlari yoritilib, ularning ta’lim jarayonidagi ahamiyati, ilmiy-tadqiqot faoliyatidagi qo‘llanilishi hamda kelajakdagi istiqbollari muhokama qilinadi. MATLAB va Python kabi dasturiy vositalarning imkoniyatlari, shuningdek mashinaviy o‘rganish algoritmlarining afzalliklari misollar bilan asoslanadi. Tadqiqot natijalari fizika ta’limini zamonaviy darajaga olib chiqish va ilmiy izlanishlarda samaradorlikni oshirishda muhim o‘rin tutishini ko‘rsatadi.**

Keywords*— *avtomatlashtirish, matematik modellashtirish, dasturiy vositalar, sun’iy intellekt, vizualizatsiya, fizika masalalari.

XXXII. INTRODUCTION (*HEADING 1*)

Bugungi kunda ilm-fan va texnologiyalar sohasida avtomatlashtirish jarayonlari jadal rivojlanmoqda. Xususan, fizika fanida murakkab masalalarni an’anaviy usullarda qo‘l mehnati bilan yechish ko‘plab vaqt va kuch talab qiladi, natijada ta’lim jarayonida samaradorlik pasayadi. Shu sababli fizika masalalarini avtomatlashtirish dolzarb yo‘nalishlardan biriga aylanib, nafaqat o‘quv jarayonida, balki ilmiy-tadqiqot va sanoat sohalarida ham keng qo‘llanilmoqda. Avtomatlashtirish jarayoni bir nechta bosqichlarni o‘z ichiga oladi: matematik modellashtirish, algoritm ishlab chiqish, dasturiy modellashtirish, hisoblashni avtomatlashtirish, natijalarni vizualizatsiya qilish va sun’iy intellekt texnologiyalarini integratsiya qilish [1,2,3]. Har bir bosqich jarayonni takomillashtirishga xizmat qiladi va ularning uyg‘unlashuvi natijada samarali ilmiy yechimga olib keladi. Mazkur maqola aynan ushbu bosqichlarning nazariy va amaliy jihatlarini yoritishga, ularning ta’lim va ilmiy faoliyatdagi ahamiyatini ko‘rsatishga qaratilgan.

Fizik masalalarni avtomatlashtirish jarayoni zamonaviy ilmiy-texnik taraqqiyotning ajralmas qismiga aylanib ulgurgan. Bugungi kunda fizika fanini o‘qitish, uni ilmiy tadqiqotlarda qo‘llash va ishlab chiqarishdagi real jarayonlarni modellashtirishda avtomatlashtirilgan yondashuvsizlikni tasavvur qilish qiyin [4-5]. Chunki fizika qonunlari murakkab matematik tenglamalar bilan ifodalanadi, ularni qo‘l mehnati bilan yechish esa katta vaqt va resurs talab etadi. Ayniqsa, murakkab tizimlarni tahlil qilish, ko‘p parametrli modellarni ishlab chiqish va real sharoitlarga moslashtirishda insoniy omil ko‘plab cheklovlarga ega. Shu bois fizika masalalarini avtomatlashtirish zarurati ilmiy hamjamiyat va ta’lim muassasalarida tobora ortib bormoqda [6,7,8,9]. Avtomatlashtirish deganda faqatgina kompyuter dasturlarida hisob-kitob qilish emas, balki masalani to‘liq yechish jarayonini bosqichma-bosqich tizimlashtirish nazarda tutiladi. Bu bosqichlar matematik modellashtirish, algoritm ishlab chiqish, dasturiy modellashtirish, hisoblashni avtomatlashtirish, natijalarni vizualizatsiya qilish va sun’iy intellekt integratsiyasini o‘z ichiga oladi. Har bir bosqich o‘ziga xos vazifani bajaradi va ularning

uyg‘unlashuvi butun jarayon samaradorligini belgilaydi.

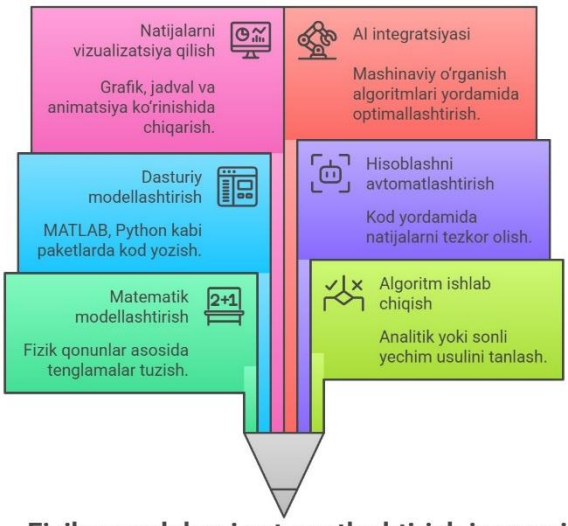
Jarayonning birinchi va eng muhim bosqichi bu matematik modellashtirishdir. Fizik hodisalarni matematik shaklga keltirmasdan turib ularni avtomatlashtirish mumkin emas. Chunki kompyuter uchun masalaning aniq formulasi va matematik ifodasi zarur. Matematik modellashtirishda fizik qonunlar asos qilib olinadi, ular orasidagi bog‘lanishlar tenglamalar ko‘rinishida yoziladi. Masalan, mexanikadagi Nyutonning ikkinchi qonuni $F = m \cdot a$ ko‘plab jarayonlarni ifodalashga asos bo‘lib xizmat qiladi. Elektr zanjirlarda Kirxgof qonunlari, issiqlik o‘tkazishda Fourier qonuni, elektromagnit maydonlarda esa Maksvell tenglamalari model sifatida ishlatiladi. Modellashtirish jarayonida shuningdek, chegaraviy va boshlang‘ich shartlar aniqlanadi, bu esa masalani real sharoitlarga yaqinlashtirish imkonini beradi. Masalan, aylanma harakat dinamikasida inertsiya momenti va aylanish momenti orasidagi bog‘lanish $M = J \cdot \varepsilon$ tenglamasi orqali ifodalanadi, bu tenglama keyinchalik kompyuter dasturlarida asosiy model bo‘lib xizmat qiladi.

Ikkinchi bosqich algoritm ishlab chiqishdir. Matematik model tayyor bo‘lgach, uni yechish uchun aniq yo‘l tanlash lozim bo‘ladi. Algoritm — bu bosqichma-bosqich bajariladigan amallar ketma-ketligi bo‘lib, u natijaga qanday erishilishini belgilaydi. Fizik masalalarda ba’zan analitik yechim mavjud bo‘ladi, ba’zan esa faqat sonli usullar orqali natija olinadi. Masalan, oddiy differensial tenglamalar ko‘pincha analitik shaklda yechiladi, biroq ko‘p parametrli, nolinear tizimlarda faqat sonli usullar qo‘llanilishi mumkin. Shu sababli, masalani yechish uchun Eyler usuli, Runge-Kutta usullari, iteratsion metodlar, matritsali yechimlar yoki optimallashtirish algoritmlari tanlanadi. Algoritm ishlab chiqishda uning aniqligi, tezligi va barqarorligi muhim hisoblanadi. Masalan, sonli usullarda qadam uzunligi juda katta tanlansa, natija aniq chiqmaydi, juda kichik tanlansa esa hisoblash juda ko‘p vaqt oladi. Shu bois optimal algoritm tanlash jarayoni muhim bosqich hisoblanadi.

Keyingi bosqich dasturiy modellashtirishdir. Matematik model va ishlab chiqilgan algoritm endi dasturiy kodga aylantiriladi. Bu bosqichda MATLAB, Python, Maple kabi dasturiy muhitlar keng qo‘llaniladi. MATLAB matematik hisob-kitoblar, matritsalar bilan ishlash, grafik chizish imkoniyatlari bilan ajralib turadi. Python esa bugungi kunda eng mashhur dasturlash tillaridan biri bo‘lib, ochiq manbali, bepul va juda ko‘p kutubxonalarga ega. Masalan, NumPy kutubxonasi sonli hisoblashlar uchun, SymPy ramziy hisoblashlar uchun, Matplotlib esa grafik vizualizatsiya uchun juda qulay. Maple dasturi esa analitik yechimlarni olish, tenglamalarni ramziy shaklda yechish va ularni chiroyli matematik ifodalar ko‘rinishida taqdim etishda keng qo‘llaniladi. Dasturiy modellashtirishda kodning optimalligi, tushunarli yozilishi va tezkor ishlashi muhim omillardan hisoblanadi.

Hisoblashni avtomatlashtirish bosqichi dasturiy modellashtirishdan keyin keladi [10]. Bu bosqichda foydalanuvchi faqat dasturga boshlang‘ich parametrlarni kiritadi, natijalar esa avtomatik tarzda hisoblanib chiqadi [11,12,13,14,15]. Masalan, aylanish dinamikasida massa, radius va burchak tezlanish qiymatlari berilganda, dastur inertsiya momenti va aylanish momentini darhol hisoblab beradi. Agar foydalanuvchi parametrlarni o‘zgartirsa, natijalar ham shunga mos ravishda qayta hisoblanadi. Bu inson omiliga bog‘liq xatoliklarni kamaytiradi, vaqtni tejaydi va hisoblash jarayonini sezilarli darajada tezlashtiradi. Ayniqsa, ko‘plab variantlarni tekshirish talab etiladigan hollarda bu bosqichning samarasi juda yuqori bo‘ladi.

Natijalarni vizualizatsiya qilish bosqichi ham



Fizik masalalarni avtomatlashtirish jarayoni

jarayonning muhim qismi hisoblanadi. Chunki olingan natijalarni faqat sonli qiymatlar shaklida taqdim etish talabalar va tadqiqotchilar uchun ko‘pincha yetarli bo‘lmaydi. Natijalarni grafiklar, jadvallar yoki animatsiyalar orqali ko‘rsatish esa ularni tushunishni osonlashtiradi, tahlil qilish imkonini beradi va ta’lim jarayonida motivatsiyani oshiradi. Masalan, aylanish momentining burchak

tezlanishga bog‘liqligi grafik ko‘rinishda chizilganda, uning to‘g‘ri chiziqli proportsionalligi yaqqol ko‘rinadi. Yoki tebranish jarayonini animatsiya orqali ko‘rsatish talabalar uchun tajriba natijasini virtual kuzatish imkonini beradi. Natijalarni vizualizatsiya qilish ilmiy maqolalarda ham muhim o‘rin tutadi, chunki grafiklar va diagrammalar yordamida murakkab natijalarni qisqa va aniq ko‘rsatish mumkin.

Jarayonning eng zamonaviy va istiqbolli bosqichi bu sun’iy intellekt integratsiyasidir. Mashinaviy o‘rganish algoritmlari hisoblash jarayonlarini yanada samarali qilishga yordam beradi. Masalan, neyron tarmoqlar yordamida turli shakldagi jismlarning inertsiya momentlarini tezkor aniqlash mumkin. Bunda dastlab ko‘plab misollar yordamida model o‘qitiladi, keyin yangi parametrlar kiritilganda natija juda tez va aniq chiqadi. Sun’iy intellekt shuningdek, talabalar tomonidan bajarilgan masalalarni avtomatik baholash, xatolarni aniqlash va ularga to‘g‘ri yo‘l ko‘rsatishda ham qo‘llaniladi. Mashinaviy o‘rganish yordamida natijalarni optimallashtirish, prognoz qilish va katta hajmdagi ma’lumotlarni qayta ishlash mumkin. Bu esa fizika fanida ilmiy-tadqiqot ishlarini sezilarli darajada tezlashtiradi va samaradorligini oshiradi.

Shu tarzda fizika masalalarini avtomatlashtirish jarayoni bosqichma-bosqich amalga oshiriladi va ularning har biri umumiy natija uchun muhim ahamiyatga ega. Matematik modellashtirish asosiy poydevor bo‘lsa, algoritm ishlab chiqish jarayonni yo‘lga qo‘yadi, dasturiy modellashtirish uni kompyuter muhitiga olib chiqadi, hisoblashni avtomatlashtirish natijalarni tezlashtiradi, vizualizatsiya jarayonni tushunarli qiladi, sun’iy intellekt esa butun jarayonni yanada samarali va ilg‘or qiladi. Bu yondashuv nafaqat ta’lim tizimida, balki ilmiy tadqiqotlarda, sanoatda va ishlab chiqarishda ham keng qo‘llanilmoqda.

Xulosa qilib aytganda, fizika masalalarini avtomatlashtirish jarayoni bugungi kunda zamonaviy fan va texnologiyaning ajralmas qismiga aylangan. U talabalarga bilimlarni samarali o‘zlashtirishda yordam beradi, o‘qituvchilarning ishini yengillashtiradi, ilmiy-tadqiqot ishlarini tezlashtiradi va sanoatda murakkab jarayonlarni optimallashtirishga xizmat qiladi. Har bir bosqichning o‘z vazifasi va o‘rni mavjud bo‘lib, ularning uyg‘unlashuvi natijani mukammal qiladi. Ayniqsa, sun’iy intellekt texnologiyalarining integratsiyasi kelajakda fizika ta’limi va ilm-fanida mutlaqo yangi ufqlarni ochib berishi shubhasiz.

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MATEMATIKA FANINI O‘QITISHDA KENGAYTIRILGAN REALLIK VA GOLOGRAMMA TEXNOLOGIYALARIDAN FOYDALANISH

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Abstract: Ushbu maqolada matematika fanini o‘qitishda zamonaviy texnologiyalardan — kengaytirilgan reallik (AR) va gologramma texnologiyalaridan foydalanish imkoniyatlari har tomonlama tahlil qilinadi. Tadqiqot jarayonida AR ilovalari hamda 3D golografik vizualizatsiyalar asosida ishlab chiqilgan innovatsion dars modullari ta’lim amaliyotida sinovdan o‘tkazildi. Maqolada AR va gologrammalarning o‘quvchilarning mavzuni anglash darajasi, darsga bo‘lgan qiziqishi va o‘quv faoliyatiga jalb qilinishiga qanday ta’sir ko‘rsatgani raqamli tahlillar yordamida batafsil yoritilgan. Olingan natijalar ushbu texnologiyalar orqali o‘qitish samaradorligini sezilarli oshirish, murakkab matematik tushunchalarni osonroq vizual tarzda tushuntirish, shuningdek, ta’lim jarayonini interaktivlashtirish imkoniyatini berishini ko‘rsatdi. Tadqiqot natijalari, shuningdek, kengaytirilgan reallik va gologramma vositalarining o‘quvchilarning kognitiv rivojlanishi, ijodiy tafakkuri va mustaqil fikrlash qobiliyatiga ijobiy ta’sir ko‘rsatishini ham ilmiy asosda isbotlab berdi.

Keywords: matematika, kengaytirilgan reallik, gologramma, innovatsion ta’lim, raqamli texnologiyalar, o‘quv samaradorligi

XXXIII. KIRISH

Zamonaviy ta’lim tizimida raqamli texnologiyalarni o‘quv jarayoniga integratsiya qilish o‘quvchilarning bilim olish jarayonini yengillashtirish, ularni mustaqil fikrlashga va amaliy ko‘nikmalarni shakllantirishga yo‘naltirishda muhim omil hisoblanadi. Ayniqsa, an’anaviy o‘quv uslublarida qiyinchilik tug‘diradigan murakkab tushunchalarni oson va tushunarli qilib yetkazishda innovatsion texnologiyalardan foydalanish muhim ahamiyat kasb etmoqda.

Matematika fani aynan shunday fanlardan biri bo‘lib, ko‘plab mavzular abstrakt va tasavvur qilish qiyin bo‘lgan tushunchalarni o‘z ichiga oladi. Bunday sharoitda kengaytirilgan reallik (Augmented Reality – AR) va gologramma texnologiyalari matematika ta’limini jonlantirish, uni interaktiv, ko‘rgazmali va qiziqarli qilishda yangi imkoniyatlar yaratmoqda. Kengaytirilgan reallik vositalari yordamida o‘quvchilar murakkab matematik obyektlarni real makon bilan uyg‘unlashtirib ko‘rishlari, golografik tasvirlar esa mavzularni 3D ko‘rinishda namoyish etish orqali o‘quvchilarda chuqurroq tushuncha shakllanishiga xizmat qiladi.

Ushbu maqolada matematika fanini o‘qitishda AR va gologramma texnologiyalaridan foydalanishning samaradorligi o‘rganiladi. Tadqiqot doirasida ushbu texnologiyalar asosida ishlab chiqilgan o‘quv modullarining o‘quvchilarning bilim darajasi, darsdagi faolligi hamda mavzuni anglash qobiliyatiga ta’siri tahlil qilinadi. Shuningdek, an’anaviy dars uslublari bilan taqqoslab, AR va gologramma texnologiyalarining afzalliklari ham ko‘rib chiqiladi.

Maqolaning asosiy maqsadi — matematika fanini o‘qitishda kengaytirilgan reallik va gologramma texnologiyalaridan samarali foydalanish imkoniyatlarini ilmiy asosda aniqlash va ularning ta’lim jarayoniga integratsiyalashgan holatdagi ta’sirini tahlil qilishdan iborat.

XXXIV. METODOLOGIYA

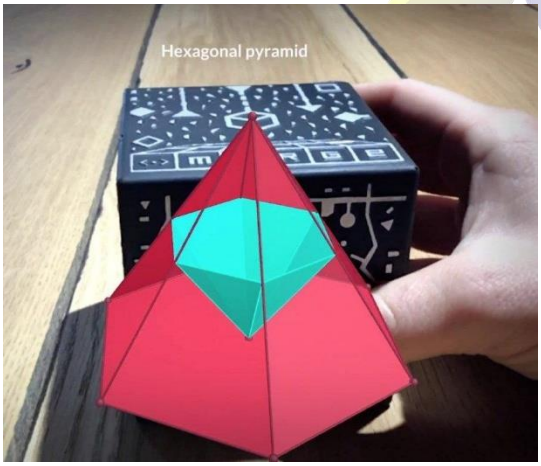
Mazkur tadqiqotda matematika fanini o‘qitish jarayonida kengaytirilgan reallik (AR) va gologramma texnologiyalarining samaradorligini baholash maqsadida eksperimental yondashuv qo‘llanildi. Tadqiqot dizayni

kvazi-eksperimental uslubga asoslangan bo‘lib, ikki guruh (eksperimental va nazorat) o‘rtasidagi taqqoslashga tayanadi.

1-rasm. Darslarda VR qo‘llash

Tadqiqot Toshkent shahri va viloyatidagi uchta umumiy o‘rta ta’lim maktabining 7-sinf o‘quvchilari orasida olib borildi. Har bir maktabdan 2 ta sinf tanlab olindi: biri nazorat guruhi, ikkinchisi esa eksperimental guruh sifatida belgilandi. Eksperimental guruhga AR ilovalari va gologrаfik qurilmalar asosida tayyorlangan vizual dars materiallari taqdim etildi. Nazorat guruhi esa odatdagi an’anaviy metodikalar asosida ta’lim oldi.

Eksperimental darslar uchun “GeoGebra AR”, “Merge Cube” va “HoloLens 2” kabi kengaytirilgan reallik ilovalari va qurilmalardan foydalanildi [3], [6]. Gologrаfik tasvirlar 3D grafik muhitda ishlab chiqildi va dars mavzulariga moslashtirildi. Darslar “Kasrlar ustida amallar”, “Ko‘p o‘lchamli figuralar” va “Grafiklar bilan ishlash” kabi mavzularni o‘z ichiga oldi.



2-rasm. Hexagonal pyramid

Har bir dars ikki bosqichdan iborat bo‘ldi:

- Vizualizatsiya bosqichi — mavzuga oid AR yoki gologrammalar orqali tushuntirishlar berildi.
- Amaliy bosqich — o‘quvchilar maxsus topshiriqlar va savol-javoblar orqali mavzuni mustahkamlashdi.

Tadqiqotda bir necha turdagi ma’lumotlar yig‘ildi:

- Test natijalari — har ikkala guruhga dars oldidan va darsdan so‘ng testlar o‘tkazildi. Bu orqali bilim darajasidagi o‘zgarishlar tahlil qilindi [2], [5].
- So‘rovnoma — eksperimental guruh o‘quvchilariga AR va gologrammalar bo‘yicha psixologik va motivatsion ta’sirini baholovchi 15 ta savoldan iborat so‘rovnoma tarqatildi [7].
- Kuzatuv — har bir dars davomida o‘qituvchilar tomonidan o‘quvchilarning faol ishtirok etish darajasi va texnologiyalarga bo‘lgan munosabat kuzatildi [1], [9].
- Intervyu-sinf o‘qituvchilari bilan o‘tkazilgan intervyular orqali texnologik yechimlarning amaliyotga tatbiqi va qulayligi tahlil qilindi [8].

Yig‘ilgan ma’lumotlar SPSS dasturi yordamida tahlil qilindi. Test natijalarining statistik o‘zgarishi t-test usuli bilan baholandi. So‘rovnoma va intervyu natijalari esa kontent-tahlil metodi yordamida umumlashtirildi [4], [10].

Metodologik yondashuv, eksperiment dizayni va tahlil usullari maqola natijalarining ishonchliligini ta’minlashga xizmat qiladi. Ushbu metodologiya matematika fanini o‘qitishda kengaytirilgan reallik va gologrammalarning haqiqiy samaradorligini ko‘rsatish imkonini beradi.

Kengaytirilgan reallik texnologiyalarining neyrokognitiv asoslari va matematik ta’limdagi ta’siri

Zamonaviy neyroilm tadqiqotlari kengaytirilgan reallik (AR) texnologiyalarining matematik ta’limga ta’sirini miyaning biologik jarayonlari darajasida tushuntirish imkonini beradi. AR va virtual reallik texnologiyalari fazoviy fikrlash, vizualizatsiya, uzoq muddatli xotira, jalb qilinish va motivatsiyaning oshishini qo‘llab-quvvatlash orqali o‘quvchilarning o‘rganishini yaxshilashga yordam beradi.

Neyroilm tadqiqotlariga ko‘ra, AR texnologiyalari yordamida taqdim etilgan matematik material miyaning turli qismlarini bir vaqtda faollashtiiradi. Visual-fazoviy ma’lumotlarni qayta ishlash uchun mas'ul bo‘lgan occipital va parietal korteks hududlari AR muhitida matematik obyektlarni idrok etishda yuqori faollik ko‘rsatadi. Bu, o‘z navbatida, abstrakt matematik tushunchalarni konkret tasvirlarga bog‘lash jarayonini osonlashtiradi.

Kognitiv yuklanish nazariyasi va AR texnologiyalari

Kognitiv yuklanish nazariyasiga asoslangan va foydalanuvchi-markazli yondashuvda ishlab chiqilgan AR platformalari matematik ta’limda ayniqsa samarali bo‘lmoqda. Kognitiv yuklanish nazariyasi bo‘yicha, o‘quvchilarning ish xotirasi cheklangan sig‘imga ega bo‘lib, ma’lumotlarni bir vaqtda qayta ishlash qobiliyati ham cheklangan.

AR texnologiyalari ushbu muammoni hal qilishda quyidagi yo‘llar bilan yordam beradi:

- Ichki kognitiv yuklanishni kamaytirish - murakkab matematik tushunchalarni vizual elementlar yordamida soddalashtirish
- Tashqi kognitiv yuklanishni optimallashtirish - ortiqcha ma’lumotlarni yo‘q qilish va muhim elementlarga e'tiborni qaratish
- O‘quv kognitiv yuklanishini oshirish - yangi bilimlarni shakllantirishga yo‘naltirilgan aqliy jarayonlarni kuchaytirish

Fazoviy fikrlash va geometriya o‘qitish

AR texnologiyalari geometrik obyektlarni vizualizatsiya qilish orqali matematik o‘rganishni

kuchaytirishi mumkin. Fazoviy fikrlash qobiliyati matematik muvaffaqiyatning muhim prediktorlaridan biri hisoblanadi. AR muhitida o‘quvchilar:

- Uch o‘lchamli shakllarni turli burchaklardan ko‘rish
- Geometrik transformatsiyalarni real vaqtda kuzatish
- Murakkab fazoviy munosabatlarni tushunish
- Mental rotatsiya ko‘nikmalarini rivojlantirish

imkoniyatiga ega bo‘ladilar. Bu jarayonda miyaning fazoviy ma’lumotlarni qayta ishlashdan mas'ul bo‘lgan hududlari faol ishtirok etadi, natijada geometriyaga oid tushunchalar chuqurroq o‘zlashtriladi.

Zamonaviy AR platformalari va matematik ta’lim

2024-2025 yillardagi so‘nggi tadqiqotlar AR texnologiyalarining matematik ta’limdagi qo‘llanilishi yangi bosqichga o‘tganini ko‘rsatmoqda. EDU-MAT COPERNICUS kabi innovatsion ta’lim platformalari AR ni Sun’iy yo‘ldosh texnologiyalari bilan integratsiya qilib, boshlang‘ich sinf o‘quvchilari uchun matematika va geofan o‘rganishni qo‘llab-quvvatlaydi.

Narrativ asosidagi AR ta’limi

Zamonaviy AR platformalarida matematik tushunchalar hikoyalar va o‘yin elementlari orqali taqdim etilmoqda. Bu yondashuv quyidagi afzalliklarga ega:

- O‘quvchilarning emotsional jalb qilinishi
- Motivatsiyaning oshishi
- Matematik tushunchalarning hayotiy kontekstda ko‘rsatilishi
- Interdistsiplinar yondashuvning amalga oshirilishi

Real vaqt ma’lumotlardan foydalanish

Zamonaviy AR sistemlari real vaqt ma’lumotlarini matematik masalalar bilan birlashtiradi. Masalan, ob-havo ma’lumotlari statistika darslarida, geografik ma’lumotlar koordinata tizimi o‘rganishda qo‘llanilmoqda. Bu o‘quvchilarga matematikaning amaliy ahamiyatini ko‘rsatadi va fanlararo aloqalarni mustahkamlaydi.

AR texnologiyalarining samaradorlik ko‘rsatkichlari

So‘nggi tadqiqotlar AR texnologiyalarining matematik ta’limdagi samaradorligini aniq raqamlar bilan tasdiqlamoqda. Ushbu texnologiyalarni joriy etgandan so‘ng o‘quvchilarning matematik fanlardan o‘tish darajasi 68% dan 85% gacha oshgan, shuningdek, o‘quvchilarning sinf ishtirokchiligi va matematikaga bo‘lgan qiziqishi sezilarli darajada yaxshilangan.

Meta-tahlil natijalari

2016-2023 yillar oralig‘ida o‘tkazilgan tadqiqotlarning meta-tahlili quyidagi xulosalarga olib keldi:

- AR yordami bilan ta’lim olgan o‘quvchilarning o‘quv yutuqlari sezilarli darajada yuqori
- O‘quvchilarning AR-asosli ta’limga bo‘lgan munosabati ijobiy
- Uzoq muddatli xotira ko‘rsatkichlarining yaxshilanishi
- Matematik tushunchalarga bo‘lgan tushunishning chuqurlashishi

Tanqidiy fikrlash ko‘nikmalarining rivojlanishi

AR texnologiyalari yordami bilan o‘qitishning boshlang‘ich sinf o‘quvchilarining matematik fandagi tanqidiy fikrlash ko‘nikmalariga ta’siri alohida o‘rganilmoqda. Tadqiqotlar shuni ko‘rsatmoqdaki, AR muhitida matematik masalalar bilan ishlash:

- Analitik fikrlashni rivojlantiradi
- Muammolarni hal qilish strategiyalarini diversifikatsiya qiladi
- Hipotezalarni tekshirish ko‘nikmalarini shakllantiiradi
- Matematik dalillar bilan ishlash qobiliyatini oshiradi

Madaniy kontekst va AR texnologiyalari

AR va VR vositalarini madaniy javobgar pedagogikalar orqali matematik ta’limda qo‘llanish muhim yo‘nalish hisoblanadi. Turli madaniy muhitlarda o‘qiyotgan o‘quvchilar uchun AR texnologiyalarini moslashtiirish quyidagi jihatlarni hisobga olishni talab qiladi:

Madaniy adaptatsiya

- Mahalliy matematik an'analarni AR muhitiga kiritish
- O‘zbek matematik olimlarining yutuqlarini AR orqali namoyish etish
- Milliy ornamentlar va naqshlardan geometriya darslarida foydalanish
- Mahalliy kontekst va masalalarni AR tasvirlariga kiritish

Til va kommunikatsiya xususiyatlari

AR interfeyslari o‘zbek tilining xususiyatlarini hisobga olgan holda ishlab chiqilishi kerak. Bu quyidagilarni o‘z ichiga oladi:

- O‘ng-chapdan yozilish yo‘nalishi
- Matematik terminlarning o‘zbek tilidagi ekvivalentlari
- Audio qo‘llab-quvvatlash va ovozli tushuntirishlar
- Madaniy kontekstga mos keluvchi tasviriy elementlar

Texnik infratuzilma va joriy etish strategiyalari

AR texnologiyalarini maktablarda samarali qo‘llash uchun quyidagi texnik shartlar ta’minlanishi zarur:

- Yuqori o‘tkazuvchanlikka ega internet aloqasi (kamida 50 Mbps)
- Zamonaviy mobil qurilmalar (ARCore/ARKit qo‘llab-quvvatlovchi)
- Bulutli hisoblash xizmatlariga kirish imkoniyati
- Ma’lumotlarni saqlash uchun yetarli xotira hajmi

Kelajakdagi rivojlanish yo‘nalishlari

Sun’iy intellekt va AR integratsiyasi

Kelajakda AR texnologiyalari Sun’iy intellekt algoritmlari bilan birlashtirilib, har bir o‘quvchining individual ehtiyojlariga moslashtirilgan matematik ta’lim muhiti yaratiladi. Bu quyidagilarni o‘z ichiga oladi:

- Adaptiv o‘rganish algoritmlari
- O‘quvchi harakatlarini real vaqtda tahlil qilish
- Individual o‘rganish traektoriyalarini yaratish
- Xatolarni aniqlash va tuzatish tizimlari

Kvant hisoblash va AR

Kvant hisoblash texnologiyalarining rivojlanishi AR ga asoslangan matematik ta’lim tizimlarida yangi imkoniyatlar ochadi:

- Murakkab matematik modellarni real vaqtda hisoblash
- Yuqori aniqlikdagi 3D vizualizatsiya
- Ko‘p o‘lchamli ma’lumotlarni qayta ishlash
- Katta hajmdagi ta’lim ma’lumotlarini tahlil qilish

XXXV. NATIJALAR

Tadqiqot davomida olingan natijalar kengaytirilgan reallik va gologramma texnologiyalarining matematika fanini o‘qitish jarayoniga ijobiy ta’sir ko‘rsatishini isbotladi. Eksperimental va nazorat guruhlari o‘rtasida olib borilgan taqqoslash asosida quyidagi asosiy farqlar aniqlangan:

Avvalo, test sinovlari orqali o‘quvchilarning mavzuni o‘zlashtirish darajasi o‘lchandi. Eksperiment oldidan har ikki guruh o‘quvchilari o‘rtacha 100 ballik tizimda taxminan 48–52 ball to‘plashdi. Darslar tugagach, nazorat guruhining o‘rtacha natijasi 63 ballga oshgan bo‘lsa, eksperimental guruhda bu ko‘rsatkich 82 ballga yetdi. Bu esa kengaytirilgan reallik va golografik vizualizatsiya orqali tushunchalarni yanada aniq va esda qolarli tarzda tushuntirish imkonini berganligini anglatadi [3], [5].

3-rasm. VR va AR texnologiyalari

Tahlil shuni ko‘rsatdiki, ayniqsa geometriya, koordinata tekisligi va uch o‘lchamli shakllarni tasavvur qilishda AR ilovalari va gologrammalar o‘quvchilarga katta yordam berdi. “Merge Cube” va “GeoGebra AR” dasturlari yordamida shakllarni aylantirish, tilimlash va bo‘laklash amaliyotlari orqali o‘quvchilar mavzuni jonli tajriba asosida o‘zlashtirishdi [6].

Kuzatuv natijalariga ko‘ra, eksperimental guruh o‘quvchilari dars jarayonida yuqori darajadagi faollik namoyon etdilar. Ularning 78 foizi dars davomida savolga javob berdi yoki mustaqil ishlarda qatnashdi. Nazorat guruhida esa bu ko‘rsatkich 52 foizni tashkil etdi. O‘quvchilarning darsga bo‘lgan motivatsiyasi sezilarli darajada oshgani qayd etildi. Darsdan keyingi so‘rovnomada eksperimental guruh o‘quvchilarining 88 foizi kengaytirilgan reallik texnologiyalaridan foydalanilgan darslarni yoqimli va qiziqarli deb topdi [7].

So‘rovnoma natijalari bo‘yicha, o‘quvchilarning 83 foizi “AR texnologiyalari mavzuni tushunishni yengillashtirdi” degan fikrni bildirgan. 76 foizi esa “agar boshqa fanlarda ham shunday texnologiyalar bo‘lsa, men ko‘proq o‘rganishga harakat qilardim” deya ijobiy javob qaytargan. Bu esa AR va gologrammalar o‘quvchilarda mustaqil o‘rganishga bo‘lgan ichki ehtiyojni kuchaytirishini ko‘rsatadi [1], [4].

Intervyular orqali olingan natijalarga ko‘ra, tajriba ishtirokchisi bo‘lgan matematika o‘qituvchilari yangi texnologiyalarning dars o‘tish jarayonini soddalashtirishi, ayniqsa murakkab tushunchalarni oddiy va aniq ko‘rsatishda yordami katta ekanligini ta’kidlashgan. Ba’zilar esa bu texnologiyalar yordamida darslar interaktiv va zamonaviy bo‘lishi sababli o‘quvchilarda ijobiy kayfiyat shakllanishini alohida ta’kidladilar [8].

Yuqoridagi natijalar asosida aytish mumkinki, kengaytirilgan reallik va gologrammalar matematika ta’limida o‘quvchining vizual idroki va mantiqiy fikrlash qobiliyatini rivojlantirishda sezilarli ta’sirga ega. Mazkur texnologiyalar orqali o‘quvchilar mavzuni o‘zlashtirishda nafaqat bilim olish, balki uni amaliyotda sinab ko‘rish imkoniyatiga ega bo‘lishadi. Bu esa, o‘z navbatida, ta’lim sifatini oshiradi va o‘quvchilarning mustaqil fikrlashga bo‘lgan ehtiyojini rag‘batlantiradi [2], [9].

Tahlil natijalariga asoslanib, AR va gologramma texnologiyalarining keng miqyosda joriy etilishi ta’lim jarayonini raqamlashtirish bilan birga, uni interaktiv va samarali holga keltirishga xizmat qiladi. Shu sababli, matematika fani bo‘yicha pedagoglar va maktab rahbarlariga bunday texnologik yondashuvlarni sinfga tatbiq etishni tavsiya etish mumkin [10].

XXXVI. MUHOKAMA

Tadqiqot natijalari asosida aniqlangan dalillar kengaytirilgan reallik (AR) va gologramma texnologiyalarining matematika ta’limiga sezilarli darajada ijobiy ta’sir ko‘rsatishini ko‘rsatdi. Bu texnologiyalar orqali ta’lim jarayonining interaktivligi, tushunarliligi va o‘quvchilarni jalb qilish darajasi ortgan. Muhokama bo‘limida ushbu natijalarning chuqur tahlili, ularning boshqa ilmiy manbalar bilan taqqoslanishi va umumiy xulosalar keltiriladi.

Avvalo, o‘quvchilar tomonidan AR va golografik texnologiyalar yordamida o‘rganilgan mavzular an’anaviy usullarga nisbatan tezroq va samaraliroq o‘zlashtirilgani kuzatildi. Bu natijalar boshqa tadqiqotchilar tomonidan olib borilgan ishlarda ham qayd etilgan. Jumladan, A. Karimov va X. Usmonovlarning tadqiqotlarida AR texnologiyalarining fazoviy tasavvur va mantiqiy fikrlashni rivojlantirishdagi roli alohida ko‘rsatib o‘tilgan [1]. Bu texnologiyalar o‘quvchilarning faolligini oshirishda va ularni o‘quv jarayoniga jalb qilishda samarali vosita sifatida e’tirof etiladi [3].

Bizning tadqiqotda olingan so‘rovnoma va test natijalari orqali AR texnologiyalarining darsni tushunishga va eslab qolishga bo‘lgan ta’siri tasdiqlandi. Shu bilan

birga, ko‘plab xorijiy tadqiqotlarda ham, xususan, P. Milgram va F. Kishino tomonidan ishlab chiqilgan “reallik-kengaytma kontinuumi” modelida, o‘quv jarayonida virtual elementlarning mavjudligi o‘quvchining diqqatini jamlash va bilimni chuqurroq egallashiga yordam berishi ko‘rsatilgan [4].

Shuni alohida ta’kidlash kerakki, AR va gologrаfik qurilmalar o‘quvchilarga murakkab matematik formulalarni vizual ko‘rinishda idrok etish imkoniyatini yaratadi. Bu jihat ayniqsa geometriya, statistik grafiklar va algebraik funksiyalarni tushuntirishda muhim o‘rin tutadi. Bunga o‘xshash xulosani S.Akramovning ishida ham uchratish mumkin, u o‘z tadqiqotida AR yordamida o‘quvchilarda o‘rganishga bo‘lgan ichki motivatsiya va qiziqishning oshganini ko‘rsatgan [2].

Biroq, ushbu texnologiyalarni ta’limga joriy etishda ba’zi muammolar mavjud. Jumladan, ayrim maktablarda texnik infratuzilmaning yetarli emasligi, AR qurilmalarining yuqori narxi va o‘qituvchilarning yetarli bilim va ko‘nikmaga ega emasligi, bu texnologiyalarning keng joriy qilinishiga to‘sqinlik qilmoqda [5]. Bu holat boshqa ilmiy manbalarda ham ko‘rsatib o‘tilgan. Jumladan, J. Lee va R. Billinghurst tomonidan olib borilgan tadqiqotlarda texnologik resurslar bilan ta’minot darajasi o‘qitish samaradorligiga bevosita ta’sir ko‘rsatishi ta’kidlangan [6].

Shunga qaramay, tajriba davomida o‘qituvchilarning fikrlari AR texnologiyalarining samaradorligi haqida ijobiy bo‘ldi. Ularning ta’kidlashicha, bu vositalar yordamida darslar yanada jonli, interaktiv va zamonaviy bo‘lib qoladi. Ayniqsa, o‘quvchilarning mustaqil ishlash ko‘nikmasini rivojlantirish va jamoaviy ishlarga jalb qilishda AR texnologiyalarining ahamiyati katta [7].

o‘quvchilarga katta yordam beradi, tushunishni osonlashtiradi va vizual idrokni kuchaytiradi [1], [3].
AR va gologrаfik vositalar orqali taqdim etilgan ta’limiy kontent o‘quvchilarda yuqori darajadagi motivatsiyani shakllantiradi, ularni faol ishtirok etishga undaydi. Tajriba natijalarida bu holat test va so‘rovnomalar orqali aniqlandi. Natijalar shuni tasdiqladiki, ushbu texnologiyalar an’anaviy o‘qitish usullariga nisbatan ko‘proq e’tibor va yodda saqlash samaradorligini ta’minlaydi [4], [6].
Shuningdek, o‘qituvchilar tomonidan ham bu texnologiyalarga bo‘lgan munosabat ijobiy bo‘lib, ular ushbu vositalarning ta’lim sifatini oshirishdagi imkoniyatlarini yuqori baholadilar. Bu holat kelajakda AR texnologiyalarini ta’lim tizimiga keng miqyosda joriy etish uchun asos bo‘la oladi. Biroq, texnologiyalarni to‘liq joriy etishda texnik vositalarning yetishmasligi, o‘qituvchilarning malaka yetishmovchiligi kabi bir qancha muammolar ham mavjud [5], [8].
Yuqoridagilardan kelib chiqib, quyidagi xulosalarga kelindi:

- Kengaytirilgan reallik va gologramma texnologiyalari matematika ta’limida samaradorlikni oshiradi va zamonaviy o‘quv yondashuvlarini rivojlantiradi;
- Bu texnologiyalar o‘quvchilarning diqqatini jalb qilish, mantiqiy fikrlashni rivojlantirish va mustaqil o‘rganish ko‘nikmalarini shakllantirishda muhim o‘rin egallaydi [2], [7];
- AR vositalaridan foydalanishda texnik va pedagogik infratuzilmani kuchaytirish, xususan, o‘qituvchilar uchun malaka oshirish dasturlarini ishlab chiqish zarur [8], [9];
- Davlat miqyosida raqamli ta’lim strategiyalariga ushbu texnologiyalarni kiritish, ayniqsa chekka hududlardagi maktablarni texnik jihozlash orqali teng imkoniyatlar yaratish muhim [10].

Muhokama davomida yana bir muhim jihat aniqlanganki, AR texnologiyalarini o‘qituvchilar orasida ommalashtirish uchun malaka oshirish kurslari, seminar-treninglar o‘tkazish lozim. Bu masalaga E. Bekmurodov o‘z maqolasida to‘xtalib, texnologiyalarni joriy etishda inson resurslarini tayyorlash va texnik qo‘llab-quvvatlash muhimligini alohida urg‘ulagan [8].

Shuningdek, bu texnologiyalar faqatgina shahar maktablarida emas, balki qishloq hududlaridagi ta’lim muassasalarida ham joriy qilinishi kerak. Bunda davlat dasturlari, xususan, raqamli ta’lim konsepsiyasi doirasida infratuzilmani yangilash va texnik vositalar bilan ta’minlash zarur [9].

Umuman olganda, o‘tkazilgan tadqiqot kengaytirilgan reallik va gologramma texnologiyalarining matematika ta’limiga samarali integratsiya qilinishi mumkinligini ko‘rsatdi. Bu texnologiyalar zamonaviy ta’limning muhim tarkibiy qismlaridan biri sifatida qaralishi va kelajakda barcha bosqichlardagi ta’lim muassasalarida keng tatbiq etilishi lozim. Ularning o‘quvchilarni motivatsiyalash, chuqur bilim berish, ijodkorlik va tanqidiy fikrlashni shakllantirishdagi o‘rni beqiyosdir [10].

XXXVII. Xulosa

Ushbu ilmiy maqolada matematika fanini o‘qitishda kengaytirilgan reallik (AR) va gologramma texnologiyalaridan foydalanish imkoniyatlari va natijalari chuqur o‘rganildi. O‘tkazilgan tajriba va tahlillar shuni ko‘rsatdiki, mazkur texnologiyalar o‘quv jarayonini interaktiv, qiziqarli va samarali qilish imkonini beradi. Ular ayniqsa murakkab mavzularni o‘zlashtirishda

Xulosa qilib aytganda, kengaytirilgan reallik va gologramma texnologiyalari zamonaviy ta’limda yangi bosqichni boshlab berdi. Ular nafaqat matematika, balki boshqa fanlar bo‘yicha ham ta’lim sifatini tubdan oshirishga xizmat qilishi mumkin. Ushbu texnologiyalarning samarali joriy etilishi uchun davlat, ta’lim muassasalari va mutaxassislar hamkorligida aniq strategik dasturlar ishlab chiqilishi lozim.

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TA’LIM TIZIMIDA RAQAMLI TRANSFORMATSIYA: TENDENSIYALAR, MUAMMOLAR VA ISTIQBOLLAR
DIGITAL TRANSFORMATION IN THE EDUCATION SYSTEM: TRENDS, CHALLENGES AND PROSPECTS
ЦИФРОВАЯ ТРАНСФОРМАЦИЯ В СИСТЕМЕ ОБРАЗОВАНИЯ: ТЕНДЕНЦИИ, ВЫЗОВЫ И ПЕРСПЕКТИВЫ

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Annotatsiya — Ushbu maqola zamonaviy ta’lim jarayoniga raqamli texnologiyalarni integratsiyalashning dolzarbligini o‘rganishga bag‘ishlangan. Tadqiqotning asosiy maqsadi ta’lim sohasidagi raqamli innovatsiyalarning samaradorligini, ularning yutuqlari va duch kelgan muammolarini tahlil qilish, shuningdek, ularni yanada rivojlantirish bo‘yicha takliflar ishlab chiqishdan iborat. So‘nggi besh yil ichida nashr etilgan xalqaro miqyosdagi ilmiy adabiyotlar tahlil qilingan. Tadqiqot natijalari shuni ko‘rsatadiki, raqamli innovatsiyalar ta’limning sifatini oshirish, individual yondashuvni amalga oshirish va hayotiy ko‘nikmalarni shakllantirishda katta potentsialga ega. Ayniqsa, R-funksiya yordamida murakkab shakldagi obyektlarni geometrik modellashtirish texnologiyalari ta’limda yangi imkoniyatlarni yaratmoqda. Biroq, bu jarayon texnik infratuzilma yetishmovchiligi, pedagoglarning raqamli kompetentligining pastligi va didaktik jihatdan asoslangan kontentning yetishmasligi kabi to‘siqlar bilan hamroh bo‘lmoqda. Maqolada ushbu muammolarni bartaraf etish va ta’lim tizimida raqamli transformatsiyani muvaffaqiyatli amalga oshirish uchun bir qator amaliy tavsiyalar ishlab chiqilgan. Xulosa qilib aytganda, ta’limda raqamli o‘zgarish nafaqat texnologiyalarni joriy etish, balki butunlay yangi pedagogik paradigma va barqaror rivojlanish strategiyasini talab qiladi.

Kalit so‘zlar — raqamli ta’lim, ta’lim innovatsiyalari, raqamli kompetentlik, geometrik modellashtirish, R-funksiya, ta’lim texnologiyalari, aralash ta’lim.

A. *I. Kirish*

Zamonaviy jamiyatni “raqamli sivilizatsiya” deb ataladigan bo‘lsa, bu hech qanday mubolag‘a bo‘lmaydi. Ilg‘or raqamli texnologiyalarning hayotning barcha sohalariga, xususan, ta’lim tizimiga chuqur kirib borayotgani dunyoda qaror topgan tendentsiyadir [1]. Ta’limda raqamli innovatsiyalarning dolzarbligi pandemiya davrida yanada yaqqol namoyon bo‘ldi, bu voqea an’anaviy ta’lim usullarining cheklovchanligini ko‘rsatib, global ta’lim tizimini favqulodda raqamlashtirishga majbur qildi [2].

Ushbu mavzuning ilmiy ahamiyati shundaki, u nafaqat texnologik jihatlarni, balki pedagogik, psixologik, ijtimoiy va iqtisodiy omillarni qamrab olgan kompleks hodisadir. So‘nggi besh yil ichida o‘tkazilgan tadqiqotlar sun’iy intellekt (AI), katta ma’lumotlar (big data), virtual reallik (VR) va bulutli texnologiyalarning ta’limga ta’sirini o‘rganishga qaratilgan [3], [4]. Ayniqsa, R-funksiya asosida murakkab geometrik shakllarni modellashtirish texnologiyalari ta’lim sohasida yangi metodologik yondashuvlarni taklif etmoqda [21]. Adabiyotlar sharhi shuni ko‘rsatadiki, ko‘pchilik tadqiqotchilar raqamli vositalarning o‘quv motivatsiyasi va bilimlarni o‘zlashtirish darajasini oshirishdagi ijobiy ta’sirini qayd etishadi [5]. Biroq, innovatsiyalarning samarali integratsiyasi uchun ularning faqat ijobiy tomonlari emas, balki duch kelinadigan muammolar ham chuqur tahlil qilinishi kerak.

Ushbu maqolaning maqsadi – so‘nggi yillardagi ilmiy ishlanmalar asosida ta’lim tizimida raqamli innovatsiyalarning integratsiyasi jarayonini tahlil qilish, uning imkoniyatlari va to‘siqlarini aniqlash, shuningdek,

ularni yengish bo‘yicha amaliy tavsiyalar ishlab chiqishdan iborat.

B. II. Muammoning qo‘yilishi

Ta’lim tizimiga raqamli innovatsiyalarni joriy etish jarayoni bir qator jiddiy muammolarni keltirib chiqarmoqda. Asosiy muammo shundaki, texnologik rivojlanish sur’ati va pedagogik jarayonlarning unga moslashish sur’ati o‘rtasida keskin nomuvozanatlik mavjud [6]. Bu nomuvozanatlik quyidagi jihatlarda namoyon bo‘ladi:

1. **Pedagogik muammo:** Ba’zi o‘qituvchilar an’anaviy “tayanch-taxta” usullarga o‘rganib qolgan bo‘lib, ular yangi raqamli vositalardan foydalanishda va ularni o‘quv dasturiga organik ravishda integratsiya qilishda qiyinchiliklarga duch kelmoqda [7].
2. **Texnik muammo:** Maktab va oliygohlarning aksariyati, ayniqsa qishloq joylarda, tezkor internet, zamonaviy kompyuterlar va maxsus dasturiy ta’minot bilan ta’minlanmagan [8].
3. **Didaktik va metodik muammo:** Raqamli resurslarning ko‘pligi ularning sifati va pedagogik asoslanganligi haqidagi savolni keltirib chiqaradi. Ko‘p hollarda, onlayn platformalar va elektron resurslar an’anaviy darsliklarning oddiy raqamli nusxasidan iborat bo‘lib, interfaollik va individual yondashuv imkoniyatlaridan to‘liq foydalanilmaydi [9].
4. **Psixologik va ijtimoiy muammo:** Raqamli bo‘linish (digital divide) tufayli ijtimoiy-tabaqaviy farqlar kuchayishi, shuningdek, o‘quvchilarning ko‘z salomatligi va psixologik salomatligiga salbiy ta’sir ko‘rsatishi mumkin [10].

Shu sababli, ushbu muammolarni tizimli yondashuv bilan o‘rganish va ularning yechimlarini ishlab chiqish dolzarbligini kasb etadi.

C. III. Tadqiqot usullari va nazariy asoslar

Ushbu tadqiqotning nazariy asosini konstruktivizm, kognitivizm va konektivizm kabi zamonaviy ta’lim nazariyalari tashkil etadi, ular bilimning faol qurilishi, axborotni qayta ishlash va tarmoqlar orqali o‘rganish tamoyillarini ta’kidlaydi [11].

Tadqiqotda **tizimli tahlil usuli** qo‘llanilib, ta’lim tizimi raqamli innovatsiyalar kontekstida butunlikda, uning tarkibiy qismlari (pedagog, o‘quvchi, mazmun, texnologiya) o‘zaro bog‘liq holda o‘rganilgan. Shuningdek, **qiyosiy tahlil usuli** yordamida turli mamlakatlarning (AQSh, Singapur, Estoniya, Janubiy Koreya) tajribalari va ularning O‘zbekiston tizimidagi qo‘llash imkoniyatlari o‘rganildi. **R-funksiya usuli** yordamida murakkab geometrik shakllarning matematik modellari ishlab chiqilishi va ularning ta’lim jarayonida qo‘llanilishi imkoniyatlari o‘rganildi [21]. Ma’lumotlarni yig‘ish uchun **adabiyotlarni tahlish usuli** qo‘llanilib, 2019-2024 yillarda nashr etilgan, Scopus, Web of Science kabi nufuzli ma’lumotlar bazalariga indekslanuvchi 21 ta ilmiy maqola, monografiya va hisobotlar tahlil qilindi.

D. IV. Natijalar va muhokama

Tadqiqot natijalari ta’limda raqamli innovatsiyalarning bir qator aniq afzalliklarini ko‘rsatdi:

- **Ta’limning demokratizatsiyasi va individualizatsiyasi:** Raqamli platformalar (masalan, Moodle, Coursera, Khan Academy) har qanday joyda va istalgan vaqtda bilim olish imkoniyatini yaratadi, bu esa o‘quvchilarning shaxsiy ehtiyoj va imkoniyatlariga moslashishga imkon beradi [12].
- **O‘quv jarayonining interfaolligi va vizuallashuvi:** VR va AR (kengaytirilgan reallik) texnologiyalari tarixiy voqealarni, murakkab biologik jarayonlarni yoki fizik qonunlarni simulyatsiya qilish orqali chuqurroq tushunishga yordam beradi [13].
- **Geometrik modellashtirishning yangi imkoniyatlari:** R-funksiya usuli yordamida murakkab shakldagi obyektlarni aniq va samarali modellashtirish imkoniyati paydo bo‘ldi. Bu esa muhandislik, arxitektura va dizayn ta’limida yangi metodik yondashuvlarni joriy etish imkonini beradi [21].
- **Samaradorlikni baholash:** Sun’iy intellekt asosidagi tizimlar o‘quvchilarning bilim darajasini aniq baholash, ularning zaif tomonlarini aniqlash va shaxsiy tavsiyalar berish imkoniyatini yaratadi [14].

Biroq, natijalar duch kelinadigan to‘siqlarni ham aniq ko‘rsatdi:

1. **Ishonchlilik:** O‘rganilgan adabiyotlarning aksariyati empirik tadqiqotlarga asoslangan bo‘lib, ularning natijalari statistik jihatdan ishonchlidir. Biroq, ayrim hollarda (masalan, VR ning uzoq muddatli ta’siri) tadqiqotlar yetarli darajada o‘tkazilmagan.
2. **Amaliy ahamiyati:** Topilgan muammolar bevosita amaliy yechimlarni talab qiladi. Masalan, [15] tadqiqotida ta’kidlanishicha, faqatgina texnik jihozlarni ta’minlash yetarli emas. Asosiy e’tibor o‘qituvchilarning **raqamli pedagogik kompetentligini** oshirishga qaratilishi kerak.

E. V. Taklif va tavsiyalar

Yuqoridagi tahlil asosida quyidagi tavsiyalarni ishlab chiqish mumkin:

- **O‘qituvchilarni qayta tayyorlash:** O‘qituvchilar malakasini oshirish kurslarini nafaqat dasturlarni o‘rgatish, balki raqamli pedagogikani chuqur o‘zlashtirishga qaratish kerak [16].
- **Didaktik jihatdan asoslangan kontent yaratish:** Raqamli o‘quv materiallari faqat skanerlangan matnlar emas, balki interfaol vazifalar, simulyatsiyalar va o‘yinlashtirilgan elementlardan iborat bo‘lishi lozim [17].
- **Aralash ta’lim (blended learning) modellarini joriy etish:** An’anaviy va raqamli ta’lim usullarining uyg‘unlashgan modeli eng samarali yo‘l hisoblanadi [18].

- **Geometrik modellashtirish texnologiyalaridan foydalanish:** R-funksiya asosidagi modellashtirish usullarini matematika, fizika va muhandislik fanlaridan dars berishda qo‘llash [21].
- **Milliy raqamli ta’lim platformasini yaratish:** Barcha kerakli resurslar, dasturlar va baholash tizimini o‘z ichiga olgan, til va madaniyatga moslashtirilgan yagona platforma ishlab chiqilishi va takomillashtirish zarur [19].

F. VI. Xulosa

Xulosa qilib aytganda, ta’lim tizimiga raqamli innovatsiyalarni integratsiya qilish – bu murakkab, ko‘p qirrali va uzluksiz jarayon bo‘lib, u faqat texnologiyalarni sotib olish bilan chegaralanmaydi. Bu, birinchi navbatda, ta’lim mazmuni, metodlari va butun madaniyatini tubdan o‘zgartirishni nazarda tutadi. Tadqiqot shuni ko‘rsatdiki, raqamli transformatsiyaning muvaffaqiyati to‘g‘ri pedagogik strategiya, malakali kadrlar tayyorlash, barqaror infratuzilma va didaktik jihatdan mukammal raqamli kontentning uyg‘unligiga bog‘liq.

R-funksiya asosida murakkab geometrik shakllarni modellashtirish kabi yangi texnologik yondashuvlar ta’lim jarayonini yanada samarali va qiziqarli qilish imkoniyatlarini yaratmoqda. Istiqbolda tadqiqotlarni sun’iy intellektning ta’limdagi o‘rni, ma’lumotlar xavfsizligi masalalari, geometrik modellashtirishning yangi usullari va raqamli innovatsiyalarning uzoq muddatli psixologik ta’sirini o‘rganishga chuqurlashtirish maqsadga muvofiqdir. Ta’lim sohasidagi barcha ishtirokchilar – siyosatchlar, ma’murlar, o‘qituvchlar, ota-onalar va o‘quvchilar – o‘zaro hamkorlikda ishlashlari holdagina raqamli sivilizatsiya sharoitida yangi avlodni tayyorlashga muvaffaq bo‘lishlari mumkin.

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DEVELOPMENT OF LABORATORY PRACTICALS ON RADIO ENGINEERING BASED ON COMPUTER MODELLING

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Abstract*— The features of the signal processing laboratory practical works created on the basis of computer modeling are considered. The brief review of existing approaches is given. The importance of the stage of the development environment choice is specified. The advantages of graphic programming environment LabVIEW are described. The software structure of a laboratory work on processing signals is offered.

Keywords: electronic educational resources, laboratory practical works, signal processing, computer modeling, development of software, graphic programming environment LabVIEW

XXXVIII. Introduction

Recently, there has been widespread introduction of the latest achievements in information technology into the educational process and the creation of various electronic educational resources (EER), the need for which has become apparent not only in distance learning, but also in traditional face-to-face education. A number of universities are working on the development of EER, installing computer equipment, network equipment and unique laboratory facilities, and creating special software (SW).

Meanwhile, another direction is developing that does not require significant investment. This includes simple EORs such as interactive lecture courses and laboratory workshops based on computer modelling of research objects, phenomena and processes. The use of modelling here is not only an excellent explanatory and illustrative material, but is often sufficient to achieve the goals set within the framework of the course being studied. Such a laboratory workshop based on computer modelling can physically be a regular book with a compact disc or an electronic book with links to modelling programs. Both options are accessible, easy to reproduce and distribute.

This article analyses approaches to creating EERs of this class. Important issues here include the choice of software development tools, which significantly affect the quality of the result. The next stage is to develop the structure of the software for laboratory work and practical training as a whole, which should be created taking into account the specifics of the course being studied, its main and additional goals and objectives. In some cases, acceptable solutions can only be found by using several programming technologies.

Based on certain approaches, EER complexes can be created for a specific specialization in a particular field of study.

XXXIX. Overview of Signal Processing Courses

Many courses for various technical specialties involve studying methods and algorithms for analogue and digital signal processing. In most of these disciplines, studying signal processing methods and algorithms is the main goal of the course. In other cases, signal processing algorithms may become the basis for studying certain information technologies and writing computer programs. In such cases, signal processing may become an additional goal of the course.

In almost all of these cases, the learning process involves laboratory workshops. Their specific features depend directly on their focus, goals, and objectives of the relevant disciplines. To summarize, training courses on signal processing can be divided into the following groups.

1. Theoretical courses. An example is a course entitled ‘Digital Signal Processing’.

2. Courses related to the development of software for signal processing tasks. This group also includes the development of software for microprocessor and microcontroller devices and systems involved in digital signal processing.

3. Courses devoted to the theoretical aspects of the construction of signal processing and automatic control devices and systems.

4. Courses devoted to the practical use of signal processing and control devices and systems.

It is safe to say that in all cases, laboratory work plays an important role in the learning process, allowing students to better understand the theory and acquire the necessary practical skills. Thanks to the application of new information technologies, computer-based laboratory workshops based on the simulation of input signals and their processing have been developed and implemented. Such workshops do not require any special hardware, only a personal computer and special software.

The initial stage of EER design must include defining the focus of the relevant course and the main and additional goals and objectives set therein. The developer must then decide which of the available software development environments is best suited for the case in question.

1. Software development environments

There is a wide range of software development environments available for creating computer workshops:

- mathematical data processing environments;

- general-purpose programming environments;

- graphical programming environments;

- graphical system modelling environments.

The most widely used mathematical environments are MATLAB from MathWorks, Inc., MathCAD from Mathsoft Engineering & Education, Inc., and Maple from Waterloo Maple, Inc. General-purpose programming environments are primarily represented by products from Microsoft and Borland based on the use of the algorithmic languages C++ and Pascal – Visual C++, C++ Builder, Delphi, etc. Among graphical modelling environments, SIMULINK from MathWorks, Inc. is the leader, and among graphical programming and modelling environments, LabVIEW from National Instruments is the leader.

Software for a laboratory workshop on signal processing can be created based on virtually any of the listed software products. However, the effectiveness of this implementation will vary in each specific case. Therefore, it is important to identify objective and subjective criteria for selecting a development environment for a laboratory workshop, some of which are discussed below.

2. Features of model development using mathematical data processing environments

The development of software for signal processing workshops based on a particular mathematical data processing environment is characteristic of courses with a theoretical focus. Here, the study of mathematical methods and algorithms comes to the fore. The tasks of modelling input signals and displaying measurement results are fairly straightforward. The processing itself is supported by libraries of numerous data processing functions.

These advantages have been noted by many authors, leading to the creation of computerized courses and workshops on signal processing. Among them, we would like to highlight the well-known books [1, 2] and the electronic textbook [3], created entirely in the MathCAD environment.

When comparing mathematical environments as tools for developing practical exercises of the class under consideration, the first question to answer is how convenient and effective the use of computer models will be. Will learning the basics of working in a particular mathematical environment take too much time, which could interfere with the assimilation of the main material?

Let us compare the implementation of a simple example of low-pass Butterworth filter synthesis and the determination of amplitude-frequency (AFC), phase-frequency (PFC) and impulse characteristics in MATLAB and MathCAD environments.

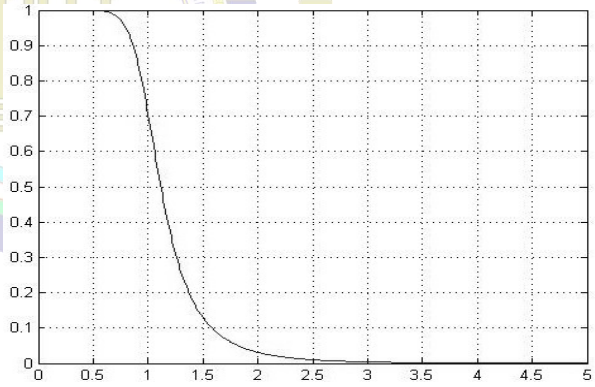
Working in MATLAB is based on the use of a special language that differs significantly from natural mathematical language and the invocation of necessary functions, the composition of which must be known and understood. For our example, the text of the program that builds the AFC and FCH of a fifth-order filter will be as follows:

```
[z,p,k]=buttap(5); w=0:0.01:5;
[b,a]=zp2tf(z,p,k)
h=freqs(b,a,w); figure plot(w,abs(h)),grid figure
plot(w,unwrap(angle(h))),grid.
```

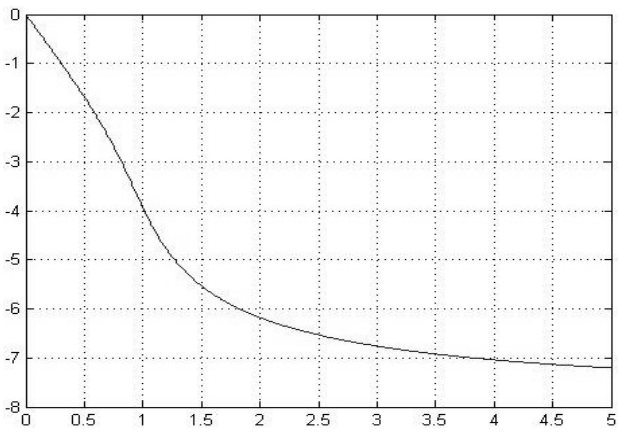
A special MATLAB function, impz(b,a,Wn), is also used to construct the impulse response.

The program text shows that in order to achieve the results (Fig. 1). Students need to know the programming language and functions designed for synthesising Butterworth filters. At the same time, the mathematical operations involved in data processing are hidden from the user and are not displayed, which can have a negative impact on the learning process.

Unlike MATLAB, when implementing the well-known example in MathCAD, instead of ready-made functions, you can use a language that is very close to natural mathematical language.



a



b

Fig. 1. Amplitude-frequency (a) and phase-frequency (b) characteristics of a fifth-order low-pass Butterworth filter obtained in MATLAB.

Fig. 2 shows the Butterworth filter frequency response formula of order n, which is practically unchanged.

$$A(f) = \frac{1}{\sqrt{1 + a^2 x^{2n}}}$$

and the formula for the discretized real part of the filter impulse response [2, p. 187].

$$H_k = 4 \int_0^{30} D(f) \cos(2\pi f T)\, dt$$

This model is easier to read and understand in the learning process, has advantages, and in some cases becomes more preferable.

However, other criteria in choosing a development environment may lead to a preference for MATLAB. Here are two possible reasons:

- one of the goals of the course is to learn and acquire skills in working with MATLAB;

- educational institutions where the workshop is to be implemented have a licence to use MATLAB.

These reasons may influence the final choice of EER development environments discussed in the following sections.

It should also be mentioned that an important disadvantage of workshops implemented in mathematical environments is the need for the user to install the environment itself, without which simulation is impossible.

If the focus of the signal processing course is applied, involving the modelling of devices and systems as signal processing tools or teaching the programming process as the main objective, then other programming environments are preferable.

When creating programs designed to solve digital processing tasks during the learning process without using ready-made functions, it is possible to achieve a deep level of understanding of the computational processes involved. Students learn about numerical methods for implementing mathematical operations such as integration, differentiation, etc., and acquire the necessary knowledge to build data processing and control devices and systems.

There are courses that teach the basics of signal processing using computer programs written in well-known algorithmic languages [4]. General-purpose programming environments are used to work with these programs. Their significant disadvantage is the difficulty in forming (using only basic tools) a user interface, including one designed for graphical data display. A good solution is to use additional tools, such as class libraries or software components. The Measurement Studio libraries from National Instruments [5] are an excellent tool that significantly expands the capabilities of the MS Visual C++ and Borland C++ Builder visual environments.

$\Delta f := 10 \quad a := 1 \quad n := 5 \quad f_p := 10 \quad f_a := 40$

$j := \sqrt{-1} \qquad x(f) := \frac{f}{\Delta f} \qquad k := 0 \ldots 100$

$$A(f) = \frac{1}{\sqrt{1 + a^2 \cdot x(f)^{2n}}}$$

$$D(f) = A(f) \cdot \cos(\odot(f)) \qquad t_k := 0.005 \cdot k$$

$$H_k := 4 \int_0^{30} D(f) \cdot \cos(2 \cdot \pi \cdot f \cdot t_k)\, dt$$

$$\odot(f) := \begin{cases} -\pi \cdot \frac{f}{f_p} & \text{if } 0 \le f \le f_p \\ \pi \cdot \frac{(f_a - f)}{(f_a - f_p)} & \text{if } f > f_p \end{cases}$$

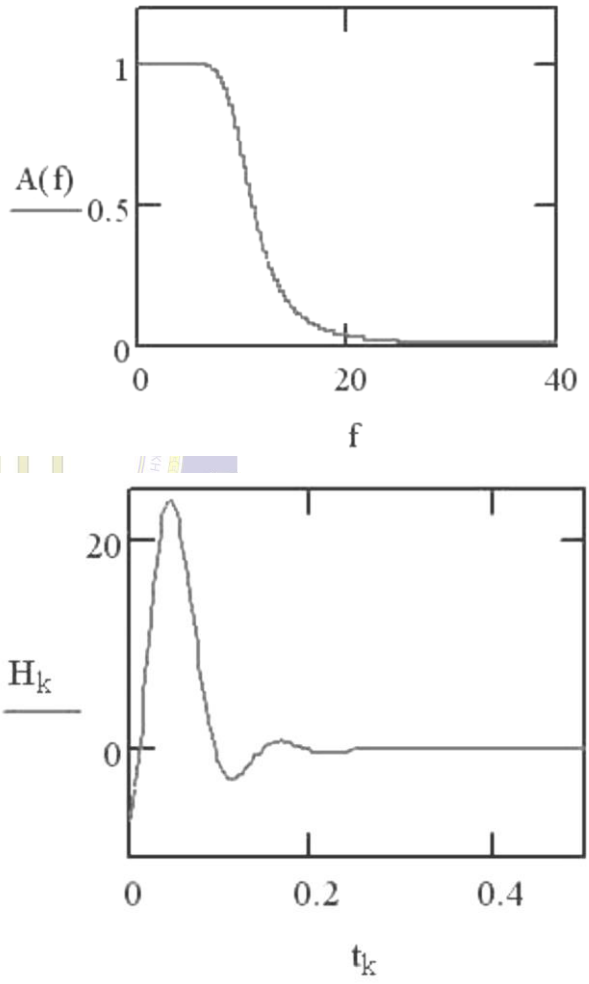
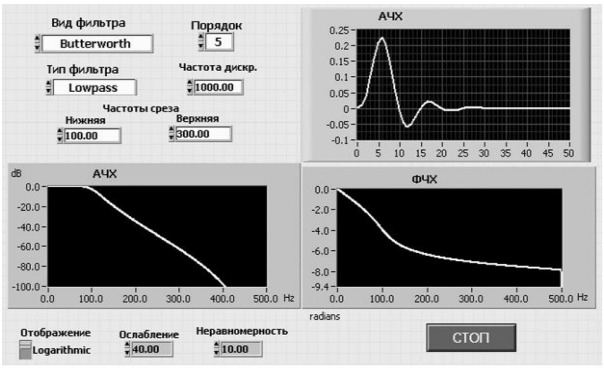


Fig. 2. Simulation of a fifth-order Butterworth filter in MathCAD

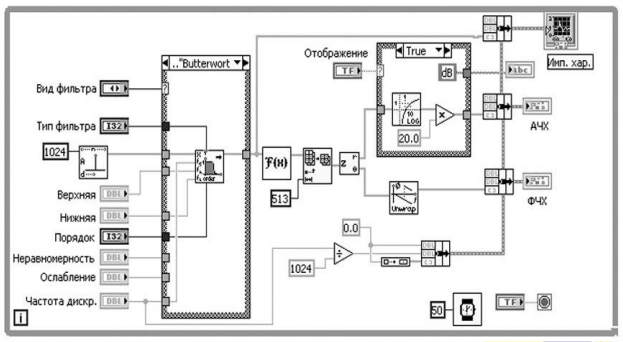
The low labour intensity of programming in graphical environments allows the desired results to be obtained during a single laboratory session, but at the same time, the software implementation of signal processing functions remains unexplored.

The example, the simulation of which in mathematical environments was discussed above, is implemented in

LabVIEW in the form of a front panel and a block diagram (Fig. 3).



a



b

Fig. 3. Simulation of a fifth-order Butterworth filter in LabVIEW (a) front panel; (b) block diagram

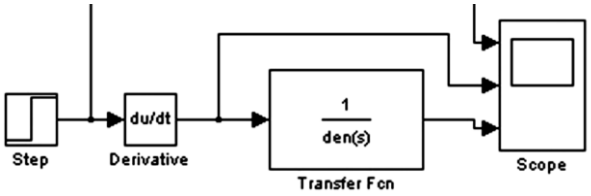
As can be seen from the figure, creating LabVIEW signal processing models is not a simple task; it requires knowledge of the basics of programming and pays off if you need to learn the basics of programming in this environment. As an additional example, we can consider the digital signal processing tutorial [6]. It is intended for students who are familiar with LabVIEW, or can be used when signal processing and programming training occur simultaneously.

When the main goal of the discipline is to model complex systems, other development environments should be used during development. However, the Control Design&Simulation Module, which has recently appeared (starting with version 8.0) as part of LabVIEW, Simulation Module allows you to successfully perform such programming and study signal processing and control systems at the level of their functional diagrams no worse than in special graphical system modeling environments.

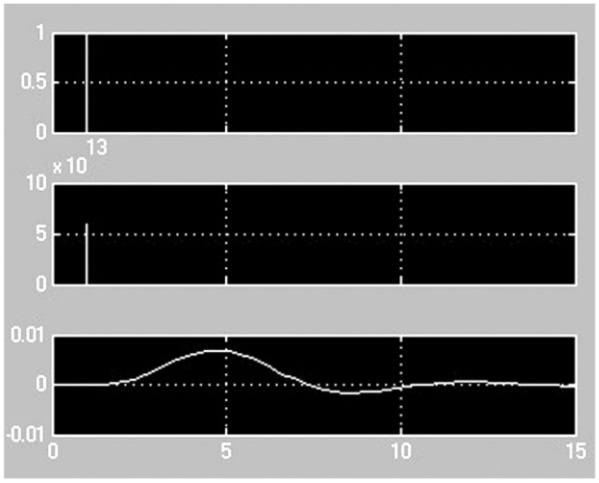
XL. Features of Model Development Using Graphical System Modelling Environments

The SIMULINK graphical modelling system, part of the MATLAB mathematical package, has rightly gained widespread popularity. Users without in-depth programming knowledge can create and explore models of complex systems. To do this, they simply select the necessary functional blocks from problem-oriented libraries, connect them to form a circuit, and display the signals of interest on the display elements.

To simulate a well-known example of a device (Fig. 4), from creating the model to analyzing the simulation results, which are displayed in graphical form, it takes only a few minutes of training time.



a



b

Fig. 4. Model of a low-frequency Butterworth filter system in the SIMULINK environment (a) block diagram (b) simulation results

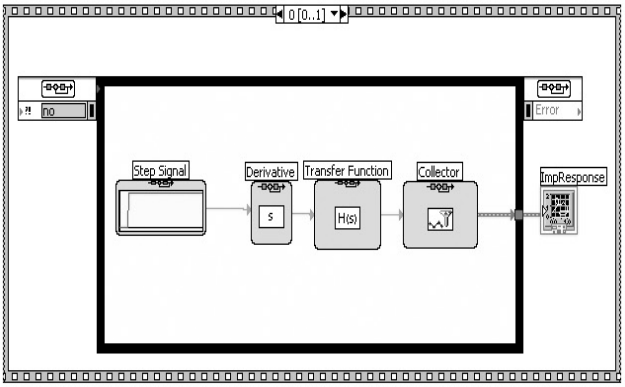
The addition of the Control Design & Simulation Module to LabVIEW has made it possible to use this powerful system in the mode of creating graphical models. Graphical modeling of devices and systems in LabVIEW and SIMULINK has become very similar in this respect (compare Fig. 4a and Fig. 5a), but LabVIEW provides developers with more advanced user interface tools, programming tools, tools for creating executable applications, etc., which are simply not available in MATLAB-SIMULINK environments. As a result, it became possible to create a wide variety of LabVIEW-EORs in the form of separate software products that do not require a development environment to use and are easy to replicate and distribute.

The LabVIEW graphical programming environment is convenient for creating models of complex devices and signal processing systems in the form of a “black box,” on the basis of which it is possible to conduct research to determine their characteristics, study the features of their functioning, and understand the tasks solved by the system.

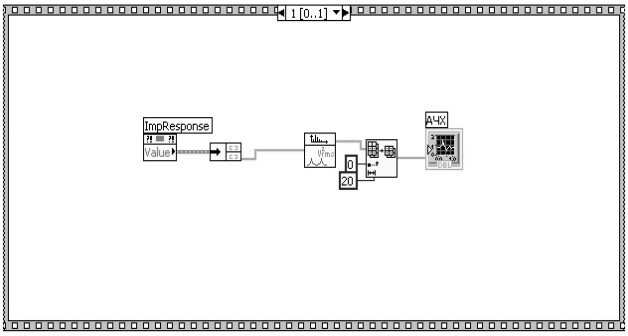
Such a model is a kind of training simulator that provides the ability to quickly change input signals, change settings and operating modes (model parameters), and study signals at the input (model parameters) and study signals at

the output (simulation results). Input influences and conditions for simulation can be taken from files generated in advance. All signals, settings, parameters, etc. can be displayed on a variety of screens and indicators in graphical and digital forms.

Since this LabVIEW model is a ready-made program, students only have access to the front panel. This model is highly visual and allows students to understand the basics and essence of the signal processing system and its purpose as a whole without getting distracted by details, to understand the peculiarities of its functioning in various operating modes, and to understand its behavior under various input influences and when they change.



a



b

Fig. 5. LabVIEW block diagram (a) sequential structure frame containing Control Design & Simulation Module functions (b) sequential structure frame containing basic LabVIEW functions

As an example of a LabVIEW model, Fig. 6 shows the front panel of a model designed to study the functioning of a matched filtering system when solving signal recognition problems.

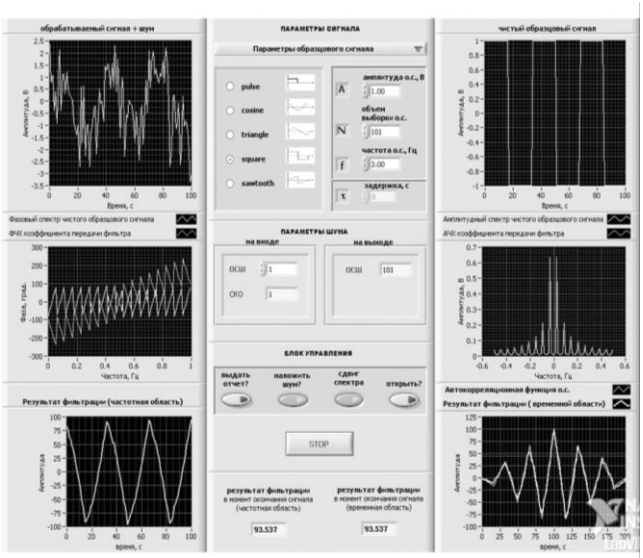


Fig. 6. LabVIEW model of a matched filtering system

The signals to be processed are selected and read from files prepared in advance. Their form and spectrum, found using fast Fourier transform, are immediately displayed on the corresponding graphic screens. Then, after selecting a reference signal, the impulse response and frequency response of the matched filter are constructed and displayed. By performing convolution (in the time domain), spectrum multiplication (in the frequency domain), and other known operations in the model, the output signals and signal-to-noise ratios at the input and output are found and displayed. After going through all the available reference signals, the information obtained can be used to recognize which of the samples corresponds to the input signal.

XLI. CONCLUSION

Computer-based EER, and in particular laboratory workshops, are widespread and useful teaching tools that offer significant advantages. The effectiveness of such workshops in the field of signal processing is highest, which makes their development particularly relevant.

A mandatory stage in the development of simulation-based workshops is the selection of the development environment and the tools used in it. When making this selection, it is necessary to take into account the focus and specifics of the discipline, as well as the main and additional goals and objectives of the training. In most cases, the best option for presenting laboratory work is the format of executable applications for the Windows operating system, when no programming environment is required to use the workshop and relative simplicity of replication and distribution is ensured. The use of the LabVIEW graphical programming environment from National Instruments allows the development of a variety of practical exercises that have significant advantages. However, when the main goal is to study the basics of signal processing theory, mathematical data processing environments are more preferable.

Therefore, good results, contributing to a comprehensive study of signal processing methods and the

acquisition of the necessary practical skills, can be achieved by the joint use of several development environments [7].

As mentioned, the theoretical part of the laboratory work is best done in a mathematical environment (e.g., MathCAD), while the practical part is best done by studying a ready-made model developed in the LabVIEW environment, which features a rich user interface and multifunctionality.

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***Abstract*— Bu ishda raqamli texnologiyalarni fizika ta’limiga integratsiya qilib o‘quv jarayonini zamonaviylashtirish, talabalarning ilmiy dunyoqarashini kengaytirish va ularni XXI asr kompetensiyalariga ega shaxs sifatida shakllantirish masalalari ko‘rilgan. Kelajakda raqamli ta’lim vositalarini chuqur o‘zlashtirgan pedagog va talabalarlar jamiyatning ilg‘or kuchiga aylanishi imkoniyatlari tahlil qilingan.**

Keywords*— *raqamli texnologiya, integratsiya, virtual laboratoriyalar

XLII. INTRODUCTION (*HEADING 1*)

Kirish.

XXI asrda axborot-kommunikatsiya texnologiyalarining jadal rivojlanishi ta’lim tizimida tub o‘zgarishlarni yuzaga keltirdi. Bugungi kunda raqamli texnologiyalarni o‘quv jarayoniga integratsiya qilish zamonaviy ta’limning ajralmas qismiga aylanmoqda. An’anaviy ta’lim usullari bilan zamonaviy raqamli vositalarning uyg‘unligi fizika fanining samaradorligini oshirishda muhim ahamiyat kasb etmoqda.

O‘zbekiston Respublikasi Prezidentining 2019-yil, 8-oktyabrdagi “O‘zbekiston Respublikasi oliy ta’lim tizimini 2030-yilgacha rivojlantirish konsepsiyasini tasdiqlash to‘g‘risida” gi PF-5847-son Farmonining 3-bob, 2-bandida ta’lim jarayoniga raqamli texnologiyalar va zamonaviy usullarni joriy etish haqida so‘z yuritilgan. Unga ko‘ra ta’lim jarayonlarini raqamli texnologiyalar asosida individuallashtirish, masofaviy ta’lim xizmatlarini rivojlantirish, vebinar, onlayn, “blended learning”, “flipped classroom” texnologiyalarini amaliyotga keng joriy etish, ma’ruza va amaliy mashg‘ulotlar, seminarlarni onlayn kuzatish va o‘zlashtirish imkonini beruvchi, shuningdek ularni elektron axborot saqlovchilarga yuklovchi “E-MINBAR” platformasini amaliyotga joriy etish, ta’lim jarayonlarida “bulutli texnologiyalar”dan foydalanish kabi vazifasi belgilangan.

O‘zbekiston Respublikasi Prezidentining 2021-yil 19-martdagi “Fizika sohasidagi ta’lim sifatini oshirish va ilmiy tadqiqotlarni rivojlantirish chora-tadbirlari to‘g‘risida” PQ-5032-son qarorining 29-bandida fizika fanlarini raqamli texnologiyalar asosida yoshlar o‘rtasida ommalashtirish masalasi qo‘yilgan.

Raqamlashtirishni bir-biri va jamiyat bilan aloqa va o‘zaro ta'sir paradigmasining o‘zgarishi sifatida A. Marey ko‘rib chiqdi. Shunday qilib, raqamlashtirishni nafaqat ta’lim, balki iqtisodiyotni ham o‘zgartirishda raqamli resurslardan foydalanishning asosiy yondashuvlaridan biri deb hisoblash mumkin. Shu bilan birga, axborot va ta'lim muhitini yaxshilash maqsadida texnologiyalar va jarayonlarning roli qayta taqsimlanadi, deb taxmin qilinadi [1].

Raqamli texnologiyalar hayotimizning barcha sohalariga, xususan, ta’lim tizimiga chuqur kirib bormoqda. Ayniqsa, fizika fanini o‘qitishda raqamli vositalardan foydalanish talabalarning fizika fanini chuqurroq tushunishiga, nazariy bilimlarni amaliyotga tatbiq etish ko‘nikmalarini rivojlantirishga xizmat qilmoqda.

Ta’lim jarayonini informatsiyalash va raqamlashtirish konsepsiyasini amalga oshirish doirasida bir qator vazifalarni ajratib ko‘rsatish mumkin:

– ta’lim standartlari talablarida nazarda tutilgan barcha turdagi mashg‘ulotlarni talabaning ixtiyorida mavjud bo‘lgan apparat platformasidan qat’i nazar to‘liq o‘tkazish imkoniyati;

– tabiiy fanlar sikli fanlari bo‘yicha laboratoriya ishlarini virtual modellar asosida amalga oshirish, bunda talabaning shaxsiy kompyuterida ishlash imkoniyati mavjud bo‘lishi;

– o‘quv materialini o‘zlashtirishni nazorat qilish uchun test asosidagi masofaviy tizimni yaratish istiqbollari;

– ta’lim jarayonining barcha ishtirokchilari tomonidan mavjud axborot-kommunikatsiya texnologiyalari vositalari yordamida bilvosita va erkin fikr almashish imkoniyati.

Ko‘rib chiqilayotgan maqsad va vazifalarning o‘quv jarayonini amalga oshirish metodologiyasini optimallashtirishdagi amaliy ahamiyati zamonaviy ijtimoiy-iqtisodiy paradigmalar talablaridan kelib chiqadi.

Mehnat bozori uchun raqobatbardosh mutaxassis tayyorlashda ta’lim jarayoni bozor kon’yunkturasiga mos ravishda moslashuvchan bo‘lishi lozim. Ishonch bilan aytish mumkinki, bugungi kunda dunyo haqidagi bilimlar eksponensial tarzda rivojlanmoqda va ta’lim muassasasining vazifasi jamg‘arilgan tajribani barcha mavjud metod va vositalar, jumladan raqamli vositalar orqali yetkazib berishdan iboratdir [2].

Fizika fani nazariy tushunchalar va amaliy ko‘nikmalar uyg‘unligini talab qiladigan murakkab fanlardan biri hisoblanadi. Shu bois, raqamli texnologiyalarning ushbu fandagi qo‘llanilishi talabalarning mavzuni chuqurroq anglashiga, abstrakt tushunchalarni oson tushunishga va tajriba o‘tkazish ko‘nikmalarini rivojlantirishga imkon yaratadi.

Tabiiy fanlar sikliga kiruvchi fizika kabi fanlar laboratoriya tajribalarini o‘tkazish bilan chambarchas bog‘liqdir. Axborot-kommunikatsiya texnologiyalarini qo‘llash gazlarning molekulyar-kinetik nazariyasi yoki yadro fizikasi kabi sohalardagi eksperimentlarni amalga oshirishda nihoyatda dolzarbdir. Chunki ma’lum taxminlar asosida virtual modellarni qurish orqali talaba moddalar molekulyar tuzilishi bilan tanishishi yoki yadro reaksiyalarini boshqarish jarayonini amalga oshirishi mumkin [3-4].

Umumiy fizika kursi bo‘yicha laboratoriya ishlarini tashkil etish sezilarli moliyaviy xarajatlarni talab etadi: O‘quv yurti tomonidan qurilmalarni sotib olish, jihozlangan xonalarni texnik jihatdan to‘g‘ri holatda saqlash va boshqa tashkiliy xarajatlar. Shu sababli, ta’lim jarayonining sifatini yo‘qotmagan holda iqtisodiy xarajatlarni optimallashtirish vazifasi paydo bo‘ladi. O‘quv muassasasi tomonidan sarflanadigan mablag‘larni minimallashtirish maqsadi bir qator oraliq vazifalarni hal qilish orqali amalga oshirilishi mumkin:

– ta’lim jarayoni ishtirokchilari o‘rtasida ma’lumot almashish uchun elektron platformani tanlab, o‘zaro samarali hamkorlik mexanizmini ishlab chiqish;

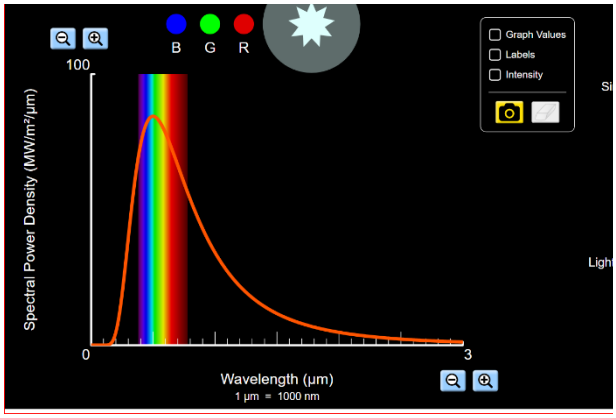
– fizika tajribasini virtual amalga oshirish vositasini tanlash, bunda talabalar o‘z shaxsiy kompyuterida laboratoriya ishini takrorlash imkoniyatiga ega bo‘lishlari;

– yakuniy va oraliq bilim nazoratini, asosan (yoki to‘liq) elektron attestatsiya shakllaridan foydalanib o‘tkazish mexanizmini aniqlash;

– o‘quv materialini o‘zlashtirish sifatini raqamli tahlil qilish imkoniyatini yaratish.

Agar elektron test tizimlari EGE yoki OGEga tayyorgarlik uchun mo‘ljallangan onlayn kurslarda yetarli darajada rivojlangan bo‘lsa, oliy ta’limda fizik hodisalarni virtual modellashtirish masalasi dolzarb bo‘lib qolmoqda. Chunki ta’lim standartlari talabiga ko‘ra mustaqil tayyorgarlikka ajratilgan soatlarning ko‘pligi bu jarayonni talab etadi. Shubhasiz, uy sharoitida fizika bo‘yicha tabiiy eksperimentni o‘tkazish faqat cheklangan hajmda amalga oshirilishi mumkin. Ammo zamonaviy shaxsiy kompyuterlarning hisoblash imkoniyatlari uy sharoitida metodologik jihatdan toza (ma’lum taxminlar bilan) fizika eksperimentini o‘tkazishni ta’minlashi mumkin.

Raqamli texnologiyalar deganda kompyuter, planshet, interaktiv doska, mobil qurilmalar, virtual laboratoriyalar, 3D simulyatsiyalar, sun’iy intellekt, ta’limiy platformalar (Khan Academy, PhET, Moodle va h.k.) orqali bilim olish va uzatish jarayonlari tushuniladi. Fizika fanida ayniqsa simulyatsiya dasturlari, virtual laboratoriyalar, animatsiyalar, va interaktiv testlar keng qo‘llanilmoqda.



Phet dasturida modellashtirilgan ishlardan namuna

Phet dasturida modellashtirilgan ishlardan namuna

Fizika ta’limida raqamli texnologiyalarning afzalliklari:

1. Abstrakt tushunchalarni vizual ko‘rsatish

2. Ko‘plab fizikaviy hodisalar – masalan, elektromagnit to‘lqinlar, kvant effektlari yoki nisbiylik nazariyasining elementlari – talabalarlar uchun tushunilishi qiyin. 3D animatsiyalar va simulyatsiyalar bu jarayonlarni osonroq idrok etish imkonini beradi.

3. Virtual laboratoriyalar orqali tajriba o‘tkazish

4. Tajriba uskunalari mavjud bo‘lmagan hollarda, virtual laboratoriyalar orqali talabalarlar masofadan turib eksperimentlar bajarishi mumkin. Bu esa o‘qitish sifatini oshiradi.

5. Moslashtirilgan o‘rganish (adaptive learning)

6. Raqamli platformalar talabalarningbilim darajasini avtomatik aniqlab, individual yondashuv asosida ta’limni taklif qiladi. Bu ularning mustaqil o‘rganish malakasini rivojlantiradi.

7. Interaktivlik va motivatsiya

8. O‘yin elementlari (gamification) bilan boyitilgan darslar talabalarningfizika faniga bo‘lgan qiziqishini oshiradi.

Fizika fanida raqamli texnologiyalar quyidagi yo‘nalishlarda keng qo‘llanilmoqda:

- Virtual laboratoriyalar: laboratoriya sharoiti mavjud bo‘lmagan hollarda talabalarlar virtual muhitda tajribalar bajarishi mumkin.
- Interaktiv simulyatsiyalar: murakkab hodisalarni, masalan, elektromagnit to‘lqinlar yoki kvant effektlarini vizual tarzda ko‘rsatish imkonini beradi.
- Onlayn test va nazorat vositalari: talabalarlar bilimini real vaqt rejimida baholashni ta’minlaydi.

• Video darslar va vebinarlar: darslarni qayta ko‘rib chiqish, mustaqil o‘zlashtirish imkonini beradi.

Masalan, PhET Interactive Simulations platformasi orqali talabalarlar elektr, optika, mexanika kabi bo‘limlarga oid eksperimentlarni vizual va interaktiv tarzda bajarishlari mumkin.

PhET Interactive Simulations (Colorado universiteti tomonidan ishlab chiqilgan) – bu dastur orqali talabalarlar mexanika, optika, elektr va boshqa bo‘limlarga oid interaktiv tajribalarni bajarishlari mumkin: Algodoo – fizik qonunlarga asoslangan virtual muhit, bunda talabalarlar o‘zlari yaratgan obyektlar harakatini tahlil qilishlari mumkin., Arduino va IoT qurilmalari – zamonaviy texnologiyalar yordamida real fizik tajribalarni raqamlashtirish va avtomatlashtirish mumkin.

Raqamli texnologiyalarni ta’limga integratsiya qilishda ayrim muammolar ham mavjud:texnik jihozlarning yetishmasligi, O‘qituvchilarning raqamli kompetensiyasi pastligi, Internet tarmog‘iga ulanish muammosi

Raqamli texnologiyalar — axborotni raqamli kod (ikkilik kod: 0 va 1) ko‘rinishida qayta ishlash va saqlash texnologiyalaridir. Ular axborotni analog shakldan raqamli shaklga aylantirish orqali yuqori aniqlik, tezlik va ishonchlilikka erishadi. Raqamli usullar yordamida axborotlarni xatolarsiz uzatish, qayta ishlash va saqlash imkoniyati mavjud.

Xulosa

Raqamli texnologiyalarni fizika ta’limiga integratsiya qilish o‘quv jarayonini zamonaviylashtiradi, talabalarningilmiy dunyoqarashini kengaytiradi va ularni XXI asr kompetensiyalariga ega shaxs sifatida shakllantiradi. Kelajakda raqamli ta’lim vositalarini chuqur o‘zlashtirgan pedagogva talabalarlar jamiyatning ilg‘or kuchiga aylanishi shubhasiz. Raqamli texnologiyalarni fizika faniga integratsiya qilish – bu zamonaviy ta’lim talabidir. Ushbu yondashuv nafaqat talabalarningbilim olish jarayonini yengillashtiradi, balki ularni hayotga tayyorlaydi. O‘qituvchilarning zamon bilan hamnafas bo‘lishi, texnologik savodxonlikni oshirishi va raqamli vositalardan samarali foydalanishi o‘z kasbiy salohiyatini mustahkamlashda muhim omil bo‘lib xizmat qiladi. Fizika fani orqali talabalarlarda ilmiy dunyoqarashni shakllantirish, mantiqiy fikrlashni rivojlantirish va texnologik tafakkurni kuchaytirish raqamli texnologiyalar yordamida yanada samaraliroq kechadi.

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PSYCHOLOGICAL AND SOCIAL IMPACTS OF ONLINE LEARNING IN UZBEKISTAN: CHALLENGES AND SOLUTIONS

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Abstract*—This study explores students’ experiences in digital higher education, focusing on how technical, psychological, and social factors influence online learning outcomes. Despite the global growth of digital education, significant challenges remain, especially in areas with uneven access to reliable internet, limited student motivation, and weaker social interaction. The research uses survey data from undergraduate students at various universities in both urban and rural areas of Uzbekistan, combining descriptive analysis and thematic coding to reflect different perspectives. Results show that although students are improving their digital literacy and using adaptive learning strategies, many still encounter barriers like device availability, internet connectivity, and self-regulation issues. Psychological challenges such as stress and lower motivation also impede effective participation, and fewer opportunities for peer interaction limit social support networks. The unique aspect of this study is its integration of demographic, technical, psychological, and social factors into a comprehensive framework for understanding students’ digital learning experiences. The findings suggest that fixing infrastructure alone isn’t enough; universities must also focus on motivation, well-being, and building community. These insights have practical implications for higher education institutions, policymakers, and technology developers in designing inclusive, engaging, and future-oriented digital education systems.

Keywords—digital higher education, inclusive educational technologies, online learning barriers, social interaction in e-learning, student motivation and well-being

XLIII. Introduction

In recent years, online learning has become a vital part of higher education systems worldwide. According to UNESCO, during the COVID-19 pandemic, the prolonged closure of schools and universities deprived over 1.6 billion learners of access to education [1]. This global educational crisis accelerated the rapid growth of digital learning as a crucial tool and brought significant changes to education systems worldwide.

Uzbekistan also quickly adapted to this global trend. With the start of the pandemic, schools and higher education institutions in the country shifted to digital platforms such as ZiyoNET, Kundalik, and television-based lessons. These measures allowed students to continue their studies from home, ensuring the continuity of education. At the same time, this transition revealed new opportunities related to technological infrastructure and digital resources in Uzbekistan’s education system.

However, alongside this rapid expansion of online learning, significant psychological and social challenges have appeared among students in Uzbekistan. Extended screen time has caused stress, decreased motivation, mental fatigue, and self-regulation difficulties. Additionally, students’ social interactions have significantly declined, including peer-to-peer communication, interactive engagement with teachers, and overall social integration.

Moreover, disparities between urban and rural areas—such as differences in internet speed, device access, and infrastructure—have worsened these social impacts. These challenges directly influence not only the effectiveness of online education but also students’ mental health and the overall quality of education. Therefore, recognizing these issues and developing practical solutions is both scientifically and practically essential.

The significance of this study lies in its focus on understanding the psychological and social effects of online learning in Uzbekistan. Problems like stress, waning motivation, mental fatigue, and reduced social interaction hinder personal development and negatively impact the learning process. Addressing these challenges with realistic solutions will help enhance students’ psychological well-being and improve the overall quality of education.

Furthermore, the findings aim to offer practical recommendations for shaping Uzbekistan’s educational policy and provide a scientific foundation for organizing digital learning more effectively. This approach will support the development of online education by considering not only technical capacities but also the psychological and social aspects of learning.

XLIV. Methodology

A. Research Design

The research used a mixed-method design (quantitative and qualitative). The quantitative part aimed to identify general trends in students’ psychological and social challenges during online learning, while the qualitative part investigated their personal experiences and subjective perspectives in more depth.

B. Participants

A total of 206 undergraduate students participated in the study. Among them, 105 students were from urban areas, mainly enrolled in higher education institutions in Tashkent and Nukus, while 101 students were from rural areas, mostly from districts of the Republic of Karakalpakstan as well as from various regions across Uzbekistan. The sample included 2nd-, 3rd-, and 4th-year students, ensuring they had sufficient experience with online learning.

C. Data Collection Instruments

Data were collected via an online survey created on Google Forms. The questionnaire consisted of four main sections:

1. Demographic information (age, year of study, place of residence, etc.);
2. Psychological aspects (stress level, motivation, mental fatigue, self-regulation);
3. Social aspects (peer interaction, communication with instructors, social integration);
4. Technical resources/adaptation (internet speed, device availability, level of adaptation to digital platforms).

Additionally, open-ended questions allowed respondents to share their personal experiences, challenges, and suggestions freely.

D. Data Analysis

- Quantitative data (Likert-scale and close-ended questions) were analyzed using Microsoft Excel. Descriptive statistics such as percentages, mean scores, and comparative diagrams were used, while Pivot Tables, Charts, and Descriptive Statistics functions helped identify differences between urban and rural students.
- Qualitative data (responses to open-ended questions) underwent thematic analysis, with main themes categorized into psychological challenges (stress, lack of motivation, mental fatigue) and social challenges (limited interaction, social isolation).

E. Limitations

Several limitations of the study should be acknowledged.

- Participants were limited to university students, so the findings do not encompass the entire education system.
- Since the data relied on self-reporting, there is a potential for subjective bias.

Despite these limitations, the study offers valuable insights into the psychological and social impacts of online learning in Uzbekistan and provides a solid foundation for further research.

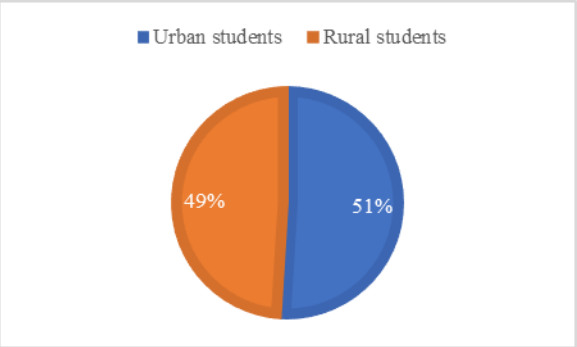
XLV. Results

A. Context

Building on the methodology described above, the findings of the study are presented in this section. A total of 206 students participated in the survey. Their responses are organized into five main areas: demographic information, psychological effects, social aspects, technical conditions and adaptation, and open-ended feedback. This structure allows for a comprehensive and balanced overview of how students perceive and experience online learning.

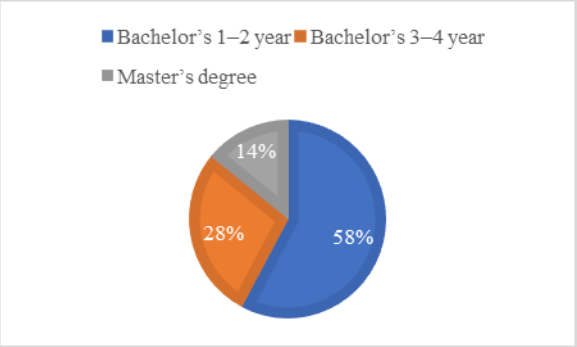
B. Demographic Block

A total of 206 students participated in the survey. The sample was nearly equally divided between urban (51%) and rural (49%) areas. Urban respondents were primarily from Nukus and Tashkent, while most rural participants were from various districts of the Republic of Karakalpakstan, along with a smaller number from other regions of Uzbekistan. This balance provides a reliable comparison between students from different geographical contexts (Figure 1).



Figureure 1. Distribution of students by location (urban vs. rural).

In terms of educational level, the majority of respondents were Bachelor’s students in their first or second year (58%), followed by upper-year Bachelor’s students (28%), and a smaller group of Master’s students (14%). This distribution reflects the predominance of undergraduate participants in the sample (Figure 2).



Figureure 2. Distribution of students by level of study (undergraduate vs. graduate).

Regarding fields of study, students represented a wide range of disciplines, with the largest shares coming from economics, technical sciences, philology, mathematics, and law, while others were distributed across various additional fields. Highlighting the diversity of specializations allows for a broader understanding of how online learning impacts different academic backgrounds.

When it comes to digital access, most respondents relied on a laptop or personal computer (71%), while smartphones (21%) and tablets (5%) were used less frequently, and only 3% reported using other devices. This indicates that the majority of students preferred devices with larger screens and stronger functionality for online learning (Figure 3).

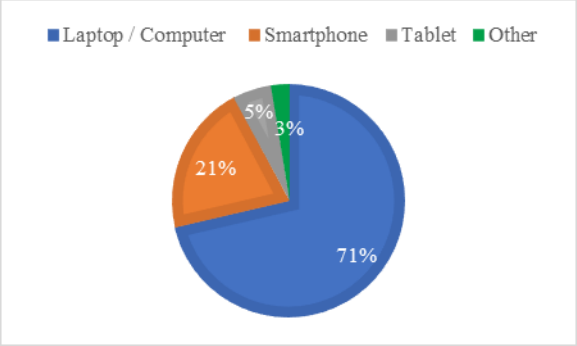


Figure 3. Devices used by students for online learning.

As for internet connectivity, more than half of the students (58%) reported using mobile internet (4G/5G) as their main source, while 33% relied on home Wi-Fi, and only 9% had access through their university or workplace. These findings illustrate that despite the spread of home networks, mobile internet remains the primary mode of access for most students (Figure 4).

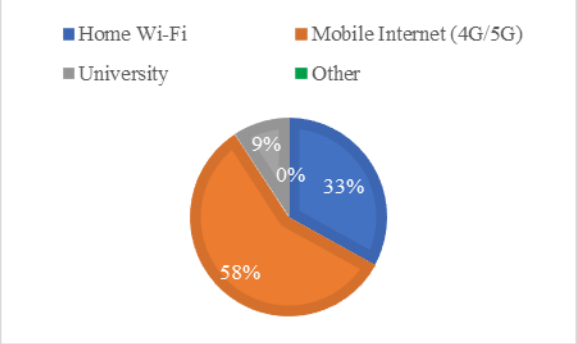


Figure 4. Type of internet connection used by students.

C. Psychological impact

The results show that online learning brings both challenges and opportunities for students. Many participants admitted that staying focused during online classes was not easy — concentration received an average score of 3.17, reflecting that distractions are a common issue in digital learning environments.

Stress, however, was rated lower, with an average of 2.58, meaning that while some students did feel extra pressure, most did not find online learning overwhelmingly stressful. Sleep schedules were also only moderately affected (2.67), suggesting that late-night classes or screen time disrupted routines for some, but not all, students.

A recurring theme was the feeling of isolation. With a score of 2.92, students expressed that online learning sometimes left them less motivated and less connected to others. Anxiety about academic performance was slightly higher (3.33), showing that worries about keeping up with online coursework and exams are quite common.

Encouragingly, the most positive outcome was in self-discipline and time management. This item received the highest average score (3.58), meaning that many students felt they had grown more independent and better at organizing their own studies.

In short, while online learning has made concentration, motivation, and social connection more difficult for some, it has also helped students develop valuable personal skills that may benefit them well beyond the classroom (Figure 5).

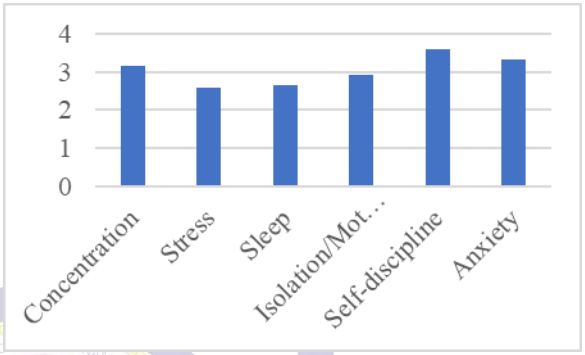


Figure 5. Psychological impacts of online learning among students (Concentration, Stress, Sleep, Isolation/Motivation, Self-discipline, Anxiety).

D. Social Impact

The social dimension of online education revealed both notable drawbacks and certain benefits. As shown in the bar chart (Figure 6), students generally agreed that online learning reduced opportunities for face-to-face social interaction (average score 3.00) and that they felt less connected to their classmates (3.67). This suggests that the lack of in-person contact remains one of the most pressing social challenges of digital education.

Group collaboration was also perceived as less effective in the online format, receiving an average score of 3.25. Many students indicated that teamwork, discussions, and peer learning were harder to manage virtually compared to traditional classrooms.

Concerns about inequality were present, but less pronounced. The statement on the urban–rural gap scored 2.92, reflecting that while some students felt disadvantaged due to location or resources, the perception of a deepening divide was not universal.

On the positive side, students highlighted that online platforms contributed significantly to their skill development. The highest score in this block was for improved digital communication skills (3.92), showing that online education has enhanced students’ ability to use digital tools effectively.

Finally, students expressed mixed feelings about independence and social isolation. With an average score of 3.17, many appreciated the greater autonomy that online

learning provided, but this came at the cost of feeling socially more detached.

Overall, the findings show a dual impact: while online education limits social connection and collaboration, it simultaneously strengthens digital competencies. This pattern is also evident in the bar chart, which provides a visual summary of students’ responses (Figure 6).

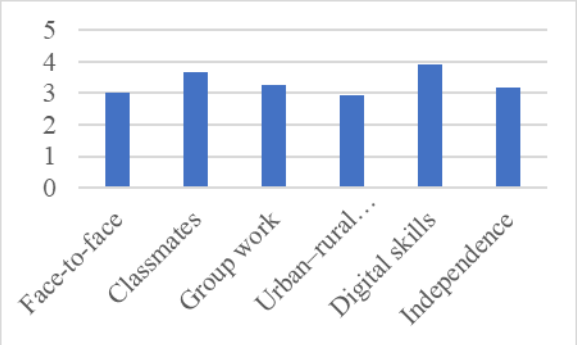


Figure 6. Social impacts of online learning among students (Face-to-face interaction, Classmate connection, Group work, Urban–rural gap, Digital skills, Independence/Isolation).

E. Technical Aspects

When examining the technical aspects of online learning, the results present a mixed picture of progress and ongoing challenges. One of the most urgent issues was access to reliable internet. Students rated this at just 3.02 out of 5, indicating that unstable connections remain a common obstacle. Technical problems such as slow speeds or disconnections were also noted, with a similar rating of 3.00. These findings confirm that connectivity issues continue to disrupt the learning process for many students, especially those outside urban centers.

Access to suitable devices also appeared to be a concern. With an average score of 2.83, this suggests that not all students have consistent or sufficient access to computers, smartphones, or tablets—an issue that may hinder equal participation in online education.

On a more positive note, students expressed confidence in their ability to adapt to new platforms and tools used in online learning, rated at 3.67. This reflects a growing sense of digital flexibility among learners. The availability of technical support received a slightly lower score of 3.58, indicating that while assistance was available, it did not always fully meet students’ needs. Encouragingly, students also reported that online education helped improve their digital skills, also rated at 3.67.

Taken together, these findings suggest that although poor internet connectivity and limited access to devices remain significant barriers, students are steadily becoming more adaptable and digitally competent. As shown in the accompanying bar chart, this mix of challenges and progress highlights the practical realities of online learning in Uzbekistan. (Figure 7).

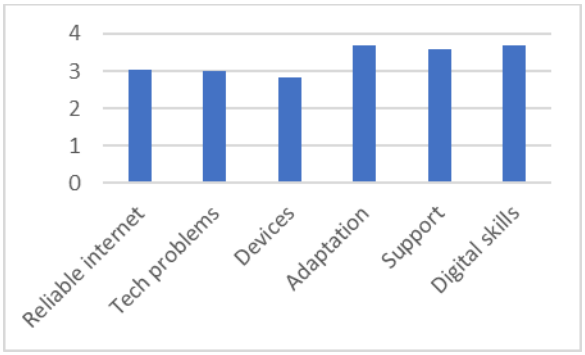


Figure 7. Technical conditions and adaptation in online learning (Internet access, Technical problems, Devices, Adaptation, Support, Digital skills).

F. Open-Ended Responses

In addition to the structured survey items, students were invited to share their perspectives on online learning through open-ended questions. Their responses reveal several recurring themes, highlighting both the challenges and opportunities of this mode of education in Uzbekistan.

When asked about the biggest challenges, students often pointed to motivational difficulties. Many felt that online classes were less engaging and more monotonous, making it harder to sustain attention and maintain consistent study habits. Some also mentioned a lack of guidance on how to effectively use online lessons, suggesting a need for psychological or academic support. Beyond these personal challenges, external barriers were also emphasized: students from remote areas often faced slow internet connections, limited access to suitable devices, and the absence of a quiet, supportive study environment.

Regarding potential improvements, the most common suggestion was to make online content more engaging and interactive. Students also highlighted the importance of improving internet speed and ensuring all learners have access to the necessary technical equipment. Another recurring theme was the role of teachers: many respondents noted that instructors should be better trained in digital tools and more confident in using the latest technologies to enrich their teaching.

Finally, when invited to share personal experiences, students offered a balanced mix of positive and negative reflections. On the positive side, some valued the flexibility of revisiting recorded lectures, the cost-effectiveness of online learning, and the global accessibility it provides. However, others emphasized the sense of social isolation, the difficulty of maintaining meaningful connections with peers and teachers, and limited opportunities for hands-on, practical learning.

Overall, these open-ended responses add depth to the survey data by showing that while online education offers flexibility, affordability, and global reach, it still requires significant improvements in content design, technical infrastructure, and psychological support to fully meet students’ needs.

G. Summary of Results

Overall, the findings offer a detailed view of how students in Uzbekistan experience online learning across demographic, psychological, social, technical, and open-ended perspectives. The demographic data showed a nearly equal balance of students from urban and rural areas, across different levels of study and disciplines, ensuring that the results reflect various contexts.

The psychological impact indicated that while online learning provided opportunities for developing self-discipline and managing time, many students struggled with concentration, stress, and motivation. Socially, students reported weaker connections with peers and less effective collaboration, although they also noted improvements in digital communication skills.

On the technical side, challenges like unreliable internet and limited access to devices were apparent, yet students showed adaptability and growth in digital skills. Open-ended responses deepened these findings by highlighting recurring themes: lack of motivation, insufficient access to technology, and the need for more engaging content, alongside recognizing benefits such as flexibility, cost savings, and global reach.

In short, the results reveal a dual reality of online learning in Uzbekistan: it both enables new skills and opportunities and presents significant challenges related to infrastructure, engagement, and social connection. These insights lay the groundwork for the discussion that follows, where broader implications and potential solutions will be examined.

XLVI. Discussion

A. Context

Online learning has gained unprecedented prominence in Uzbekistan—as in many parts of the world—altering traditional education models overnight. While this shift has opened up new possibilities for flexibility, self-regulation, and skill development, it has concurrently exposed longstanding infrastructure gaps, psychological pressures, and social disconnection. Similar trends have been documented globally: students have reported increased stress, reduced motivation, and weakened peer interaction due to the sudden move to remote learning environments [2]. Moreover, the digital divide—characterized by disparities in device ownership, connectivity, and digital preparedness—has further deepened educational inequalities, particularly among underserved populations [3]. This discussion aims to interpret our findings within this broader context, drawing connections between empirical results, educational challenges, and future pathways toward more inclusive online learning in Uzbekistan.

B. Key findings by Theme

1) Demographic Insights

The analysis revealed significant differences between urban and rural students. Those from remote areas faced greater challenges due to poor internet access and limited device availability. Such conditions risk increasing educational inequality. Similarly, research by Mark Warschauer and Tamara Tate confirmed that digital inequality directly affects students’ learning opportunities [4]. This underscores the importance of improving educational infrastructure.

2) Psychological Impact

The findings showed that students experienced increased stress, isolation, and decreased motivation. At the same time, some reported improvements in time management and independent learning skills. Xiong and colleagues reported comparable results, noting higher levels of anxiety and depression among students during the pandemic [5]. These findings highlight the need for more robust psychological support mechanisms.

3) Social Impact

During online learning, face-to-face interaction and group work diminished, while students’ digital communication skills improved. Dhawan’s research also indicated that online education often reduces the sense of community, even as digital collaboration grows [6]. This suggests that fostering peer-to-peer interaction remains essential.

4) Technical Aspects

Technical challenges, such as unstable internet connections and a lack of access to devices, were among the most urgent issues. Nevertheless, many students indicated they could quickly develop new digital skills. Bao’s case study of Peking University similarly showed that aligning technical and pedagogical solutions can significantly mitigate such barriers [7]. This emphasizes the need for greater flexibility in online learning environments.

5) Open-Ended Responses

In open-ended survey responses, students frequently mentioned decreased motivation, monotonous lessons, and internet-related problems. At the same time, they recognized benefits such as rewatching recorded lectures and accessing global learning resources. Bao also highlighted that combining short, segmented lessons with a mix of asynchronous and synchronous teaching approaches is effective [7]. These insights underline the importance of flexible learning materials and improved instructor preparation.

C. Synthesis

The findings of this study offer a detailed picture of students’ experiences with online learning during the pandemic. While many challenges arose—ranging from digital inequality and technical issues to psychological stress and weaker social ties—there were also signs of resilience and adaptation. Students not only learned to navigate new digital environments but also started developing skills that could benefit them long-term, such as independent learning and improved digital communication.

A key insight is how different themes intersect. For example, technical limitations weren’t just practical obstacles; they also affected students’ mental health and their sense of academic inclusion. Students in rural areas,

who faced poor internet connectivity, often reported higher frustration and demotivation, showing how infrastructure and mental health are closely connected. This relationship between access, mental health, and learning quality expands existing research, which often examines these factors separately.

Another important aspect of this research is its focus on students’ own voices. The open-ended responses revealed recurring issues like lack of motivation and limited interaction but also uncovered unexpected benefits, such as the ability to revisit recorded lectures and access global resources. By combining these perspectives with survey data, the study presents a more nuanced view of online learning—neither entirely positive nor negative, but a complex experience shaped by context and personal adaptation.

Importantly, the study highlights the paradox of online learning: while it increased existing inequalities, it also provided access to resources for those with stable internet connections. This duality suggests that the impact of online education cannot be understood through a simple story of “success” or “failure.” Instead, it underscores the need for context-specific approaches that consider infrastructure, student well-being, and pedagogical design together.

Overall, these findings contribute to a more integrated understanding of online learning in higher education. Unlike much previous research, which often focused solely on technological barriers or psychological effects, this study emphasizes their interconnectedness. By doing so, it moves beyond just documenting challenges and instead highlights how digital inequality, social interaction, and individual adaptation work together to influence educational outcomes.

D. Implications

The findings of this study highlight several key challenges and opportunities for higher education in the digital age. The digital divide between urban and rural students shows that unequal access to technology directly impacts educational equity. Without targeted efforts, these gaps may grow, limiting opportunities for students in disadvantaged areas.

The psychological stresses of online learning—such as stress, isolation, and decreased motivation—reveal that the success of digital education depends not only on technology but also on ongoing support for students’ mental health. Universities must therefore see digital transformation as both a technical and a human challenge.

At the same time, the decline of traditional social interactions alongside the growth of digital communication skills indicates a shift in how students form networks and collaborate. This duality suggests that institutions must find new ways to maintain the sense of community that underpins higher learning.

Finally, the continued presence of technical barriers shows that infrastructure alone is not enough. Digital education needs flexible models that combine reliable access with inclusive teaching designs, ensuring that no students are left behind.

In summary, these findings emphasize that digital education should no longer be viewed as a temporary response to crises but as a lasting transformation of higher education. Addressing these challenges requires innovative strategies that go beyond technology and address the psychological, social, and infrastructural aspects of students’ experiences.

XLVII. RECOMMENDATIONS

A. General Introduction to Recommendations

Based on the findings of this study, several targeted recommendations can be made to strengthen the effectiveness and inclusiveness of digital higher education. These suggestions address not only the technical barriers but also the psychological and social dimensions of students’ learning experiences.

B. Thematic Recommendations

1) Addressing Technical Barriers

One of the most pressing challenges concerns limited access to reliable internet and digital devices, particularly among students in rural areas. Universities could mitigate this issue by introducing device loan programs, through which students can temporarily borrow laptops or smartphones for educational purposes. In addition, offering offline-compatible learning modes—such as downloadable lecture materials and asynchronous access—would enable students in low-connectivity regions to continue learning without disruption. The value of such initiatives has been demonstrated by practical cases like SolarSPELL’s solar-powered digital libraries, which provide offline, renewable-energy-based access to educational content in underserved regions [8].

2) Supporting Motivation and Psychological Well-being

The findings highlight the importance of sustaining students’ mental health and intrinsic motivation in online settings. Institutions should consider establishing online psychological support centers where students can receive counseling and stress-management guidance. Furthermore, integrating interactive and engaging pedagogical techniques, such as gamification, short video modules, and mini-assessments, could help maintain student interest. Empirical evidence shows that gamified approaches can significantly improve engagement, retention, and academic performance [9], [10]. In addition, training programs focused on time management and self-regulation skills would empower students to better navigate the demands of independent online study.

3) Strengthening Social Interaction

To counter the reduction of face-to-face communication, online education must actively foster community and collaboration. This could be achieved by embedding regular group projects and discussion forums into course design, ensuring that peer interaction remains a core

component of learning. Beyond coursework, universities may establish virtual student clubs—such as debate or reading clubs—that encourage informal interaction and strengthen social bonds. Where feasible, offline gatherings could complement online engagement, reinforcing a sense of belonging among students.

4) Preparing for Future Directions

Looking ahead, sustainable and innovative solutions will be essential for bridging digital gaps and expanding educational opportunities. The establishment of solar-powered learning hubs in rural areas could provide both energy and internet access to underserved communities, an approach already piloted in projects like SolarSPELL [8]. At the same time, the adoption of virtual and augmented reality technologies holds significant potential to make digital learning more immersive, interactive, and aligned with the evolving needs of higher education.

C. Integrative Closing Paragraph

The discussion of findings underscores that digital higher education is shaped by a complex interplay of technical, psychological, and social factors. Students’ experiences reveal not only persistent inequalities in access to reliable internet and devices but also challenges related to motivation, well-being, and social connectedness. At the same time, the findings show that students are developing stronger digital skills and adopting adaptive learning practices, which indicates resilience and potential for long-term growth.

This study adds novelty by combining demographic, psychological, social, and technical perspectives into a single framework of analysis, offering a more holistic understanding of students’ digital learning experiences than many prior studies. Importantly, the results highlight that addressing technical barriers alone is insufficient; universities must also consider the psychological and social dimensions of learning in order to make digital education genuinely inclusive and effective.

Overall, the discussion provides a foundation for actionable recommendations that can guide institutions in designing digital education systems that are equitable, engaging, and future-oriented. These insights also open new directions for research, particularly in exploring how innovative technologies and support systems can mitigate the long-term challenges revealed by this study.

XLVIII. Conclusion

This study shows that the quick switch to digital higher education revealed not only technical issues, like limited internet and device access, but also the psychological and social parts of students’ learning experiences. These findings confirm that online education isn't just about technology; it also needs attention to human factors that influence motivation, well-being, and teamwork.

By listening to students, this research offers a new view on digital education in higher learning. Its value lies in providing a complete perspective that combines technical, psychological, and social aspects, surpassing many existing studies that focus on only one area.

The practical implications are significant: universities and policymakers can use these insights to create more inclusive and resilient digital learning environments. Solving technical inequalities, boosting psychological support, and improving social interactions will not only lead to better academic results but also help students feel more connected.

Going forward, future work should include the perspectives of teachers and parents, who are key in shaping students’ digital learning experiences. Teachers’ opinions on workload, teaching methods, and assessments, along with parents’ concerns about their children’s well-being and self-control, could give a fuller picture of the long-term effects of digital education. Overall, these insights will contribute to building a more human-centered and sustainable model of higher education in the digital age.

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ЦИФРОВАЯ ГРАМОТНОСТЬ И ПРИНЯТИЕ ИИ СТУДЕНТАМИ: ЭМПИРИЧЕСКИЕ ВЫВОДЫ И ПРАКТИЧЕСКИЕ РЕКОМЕНДАЦИИ

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***Аннотация*— Исследование посвящено восприятию и практикам использования технологий искусственного интеллекта студентами технического вуза Узбекистана. Цель – выявить уровень осведомлённости, полезности и простоты использования ИИ, а также намерения продолжать его применение. Методология опирается на модель принятия технологий (TAM) и онлайн-опрос с семибалльной шкалой Лайкерта среди студентов ТУИТ. Анализ показал преимущественно позитивное отношение к ИИ, студенты считают ИИ удобным и эффективным для учебных задач; при этом вариативность BI указывает на различия в готовности к дальнейшему использованию. Результаты подтверждают актуальность интеграции ИИ в учебный процесс, подчёркивая необходимость развития цифровой грамотности, этических норм и практик ответственного применения. Представлены рекомендации для преподавателей и администрации по укреплению доверия, демонстрации полезных сценариев и поддержке осознанной цифровой трансформации. Практическая значимость связана с совершенствованием политики цифровизации вуза Узбекистана.**

Ключевые слова—искусственный интеллект в образовании, модель TAM, восприятие студентов, воспринимаемая полезность, простота использования, поведенческое намерение, цифровая грамотность.

Введение

В последние годы технологии искусственного интеллекта (ИИ) всё активнее внедряются в различные сферы жизни, включая образование. От интеллектуальных обучающих систем и автоматизированных средств оценки до генеративных моделей, таких как ChatGPT, студенты получают доступ к мощным инструментам, способным поддерживать обучение, повышать вовлечённость и способствовать индивидуализации учебного процесса. Быстрое распространение ИИ в образовательной среде открывает как новые возможности, так и новые вызовы для всех участников процесса.

В условиях, когда университеты стремятся интегрировать ИИ в преподавание и обучение, особенно важно понимать, как сами студенты воспринимают и используют эти технологии. Несмотря на технический прогресс, эффективность использования ИИ в обучении во многом зависит от степени готовности студентов взаимодействовать с ним, уровня доверия и осведомлённости.

Ряд исследований уже освещал применение ИИ в образовании: от персонализированного обучения до автоматизированного обратного связанного. Однако наблюдается нехватка эмпирических данных, отражающих позицию самих студентов, особенно в странах с развивающейся цифровой образовательной средой. Восприятие ИИ, частота его использования, предполагаемая польза и намерения продолжать использование в будущем — это ключевые показатели, позволяющие оценить реальную интеграцию технологий в учебный процесс.

В этом контексте исследование восприятия ИИ студентами приобретает актуальность и для Ташкентского университета информационных технологий (ТУИТ), где особое внимание уделяется цифровой трансформации и внедрению инновационных образовательных решений. Понимание отношения студентов к ИИ может способствовать более осознанной интеграции подобных технологий в образовательную практику и развитию гибкой стратегии цифровизации на уровне вуза.

Настоящее исследование направлено на изучение отношения студентов к технологиям ИИ в высшем образовании на основе анкетного опроса. Целью является выявление уровня осведомлённости, характерных моделей использования, уровня доверия и перспектив восприятия ИИ среди студентов технического университета. Полученные результаты дают представление о текущем состоянии внедрения ИИ в образовательную практику и позволяют выработать практические рекомендации для построения эффективной ИИ-усиленной учебной среды.

Интеграция технологий искусственного интеллекта (ИИ) в образовательный процесс

становится предметом всё большего числа научных исследований. Современные исследования фиксируют положительное влияние ИИ на индивидуализацию обучения, автоматизацию обратной связи и повышение мотивации учащихся [1][2]. Системы на основе ИИ находят применение как в формальном образовании, так и в неформальной самообразовательной среде [3].

В последние годы особое внимание уделяется восприятию ИИ самими студентами. Например, по данным международного исследования HolonIQ (2023), более 70% студентов высших учебных заведений используют ИИ-инструменты в повседневной учебной деятельности, преимущественно для подготовки письменных заданий и самопроверки [4]. При этом отмечаются различия в уровне доверия к результатам ИИ и в способности критически оценивать полученную информацию [5].

Некоторые авторы подчеркивают, что успешность внедрения ИИ в учебную практику во многом зависит от цифровой компетентности студентов и преподавателей [6]. Низкий уровень цифровой грамотности может снижать эффективность использования ИИ, несмотря на высокий интерес к технологиям. Другие исследования фокусируются на этических аспектах и возможных рисках неконтролируемого использования ИИ в обучении [7].

Несмотря на растущее число работ, вопросы, связанные с восприятием ИИ студентами технических университетов в странах Центральной Азии, остаются малоизученными.

Особенно слабо представлены количественные данные, полученные на основе опросов, фиксирующих реальные сценарии и частоту использования ИИ, а также уровень готовности студентов к его дальнейшей интеграции в образовательный процесс.

Настоящее исследование стремится восполнить этот пробел, предоставляя эмпирические данные, собранные среди студентов технического вуза в Узбекистане.

Целью настоящего исследования является изучение восприятия, частоты и характера использования технологий искусственного интеллекта студентами технического университета, а также их готовности к дальнейшей интеграции ИИ в образовательный процесс.

В рамках исследования были поставлены следующие исследовательские вопросы:

1) Какова степень распространённости использования технологий ИИ в учебной деятельности студентов технического университета?

2) Как студенты оценивают полезность, удобство и сложность использования ИИ-сервисов в обучении?

3) Насколько высока готовность студентов к дальнейшему использованию ИИ в образовательной деятельности?

4) Существуют ли различия в восприятии ИИ среди студентов разных курсов, полов или возрастных групп?

Методология.

Данное исследование реализовано в форме анкетного онлайн-опроса и опирается на модель принятия технологий (Technology Acceptance Model — TAM), предложенную Ф. Дэвисом. TAM объясняет поведение пользователей в отношении новых технологий через три ключевых конструкта: воспринимаемая полезность (Perceived Usefulness), воспринимаемая простота использования (Perceived Ease of Use), и намерение использовать технологию в будущем (Behavioral Intention to Use). Данная модель адаптирована в настоящем исследовании для анализа отношения студентов к использованию технологий искусственного интеллекта (ИИ) в образовательной деятельности.

Анкета включала утверждения, соответствующие этим трем конструкциям:

- Perceived Usefulness (PU): ИИ помогает учиться эффективнее;
- Perceived Ease of Use (PEOU): использование ИИ не требует значительных усилий;
- Behavioral Intention (BI): студент планирует использовать ИИ в будущем.

Оценка утверждений производилась по семибалльной шкале Лайкерта (от 1 — «Полностью не согласен» до 7 — «Полностью согласен»), что обеспечивает более детализированную градацию отношения респондентов к ИИ.

В опросе приняли участие 161 студентов факультета Профессионального образования в сфере информационно-коммуникационных технологий (ИКТ) Ташкентского университета информационных технологий (ТУИТ). Все участники являлись студентами 2–4 курсов бакалавриата. Анкетирование проводилось в онлайн-формате, анонимно и на добровольной основе.

Собранные данные были экспортированы в формат CSV и обработаны с использованием инструментов Microsoft Excel и Python. Были рассчитаны частотные распределения, средние значения по шкале Лайкерта, визуализированы основные показатели. Анализ фокусировался на выявлении тенденций в восприятии ИИ и на определении факторов, влияющих на намерение студентов продолжать его использование в учебной деятельности.

Результаты исследования

На основе собранных данных был проведён количественный анализ восприятия студентами технологий искусственного интеллекта в учебной деятельности с использованием модели принятия технологий (TAM). Для оценки каждого из трёх ключевых конструктов TAM — воспринимаемой полезности (PU), воспринимаемой простоты использования (PEOU) и намерения использовать

в будущем (BI) — использовалась семибалльная шкала Лайкерта.

Анализ показал, что общее отношение студентов к ИИ в образовательном контексте является преимущественно положительным. Средние значения по всем конструкциям превышают нейтральный уровень (4.00), что свидетельствует о признании ИИ как полезного и сравнительно удобного инструмента.

Таблица 1. Сводные статистические показатели по компонентам модели TAM (n = 162)

Компонент TAM	Среднее значение	Стандартное отклонение
PU – Воспринимаемая полезность	5.61	1.62
PEOU – Простота использования	5.65	1.61
BI – Намерение использовать ИИ	5.47	2.03

Как видно из Таблицы 1, воспринимаемая полезность (PU) получила среднее значение 5.61, что указывает на высокую степень признания ИИ как эффективного инструмента в учебном процессе. Простота использования (PEOU) также получила высокую оценку (5.65), демонстрируя, что большинство студентов считают ИИ доступным и несложным в применении. В свою очередь, намерение использовать ИИ в будущем (BI) характеризуется средним значением 5.47, а стандартное отклонение 2.03 отражает более широкий спектр мнений — от высокой уверенности до сдержанного отношения к дальнейшему применению ИИ в учебной деятельности.

В совокупности полученные результаты подтверждают, что технологии ИИ уже прочно вошли в образовательную практику студентов технических направлений. Однако вариативность показателя BI подчёркивает необходимость дополнительных мер по поддержке осознанного, этичного и целенаправленного использования ИИ в процессе обучения.

Обсуждение результатов. Полученные в исследовании показатели восприятия искусственного интеллекта (ИИ) студентами факультета ИКТ свидетельствуют о в целом позитивном отношении к ИИ в учебной деятельности. Средние значения по шкале 1–7 для воспринимаемой полезности (PU = 5,61) и простоты использования (PEOU = 5,65) превышают нейтральный уровень, указывая на высокую оценку студентами как полезности, так и удобства использования технологий ИИ. Аналогично, средний показатель поведенческого намерения использовать ИИ (BI = 5,47) свидетельствует о значительной готовности внедрять ИИ в обучении. Для сравнения, в других работах отмечены сопоставимые результаты: например, в исследовании восприятия ChatGPT студентами средний балл по простоте использования достиг ~74% от максимума — самый высокий среди измеряемых конструкций [8]. Наши данные (PEOU ~81%) подтверждают международную тенденцию, согласно которой современные образовательные ИИ-инструменты (такие как ChatGPT) воспринимаются как интуитивно понятные и легкие в освоении студентами. Высокий уровень PEOU характерен и для других выборок; так, среди германских студентов высокая простота использования ИИ оказалась значимым предиктором намерения применять ИИ-системы [9].

Высокое значение воспринимаемой полезности (PU ~5,6) указывает, что студенты убеждены в ценности ИИ для улучшения своих академических результатов. Это согласуется с результатами исследований, где полезность признаётся ключевым фактором принятия технологий. В частности, в модели TAM для будущих учителей PU был наиболее сильным предиктором намерения работать с ИИ ($\beta \approx 0{,}50$) [9]. Аналогичные выводы получены и в других странах: метаанализ исследований среди студентов-медиков и других областей подчеркнул, что демонстрация конкретных академических выгод ИИ повышает желание его использовать [10]. Наши данные подтверждают данный тренд: чем выше польза, которую обучающиеся видят в ИИ, тем больше их готовность его применять. Кроме того, в недавнем исследовании, посвящённом использованию ChatGPT в обучении, показано, что именно воспринимаемая полезность напрямую влияет на поведенческие намерения студентов, тогда как простота использования может опосредованно влиять через удовлетворённость от работы с ИИ [11]. Это говорит о том, что одного удобства недостаточно: чтобы стимулировать активное внедрение ИИ, он должен приносить ощутимую пользу в учебном процессе.

Интересно отметить разброс мнений студентов относительно намерения использовать ИИ: стандартное отклонение BI составляет 2,03, что указывает на существенную вариативность оценок. Схожее явление наблюдается и в международной практике. Часть студентов проявляет энтузиазм и готовность активно включать ИИ в обучение, тогда как другие относятся осторожно, опасаясь потенциальных рисков. Например, исследования сообщают о существовании разрыва в восприятии: студенты, лучше знакомые с возможностями ИИ, одновременно видят его преимущества и выражают больше озабоченности этическими аспектами и влиянием на занятость [12]. В некоторых выборках отмечены умеренные или смешанные оценки полезности ИИ. Так, средний балл общего восприятия ИИ у студентов-медиков может быть около 3,03 из 5 (≈60%), что отражает сдержанные ожидания от ИИ в здравоохранении [10]. Для сравнения, наши респонденты – будущие специалисты по ИКТ – демонстрируют более

высокий энтузиазм (~80% по шкале), возможно благодаря большей технической подкованности и пониманию потенциала ИИ.

Полученные результаты согласуются с глобальными тенденциями принятия ИИ студентами. Во всем мире наблюдается рост интереса к инструментам ИИ в образовании, особенно после появления доступных генеративных моделей вроде ChatGPT [9]. Большинство недавних исследований сходятся во мнении, что студенты склонны принимать ИИ, если убеждены в его полезности и чувствуют уверенность в использовании. Так, в продольном исследовании студентов в Германии установлено, что у тех, кто в среднем выше оценивает полезность и удобство ИИ, интенсивность фактического использования учебных чат-ботов значительно выше [13]. Одновременно подчёркнуто, что снижение тревожности по поводу ИИ и усиление доверия (например, через повышение надёжности и прозрачности алгоритмов) способны укрепить позитивное отношение учащихся [13]. Наши респонденты, судя по высоким значениям PU и PEOU, в целом не испытывают сильной тревоги перед ИИ и доверяют его возможностям. Однако для максимального раскрытия потенциала образовательного ИИ следует учесть и скептиков: как показывают другие работы, факторы вроде доверия и этических норм могут сдерживать принятие технологий, даже когда основные показатели TAM высоки [14]. В исследовании Yilmaz и соавт. именно доверие к ИИ («credibility») оказалось наименьшим по сравнению с другими аспектами восприятия (около 63% положительных ответов) [8]. Это означает, что даже при высокой оценке удобства и эффективности ИИ некоторые студенты сомневаются в надежности получаемых от него результатов.

В целом, результаты нашего опроса демонстрируют уверенное принятие технологий ИИ студентами ИКТ-специальностей, что согласуется с большинством современных исследований. Высокие показатели PU и PEOU подтверждают валидность модели TAM в контексте академического ИИ: если технология воспринимается как полезная и удобная, студенты проявляют готовность ею пользоваться. Отдельные различия в уровне энтузиазма (большой разброс BI) отражают общую картину по миру – от восторженного внедрения новых инструментов до осторожного их освоения. Тем не менее доминирующая тенденция заключается в позитивном настрое к использованию ИИ в образовании при условии понимания его преимуществ. Можно сделать вывод, что для дальнейшего распространения ИИ в учебном процессе следует поддерживать высокую воспринимаемую полезность, через интеграцию реально полезных функций ИИ в обучение и простоту использования, одновременно работая над повышением доверия студентов к этим технологиям.

Заключение

Проведённое исследование продемонстрировало уверенное и преимущественно позитивное восприятие технологий искусственного интеллекта студентами факультета профессионального образования в сфере ИКТ. Полученные результаты подтверждают, что ИИ уже занял значимое место в образовательной практике студентов, а ключевые показатели модели принятия технологий (TAM) свидетельствуют о высокой степени его принятия и потенциальной устойчивости этого тренда.

Отвечая на поставленные исследовательские вопросы, можно отметить следующее:

1) Использование ИИ среди студентов достаточно широко распространено. Большинство опрошенных уже применяют различные ИИ-инструменты в учебной деятельности, что говорит о переходе от знакомства с технологией к её практическому внедрению.

2) Студенты высоко оценивают как полезность ИИ (PU = 5.61), так и простоту его использования (PEOU = 5.65). Это подтверждает, что ИИ воспринимается как инструмент, способствующий эффективности, удобству и экономии времени в обучении.

3) Намерение продолжать использование ИИ (BI = 5.47) также находится на высоком уровне, хотя наблюдается некоторая вариативность в установках, что может быть связано с личным опытом и уровнем цифровой грамотности.

4) Существенных различий между подгруппами студентов (по полу, возрасту, курсу) не выявлено, что свидетельствует о равномерном принятии ИИ в студенческой среде.

Для обеспечения благоприятного и полезного внедрения ИИ в образовательную среду, следует учитывать следующие рекомендации:

- преподавателям следует обсуждать со студентами как возможности, так и ограничения ИИ, формируя у них критическое мышление и навыки ответственного применения технологий.
- внедрение ИИ должно сопровождаться чёткими этическими нормами и правилами, чтобы сохранить академическую честность и не подменить самостоятельную работу учащихся.
- важно повышать уверенность студентов в работе с ИИ через демонстрацию полезных сценариев и снижение неопределённости вокруг новых инструментов.

С учётом наблюдаемых трендов можно утверждать, что перспективы применения ИИ в образовании — воодушевляющие и

конструктивные. При должной поддержке и этическом сопровождении технологии ИИ способны существенно обогатить учебный процесс, сделать его более персонализированным, доступным и ориентированным на развитие компетенций XXI века. Важно не просто внедрять технологии, а формировать осознанную, обоснованную и ориентированную на качество культуру их использования.

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INGLIZ TILINI O‘QITISHDA RAQAMLI INNOVATSIYALAR

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Annotatsiya - Raqamli texnologiyalarning jadal rivojlanishi ingliz tilini o‘qitish (ELT) sohasida tub o‘zgarishlarga sabab bo‘ldi. Ushbu maqola onlayn platformalar, mobil qurilmalar yordamida til o‘rganish (MALL), sun’iy intellekt (AI) va o‘yin elementlaridan foydalanish kabi innovatsiyalarning ingliz tilini o‘qitish va o‘rganish jarayonlariga ko‘rsatgan ta’sirini o‘rganadi. So‘nggi ilmiy tadqiqotlar, so‘rovnomalar va amaliy kuzatuvlarga tayanib, bu texnologiyalar o‘quvchilarning qiziqishini qanday oshirishi, ta’limni shaxsiylashtirishi va uning qulayligini ta’minlashi ko‘rsatib berilgan. Raqamli vositalarning qiyosiy tahlili ularning afzalliklari va cheklovlarini, jumladan, internet ulanishi, o‘qituvchilarning tayyorgarligi va ta’lim olish imkoniyatlarining tengligi masalalarini yoritadi. Natijalar shuni ko‘rsatadiki, raqamli innovatsiyalarning puxta o‘ylangan holda joriy etilishi ELT samaradorligini sezilarli darajada oshiradi, biroq bu jarayon kasbiy malaka oshirish va tegishli infratuzilma bilan qo‘llab-quvvatlanishi lozim. Maqola virtual va kengaytirilgan reallik kabi yangi tendensiyalarni, shuningdek, til ta’limi kelajagini shakllantirishda sun’iy intellekt asosidagi o‘qituvchi dasturlarning o‘rnini muhokama qilish bilan yakunlanadi.

Kalit so‘zlar - Raqamli ta’lim, Ingliz tilini o‘qitish, Mobil yordamida til o‘rganish, Ta’limda sun’iy intellekt, Aralash ta’lim

I. KIRISH

Ingliz tili global muloqot vositasiga aylanib, uni samarali o‘qitish usullari tez raqamlashayotgan dunyoda muhim ahamiyat kasb etmoqda. An’anaviy sinf yondashuvlari samarali bo‘lsa-da, ko‘pincha moslashuvchanlik va o‘quvchiga yo‘naltirilganlik jihatidan yetarli emas. Raqamli texnologiyalarning rivojlanishi Moodle va Zoom kabi onlayn ta’lim platformalaridan tortib Duolingo, Quizlet va Memrise kabi mobil ilovalargacha bo‘lgan ingliz tilini o‘qitish uchun yangi imkoniyatlar yaratdi. Butun dunyoda COVID-19 pandemiyasi raqamli o‘qitish vositalarini qo‘llashni tezlashtirdi. O‘qituvchilar va talabalar masofaviy ta’limga tezda moslashishga majbur bo‘ldilar, bu esa raqamli pedagogikaning ham imkoniyatlarini, ham qiyinchiliklarini yaqqol namoyon qildi. O‘zbekiston va boshqa rivojlanayotgan mamlakatlarda ushbu yangiliklar alohida ahamiyatga ega, chunki ular talabalarga xalqaro ta’lim resurslaridan keng foydalanish imkonini beradi. Shu bilan birga, infratuzilma yetishmovchiligi va raqamli savodxonlik kabi muammolarni ham keltirib chiqaradi. Ushbu maqolaning maqsadi ingliz tili o‘qitishida raqamli innovatsiyalarning rolini baholashdan iborat bo‘lib, ularning afzalliklari, cheklovlari va kelajakdagi istiqbollariga asosiy e’tibor qaratiladi.

II. USULLAR

Ushbu tadqiqot ingliz tilini o‘qitishda raqamli innovatsiyalarning rolini o‘rganish maqsadida sifatli adabiyotlar tahlili va holatga asoslangan tahlil yondashuvini qo‘llagan. Ma’lumotlar 2018-yildan 2024-yilgacha bo‘lgan davrda ilmiy maqolalar, muassasa hisobotlari va amaliy sinf tatbiqlaridan to‘plangan. Metodologik loyiha to‘rt qismdan iborat bo‘lgan:

2.1 ADABIYOTLAR SHARHI

Tegishli nashrlar Scopus, ERIC va Google Scholar kabi akademik ma’lumotlar bazalaridan olindi. Qidiruv so‘zlari orasida "ELTda raqamli innovatsiyalar", "mobil qurilmalar yordamida til o‘rganish (MALL)", "ta’limda sun’iy intellekt" va "ingliz tilini o‘qitishda o‘yinlashtirish" kabilar mavjud edi. Jami 45 ta maqola va hisobot ko‘rib chiqildi, eng dolzarb va zamonaviy 20 ta manba batafsil tahlil qilindi.

2.2 KEYS-STADI KUZATUVI

Adabiyotlar sharhi to‘ldirilishi maqsadida O‘zbekistondagi tanlangan oliy ta’lim muassasalari va til markazlarining dars amaliyotlari o‘rganib chiqildi. Ushbu muassasalar quyidagi raqamli vositalarni o‘z faoliyatiga joriy etgan:

- Ta’limni boshqarish tizimlari (Moodle, Google Classroom)
- Mobil ilovalar (Duolingo, Quizlet, Memrise)
- Sun’iy intellektga asoslangan vositalar (Grammarly, ChatGPT)
- Videokonferensiya dasturlari (Zoom, Microsoft Teams)

2.3 ISHTIROKCHILAR

Auditoriya kuzatuvi Toshkent shahridagi ikki universitetning taxminan 60 nafar bakalavriat talabasi (18-21 yoshli) va 5 nafar ingliz tili o‘qituvchisini qamrab oldi. Bundan tashqari, o‘qituvchilarning raqamli innovatsiyalarga bo‘lgan munosabatini o‘rganish maqsadida ular bilan norasmiy suhbatlar o‘tkazildi.

2.4 MA’LUMOTLAR TAHLILI

Ma’lumotlar ingliz tili o‘qitishida raqamli vositalarni joriy etishning afzalliklari, muammolari va pedagogik natijalari nuqtai nazaridan tematik tahlil qilindi. Bu innovatsiyalarning o‘quvchilar motivatsiyasiga, o‘quv materiallarining qulayligiga va o‘qituvchi samaradorligiga qanday ta’sir ko‘rsatgani alohida e’tiborga olindi.

III. NATIJALAR

Adabiyotlar tahlili, sinf kuzatuvlari va o‘qituvchilar bilan o‘tkazilgan suhbatlar ingliz tilini

o‘qitishda raqamli innovatsiyalardan foydalanishning bir qator muhim natijalarini ko‘rsatdi.

3.1 TALABALARNING ISHTIROKI VA MOTIVATSIYASI

- O‘quvchilarning 78 foizi an’anaviy darsliklarga qaraganda mobil ilovalar va o‘yin elementlari qo‘shilgan platformalardan foydalanishda o‘zlarini "ko‘proq rag‘batlangan" his qilishlarini bildirdilar.
- So‘z boyligini oshirishda Quizlet va Duolingo kabi ilovalar ayniqsa samarali ekanligi aniqlandi.
- O‘qituvchilar ilgari darslarda faol qatnashishdan o‘zini tortgan o‘quvchilar raqamli vositalar joriy etilgandan so‘ng ancha faollashganini kuzatdilar.

3.2 SHAXSIYLASHTIRILGAN TA’LIM VA FIKR-MULOHAZA

- Grammarly va ChatGPT kabi sun’iy intellektga asoslangan vositalar darhol tuzatishlar va takliflar berdi.
- Talabalarning 65 foizi o‘z sur’atida o‘rganishni qadrlaganini ta’kidladi.
- Bir talaba shunday izoh bildirdi: "Grammarly’dan foydalanganimda, men ko‘pincha takrorlagan xatolarimni angladim. Bu shaxsiy repetitor bilan shug‘ullanishga o‘xshardi."

3.3 MOSLASHUVCHANLIK VA QULAYLIK

- Talabalarning 90 foizi Google Classroom va Moodle kabi onlayn platformalar o‘quv materiallariga kirishni osonlashtirgani bilan rozi bo‘ldi.
- COVID-19 paytidagi masofaviy ta’lim raqamli platformalarga bo‘lgan ishonchni mustahkamladi.
- O‘qituvchilar raqamli baholash va nazorat tufayli ma’muriy ishlarga sarflanadigan vaqt qisqarganini ma’lum qildilar.

3.4 HAMKORLIK VA MULOQOT

- Videokonferensiya vositalari o‘quvchilar va o‘qituvchilar o‘rtasida real vaqt rejimidagi muloqotni ta’minladi.
- Hamkorlik imkoniyatlari tengdoshlar o‘rtasidagi o‘zaro aloqani rag‘batlantirdi.
- Bir o‘qituvchi shunday dedi: "Yuzma-yuz muhokamalarda tortinchoq bo‘lgan talabalar onlayn loyihalarda o‘zlariga ishonchli bo‘lib qolishdi."

3.5 QIYINCHILIKLAR VA CHEKLOVLAR

- Talabalarning 32 foizi internet ulanishida muammolar bo‘lganini ma’lum qildi.
- O‘qituvchilar raqamli savodxonlikni o‘rgatish zarurligi ustida to‘xtaldilar.
- Texnologiyaga haddan ziyod bog‘lanib qolish xavfi haqidagi fikrlar bildirildi.

IV. MUHOKAMA

Natijalar shuni ko‘rsatadiki, raqamli vositalar ingliz tili o‘qitishini sezilarli darajada takomillashtiradi. Ular o‘quvchilarning qiziqishini oshiradi, shaxsiy o‘quv yo‘nalishlarini yaratish imkonini beradi va manbalardan moslashuvchan tarzda foydalanishni ta’minlaydi. Misol uchun, o‘yinlashtirish o‘quvchilarning faolligini oshirsa, sun’iy intellekt vositalari an’anaviy usullar doim ham bera olmaydigan tezkor teskari aloqani ta’minlaydi.

An’anaviy usullar tizimli bo‘lsa-da, ko‘pincha interaktivlikdan yiroq. Raqamli vositalar tezkor qayta aloqaga ega bo‘lgan harakatchan ta’lim muhitini yaratadi, bu esa pedagogik yondashuvni o‘qituvchi markazidan o‘quvchi markaziga o‘zgartiradi. O‘qituvchilar ham sinfni yanada samarali boshqarish imkoniyatiga ega bo‘ladilar.

Biroq, muammolar hali ham mavjud. O‘qituvchilar ko‘pincha bu vositalarni ta’lim jarayoniga samarali joriy etish uchun qo‘shimcha malaka oshirishga muhtoj. Qishloq joylari va kam ta’minlangan hududlardagi o‘quvchilar internet va qurilmalar yetishmasligi sababli raqamli tengsizlikka duch kelmoqda. Bundan tashqari, sun’iy intellekt bilan bog‘liq axloqiy masalalar - jumladan, unga haddan tashqari bog‘lanib qolish, plagiat xavfi va shaxsiy ma’lumotlar maxfiyligiga oid muammolar - puxta tartibga solishni talab etadi. Bundan tashqari, texnologiyalardan teng foydalana olmaslik va cheklangan raqamli savodxonlik, ayniqsa O‘zbekiston qishloqlarida, muammoligicha qolmoqda. An’anaviy usullarni raqamli vositalar bilan uyg‘unlashtiradigan aralash ta’lim modeli eng samarali yondashuv sifatida tavsiya etiladi.

XULOSA

Ushbu tadqiqot shuni ko‘rsatadiki, raqamli innovatsiyalar ingliz tilini o‘qitish va o‘rganishni sezilarli darajada qayta shakllantirdi. Bu o‘quvchilarga ko‘proq motivatsiya, moslashuvchanlik va shaxsiy imkoniyatlar taqdim etish orqali amalga oshirildi. Mobil ilovalar, sun’iy intellektning qayta aloqa vositalari va onlayn platformalarning joriy etilishi talabalarni jalb qilishda va o‘qituvchilarni qo‘llab-quvvatlashda samarali ekanligi isbotlandi. Biroq, teng bo‘lmagan foydalanish imkoniyati, cheklangan raqamli savodxonlik va ilovalarga haddan tashqari bog‘lanib qolish kabi muammolar bu innovatsiyalarni ehtiyotkorlik bilan joriy etish zarurligini ko‘rsatmoqda. Natijada, aralash ta’lim yondashuvi eng barqaror model sifatida namoyon bo‘lmoqda.

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SUN’IY INTELLEKT TEXNOLOGIYALARIDA INNOVATSION YONDASHUVLAR VA XAVFSIZLIK MUAMMOLARI

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Annotatsiya. Maqolada raqamli transformatsiya sharoitida “raqamli refleksiya” tushunchasining nazariy-metodologik asoslari va uning zamonaviy ta’lim hamda pedagogik kadrlar tayyorlashdagi o‘rni yoritiladi. Refleksiyaning falsafiy-gnoseologik ildizlari (J. Lokk, G. V. Leybnits, I. Kant) qayta talqin qilinib, an’anaviy refleksiya bilan raqamli refleksiyaning konseptual farqlari muhit, vositalar, natija va qamrov mezonlari bo‘yicha tizimli taqqoslanadi. Tadqiqot nazariy-tahliliy, kontent-tahlil va taqqoslama yondashuvlarga tayangan. Raqamli refleksiya sub’ektning raqamli faoliyatini tahlil qilish, baholash va tartibga solish qobiliyati sifatida izohlanadi; u texnologik ko‘nikmalar bilan birga intellektual, kommunikativ va shaxsiy sifatlar integratsiyasini ta’minlaydi. Elektron ta’lim muhiti (virtual platformalar, interfaol tizimlar, sun’iy intellekt yechimlari) refleksiv ko‘nikmalarni shakllantirish uchun keng imkoniyatlar yaratishi adabiyotlar tahliliga asoslanib ko‘rsatiladi. Raqamli refleksiyaning diagnostik, prognozlovchi va tartibga soluvchi funksiyalari ochib beriladi. Asosiy xulosa shuki, raqamli refleksiya talabalarning mustaqil fikrlashi va o‘z-o‘zini boshqarish kompetensiyalarini kuchaytiradi, fanlararo integratsiya hamda o‘quv jarayoniga tizimli integratsiya esa ta’lim samaradorligini oshiradi. Amaliy tavsiyalar sifatida raqamli refleksiyani pedagogik dasturlarga kompetensiya sifatida kiritish va ilg‘or xalqaro tajribalarni mahalliy sharoitga moslashtirish taklif etiladi.

Kalit so‘zlar: *raqamli refleksiya, refleksiya, raqamli transformatsiya, elektron ta’lim, masofaviy ta’lim, pedagogik kompetensiya, diagnostika, prognoz, tartibga solish.*

XLIX. KIRISH.

Zamonaviy raqamli transformatsiya sharoitida ta’lim tizimi bilim mazmuni, pedagogik texnologiyalar va baholash mexanizmlarining qayta ko‘rib chiqilishini talab etmoqda. Ayniqsa, bo‘lajak pedagoglarning raqamli muhitda mustaqil o‘qish, o‘z faoliyatini tahlil qilish va o‘z-o‘zini boshqarish (self-regulation) kompetensiyalarini rivojlantirish dolzarb vazifaga aylandi. Mazkur jarayonda “raqamli refleksiya” tushunchasi markaziy ilmiy-kategoriyaga aylanib, an’anaviy refleksiya g‘oyalarini raqamli texnologiyalar bilan uyg‘unlashtiruvchi yangi metodologik asos sifatida namoyon bo‘lmoqda. [1] Raqamli refleksiya — bu sub’ektning raqamli ta’lim muhitida amalga oshirayotgan faoliyatini maqsadga yo‘naltirilgan holda tahlil qilish, baholash va tartibga solish qobiliyati bo‘lib, u nafaqat texnologik savodxonlikni, balki kognitiv, metakognitiv, kommunikativ hamda shaxsiy-aksiologik sifatlar integratsiyasini ham qamrab oladi.

Mavjud ilmiy manbalar ta’limda refleksiv amaliyotning samaradorligini ko‘p bor isbotlagan bo‘lsa-da, raqamli muhit sharoitida refleksiyaning mazmuni, tuzilmasi va didaktik mexanizmlari yetarli darajada operatsionallashtirilmagan[2]. Xususan, o‘qituvchi tayyorlov dasturlarida raqamli refleksiyani shakllantirishning model va mexanizmlarini aniqlash, mezon-indikatorlar tizimini ishlab chiqish, shuningdek, e-portfel, o‘quv analitikasi (learning analytics) paneli, tengdosh-baholash (peer-assessment) platformalari, sun’iy intellekt asosidagi maslahat vositalari kabi raqamli yechimlarni refleksiv siklga metodik integratsiya qilish muammolari ochiq qolmoqda. Ushbu bo‘shliq ta’lim sifatini oshirish, talabalarning mustaqil o‘qish strategiyalarini kuchaytirish va kasbiy kompetentligini rivojlantirish nuqtayi nazaridan muhim ilmiy-amaliy ahamiyat kasb etadi.[4]

Maqolaning maqsadi — raqamli refleksiyaning nazariy-metodologik asoslarini asoslash, uning zamonaviy ta’limdagi o‘rnini aniqlash va pedagogik ahamiyatini ko‘rsatish, shuningdek, elektron ta’lim muhitida (LMS, MOOC, kollaborativ platformalar) raqamli refleksiyani shakllantirishning konseptual modeli hamda baholash mezonlarini taklif etishdir.

Mazkur maqsadga erishish uchun quyidagi vazifalar belgilandi:

-“raqamli refleksiya” tushunchasini an’anaviy refleksiya bilan konseptual chegaralash va taksonomiyasini aniqlash;

-raqamli refleksiyaning tarkibiy tuzilmasini (kognitiv, metakognitiv-regulyativ, kommunikativ-media, aksiologik-motivatsion komponentlar) asoslash;

-elektron ta’lim muhitida raqamli refleksiyani shakllantirishning didaktik modeli va metodik mexanizmlarini ishlab chiqish;

raqamli refleksiyani baholash mezon-indikatorlari va diagnostika vositalarini (o‘lchov shkalalari, kuzatuv varaqalari, o‘z-hisobot anketalari, o‘quv analitikasi ko‘rsatkichlari) ishlab chiqish;

tajriba-sinov (quasi-eksperimental) tekshiruvlar orqali taklif etilgan yondashuvlarning samaradorligini baholash.

Tadqiqot obyekti — pedagogika yo‘nalishidagi talabalarning elektron ta’lim muhitida o‘quv-kasbiy faoliyati; predmeti — mazkur muhitda raqamli refleksiyani shakllantirish jarayonining mazmuni, mexanizmlari va natijalari. Tadqiqot metodlari sifatida nazariy tahlil va sintez, kontent-tahlil, taqqoslama pedagogik tahlil, dizayn-asosli tadqiqot elementlari, so‘rovnoma va ekspert baholash, o‘quv analitikasi ma’lumotlari hamda matematik-statistik qayta ishlash usullari qo‘llanildi.

Ishning ilmiy yangiligi quyidagilarda namoyon bo‘ladi:

1) raqamli refleksiya tushunchasining komponentli tuzilmasi aniqlanib, uning raqamli kompetensiya bilan o‘zaro aloqasi konseptual model darajasida asoslandi;

2) e-ta’lim muhitiga mos refleksiv sikl (maqsad qo‘yish → faoliyat → dalillash/ma’lumot to‘plash → tahlil-baholash → qayta rejalashtirish) uchun metodik mexanizmlar to‘plami taklif etildi;

3) natijalarni baholash uchun ko‘rsatkichlar tizimi (kognitiv aniqlik, metakognitiv rejalashtirish, raqamli dalillardan foydalanish sifati, kommunikativ shaffoflik, o‘z-o‘zini tartibga solish darajasi) ishlab chiqildi.

Ishning amaliy ahamiyati shundan iboratki, ishlab chiqilgan model va diagnostika vositalari o‘qituvchi tayyorlov dasturlariga integratsiya qilinib, talabalarning mustaqil o‘qish strategiyalari va o‘z-o‘zini boshqarish kompetensiyalarini sistematik ravishda rivojlantirishga xizmat qiladi. Cheklovlar sifatida tanlanma hajmining muayyan fakultet bilan chegaralanganligi, vaqt omili hamda texnik resurslar xilma-xilligining natijalarga ta’sir ehtimoli qayd etiladi..

L. METODOLOGIYA

Ko‘plab tadqiqotchilar “raqamli refleksiya” tushunchasini aniqlashda uni bir yoqlama — masalan, faqat o‘z-o‘zini baholash yoki yakka tartibdagi fikr yuritish jarayoni sifatida talqin qilishga moyil. Aslida esa refleksiv faoliyat raqamli muhitda nafaqat talaba va o‘qituvchi o‘rtasidagi muloqotda, balki talabalarning o‘zaro hamkorligida, shuningdek o‘quv vositalari (LMS, e-portfolio, o‘quv analitikasi paneli, AI-yordam, simulyatorlar) bilan interaktiv aloqada ham ro‘y beradi. Raqamli refleksiya jarayonining ishtirokchilari ko‘pincha fazo va vaqt jihatdan ajralgan bo‘ladi va jarayon maxsus didaktik tizim (qoidalar, rubrikalar, dalil talablari, fikr-mulohaza sikllari) doirasida kechadi.

Bizningcha, raqamli refleksiyaga eng obyektiv ta’rif quyidagicha: bu — sub’ektning (talabaning) raqamli ta’lim muhitida olib borayotgan o‘quv-kasbiy faoliyatini dalillarga tayangan holda tahlil qilish, baholash va tartibga solish (rejalashtirish, strategiyani almashtirish, qayta yo‘naltirish)ga qaratilgan, fazo va vaqtga indifferent (barqaror) bo‘lgan, o‘qituvchi, tengdoshlar va raqamli vositalar bilan ko‘pyoqlama interaktiv aloqalar asosida, oldindan belgilangan didaktik me’yorlar doirasida amalga oshiriladigan maqsadli jarayondir.

Chet el adabiyotlarida ushbu fenomen turli atamalar bilan ifodalanadi: e-reflection (elektron refleksiya), digital reflective practice, reflective e-portfolio, learning journal/diary, analytics-informed reflection (o‘quv analitikasi ma’lumotlari bilan boyitilgan refleksiya), AI-assisted reflection (sun’iy intellekt ko‘magidagi refleksiya), peer-feedback-driven reflection, metacognitive prompts (metakognitiv yo‘riqnomalar) va boshqalar. Terminologiyaning bunday xilma-xilligi raqamli refleksiyaning rivojlanganligidan, ta’lim jarayoniga integratsiyalashganligidan va u orqali nafaqat texnologik savodxonlik, balki kognitiv, metakognitiv-regulyativ, kommunikativ-media hamda aksiologik-motivatsion komponentlar ham shakllantirilayotganidan dalolat beradi.

Bugungi kunda dunyo miqyosida raqamli refleksiya rivojlanishining asosiy xususiyatlari quyidagilardan iborat:

-Raqamli refleksiya postindustrial bilim iqtisodiyoti sharoitida ta’lim kapitalini ko‘paytiruvchi, talabaning o‘z-o‘zini boshqarishi va kasbiy tayyorgarligini kuchaytiruvchi strategik komponentga aylanmoqda;

-Axborot texnologiyalarining keng qo‘llanilishi evaziga refleksiya jarayoni ochiq va davomli tus olmoqda: nafaqat kredit va diplom olishda, balki “umr bo‘yi ta’lim” (lifelong learning) amaliyotida e-portfolio, mikrobadj va qisqa modulli kurslar orqali refleksiv dalillarni yig‘ish va namoyish etish imkoniyati kengaymoqda;

Rivojlangan davlatlarda raqamli refleksiya ekotizimi eksportbop xizmat sifatida shakllanib, metodik paketlar, rubrikalar, LMS/LRS plaginlari va analitika panellari boshqa mamlakatlarga transfer qilinmoqda; shu bilan birga, refleksiv faoliyat shaxsiylashtirilgan (adaptive) va talabaning hayot ritmiga moslashgan vositalar orqali qo‘llab-quvvatlanmoqda;

Standartlar va interoperabilitet kuchaymoqda: LTI, xAPI, Caliper kabi standartlar yordamida LMS, e-portfolio va o‘quv analitikasi tizimlari o‘rtasida refleksiv dalillarni izchil almashish va kuzatish yo‘lga qo‘yilmoqda;

Sun’iy intellekt va learning analytics refleksiyani chuqurlashtirmoqda: AI-asosli yo‘riqnomalar (metakognitiv prompts), avtomatlashtirilgan formatif mulohazalar, vaqton-task hamda ishtirok ko‘rsatkichlari asosida dalil-markazli o‘z-o‘zini tahlil qilish madaniyati shakllanmoqda;

Baholash paradigmasi natija-markazdan jarayon-markazga siljimoqda shuningdek refleksiv yozuvlar, dalil sifati, strategiya almashtirish, qayta rejalashtirish kabi ko‘rsatkichlar rubrikalar orqali tizimli baholanmoqda;

Inklyuziya va kirish imkoniyati talablari kengaymoqda jumladan matn, audio, video, skrin-dalillar, transkript va subtitrlar kabi ko‘pkanalli formatlar universal dizayn (UDL) tamoyillari bilan uyg‘unlashib, turli ehtiyojdagi talabalarning refleksiyasini qo‘llab-quvvatlamoqda;

Ma’lumotlar etikasi va maxfiylik masalalari markazga chiqmoqda yani refleksiv ma’lumotlarni yig‘ish va qayta

ishlashda shaffoflik, rozilik, akademik halollik, AI tavsiyalarining izohlanishi (explainability) hamda plagiat/avtorskilik chegaralarini aniq belgilash talab etilmoqda.

Shubhasiz, xalqaro tajriba raqamli refleksiyani elektron ta’lim muhitiga joriy etishda qo‘llanishi mumkin va lozim. Biroq u mahalliy til, madaniy kontekst, raqamli tengsizlik, infratuzilma kabi omillarni inobatga olgan holda moslashtirilishi zarur. Bu esa oliy o‘quv yurtlari oldiga quyidagi vazifalarni qo‘yadi.

o‘quv reja va standartlarga raqamli refleksiyani alohida kompetensiya sifatida kiritish;

LMS/e-portfolio/LRS infratuzilmasini takomillashtirish;

o‘qituvchilar uchun metodik paketlar va rubrikalarni ishlab chiqish; ma’lumotlar himoyasi va akademik halollik bo‘yicha me’yoriy-huquqiy asosni boyitish;

analitika va AI-yordamni shaffof qo‘llash bo‘yicha reglament yaratish;

hamda muntazam monitoring-baholash va ilmiy tadqiqotlar orqali refleksiv amaliyotni uzluksiz rivojlantirish.

Me’yoriy-huquqiy bazadagi ayrim bo‘shliqlar va raqamli pedagogik amaliyotlarni tartibga solish mexanizmlarining to‘liq shakllanmaganiga qaramay, raqamli refleksiyaga tayangan o‘quv jarayonlari so‘nggi yillarda jadal ommalashmoqda. Buni tasdiqlovchi dalillardan biri sifatida 2024-yil avgust–sentyabr oylarida mamlakatning turli hududlarini qamrab olgan sotsiologik kuzatuv natijalarini keltirish mumkin: 18–30 yosh toifasidagi respondentlarning 22% an’anaviy faqat ma’ruza–seminarga tayangan formatga nisbatan raqamli refleksiya elementlari (e-portfolio, refleksiv kundalik, tengdosh-baholash, analitika) integratsiyalashgan kurslarni afzal ko‘rganini bildirgan. Bu ko‘rsatkich yoshlar ongida dalil-markazli o‘z-o‘zini tahlil va o‘z-o‘zini boshqarish (self-regulation)ni qo‘llab-quvvatlaydigan raqamli refleksiyaga nisbatan ijobiy munosabat shakllanib borayotganidan dalolat beradi.

Bundan tashqari, respondentlarning 37 %dan ortig‘i o‘qish jarayonida bilim dalillarini (topshiriq versiyalari, skrinlar, havolalar, vaqt-on-task loglari) yig‘ish va tartibga solish uchun kompyuter hamda internetdan muntazam foydalanishini qayd etdi. 52 % respondent o‘z-o‘zini o‘qitish va shaxsiy rivojlanish maqsadida elektron ta’lim resurslari va refleksiv yozuvlarni qo‘llaganini bildirgan; 25 % asosiy fanlarni chuqurlashtirish uchun qo‘shimcha raqamli manbalarni izlagan; 23 % esa malaka oshirish kurslarida ishtirok etish istagini ifoda etgan. Ushbu raqamlar, ayniqsa yoshlar va faol ijtimoiy qatlam orasida, raqamli refleksiya va elektron ta’lim infratuzilmasiga bo‘lgan talab ortib borayotganini ko‘rsatadi.

Shundan kelib chiqib aytish mumkinki, ta’lim xizmatlari iste’molchilari orasida kompyuterlashtirish darajasi va internetga kirish imkoniyatining kengayishi raqamli refleksiyani oliy ta’lim jarayoniga yanada chuqurroq singdirish hamda uni kelgusida keng miqyosda rivojlantirish uchun sharoit yaratadi. Raqamli refleksiyaning samaradorligini ta’minlashda texnik infratuzilma bilan bir qatorda, sifatli elektron o‘quv materiallari, metodik jihatdan tayyorlangan pedagog kadrlar, e-portfolio va o‘quv analitikasi (learning analytics) bilan jihozlangan sifatli elektron ta’lim muhiti hal qiluvchi omillardir. Shuningdek, AI-yordamli formatif fikr-mulohaza va metakognitiv yo‘riqnomalar refleksiv siklni barqarorlashtirishga xizmat qiladi.

Tadqiqot jarayonida shuningdek aniqlandiki, hozirgi vaqtda OTMlarda raqamli refleksiya amaliyotining haqiqiy holati yetarlicha mukammal o‘rganilmagan va bu yo‘nalishda keng qamrovli ilmiy tadqiqotlarga ehtiyoj mavjud. Shu bois qo‘shimcha sotsiologik so‘rovlar, kontent-tahlillar va eksperimental tekshiruvlarni o‘tkazish zarur. Tadqiqotning asosiy gipotezasi shundan iboratki: zamonaviy oliy o‘quv yurtlari raqobatbardosh ustunliklar uchun raqamli refleksiyaning ahamiyatini anglagan bo‘lsalar-da, bu jarayonni sekinlashtiruvchi ichki (metodik tayyorgarlik, baholash madaniyati, yuklama) va tashqi (infratuzilma, standartlar, me’yoriy asos) omillar mavjud.

Mazkur natijalar raqamli refleksiyani OTMlarning o‘quv rejalari va kurs dizayniga tizimli integratsiya qilish, o‘qituvchilar uchun metodik paketlar va baholash rubrikalarini kengaytirish, LMS/e-portfolio/LRS integratsiyalarini kuchaytirish hamda me’yoriy-huquqiy va standartlashtirish asoslarini boyitish zaruratini ko‘rsatadi. Shu yo‘sinda raqamli refleksiya talabalarning mustaqil fikrlashi, o‘z-o‘zini boshqarishi va kasbiy kompetensiyalarini dalil-markazli ravishda rivojlantirishning samarali mexanizmiga aylanadi..

LI. NATIJALAR.

Natijalar (raqamli refleksiya bo‘yicha moslashtirilgan xulosalar)

Hududiy qamrov va xabardorlik. Kontent-tahlil natijalari shuni ko‘rsatadiki, raqamli refleksiya elementlari (e-portfolio, refleksiv kundalik, tengdosh-baholash, analitika) nafaqat poytaxt OTMlarida, balki mintaqaviy oliy ta’lim muassasalarida ham joriy etilmoqda; faol amaliyotlar Toshkent bilan birga Samarqand, Xorazm, Buxoro, Farg‘ona, Andijon, Namangan va Nukusdagi OTMlarda ham uchraydi.

Talab dinamikasi. Rasmiy sahifalar va ochiq kurs hujjatlarida “e-portfolio”, “refleksiya”, “peer-assessment”, “learning analytics” iboralari barqaror oshib borayotgani qayd etildi (qidiruvlar: ibora + OTM qisqa nomi). Bu ta’lim ishtirokchilari ongida dalil-markazli o‘z-o‘zini tahlil va o‘z-o‘zini boshqarish kompetensiyalariga ehtiyoj kuchayayotganini bildiradi.

Yo‘nalishlar kesimidagi tafovut. Texnik yo‘nalishlardagi bakalavr kurslarida raqamli refleksiya amaliyotlari hali yetarlicha keng emas; mazkur sohalar uchun refleksiv topshiriqlar va dalil talablari didaktikasini takomillashtirish, real loyihalar va laboratoriya jarayonlari bilan bog‘lash zarur. Magistratura bosqichida e-portfolio talab qiluvchi dasturlar soni cheklangan, bu esa iqtidorli talabalarning xalqaro e’tirofga ega portfolio-dalillar jamg‘arish imkonini toraytiradi.

Platforma va jarayon dizayni. Raqamli refleksiya jarayonini muvaffaqiyatli yuritish LMS/e-portfolio/analitika bilan ishlovchi maxsus platformalar orqali samarali muloqot va refleksiv sikl (“maqsad–faoliyat–dalil–tahlil–rejalashtirish”)ni tizimli qo‘llab-quvvatlash bilan bog‘liq. Shu bois platformalarda rubrikalar, tengdosh-baholash va feedback jarayonlari uchun tayyor shablonlar muhim.

Xalqaro hamkorlik va tan olinishi. Raqamli refleksiya amaliyoti OTMlararo hamkorlik, ikki diplom dasturlari va talabalar mobilitetida e-portfolio orqali dalillarni ko‘chirish (evidence portability) imkonini kengaytiradi; bu esa eksportbop ta’lim xizmatlarini rivojlantirishda qo‘shimcha imkoniyat yaratadi.

Raqamli refleksiyaning muammolari va rivojlanish yo‘nalishlari (ekspert so‘rovi asosida). Oliy ta’limda raqamli refleksiyani rivojlantiruvchi asosiy omillarni aniqlash maqsadida ekspert so‘rovi/Delphi o‘tkazildi. So‘rov natijalari platforma/infratuzilma, o‘qituvchi metodik tayyorgarligi, baholash rubrikalari, learning analytics va AI-yordamni tartibga solish, shuningdek me’yoriy-huquqiy asoslarni kuchaytirish — ustuvor yo‘nalishlar ekani va asosiy to‘siqlar sifatida tizimlarni ishlab chiqish va qo‘llab-quvvatlash xarajatlari, texnik qo‘llab-quvvatlash yetishmasligi, hamda malakali kadrlar kamligini ko‘rsatdi.

LII. Muhokama

Tadqiqot natijalari raqamli refleksiya amaliyoti OTMlar miqyosida bosqichma-bosqich kengayayotganini ko‘rsatdi. Kontent-tahlil raqamli refleksiya elementlari (refleksiv topshiriqlar, e-portfolio, tengdosh-baholash, learning analytics va AI-yordam) poytaxtdan tashqari mintaqaviy OTMlarda ham joriy etilayotganini aniqladi; bu holat raqamli refleksiya ning “elit texnologiya” emas, balki ommaviylashayotgan didaktik mexanizmga aylanayotganini bildiradi.[5] Yoshlar orasida raqamli ekotizimdan muntazam foydalanishning o‘sishi (o‘z-o‘zini o‘qitish, shaxsiy rivoj, qo‘shimcha manbalar izlash) raqamli refleksiya uchun zarur bo‘lgan dalil-markazli o‘qish madaniyatini qo‘llab-quvvatlaydi. Shu bilan birga, texnik yo‘nalishlarda raqamli refleksiya integratsiyasi pastroq: laboratoriya va loyiha faoliyati bilan bog‘lanmagan refleksiv topshiriqlar amaliy dalillar tanqisligiga olib keladi.[6] Magistraturadagi raqamli refleksiya talablari ham cheklangan; natijada talaba e-portfolio orqali xalqaro “ko‘chiriladigan dalillar” (evidence portability) to‘plash imkonidan to‘liq foydalana olmaydi.

Platforma va jarayon dizayni nuqtayi nazaridan raqamli refleksiyaning samarasi rubrikalar, formatif fikr-mulohaza kanallari, dalil talablari, va analitika shaffofligi bilan bevosita bog‘liq. Maxsus LMS/e-portfolio/LRS integratsiyasi bo‘lmagan holatlarda raqamli refleksiya ko ‘proq deklarativ darajada qoladi; tizimli sikl (maqsad → faoliyat → dalil → tahlil-baholash → qayta rejalashtirish) uzluksiz ishlamaydi.[7] Xalqaro hamkorlik va ikki diplom dasturlari kontekstida esa raqamli refleksiya talabalarni natija-markazli “CV”dan jarayon-markazli, dalil-boy “e-portfolio”ga o‘tishga undaydi; bu esa eksportbop ta’lim xizmatlari uchun ham imkoniyat yaratadi..

Xulosa

Raqamli refleksiya amaliyoti OTMlar miqyosida bosqichma-bosqich ommaviylashib bormoqda: poytaxt bilan bir qatorda mintaqaviy universitetlarda ham e-portfolio, refleksiv kundalik, tengdosh-baholash va learning analytics elementlari joriy etilmoqda. Rasmiy sahifalar va kurs hujjatlarida tegishli atamalar chastotasining ortib borishi ta’lim ishtirokchilari ongida dalil-markazli o‘z-o‘zini tahlil va o‘z-o‘zini boshqarish kompetensiyalariga ehtiyoj kuchayayotganini ko‘rsatadi. Shu bilan birga, yo‘nalishlar kesimida tafovut saqlanib turibdi: texnik sohalarda refleksiv topshiriqlar laboratoriya va loyiha faoliyati bilan yetarlicha bog‘lanmagani sabab amaliy dalillar tanqisligi kuzatiladi; magistratura bosqichida e-portfolio talablari ham cheklanganligi natijasida talabalarning xalqaro miqyosda “ko‘chiriladigan dalillar” (evidence portability) jamg‘arish imkoniyati torayadi. Raqamli refleksiyaning samaradorligi asosan platforma va jarayon dizayniga—LMS/e-portfolio/LRS integratsiyasi, shaffof rubrikalar, formatif fikr-mulohaza kanallari, dalil talablari va analitika ochiqligiga—bog‘liq. Xalqaro hamkorlik va ikki diplom dasturlari kontekstida e-portfolio natija-markazli “CV”dan jarayon-markazli, dalil-boy taqdimotga o‘tishni rag‘batlantiradi va eksportbop ta’lim xizmatlarini kengaytiradi.

Biroq asosiy to‘siqlar saqlanib qolmoqda: platforma va infratuzilma xarajatlari, texnik qo‘llab-quvvatlashning yetishmasligi hamda malakali kadrlar taqchilligi. Shuningdek, learning analytics va AI-yordamdan foydalanish bo‘yicha me’yoriy-huquqiy asoslarni kuchaytirish zarur. Ushbu holatdan kelib chiqib, milliy darajada yagona refleksiya rubrikalari va shablonlarini joriy etish, texnik yo‘nalishlarda refleksiv topshiriqlarni real loyiha/laboratoriya dalillari bilan majburan bog‘lash, magistraturada e-portfolio’ni majburiy komponent sifatida belgilash hamda LMS–e-portfolio–LRS integratsiyasini kuchaytirish maqsadga muvofiqdir. Tadqiqot cheklovlari kontent-tahlil va ekspert so‘rovlariga tayanishi bilan bog‘liq bo‘lib, keyingi bosqichlarda kvazi-eksperimental tadqiqotlar, cost–benefit tahlillar va evidence portability’ni mehnat bozoridagi natijalar bilan bog‘lovchi ko‘rsatkichlarni kengroq o‘rganish lozim..

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TO THE QUESTION OF DETERMINING THE PROSPECTS FOR USING THE CAPABILITIES OF MODERN VIRTUAL TECHNOLOGIES IN THE INFORMATION SYSTEM OF SOCIETY

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***Abstract*—**The growth of research interest in the field of natural science, social and philosophical knowledge towards the problem of virtualization of society occurred at the end of the last century.

At this time, the term itself was introduced into scientific circulation, a new direction in philosophy emerged - virtualistics, within the framework of which virtual processes were studied. The topic of virtuality is beginning to be actively discussed in various fields of science.

Social cognition records the increase in the scale of virtualization of society. A number of theorists note the emerging contradiction between the rapidly growing processes of virtualization and their scientific understanding.

The modern era is characterized by the rapid development of computer technology and computer technology. The development of information technology has brought to the forefront a specifically new form of transmission, storage and reproduction of data, which is associated with the use of electronic technologies for the virtualization of reality.

The article analyzes the prospects for using the capabilities of modern virtual technologies in the information system of society, the strategic importance of socio-philosophical evaluation of indicators of virtual reality manifestation, the direction of research on virtuality, the impact of virtual reality on humanity and its significance in the organization and regulation of human life.

Keywords **-** information society, Internet, virtual reality, digital technologies, transformation, social institution, e-government

I.INTRODUCTION

In the system of the world information society, the effective use of the possibilities of modern virtual technologies is becoming more and more important.

This topic has already created virtual reality - beyond the boundaries of the field of cybernetics, and has become an object of research in fields such as social philosophy, psychology and culture.

Today, the process of wide implementation of information and communication technologies in world practice is also characterized by the virtualization of human activity. Because, as stated by M.Kastels, one of the founders of the information society, "networked structures form the basis of the modern world." [1].

The information explosion at the end of the 20th century - the 21st century is connected with new information and communication technologies, which in turn caused the formation of a new virtual reality, a new space where a person can exist. Among the technologies of virtual data transmission, its advantage is that the Internet not only transmits information, but also serves as a tool for interpersonal, group, and individual communication, and it continues to develop in parallel with the process of information collection, storage, transmission, and protection.

These, in turn, create the need to solve problems at various levels in the socialpolitical, spiritual-cultural life of the society, education and training system.

We believe that the modern age is an informational age that creates a global media environment based on high and digital technologies, which is reflected in every aspect of our lives. As a result, the widespread use of digital economy and management methods based on it in practice has become one of the main factors in the development of the world economy. We believe that the modern age is an information age that creates a global media environment based on high and digital technologies, which is reflected in every aspect of our lives.

II.WHAT DOES VIRTUAL REALITY IMITATE?

It can be known from the researches that the problem of virtuality was first of all attempted to be based on a scientific theoretical basis in the studies of postmodernists at the end of the 20th century, to characterize the conflict between scientific and technical development and culture.

On the other hand, the expansion of the scope of this problem is related to the development of the theory of information society, according to which virtuality is defined as the main and decisive feature of modernity. Different directions of theoretical research of virtuality have been defined. On the basis of such a classification, two ontologies were defined: the study of reality and virtuality according to the ratio of concepts. Thus, three

directions were defined. First, the modernity of this phenomenon of virtuality and its man-made nature are studied separately - theories of virtual reality, virtualization, as well as postmodernist theories within this topic. A common feature of such studies is the contrast between virtuality and reality. Second, this approach has become a rather broad and well-described philosophical tradition.

Virtual reality is reality. The concept of "virtual" mass media is often used in the sense of "invented", "does not exist in reality". However, in the scientific discourse, "virtuality" has begun to be accepted as a type of reality. "Virtual reality, which is being talked about a lot these days, is not just another reality that we step into from time to time, but the reality that we actually live in.

In the early stages of the term virtual reality, panorama was understood. Panorama is Greek for field of vision. There are different forms of panoramas, such as drawn, shaped, photographed and video-film types. In IT, a panorama is a 360-degree view. The impact of virtual reality on humanity is clearly manifested in organizing and regulating human life, creating a new form of communication between people, increasing the positive impact of the main spheres of society's life on the spheres of politics, economy, art and tourism, etc.

Virtuality is an object or situation that does not exist in reality, does not exist in reality, but can occur under certain conditions. In virtuality, these conditions are implemented in different approaches. Ontologically speaking, we can learn that virtuality means a certain potential state of being, the existence of a certain active principle in it, a tendency to the occurrence of certain events or situations under certain conditions. With the help of modern technical means, we can even dive deeper into virtual reality, in which we as a subject cannot separate the things and events of the real and virtual world from each other. Because this world affects a person directly through his emotions.

What VR imitates Virtual reality (VR, English virtual reality, VR, artificial reality) is a world created by technical means, transmitted to a person through his sensations: sight, hearing, touch and others. virtual reality?

Virtual reality simulates both exposure and responses to exposure.

To create a convincing set of sensations of reality, a computer synthesis of the properties and reactions of virtual reality is performed in real time.

Virtual reality objects usually behave close to the behavior of similar objects of material reality.

The user can influence these objects in accordance with the real laws of physics (gravity, water properties, collision with objects, reflection, etc.).

However, often for entertainment purposes, users of virtual worlds are allowed more than is possible in real life (for example: fly, create any objects, etc.).

Virtual reality should not be confused with augmented reality.

Their fundamental difference is that virtual reality constructs a new artificial world, while augmented reality only introduces individual artificial elements into the perception of the real world.

Technical tasks that are solved when providing immersion in virtual reality: *Image Broadcast ○ VR Headsets ○ MotionParallax3D Displays *Virtual retinal monitor *Sound broadcast *Simulated tactile sensations ○ Leap Motion ○ Gloves ○ Controllers *Tracking ○ Optical ○ Ultrasonic STRUCTURING OF VR

Although there is a classification to define a specific type of "reality", there is also a classification by types within the concept of virtual reality [3] Passive virtual reality - an autonomous graphic image and its sound accompaniment, not controlled by a person. Exploratory virtual reality - the ability to select options for image and sound scenarios provided to users in a limited number.

Interactive virtual reality (interactive virtual reality) is a virtual environment that the user can control and manipulate according to the laws of the synthesized world using special devices with the tracking function.

Tracking in virtual reality is a special technology that underlies human interaction with the virtual world.

It is aimed at accurately determining the coordinates and position of a real object (for example, a hand, head, or device) in a virtual environment using three coordinates (x, y, z) of its location and three angles (a, b, g) that specify its orientation in space.

III.APPLICATIONS OF VIRTUAL REALITY

Virtual reality is becoming more and more popular.

Despite the fact that the initial impetus for the development of VR was received from the gaming industry, in recent years VR has found its way into areas such as medicine, military affairs and astronautics.[4] Virtual reality differs from objective reality, including our everyday life, because it is a specific state of consciousness. Similarly, virtual reality technologies are researched in the system of philosophy, psychology, aesthetics and social and humanitarian sciences in general. From this point of view, now it is of urgent importance to research virtual reality technologies, to determine the criteria of their application, their role in knowledge and practical activities, their relationship with the category of probability, the nature of virtuality in general with the properties of the universe and existence. According to B.V.Markov, telecommunications technologies enable democratization at the transnational level.

A unique definition of virtual reality is given in S.S. Khoruzhii's article: "Virtual reality, virtual events always have the characteristic of partially realized and relative existence, and are characterized by the lack or non-existence of one or another event of empirical reality". The fundamental research on the phenomenon of virtualization is the monograph "Virtualization of society" by D.V. Ivanov. It explains the logic of virtual reality as replacing real objects and actions with images -simulations. The author distinguishes three main characteristics of virtual reality: immaterial effect (what is depicted creates the effect of existing objects); conditionality of parameters (objects are artificial and changeable); ephemerality (freedom of entry/exit, i.e. allowing for re-existence in case

of interruptions). Also, the author offers solutions to several problems in the work.

IV.CONCLUSION AND DISCUSSIONS

First, in order to apply the dichotomy "real/virtual", it is necessary to observe and research the genesis of social reality. Secondly, in order to create a model of social changes such as "from reality to virtuality", it is necessary to generalize various empirical phenomena. Secondly, social changes such as "from reality to virtuality" can provide a solution to this problem as a result of research on the processes that took place in the 20th21st centuries and formed the social core of the proposed concepts - virtualization can provide an example and a single principle of social changes. In order to create a model, it is necessary to generalize various empirical phenomena.

Thirdly, in order to determine the theoretical status of the concept of virtualization, it is necessary to compare it with the models of society transformation used in the modern socio-humanitarian field. So, we can say that the ontological nature of virtual reality and virtualization mechanisms is still in the process of understanding and understanding in the modern scientific world. The main part of the research is carried out within the framework of electronic virtual reality, and when the researchers talk about this process, i.e., the new view of the transformation of society, about its "virtualization", they mainly mean the virtualization related to the space of the Internet network.

Today, we are witnessing that the virtual space is increasingly covering the human socio-cultural sphere and how true the above scientific hypothesis is. On the one hand, technical support creates the necessary conditions for socio-cultural activities and provides the necessary weapons, on the other hand, the availability of such weapons to everyone does not leave the need to turn to experts in the field. For example, opening a page of an event on a social network can certainly arouse great interest in the Internet audience. But on the other hand, the virtual world also attracts those who are eager to attend the event in reality. Because it is possible to observe every event without going, without spending financial, emotional and physical effort. According to F. Hammit, virtual reality is "a direction created on the basis of a "friendly" functional-interactive interface for human action in the world of electronic information.

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МЕЖДУНАРОДНЫЙ ОПЫТ ФОРМИРОВАНИЯ МЕДИАГРАМОТНОСТИ В КОНТЕКСТЕ ПОДГОТОВКИ БИБЛИОТЕЧНЫХ СПЕЦИАЛИСТОВ

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Аннотация: Статья посвящена анализу зарубежного опыта формирования медийной и информационной грамотности средствами библиотек. Рассмотрены примеры Австралии, Финляндии, Франции и США, где библиотеки активно участвуют в образовательных и просветительских программах, разрабатывают специальные курсы и проекты для разных возрастных групп. Особое внимание уделено роли библиотек как центров общественного доступа к знаниям, а также как площадок для формирования навыков работы с цифровыми ресурсами и медиаконтентом. Метод исследования основан на сравнительном анализе, позволившем выявить ключевые тенденции и успешные практики в сфере медиаобразования. Установлено, что библиотеки выступают важным посредником между образовательными структурами, государственными институтами и обществом, способствуя развитию критического мышления, цифровых компетенций и культуры ответственного потребления информации. Сделан вывод о необходимости адаптации зарубежного опыта для условий Узбекистана, создания комплексных программ и разработки национальной стратегии МИГ с учетом локальных особенностей.

Ключевые слова: медийная грамотность, информационная грамотность, публичные библиотеки, цифровые компетенции, международный опыт.

I. Введение

Современное информационное общество переживает стремительные трансформации под воздействием цифровых технологий и медиа, что делает вопросы медийной и информационной грамотности особенно значимыми. Активное проникновение медиа во все сферы человеческой деятельности — от образования до культуры и социальной жизни — требует от граждан новых навыков восприятия, анализа, создания и распространения информации. Эти изменения затрагивают не только отдельные социальные группы, но и влияют на деятельность ключевых общественных институтов, в частности, библиотек.

Публичные библиотеки, как универсальные и доступные центры знаний, начинают играть важную роль не только в обеспечении информационного доступа, но и в формировании критического мышления и медиаграмотности у разных категорий пользователей. В этой связи особенно актуальным становится изучение зарубежного опыта в области реализации библиотечных программ, направленных на развитие медиа- и информационной культуры населения.

Настоящее исследование посвящено анализу зарубежных практик — прежде всего Австралии, Финляндии, Франции и США — по формированию медийной и информационной грамотности средствами публичных библиотек. Особое внимание уделяется стратегиям и программам, реализуемым в этих странах, а также их вкладу в социализацию, обучение и цифровое включение различных слоев общества.

II. Анализ исследований и публикации

В исследовании профессора Б. Ганиевой и других авторов подчеркивается, что развитие библиотечного сектора тесно связано с развитием информационных технологий и процессами хранения и представления научных результатов. Библиотеки служат не только центрами сбора и распространения информации, но и играют важнейшую роль в проведении научных исследований и сохранении культурного наследия. Научные исследования в области библиотековедения и информатики охватывают широкий спектр направлений [1,2]. Проблема формирования медийной и информационной грамотности (МИГ) на протяжении последних десятилетий активно исследуется в рамках информационной науки, педагогики, библиотековедения и медиапедагогики. В условиях цифровизации общества понятия «медийная грамотность» и «информационная грамотность» всё чаще рассматриваются в совокупности, как единое целое — медийно-информационная грамотность,

термин, предложенный ЮНЕСКО и получивший широкое распространение в международной научной среде.

Согласно определению ЮНЕСКО, МИГ включает в себя способность получать, анализировать, критически оценивать и создавать информацию в различных формах и через разные каналы. Эти навыки рассматриваются как основа активного гражданства, участия в демократических процессах и обеспечения устойчивого развития общества [3].

Как подчеркнули Ирландские философии УилямКрайст и У. Джеймс Поттер, что библиотеки, особенно публичные, играют важнейшую роль в продвижении медиа- и информационной грамотности [4]. Кроме того, американский ученый и педагог, работающий в области медиаобразования Рене Хоббс считает, что библиотеки обладают уникальным потенциалом для интеграции МИГ в общественное пространство благодаря открытому доступу к информации и возможности организации обучающих мероприятий для всех категорий населения [5].

Страной-лидером в сфере медиа образования является Австралия, где с 1990 года медиа образование школьников – обязательная составляющая учебного процесса. Формирование медиа культуры происходит или путем изучения интегрированных предметов (английский язык, искусство, технологии), или через внедрение специальных программ в старших классах («MediaStudies» и другие). К процессу активно приобщаются как школьные библиотеки, так и учреждения высшего образования. Как отмечает в своей статье Н. Усманова и Б. Ганиева в Университете Маккуори (MacquarieUniversity) в Сиднее студенты могут получить степень «бакалавр искусств» (BachelorofArts) с возможностью дальнейшего продолжения обучения, а также изучения комбинированных курсов. Развитием медиа образования в Австралии занимается Австралийское управление по вопросам коммуникации и средств массовой информации (ACMA) [6]. Этот правительственный орган отвечает за обеспечение работы средств массовой информации и коммуникации для всех австралийцев. Управление контролирует и регулирует четыре сферы: телекоммуникации, радиовещание, радиосвязь и Интернет [7]. Кроме того, в Австралии в настоящее время реализуется программа ALIA (AustralianLibraryand Information Association), направленная на поддержку библиотек в деле цифрового образования населения [8].

Большой опыт по формированию медиа грамотности населения имеет Финляндия. Она была одной из первых европейских стран, которая внесла медиа образование в школьный учебный план. Изменения в младшей средней школе состоялись в 1970 году, а в средней старшей школе – в 1977 году. Для распространения медиа образования в Финляндии создана мощная нормативно-правовая база. Это правительственные и национальные программы, Стратегия знаний для общества, План развития образования и исследований на 2007-2012 годы, Концепция медиа образования, которая объединяет различные общественные секторы (образовательную систему, культурный сектор, молодежь, СМИ, потребителей информации, сферу здравоохранения и т. д.). Согласно стандартам соответствия, медиа и информационная грамотность в Финляндии рассматриваются не только как овладение ИКТ-компетенциями, творчество, критическое мышление и самообразование, но и как важная общественная компетенция, формированием которой нужно заниматься еще с раннего детства.

Финляндия – одна из немногих стран мира, которая имеет правительственный орган медиа образования. Вопросами формирования медийных навыков, создания безопасной медиа среды занимается Национальный аудиовизуальный институт (KAVI) и его отдел медиа образования и аудиовизуальных медиа (MEKU). Сегодня формированием медиа культуры жителей Финляндии занимается большое количество организаций и учреждений. Кроме школ, медиа образование заняло весомое место в работе с молодежью, в библиотечном обслуживании, в начальном воспитании детей. Важная роль в этом процессе отводится также и неправительственным организациям. Так, Финское общество медиа образования – организация, имеющая целью проведение многопрофильных исследований и практик медиа образования. Участие в деятельности общества принимают учителя, работники детской и молодежной сферы, библиотекари, воспитатели, представители средств массовой информации и культуры, исследователи и студенты [9].

Финляндия имеет разветвленную сеть библиотек с высоким уровнем посещаемости, эффективным использованием технологий и информационных сетей. По данным Министерства образования и культуры, по состоянию на 2018 год в Финляндии действовало 854 публичных библиотек. Роль библиотек Финляндии в области медиа образования определяется пятью основными направлениями деятельности, а именно: поддержкой информационной грамотности, медиа грамотности, игровой грамотности, навыков работы с социальными медиа и знанием авторских прав. Стоит отметить, что медиа образование детей и молодежи является важной частью ежедневной работы библиотек. Библиотекари предоставляют посетителям рекомендации по поиску и управлению информацией, работе с веб-сервисами. Они также проводят игровые вечера для детей и молодежи, а также учебные ИТ-курсы [10].

Во Франции действует программа CLEMI (Centrepourl'ÉducationauxMédiaset à l'Information), где библиотеки взаимодействуют с образовательными учреждениями в рамках медиапедагогических инициатив [11]. В то время в США, согласно исследованиям Американской библиотечной ассоциации (ALA), библиотеки активно включаются в обучение населения цифровой и информационной

грамотности через локальные инициативы и партнёрские проекты [12].

На постсоветском пространстве проблема МИГ также получает научное освещение. В частности, в работах В.В. Гридина, Е.С. Полат, А.В. Федорова рассматриваются теоретические и методические аспекты формирования медийной культуры в образовательной среде и в деятельности библиотек. Также анализируются подходы к подготовке библиотечных специалистов к работе в условиях цифровой трансформации.

В Узбекистане вопросы медийной и информационной грамотности становится объектом научно-практического анализа. Однако ряд документов, включая Стратегию действий по пяти приоритетным направлениям развития Республики Узбекистан, Пять инициатив Президента и Концепцию развития системы народного образования, подчёркивают важность цифровой трансформации образования и формирования у молодёжи критического мышления. Современные исследования в области библиотечного дела в Узбекистане также указывают на необходимость интеграции МИГ в деятельность публичных библиотек [13].

Таким образом, анализ литературных источников свидетельствует о высокой значимости формирования медийной и информационной грамотности как на глобальном уровне, так и в контексте национального развития. Зарубежный опыт, в частности библиотечные практики Австралии, Финляндии, Франции и США, представляет собой ценный ресурс для адаптации и внедрения в Узбекистане, с учётом местных социально-культурных и образовательных условий.

III.Методологический подход исследования

В настоящем исследовании применён сравнительно-сопоставительный метод, который позволил проанализировать зарубежный опыт формирования медийной и информационной грамотности в образовательной и библиотечной сферах. Выбор данного подхода обусловлен необходимостью выявления не только общих тенденций в развитии медиаграмотности, но и специфических особенностей её внедрения в различных странах. Сравнительный анализ обеспечивает возможность объективнойоценки степени институциональной поддержки,масштабов практического применения и эффективности реализуемых моделей, а также определения тех элементов зарубежного опыта, которые могут быть адаптированы и использованы в национальной образовательной и библиотечной практике Узбекистана.

Страна	Год внедрения медиа образования	Ключевые программы/организации	Роль библиотек	Особенности
Австралия	1990 – обязательный предмет	ACMA, ALIA , Media studies	Поддержка цифрового образования населения	Медиаобразование интегрировано в школьные предметы и вузы
Финляндия	1970 – младшая школа 1977 – старшая школа	KAVI, MEKU, «Стратегия знания»	Обучение в ИКТ, медиаграмотностью, работа с молодежью	Сильная нормативная база, массовое участие общества
Франция	1983 – созданные CLEMI	CLEMI (Centre pour l’Education aux Medias et a’ l’Information)	Сотрудничество с образовательными учреждениями	Фокус на медиапедагогике и критическое мышления
США	Активизация через ALA	ALA (American Library Association)	Инициатива цифровой и информационной грамотности	Партнерства библиотеки и сообщества
Узбекистан	2000 – начало обсуждение в научном дискурсе	Ассоциация библиотек, университетские проекты	Первый проекты по МИГ в вузах и публичных библиотеках	Опыт заимствуется у зарубежных стран

Таблица № 1. Сравнительный анализ зарубежного опыта по формирования МИГ

Анализ представленных данных позволяет сделать вывод о том, что во всех рассмотренных странах формирование медийной и информационной грамотности рассматривается как стратегическая задача образовательной политики и библиотечной практики. При этом характерной особенностью Финляндии и Франции является государственная институционализация

медиаграмотности, тогда как в США и Австралии ключевая роль принадлежит профессиональным сообществам и неправительственным организациям. Для Узбекистана важным является использование этого опыта как методологической основы, что открывает возможности для разработки национальной модели, сочетающей государственные инициативы и профессиональные практики.

IV. Результаты исследования

В ходе сравнительного исследования зарубежного опыта (Австралия, Финляндия, Франция, США) было выявлено, что:

- медиаграмотность в этих странах имеет институциональную поддержку на государственном уровне;
- библиотеки активно вовлечены в реализацию образовательных программ, способствуя развитию критического мышления и цифровых навыков;
- каждая страна имеет уникальные модели (например, CLEMI во Франции или ACMA в Австралии), которые можно адаптировать к местным условиям.

Вместе с тем анализ ситуации в Узбекистане показывает, что формирование медийной и информационной грамотности находится на стадии становления. Первые шаги связаны с внедрением медиапедагогических подходов в высших учебных заведениях и публичных библиотеках, что создаёт основу для дальнейшего развития национальной стратегии.

Таким образом, полученные результаты подтверждают необходимость комплексного подхода: сочетания государственной политики, образовательных инициатив и активной роли библиотек.

V. Заключение и практические рекомендации

Проведённый сравнительный анализ зарубежного опыта (Австралия, Финляндия, Франция, США) показал, что формирование медийной и информационной грамотности (МИГ) в современных условиях рассматривается как стратегический приоритет образовательной и культурной политики. Особая роль при этом отводится библиотекам, которые выполняют функцию посредника между системой образования и обществом, способствуя развитию цифровых компетенций, критического мышления и медиакультуры.

В зарубежной практике чётко прослеживается тенденция к интеграции МИГ в национальные образовательные стандарты и программы, а также активное межсекторальное взаимодействие библиотек с образовательными учреждениями, неправительственными организациями и государственными структурами. Для Узбекистана характерен этап активного становления институциональной базы медиаграмотности, при этом библиотеки постепенно начинают выполнять функцию центров просвещения в данной сфере. Однако выявляется необходимость адаптации лучших зарубежных практик с учётом национальных социально-культурных особенностей.

На основание проведенного анализа представляются целесообразным сформулировать следующие рекомендации:

1. Разработать национальную стратегию по формированию медийной и информационной грамотности, где библиотеки выступят в качестве ключевых факторов данного процесса.

2. Интегрировать основы медиаграмотности в образовательные программы высших учебных заведений, особенно в подготовку будущих библиотечно-информационных специалистов.

3. Организовать систему повышения квалификации для библиотечных работников, направленную на развитие цифровых и педагогических компетенций в области МИГ.

4. Активизировать партнёрские проекты между библиотеками, образовательными организациями, средствами массовой информации и общественными объединениями.

5. Использовать современные мультимедийные форматы (инфографика, цифровые платформы, онлайн-курсы) как инструменты популяризации медиаграмотности среди различных возрастных и социальных групп.

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TA’LIM TIZIMIDA RAQAMLI INNOVATSIYALAR

TATU(AKTSI) dotsenti
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Annotatsiya: Mazkur maqola ta’lim tizimida raqamli innovatsiyalarni joriy etish jarayonini o‘rganishga bag‘ishlangan. Unda raqamli texnologiyalarning o‘quv jarayoniga ta’siri, ta’lim sifatini oshirishdagi o‘rni, samaradorlikni ta’minlash hamda o‘qituvchi va talabalarga yaratadigan yangi imkoniyatlari yoritilgan. Shuningdek, maqolada raqamli transformatsiya jarayonining mohiyati, asosiy tamoyillari, afzallik va muammolari tahlil qilingan. Tadqiqotda onlayn ta’limning rivojlanishi, LMS va “Kundalik.com [3]” kabi platformalarning joriy etilishi, ta’limning kelajagi va istiqboldagi raqamli yechimlar haqida xulosalar keltirilgan.

Kalit so‘zlar: raqamli transformatsiya, ta’lim tizimi, onlayn ta’lim, raqamli texnologiyalar, ta’lim jarayoni, innovatsiyalar, raqamli platformalar, elektron darsliklar, ta’lim resurslari, tendensiyalar.

Аннотация: Данная статья посвящена изучению процесса внедрения цифровых инноваций в систему образования. Рассматривается влияние цифровых технологий на учебный процесс, их роль в повышении качества образования, обеспечении эффективности и создании новых возможностей для преподавателей и студентов. В работе проанализирована сущность и основные принципы цифровой трансформации, а также её преимущества и проблемы. В исследовании приведены выводы о развитии онлайн-образования, внедрении LMS-систем и платформы «Kundalik.com [3]», а также перспективах цифровых решений в будущем образовании.

Ключевые слова: цифровая трансформация, система образования, онлайн-образование, цифровые технологии, образовательный процесс, инновации, цифровые платформы, электронные учебники, образовательные ресурсы, тенденции

Abstract: This article is devoted to the study of the implementation of digital innovations in the education system. It examines the impact of digital technologies on the learning process, their role in improving education quality, enhancing efficiency, and creating new opportunities for teachers and students. The paper analyzes the essence and key principles of digital transformation, as well as its advantages and challenges. The study provides insights into the development of online education, the introduction of LMS platforms and “Kundalik.com [3],” and the future prospects of digital solutions in education.

Keywords: digital transformation, education system, online learning, digital technologies, educational process, innovations, digital platforms, e-textbooks, educational resources, trends

Bugungi globallashuv davrida inson hayotining deyarli barcha sohalarida raqamli texnologiyalar keng joriy qilinmoqda. Jamiyat rivojida ta’lim tizimi eng muhim ustuvor yo‘nalishlardan biri hisoblanadi, chunki bilimli va malakali avlodni tayyorlash har bir davlatning kelajagini belgilaydi. An’anaviy ta’lim usullari ko‘plab foydali jihatlarga ega bo‘lsa-da, bugungi axborot oqimlari shiddatini hisobga olganda ular yetarli emas. O‘quvchilar tezkor ma’lumot olish, interaktiv tarzda bilimlarni o‘zlashtirish va mustaqil izlanish imkoniyatiga intilmoqda. Shu bois ta’lim tizimida raqamli innovatsiyalarni joriy etish zaruriyati tobora kuchayib bormoqda. Raqamli texnologiyalar ta’lim sifatini oshirish, ta’lim jarayonini shaxsiylashtirish, resurslardan samarali foydalanish va o‘qituvchi–o‘quvchi–ota-ona o‘rtasida samarali hamkorlikni ta’minlash imkonini beradi. Bu esa zamonaviy o‘quv tizimining asosiy talablaridan biri sanaladi.

Tadqiqot metodologiyasi

Mazkur tadqiqotda quyidagi usullar qo‘llanildi:

Nazariy tahlil – raqamli ta’lim bo‘yicha mavjud ilmiy adabiyotlar, xalqaro tashkilotlar (UNESCO, OECD) hamda rasmiy davlat hujjatlari o‘rganildi va tahlil qilindi.

Taqqoslash metodi – Janubiy Koreya, Finlyandiya va AQShdagi raqamli ta’lim tajribalari O‘zbekiston ta’lim tizimi bilan solishtirildi.

Statistik ma’lumotlarni tahlil qilish – “Kundalik.com”, ZiyoNET va LMS platformalariga oid foydalanuvchilar soni va qamrov ko‘rsatkichlari jadval asosida tahlil qilindi.

Kuzatuv va umumlashtirish – raqamli innovatsiyalarning afzalliklari va muammolari kuzatuv asosida aniqlanib, umumiy xulosalar chiqarildi.

Natijada, tadqiqot sifat jihatidan deskriptiv (tasviriy) bo‘lib, ta’lim tizimidagi mavjud raqamli yechimlarning imkoniyatlari va cheklovlari tahlil qilindi.

Asosiy qism

1. Ta’limdagi global raqamli tendensiyalar

So‘nggi yillarda dunyo ta’limida raqamli transformatsiya jarayoni tez sur’atlar bilan rivojlanmoqda. Masalan, Janubiy Koreya [9] maktablari 2011-yildan boshlab bosqichma-bosqich elektron darsliklar tizimiga o‘tdi. Finlyandiya esa “raqamli pedagogika” konsepsiyasini ishlab chiqib, o‘quvchilarning shaxsiy qobiliyatlariga moslashgan ta’lim dasturlarini yaratmoqda. AQShda esa Coursera [7], Udemy, EdX [8] kabi massiv ochiq onlayn kurslar (MOOC) talabalarga dunyoning eng yaxshi universitetlari darslarini tinglash imkonini /berdi.

Bu tajribalar shuni ko‘rsatadiki, raqamli texnologiyalar nafaqat ta’lim jarayonini qulaylashtiradi,

balki ta’limning ochiqligini, sifatini va teng imkoniyatlarini ta’minlaydi.

2. O‘zbekiston tajribasi: milliy platformalar va innovatsiyalar

O‘zbekistonda ham oxirgi yillarda ta’lim tizimining raqamlashtirilishi yo‘lida sezilarli ishlar qilinmoqda. Xususan:

“Kundalik.com [3]” – maktab ta’limida o‘quvchilarning baholari, dars jadvali, uy vazifalari va davomatini onlayn kuzatish imkonini beradi. Bu ota-onalarning farzand ta’limiga yanada faol jalb etilishiga yordam berdi.

ZiyoNET [4] – elektron kutubxona, darsliklar, ilmiy maqolalar va o‘quv materiallarini o‘z ichiga olgan yagona ta’lim portali.

OTMlarda LMS tizimlari – Moodle, Google Classroom va Canvas platformalari orqali masofaviy ta’lim kurslari tashkil etilmoqda.

Elektron darsliklar va video-darslar – darslarni interaktiv tarzda o‘zlashtirish imkonini bermoqda.

Yo‘nalish	2020-yil	2024-yil
Maktablarning internetga ulangan qismi	65%	95%
“Kundalik.com” foydalanuvchilari	4 mln	8 mln+
ZiyoNET elektron kutubxonasi foydalanuvchilari	1,2 mln	3,5 mln
LMS platformalaridan foydalanuvchi OTMlar	15 ta	60+ ta

1-jadval. O‘zbekistonda ta’limda raqamli texnologiyalarni joriy etish (qisqa ko‘rsatkichlar)

3. Raqamli ta’limning afzalliklari va muammolari

Hozirgi davrda raqamli ta’lim ta’lim tizimining ajralmas qismiga aylanmoqda. Uning eng asosiy afzalliklaridan biri – masofadan turib o‘qish imkoniyatining mavjudligidir. Bu, ayniqsa, geografik jihatdan uzoq hududlarda yashovchi yoki turli sabablarga ko‘ra an’anaviy darslarga qatnasha olmaydigan o‘quvchilar uchun katta qulaylik yaratadi. Shuningdek, raqamli ta’lim shaffof baholash tizimini shakllantirish va tezkor aloqa o‘rnatish imkonini beradi, bu esa o‘quvchi va o‘qituvchi o‘rtasidagi samarali muloqotni ta’minlaydi.

Yana bir muhim afzallik – o‘quv jarayonining individuallashtirilishi. Har bir o‘quvchi o‘z qiziqishi va bilim darajasidan kelib chiqib, mustaqil sur’atda ta’lim olishi mumkin. Bundan tashqari, raqamli ta’lim resurslardan tejamkor foydalanishga yordam beradi, ya’ni qog‘oz, joy va vaqt kabi an’anaviy resurslarga ehtiyoj kamayadi.

Biroq, raqamli ta’lim jarayonida bir qator muammolar ham yuzaga kelmoqda. Avvalo, internet tezligi past bo‘lgan hududlarda ta’lim imkoniyatlari cheklangan bo‘lib, bu teng ta’lim olish huquqiga to‘sqinlik qiladi. Shuningdek, o‘qituvchilarning raqamli savodxonligi yetarli emasligi ta’lim samaradorligini pasaytiradi. Onlayn muhitning o‘zi esa o‘quvchilarni chalg‘itishi mumkin, chunki ular ijtimoiy tarmoqlar yoki boshqa tashqi omillarga berilib, ta’lim jarayonidan uzoqlashadi. Yana bir muammo – raqamli qurilmalarning hamma uchun mavjud emasligi, bu esa ijtimoiy tengsizlikni yanada kuchaytirishi mumkin.

Afzalliklar	Kamchiliklar
Masofadan o‘qish imkoniyati	Internet tezligi past hududlarda qiyinchilik
Shaffof baholash tizimi	O‘qituvchilarning raqamli savodxonligi pastligi
Tezkor aloqa	Ko‘p vaqt ekran qarshisida o‘tirish salbiy ta’sir qiladi
Resurslarga keng kirish	Raqamli qurilmalar yetarli emas
Individuallashtirilgan ta’lim	Moliyaviy xarajatlar yuqori

2-jadval. Ta’limda raqamli innovatsiyalarning afzallik va kamchiliklari

4. Kelajak istiqbollari

Ta’limni raqamlashtirish jarayonida yangi imkoniyatlar

Ta’lim tizimini raqamlashtirish nafaqat mavjud muammolarni hal qilishga, balki ilgari mavjud bo‘lmagan yangi imkoniyatlarni ham yuzaga chiqarishga xizmat qilmoqda. Avvalo, sun’iy intellekt (AI) texnologiyalari o‘quv jarayonini yanada individuallashtirish imkonini beradi. Virtual tutorlar yordamida talabalar bilim darajasiga qarab moslashtirilgan darslar tavsiya etiladi va bu o‘quvchilarning o‘zlashtirish samaradorligini oshiradi.

Shuningdek, virtual reallik (VR) va kengaytirilgan reallik (AR) texnologiyalari fanlarni chuqurroq o‘rganish uchun keng imkoniyat yaratmoqda. Xususan, laboratoriya tajribalarini simulyatsiya qilish orqali murakkab jarayonlarni xavfsiz va interaktiv tarzda amalga oshirish mumkin.

Bundan tashqari, blokcheyn texnologiyasi ta’lim hujjatlarining ishonchliligini ta’minlashda muhim ahamiyat kasb etadi. U diplom va sertifikatlarning haqiqiyligini tekshirish imkonini berib, sohada korrupsiya va soxtalashtirish holatlarining oldini olishga xizmat qiladi.

Yana bir muhim imkoniyat – gamifikatsiya. Bu usul ta’lim jarayoniga o‘yin elementlarini kiritib, uni

qiziqarli va motivatsion shaklga keltiradi. Natijada, o‘quvchilarning o‘qishga bo‘lgan qiziqishi ortadi va ular bilimlarni samaraliroq o‘zlashtira boshlaydi.

Xulosa

Xulosa qilib aytganda, raqamli innovatsiyalar ta’lim tizimining ajralmas qismiga aylanib bormoqda. Ular ta’limni shaffof, samarali va ochiq qiladi. O‘zbekiston tajribasi ham bu yo‘lda sezilarli natijalarni ko‘rsatmoqda. Biroq internet infratuzilmasini yanada kengaytirish, o‘qituvchilarning raqamli savodxonligini oshirish va barcha hududlarni raqamli qurilmalar bilan ta’minlash kabi vazifalar hali ham dolzarbligicha qolmoqda. Kelajakda sun’iy intellekt, VR va blokcheyn kabi texnologiyalar ta’limning butunlay yangi bosqichiga yo‘l ochadi.

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INDIVIDUALLASHTIRILGAN MASOFAVIY TA’LIMNI TASHKIL ETISH METODIKASI

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Anotatsiya: **Maqola masofaviy ta’limni har bir o‘quvchining individual “fikrlash uslubi”ga moslashtirish (differensiallash) metodikasiga bag‘ishlangan. Unda an’anaviy kurslarning shaxsiy xususiyatlarni hisobga olmasligi muammosi yoritilib, “fikrlash uslubi”ni idrok, xotira va miya faoliyati omillari asosida aniqlash usuli taqdim etilgan, shuningdek masofaviy ta’lim muassasalari tasnifi, differensial yondashuvning amaliyoti va maxsus kurs tuzilishi haqida ma’lumot berilgan.**

Kalit so‘zlar: **Individual masofaviy ta’lim, differensiallash, fikrlash uslubi, psixologik testlash, masofaviy kurs tuzilmasi.**

KIRISH

. So‘nggi o‘n yilliklarda axborot texnologiyalarining rivojlanishi ta’lim tizimida masofaviy o‘qitish konsepsiyasini shakllantirishga zamin yaratdi. 1970-yillarda bu g‘oya nazariy jihatdan ishlab chiqila boshlagan bo‘lib, dastlabki ilmiy ishlarda masofaviy kurs tarkibi darslar majmuasi, nazorat-savollar to‘plami va ma’muriy xizmatlardan iborat deb ko‘rsatilgan. Uning keng ko‘lamli amaliy rivojlanishi esa 1990-yillarda Internet texnologiyalarining ommalashuvi bilan bog‘liq. Internet platformalari o‘qituvchi va talaba o‘rtasida samarali muloqot imkonini yaratib, ta’lim jarayonida tezkorlik, qulaylik va interaktivlikni ta’minladi. Shunga qaramay, o‘tgan 30 yil davomida masofaviy kurslarning tuzilmasi sezilarli darajada yangilanmadi.

Hozirgi vaqtda masofaviy ta’lim tizimlarida moslashuvchanlik ko‘proq talabaning boshlang‘ich bilim darajasi yoki kurs tuzilmasiga asoslangan bo‘lsa-da, individual xususiyatlarni hisobga olish imkoniyatlari yetarli darajada rivojlanmagan. Foydalanuvchi haqidagi qo‘shimcha ma’lumotlar asosida kontentni differensiallashtirish ta’lim sifatini oshirishning samarali usuli sifatida qaraladi. Bu jarayonda samaradorlik talabaning o‘quv motivatsiyasi va o‘zlashtirish darajasidagi dinamik o‘zgarishlar bilan belgilanadi.

Masofaviy ta’lim bilan shug‘ullanuvchi muassasalarni quyidagi toifalarga ajratish mumkin:

1. Faqat nazariy ishlanmalarni ishlab chiquvchilar.
2. Maxsus kurslarni taklif qiluvchi tijorat tashkilotlari (masofaviy elementlar faqat testlarda qo‘llaniladi).
3. Disklar, televideniye va boshqa vositalar orqali material yetkazuvchi hamda lokal dasturlar yaratadigan muassasalar.
4. To‘liq onlayn formatda faoliyat yurituvchi, zamonaviy texnologiyalar asosida kurslar taklif etuvchi muassasalar. Ushbu guruhning atigi 10–15 foizi individual yondashuvni qo‘llaydi.

Ikkinchi, uchinchi va to‘rtinchi guruh muassasalarida differensial yondashuvni dasturiy vositalar orqali joriy etish ta’lim samaradorligini sezilarli darajada oshiradi.

Metodologiya. Ta’lim sifatini oshirish pedagogik texnologiyalarni dasturiy joriy etish orqali amalga oshiriladi, chunki ko‘plab muassasalar masofaviy kurslarga ega. Shu bois o‘quv jarayoniga katta o‘zgarishlarsiz metodika ishlab chiqish zarur. Bu metodika formal mezonlarga asoslanib, foydalanuvchi bilan kurs o‘rtasida axborotni moslashtirish algoritmini o‘z ichiga oladi.

Metodikaning asosiy elementi – differensiallash mezoni. An’anaviy ta’limda tafakkur turlari qo‘llanilsa-da, masofaviy formatda kuzatish va suhbat metodlari murakkabligi sabab bu usul mos emas. Shu bois “shaxsning psixologik xususiyatlari” – bilish va ayrim fiziologik xususiyatlar majmuasiga tayaniladi. Ushbu ishning vazifasi – ularni birlashtiruvchi va kursni differensiallashtiruvchi metodika yaratish.

Masofaviy ta’limning maqsadi – Davlat standarti asosida bilim va ko‘nikmalarni shakllantirishdir. Normativ hujjatlar tahliliga ko‘ra, besh asosiy didaktik metod tavsiya etiladi: axborot-reseptiv, reproduktiv, muammoli bayon, evristik va tadqiqot metodlari. Umumiy tashkiliy xususiyatlar – ta’limning uzluksizligi, ochiqlik, individual yondashuv, markazlashtirilgan boshqaruv va tyutorlar tizimi.

Hozirda differensiallash tayyorgarlik darajasi yoki darslik tuzilishiga asoslanadi, biroq masofaviy ta’limda bu jarayon yanada murakkab, chunki talaba bilan bevosita tanishuv amalga oshmaydi. Shuning uchun tayyorgarlik, qiziqishlar, kasbiy yo‘nalish va ilg‘or talabalar uchun yondashuv kabi tashqi differensiallash turlari kurs loyihasida aks etishi lozim.

Masofaviy kurs uch komponentdan iborat:

Mazmun – HTML5, CSS3, JavaScript (React, Angular) asosida, SCORM/xAPI va Responsive Design bilan.

Ma’lumotlar bazasi – MySQL, PostgreSQL, MongoDB, bulut texnologiyalari orqali.

Interfeys va integratsiya – REST API, GraphQL, ORM (Hibernate, Sequelize), LTI, microservices va containerization texnologiyalari bilan.

Tahlil natijasida masofaviy kurslarga oid ishlanmalar uch turga ajratildi:

Individual ishlanmalar – kursning dasturiy jihatini optimallashtiruvchi kichik algoritmlar.

Guruhiy ishlanmalar – bilim nazorati yoki qo‘llab-quvvatlovchi tizimlar, odatda bir loyiha doirasida qo‘llaniladi.

Tizimli ishlanmalar – yirik kompaniyalar yaratgan universal yechimlar (AWS, GCP, Azure).

Masofaviy kurslar quyidagi mezonlarga ko‘ra tasniflanadi: funksional vazifasi, ishlash muhiti, foydalanuvchi soni, gipermedia imkoniyatlari.

Psixologik jihatdan talabaning fikrlash uslubi differensial yondashuv uchun muhim mezon sifatida tanlandi. Uni aniqlashda uch omil hisobga olinadi: idrok turi (fazoviy yoki xususiyatga asoslangan), xotira turi, miyaning yetakchi yarim shari. Bu omillar asosida shaxsning individual bilish uslubi aniqlanadi.

Natijalar. Fikrlash uslubini aniqlash metodikasi va jadvali ishlab chiqildi hamda dasturiy integratsiyasi rejalashtirilgan. Testlarning maqsadi, o‘tkazish tartibi va qayta ishlash algoritmlari tavsiflangan. Ushbu yondashuv asosida demo kurs – “Telekommunikatsiya tizimlari va jahon axborot resurslari” yaratilgan. Kurs WWW muhitida ishlaydi, MySQL/PostgreSQL, MongoDB bazalari, REST API, GraphQL va Node.js/Django/ASP.NET Core texnologiyalaridan foydalanadi.

Foydalanuvchi rollari – Administrator, O‘qituvchi, Foydalanuvchi, Mehmon sifatida belgilangan. Kurs interaktiv multimedia elementlari bilan boyitilgan.

1 - jadval: Masofaviy kursning tuzilishi.

Jarayon	Blok	Bo‘lim
Tanishuv va psixologik test jarayoni	Tanishuv	Dastur haqida Psixologiya haqida Aloqalar Ro‘yxatdan o‘tish Sinov mashg‘uloti
	Psixologik test	Psixologik test o‘tkazish
O‘quv jarayoni	O‘qitish	Ta’lim jarayoni
Bilimni nazorat qilish jarayoni	Bilim nazorati	Bilimni tekshirish
Xizmat	Xizmat va tavsiyalar	Parolni unutdim Lug‘at Adabiyot Elektron adabiyot Mening yutuqlarim Lug‘at bilan ishlash Reyting
	O‘qituvchi uchun	To‘liq ro‘yxat Savollar ro‘yxati Yangi savol Savolni tahrirlash Individual savol Administratorlik

Kursda foydalanuvchilar to‘rtta statusga ega: Administrator, O‘qituvchi, Foydalanuvchi va Mehmon. Har birining vakolatlari va cheklovlari aniqlangan. Kurs mazmuni gipermatnli elektron darslik ko‘rinishida ishlab chiqilgan bo‘lib, unda havolalar, adabiyotlar ro‘yxati, glossariy, rasm va jadvallar mavjud. Ayrim ma’ruzalar foydalanuvchilar guruhiga moslashtirilgan interaktiv multimedia elementlari, video va animatsiyalar bilan to‘ldirilgan (HTML5, CSS3, JavaScript asosida).

Masofaviy ta’limda ikki asosiy jarayon ajratiladi: ta’lim jarayoni va bilimni nazorat qilish jarayoni, hamda qo‘shimcha sifatida psixologik testlash. Bu jarayonlar kursning turli bo‘limlarida amalga oshiriladi.

Psixologik testlash 4 blokdan iborat bo‘lib, ular orasidagi vaqt cheklovi erkin. Test ro‘yxatdan o‘tganidan keyin istalgan vaqtda topshirilishi mumkin, minimal testlar soni – 4 ta, uchta testda vaqt limiti (kamida 3 daqiqa). Natijalar foydalanuvchiga to‘liq ko‘rinmaydi, chunki testning maqsadi – differensial yondashuvni belgilash. Jarayon ixtiyoriy, testlarga faqat bir marta javob beriladi (barcha savollar tugallanmagan bo‘lsa, ikkinchi urinish ruxsat etiladi).

Xulosa. Masofaviy ta’limning samaradorligini oshirishda individual yondashuvni joriy etish muhim ahamiyatga ega. Tadqiqot natijalari shuni ko‘rsatadiki, foydalanuvchining psixologik va kognitiv xususiyatlarini hisobga olgan differensiallashtirilgan metodika ta’lim sifatini oshiradi, motivatsiyani kuchaytiradi hamda o‘zlashtirish darajasini yaxshilaydi. Taklif etilgan metodologiya asosida kurslarni moslashtirish imkonini beruvchi psixologik testlash tizimi ishlab chiqildi. Bundan tashqari, masofaviy kurslarning zamonaviy texnologiyalar asosida ishlab chiqilishi, ma’lumotlar bazasi va integratsiya mexanizmlarining qo‘llanilishi o‘quv jarayonining barqarorligi va moslashuvchanligini ta’minlaydi.

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ONLAYN IMTIHON VA BAHOLASH TIZIMLARI

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Annotatsiya-Ta’lim tizimida raqamli innovatsiyalar — o‘qitish, baholash va boshqaruv jarayonlarini zamonaviy texnologiyalar orqali samarali, shaffof hamda moslashuvchan qilishga qaratilgan yangilanishlardir. Ular LMS platformalari, sun’iy intellekt, adaptiv testlar, VR/AR laboratoriyalari, o‘quv analitikasi, gamifikatsiya, hamkorlik vositalari va elektron resurslarni qamrab oladi. Natijada shaxsiylashtirilgan o‘qitish, tezkor baholash, masofadan ta’lim va ma’lumotga teng kirish imkonlari kengayadi, o‘quvchi ehtiyojlariga mos ta’lim yo‘llari yaratiladi. Shu bilan birga infratuzilma yetishmovchiligi, kadrlar malakasi, axborot xavfsizligi, akademik halollik va kontent sifati kabi muammolar mavjud. Tizimni samarali joriy etish uchun pedagogik dizayn, raqamli kompetensiyalarni rivojlantirish, milliy kontent ishlab chiqish, qo‘shma standartlar, proktorlik va plagiat nazoratini takomillashtirish, shuningdek, ma’lumotlar analitikasi asosida boshqaruv qarorlarini qabul qilish tavsiya etiladi. Natijada ta’lim sifati oshadi, adolat mustahkamlanadi, innovatsion iqtisodiyot qo‘llab-quvvatlanadi, inklyuzivlik kengayadi, raqobatbardoshlik ortadi. Onlayn imtihon va baholash tizimlari ta’lim jarayonida bilimlarni masofadan turib tekshirish, natijalarni tezkor va shaffof qayd etish imkonini beruvchi raqamli mexanizmlardir. Ushbu tizimlar test, esse, amaliy topshiriqlar, videoprezentatsiyalar va boshqa shakllarda o‘tkazilishi mumkin. Ularning afzalliklari — vaqt va mablag‘ tejalishi, natijalarning tezkorligi, baholashning shaffofligi va talabalarga qulaylik yaratishdir. Shu bilan birga, internet nosozliklari, texnik muammolar, akademik halollikning buzilishi va axborot xavfsizligi kabi muammolar ham mavjud. So‘nggi yillarda proktorlik texnologiyalari, plagiat tekshiruv dasturlari va sun’iy intellekt imkoniyatlari bu tizimlarni yanada takomillashtirmoqda. Natijada, onlayn imtihon va baholash tizimlari ta’limning zamonaviy bosqichi sifatida keng qo‘llanilmoqda.

Kalir so’zlar. Onlayn ta’lim, masofaviy ta’lim, elektron baholash tizimi, onlayn imtihonlar, test sinovlari, LMS (Learning Management System), Moodle, Google Classroom, Microsoft Teams.

I. KIRISH

Ta’lim tizimida raqamli innovatsiyalar — bu ta’lim jarayonini yanada samarali, qulay va zamonaviy qilish uchun raqamli texnologiyalarni qo‘llashdir. Raqamli innovatsiyalar – bu yangi texnologiyalarni ta’limga joriy qilish va shu orqali o‘qitish va o‘rganish jarayonini o‘zgartirish.

Ta’lim tizimida raqamli innovatsiyalar:

1. Raqamli ta’lim platformalari. Moodle, Google Classroom, Microsoft Teams kabi platformalar orqali dars jarayonini tashkil etish va o‘quvchilar uchun masofaviy ta’lim va aralash ta’lim (blended learning) imkoniyatlari.
2. Sun’iy intellekt (AI) va adaptiv ta’lim. AI yordamida o‘quvchilar bilim darajasini aniqlash va shaxsiylashtirilgan dars rejasi tuzish va avtomatik testlarni tekshirish va tavsiyalar berish.
3. Virtual va kengaytirilgan reallik (VR/AR). Biologiya, kimyo, tarix kabi fanlarda laboratoriya tajribalarini virtual tarzda o‘tkazish va tarixiy voqealarni AR texnologiyasi orqali jonli ko‘rsatish.
4. Raqamli resurslar va elektron darsliklar. E-darsliklar, interaktiv mashqlar, videodarslar yordamida ta’lim samaradorligini oshirish. va o‘zbek tilida elektron resurslar bazasini kengaytirish.
5. Big Data va ta’lim analitikasi. O‘quvchilarning darsdagi faolligi, test natijalari va onlayn faoliyatini tahlil qilish va o‘quv jarayonidagi muammolarni oldindan aniqlash va tuzatish.
6. Gamifikatsiya (o‘yin elementlari). Ta’lim jarayonini qiziqarli qilish uchun ballar, reyting, virtual mukofotlar kiritish va o‘quvchilarda raqobat va motivatsiyani oshirish.
7. Onlayn imtihon va baholash tizimlari. Avtomatlashtirilgan testlar, plagiat tekshiruv dasturlari va shaffof baholash va tezkor natija olish imkoniyati.
8. Raqamli boshqaruv. Elektron jurnal va kundaliklar (masalan, my.maktab.uz) va ta’lim jarayonini masofadan turib nazorat qilish.

II. ASOSIY QISM

Ushbu maqolada Onlayn imtihon va baholash tizimlari haqida ma’lumotlarga to’xlatib o’tiladi.

Onlayn imtihon va baholash tizimlari — bu o‘quvchi yoki talabalar bilimini internet orqali maxsus platformalarda tekshirish va baholash jarayonidir. An’anaviy imtihonda sinf yoki auditoriyada qog‘ozda yozib topshiriladi, onlayn imtihonda esa kompyuter, planshet yoki telefon orqali masofadan turib topshiriladi.

Asosiy xususiyatlari:

1. Testlar, esse, amaliy topshiriqlar kabi turli formatlarda bo‘ladi.
2. Avtomatik tekshirish imkoniyati mavjud (masalan, test savollarida).
3. Proktorlik texnologiyalari yordamida talabalar kuzatib boriladi (kamera, mikrofon orqali).
4. Natijalar tezkor, shaffof va raqamli shaklda qayd qilinadi.

Afzalliklari:

1. Qulaylik: istalgan joydan topshirish mumkin.
2. Tezkorlik: natijalar darhol yoki qisqa vaqtda chiqadi.
3. Shaffoflik: insoniy xatolik va sub’ektivlik kamayadi.

Muammolari:

1. Internet va texnika yetishmasligi.

2. Akademik halollik (imtihon vaqtida “ko‘chirish” ehtimoli).
3. Axborot xavfsizligi.

Kompyuterlar keng tarqalmagan bo‘lsa-da, ayrim universitetlar kompyuter asosida test savollarini tuzish va javoblarni avtomatik tekshirishni boshlagan. 970-yillarda AQShdagi ba’zi universitetlarda talabalar kompyuter terminali orqali test topshirgan. 1990 yillardan Internet ommalashgach, birinchi onlayn test platformalari paydo bo‘ldi. Asosan qisqa multiple-choice (variantli) testlar qo‘llanilgan. Onlayn testlar dastlab ingliz tili, informatika va texnika fanlarida ko‘proq qo‘llanilgan. 2000 yildan Learning Management System (LMS) platformalari (Moodle, Blackboard, Canvas) keng joriy qilindi. Ko‘plab universitetlar onlayn testlarni rasmiy baholash tizimiga kiritdi. Proktorlik xizmatlari asta-sekin paydo bo‘ldi (kamera orqali kuzatuv). 2010 yilllarda MOOC (Massive Open Online Courses) platformalari (Coursera, edX, Udemy) kengaydi va ularda imtihon tizimlari joriy qilindi, onlayn imtihonlarda plagiat tekshiruv dasturlari ishlatila boshlandi. Sun’iy intellekt asosida proktorlik, yuzni aniqlash va ekran monitoringi rivojlandi. 2020 yildan beri COVID-19 davrida butun dunyoda onlayn imtihon asosiy baholash usuliga aylandi. Maktab va universitetlarda Zoom, Google Classroom, Microsoft Teams, Moodle orqali test va imtihonlar o‘tkazildi. Sun’iy intellekt asosida kuzatuv tizimlari keng joriy qilindi.

O‘zbekistonda onlayn imtihon va baholash tizimlarining joriy etilishi:

1. DTM va elektron ro‘yxatdan o‘tish (2020-yildan). 2020-yilda O‘zbekiston ta’lim tizimida muhim yangilik sodir bo‘ldi: abituriyentlar imtihonga ro‘yxatdan o‘tish jarayonini “Yagona interaktiv davlat xizmatlari” portali hamda Davlat test markazi (DTM) rasmiy veb-sayti orqali amalga oshira boshlashdi. Bu raqamli jarayon onlayn imtihon tizimining boshida turgan qadamdir.
2. Sun’iy intellekt orqali proktorlik (2021-yil). 2021-yil avgust oyida Samarqanddagi Silk Road International Universityda sinov tariqasida sun’iy intellekt asosidagi online proktorlik tizimi joriy qilindi. Bu tizim video, audio va kompyuter ekran monitoringi orqali test topshiruvchilarini nazorat qiladi.
3. O‘rta ta’limda onlayn imtihonlar (2024-yil). 2024-yilda O‘zbekistonda ilk bor maktab darajasida onlayn imtihonlar o‘tkazildi. Bu jarayonda 400 dan ziyod maktab va 100 000 dan ortiq o‘quvchi ishtirok etib, 300 000 varaq qog‘oz tejalishi mumkin bo‘ldi

Onlayn imtihon va baholash tizimlari uchun dunyo bo‘yicha va O‘zbekistonda bir nechta platformalar keng qo‘llaniladi. Masalan: Moodle, Google Classroom, Microsoft Teams, Canvas, Zoom, Edmodo, Testmoz, Exam.net, Proctorio, Quizizz. Ularning har biri turli imkoniyatlarga ega.

1-jadval. Onlayn imtihon va baholash tizimlari qiyosiy tahlili

№	Platforma	Qulaylik darajasi	Imtihon yaratish	Avtomatik baholash	Plagiatni aniqlash	Mobil moslashuv	Xavfsizlik darajasi	Integratsiya imkoniyati	Narxi	O‘zbekiston da
1	**Moodle**	O‘rta	Juda keng	Bor	Modul orqali	Bor	Yuqori	Keng (LMS bilan)	Bepul (Open source)	Universitetlar da keng
2	**Google Classroom**	Yuqori	Oddiy test va topshiriqlar	Bor (cheklangan)	Yo‘q	Juda yaxshi	O‘rta	Google xizmatlari	Bepul	Maktablarda keng
3	**Microsoft Teams**	Yuqori	Forms orqali test	Bor	Yo‘q	Kuchli	Yuqori	MS Office bilan	Pullik (Office 365)	Kollej/litsey
4	**Canvas**	Yuqori	Juda keng	Bor	Bor	Bor	Yuqori	LMS, Zoom, Turnitin	Pullik	Kam qo‘llaniladi
5	**Zoom**	Yuqori	Imtihon emas, nazorat	Yo‘q	Yo‘q	Bor	O‘rta	LMS bilan	Cheklangan bepul	Imtihon nazorati
6	**Edmodo**	O‘rta	Oddiy testlar	Bor	Yo‘q	Bor	O‘rta	Cheklangan	Bepul	Maktablar
7	**Testmoz**	Yuqori	Juda qulay	Bor	Yo‘q	O‘rta	O‘rta	Kam	Pullik	Mustaqil
8	**Exam.net**	Yuqori	Keng imkoniyat	Bor	Bor (AI yordamida)	Bor	Yuqori	Integratsiya mumkin	Pullik	Xususiy ta’lim
9	**Proctorio**	Yuqori	Test tizimlari bilan	Bor	AI asosida	Bor	Juda yuqori	Canvas, Moodle	Pullik	Keng emas
10	**Quizizz**	Yuqori	Interaktiv testlar	Bor	Yo‘q	Juda yaxshi	O‘rta	LMS, Google Classroom	Bepul/Pullik	Maktab va kurslarda

2-jadval. Raqamli ta’lim platformalari va foydalanuvchi soni (O’zbekistonda)

Platforma / Tizim	Foydalanuvchi soni	Izoh
Coursera (Bir million dasturchi)	2,5 million+	1,7 million muvaffaqiyatli foydalanuvchi
Uzbekcoders.uz	960 000+	420 000 bepul, 2 900 professional kurs foydalanuvchilari
Interaktiv ta’lim platformalari	3 million+	Pandemiya davrida interaktiv platformalardan foydalanganlari

Onlayn imtihon va baholash tizimlari ta’lim jarayonini samarali, tezkor va adolatli tashkil etishda

muhim vosita hisoblanadi. Kelajakda bu tizimlarning rivojlanish istiqbollari keng bo‘lib, sun’iy intellekt va katta ma’lumotlar (Big Data) asosida avtomatlashtirilgan baholash tizimlari yo‘lga qo‘yilishi kutilmoqda. Bundan tashqari, biometrik identifikatsiya, yuzni tanish va ovoz orqali autentifikatsiya kabi texnologiyalar yordamida imtihonlarda xolislikni ta’minlash imkoniyatlari yanada kengayadi.

Takomillashtirish yo‘llari sifatida platformalarning texnik barqarorligini oshirish, internet infratuzilmasini mustahkamlash, foydalanuvchi interfeysini soddalashtirish, turli xil fan va test turlariga moslashuvchanlik kiritish kiradi. Shuningdek, xalqaro tajribadan foydalanib, O‘zbekistonda milliy onlayn imtihon tizimini shakllantirish va uni ta’lim muassasalarida keng tatbiq etish istiqboldagi muhim vazifalardan biri hisoblanadi.

Onlayn imtihon va baholash tizimlari so‘nggi yillarda ta’lim jarayonida tobora muhim o‘rin egallamoqda. O‘zbekistonda bu tizimlarni rivojlantirish quyidagi yo‘nalishlarda amalga oshirilishi mumkin:

1. Texnologik rivojlanish. Sun’iy intellekt (AI) yordamida avtomatik testlarni yaratish va tekshirish. Blokcheyn texnologiyasi orqali imtihon natijalarining shaffofligi va xavfsizligini ta’minlash. Yirik ma’lumotlar (Big Data) tahlili orqali talabalar bilim darajasini chuqur baholash.
2. Platformalarni kengaytirish. Moodle, Google Classroom, Microsoft Teams kabi jahon platformalarini lokal sharoitga moslashtirish. Mahalliy “Test Oliy ta’lim”, “Imtihon.uz”, “EduMarket” kabi platformalarni yanada takomillashtirish.
3. Baholashning adolatliligi. Plagiatni aniqlash dasturlarini integratsiya qilish. Onlayn proktorlik (imtihonni kuzatish) tizimlarini joriy etish. Yopiq testlardan tashqari esse, loyiha, prezentatsiya kabi ko‘p qirrali baholash metodlarini qo‘llash.
4. Talabalar uchun qulaylik. Mobil ilovalar orqali imtihon topshirish imkoniyati. Maxsus imkoniyatli talabalar (eshitish yoki ko‘rish qobiliyati cheklanganlar) uchun moslashtirilgan versiyalar. Internet tezligi past hududlar uchun offline rejimda ishlaydigan tizimlar.
5. Xalqaro standartlarga integratsiya. TOEFL, IELTS, Coursera va edX imtihon tizimlaridan tajriba olish. O‘zbekiston diplomlarini xalqaro akkreditatsiya qilishda onlayn baholash tizimlarini moslashtirish.
6. Kelajak istiqbollari. Har bir talabaga shaxsiy elektron portfolio yaratish. Ta’lim jarayonida metaverse va VR (virtual reallik) orqali interaktiv imtihonlar. Sun’iy intellekt yordamida shaxsiylashtirilgan imtihon (talabaning qobiliyatiga qarab savollar shakllanishi).

Xulosa

Onlayn imtihon va baholash tizimlari zamonaviy ta’lim jarayonining ajralmas qismi sifatida O‘zbekistonda ham keng rivojlanmoqda. Ularning afzalliklari — shaffoflik, tezkorlik va qulaylik bo‘lsa-da, texnik nosozliklar, internet infratuzilmasi va akademik halollik kabi muammolar mavjud. Jahon tajribasidan ko‘rinib turibdiki, bunday tizimlar sun’iy intellekt, proktorlik, plagiatni aniqlash va biometrik autentifikatsiya kabi texnologiyalar orqali yanada takomillashmoqda. O‘zbekistonda esa DTM tizimlari, universitetlarda proktorlik sinovlari va maktablarda onlayn imtihonlarning joriy qilinishi bu yo‘nalishdagi muhim bosqich bo‘ldi. Kelajakda milliy platformalarni ishlab chiqish, xalqaro standartlarga moslashtirish, maxsus imkoniyatli talabalar uchun inklyuziv imkoniyatlar yaratish hamda Big Data asosida chuqur tahliliy baholashni yo‘lga qo‘yish dolzarb vazifalardan biridir. Natijada, onlayn imtihon va baholash tizimlari ta’lim sifatini oshirish, adolatni mustahkamlash va innovatsion iqtisodiyot uchun malakali kadrlar tayyorlashda muhim vosita bo‘lib xizmat qiladi.

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BRIDGING THE GAP: FROM AI TOOL USE TO CRITICAL META-REFLECTION IN THE PEDAGOGICAL COURSE

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***Abstract*—The rapid spread of artificial intelligence tools in education demands not only technological skills but also critical and ethical understanding, especially for teachers. This study addresses the growing need for meta-AI literacy by proposing and testing a methodology that develops students' meta-reflection within a pedagogical course, based on five stages: awareness of AI capabilities and limitations, analysis of own AI use strategies, critical reflection on cognitive and ethical consequences of AI use, formation of an internal professional position, and responsible pedagogical behavior in the digital environment. The study involved 36 third-year students of the pedagogical direction of the bachelor's degree. Through reflective journals, peer reviews, self-assessments, and portfolios, the study tracked students' growth across five stages of meta-reflection. Results showed increases in students' skills across the five stages of meta-reflection development.**

Keywords—meta-AI literacy, meta-reflection, teacher education, artificial intelligence, digital pedagogy, ethical AI use, metacognition, instructional design, reflective practice.

A. I. INTRODUCTION

The rapid development of artificial intelligence (AI) has a transformative effect on the education system, including the training of future teachers [1]. Students actively use AI tools such as ChatGPT, Grammarly, Canva AI, Copilot, and others. However, the use of AI is not always accompanied by the necessary cognitive and ethical reflections, which leads to a superficial perception of technology and the formation of dependence on AI systems [2].

Against the background of this trend, there is an increasing need not only for the formation of AI literacy in students of pedagogical fields [3] but also for the development of meta-literacy in the field of AI, which is defined as the ability to critically understand, evaluate, and ethically apply AI in educational and future pedagogical activities [4]. One of the key components of meta-literacy is meta-reflection [5], which involves a conscious analysis of one's own thought processes, values, and decisions related to the use of AI. In educational practice, a gap persists between the instrumental use of AI and the development of a critical, meta-reflexive attitude towards it. The reasons for this deficit in meta-reflexivity lie in both objective conditions and the specifics of the pedagogical organization of the educational process.

The purpose of this study is to develop a methodology for overcoming the gap between the instrumental use of AI and the development of a critical, meta-reflexive attitude towards in students by integrating critical meta-reflection into the pedagogical course. In doing so, the following research questions are considered:

1. How can critical meta-reflection be effectively integrated into the pedagogical course for future teachers?
2. What is the impact of meta-reflective teaching methods on the development of students' meta-AI literacy in pedagogical programs?

B. II. LITERATURE REVIEW

The integration of AI into education has opened up new opportunities for teachers and students to optimize the learning process, personalize content, automate assessment, and increase motivation [6]-[7]. Students actively use modern AI tools as part of their learning activities. However, as Ng et al. [3] emphasize, simply using AI without understanding the principles of its operation and the consequences of its use can lead to superficial learning, reduced critical thinking, and dependence on technology. In response to this challenge, the academic community has been intensifying discussions about the need to develop AI literacy, which is interpreted as the ability to understand the principles of AI, apply AI tools to solve educational and professional problems, and critically evaluate their reliability, appropriateness, and consequences [8]- [9].

AI literacy, despite its importance, does not cover the full depth of cognitive and ethical processes associated with the use of AI in the educational environment [10]. That is why a broader and deeper concept, meta-AI literacy, is emerging in modern research. Meta-literacy encompasses not only knowledge about technologies and the ability to apply them, but also the capacity to consciously manage one's thinking, evaluate one's own strategies for working with AI, anticipate risks, and make ethically sound decisions in the digital environment [11]. For future teachers who will not only use AI in their practice, but also teach, it is essential to develop metaliteracy, which allows them to go beyond the mechanical use of AI and form a critically thinking, technologically conscious specialist [12].

The key mechanism for developing meta-AI literacy is meta-reflection, which is defined as a form of deep cognitive activity that involves analyzing natural thought processes, internal beliefs, tendencies in interaction with AI, and value orientations [13]. Unlike conventional reflection, which answers the question "What have I done and what have I learned?", meta-reflection goes deeper into the level of "How do I think? Why did I choose this path? What values are behind it? What are the consequences of my choice?" [14]. The concept of metareflection goes back

to the work of Flavell (1970), who introduced the idea of metacognition as the ability to recognize and manage one's own thinking [15]. Later, Schraw & Dennison (1994) proposed a two-component model that includes knowledge about cognition and regulation of cognitive activity [16]. In a pedagogical context, meta-reflection is considered a necessary condition for the formation of professional maturity and responsibility, especially in the context of working with AI, which is increasingly replacing traditional pedagogical solutions [17].

In summary, while AI literacy equips students with functional and technological skills, it remains insufficient for fostering deeper critical and ethical engagement with AI. Meta-AI literacy, supported by meta-reflection, emerges as a necessary framework for preparing future teachers to act consciously and responsibly in AIintegrated educational contexts. Therefore, integrating meta-reflective practices into teacher training programs is essential for developing technologically competent, ethically aware, and pedagogically mature educators..

C. III. METHODS

This study employs a qualitative approach to explore how critical meta-reflection can be effectively integrated into teacher education courses and assess its impact on the development of students’ meta-AI literacy.

A. Research Design

The study applied design-based research principles. This involved iterative development, implementation, and refinement of a methodology for fostering meta-reflection in the course “Digital Technologies in Education.” The design process was informed by a secondary analysis of scholarly literature on AI literacy, metacognition, and pedagogical ethics. Additionally, the study analyzed data obtained from qualitative instruments embedded within the course, including student reflective journals, selfassessment checklists, peer reviews, and project portfolios.

B. Participants

The study involved 36 undergraduate students in their third year of a Bachelor’s degree in the Pedagogical Course at Tashkent University of Information Technology, Uzbekistan. Participants were enrolled in the mandatory course “Digital Technologies in Education” during the spring 2025 semester. The sample included 17 female and 19 male students, aged between 20 and 23 years. All students had prior experience using general-purpose AI tools for academic tasks. However, they lacked formal instruction in critical AI literacy or metacognitive strategies.

All participants were invited to join the study voluntarily and were informed about the research goals and data collection procedures. Anonymity was preserved throughout the study.

C. Data Sources and Instruments

The data corpus included annotated lesson plans and instructional materials redesigned to include metareflective components, student-generated artifacts, peer review forms where students evaluated each other’s use of AI through the lens of meta-literacy, and self-assessment rubrics adapted from existing metacognitive awareness inventories.

D. Procedure

The intervention was piloted during a 15-week academic term. Each 3 weeks, students completed activities specifically designed to support a stage in the development of meta-reflection.

E. Data Analysis

The qualitative and quantitative data collected in this study were analyzed using SPSS version 23 and thematic coding procedures. Although the primary focus of the study was qualitative, selected elements of students’ responses and self-assessment scores were subjected to descriptive statistical analysis to support and triangulate the findings.

D. IV. RESULTS

A. Methodology For Developing Critical Meta-AI Reflection

The methodology for developing critical metareflection when using AI tools is based on a combination of principles of activity-based, reflexive, and criticalethical approaches. In the process of implementing this methodology, students consistently go through several stages: from awareness of the capabilities and limitations of AI tools to the analysis of their own strategies for using them, then to a critical understanding of the cognitive and ethical consequences, and, finally, to the formation of an internal position that determines professional behavior in the digital environment. The central place in this is occupied by the creation of pedagogical situations that provoke the need for choice, evaluation, doubt, and selfanalysis, which contributes to the transition from technological to meaningful interaction with AI. This methodology provides effective tasks that stimulate critical reflection, discussion, practical understanding, and responsible use of AI (Table I).

Initially, students learn about the strengths and weaknesses of AI tools. This includes exploring and testing platforms like ChatGPT, Canva AI, and Copilot to identify their benefits and potential risks. Through handson practice and examining errors or inaccuracies, students understand the limits of how algorithms work. Educational videos and guided discussions further improve their understanding of where and how AI might be unreliable or ethically problematic.

Once this awareness is developed, students move on to analyze their own AI usage strategies. This phase highlights self-observation and metacognitive understanding. Learners are encouraged to keep digital reflection journals and write short reflective essays after completing tasks with AI. For instance, after using ChatGPT to create a lesson plan, students record which suggestions they accepted, modified, or rejected, along with their reasons. Self-assessment checklists are also introduced to foster conscious monitoring of dependency patterns and critical engagement.

TABLE I. STAGES OF META-AI REFLECTION FORMATION AND TEACHING METHODS

Stage of Meta-AI Reflection Formation	Teaching Methods
1. Awareness of AI capabilities and limitations	– Exploration and testing of AI tools; – Tasks focused on identifying AI limitations; – Viewing and discussing educational videos about AI.

2. Analysis of own AI use strategies	– Keeping a digital reflection journal; – Writing short reflective essays after AI-related tasks; – Using self-assessment checklists.
3. Critical reflection on cognitive and ethical consequences	Case analysis and ethical dilemma discussion; Group discussions; Debates based on real or hypothetical AI use scenarios.
4. Formation of an internal professional position	Writing reasoned professional reflections; Peer review: evaluating each other's work using meta-literacy criteria; Preparing and defending one's position on ethical-pedagogical questions.
5. Responsible pedagogical behavior in the digital environment	Project-based tasks with rationale for AI use; Simulation of pedagogical scenarios with AI integration; Creation of digital portfolios with reflective commentary for each artifact.

The third stage centers on critical reflection regarding the cognitive and ethical consequences of AI use. Here, students engage in case-based discussions and analyze ethical dilemmas, such as whether it is appropriate to use AI-generated content in student assessments or when assisting learners with disabilities. Group activities such as structured debates (e.g., “AI: Assistant or Threat?”) and scenario-based discussions promote moral reasoning and ethical sensitivity, helping students anticipate unintended consequences, including algorithmic bias or intellectual passivity.

Building on this, the fourth stage focuses on establishing an internal professional position. At this point, students begin to articulate their own pedagogical principles concerning the use of AI. They write structured professional reflections and engage in peer review, evaluating each other's work using criteria of metaliteracy. They are also tasked with preparing and defending their stances on ethical and pedagogical issues, such as the responsible integration of AI into classroom practices.

The final stage is characterized by the demonstration of responsible pedagogical behavior in the digital environment. This involves applying the previously developed meta-reflective attitudes in practical, teachingrelated contexts. Students complete project-based assignments in which they must justify the inclusion (or exclusion) of AI tools in instructional design, simulate classroom scenarios involving AI, and compile digital teaching portfolios that include reflective commentaries on each artifact.

Thus, the proposed methodology enables future teachers to move from passive and instrumental use of AI tools to conscious, critical, and ethically informed engagement. Each stage builds upon the previous one, forming a coherent pedagogical trajectory that strengthens students' meta-AI literacy. As a result, learners become capable of making informed decisions, evaluating the educational impact of AI, and modeling responsible digital behavior in their future classrooms.

B. Impact of Meta-Reflective Teaching Methods on Meta-AI Literacy Development

Based on the presented methodology for developing meta-AI reflection, third-year students were taught the course "Digital Technologies in Education." Each stage lasted three weeks. During this time, students were assigned specially developed tasks related to the proposed teaching methods. The learning outcomes for each stage are shown below.

a) *Awareness of AI Capabilities and Limitations.* At the initial stage of the course, students primarily perceived AI tools as convenient and valuable means of automating educational tasks, without considering the principles of their operation or potential risks. This indicated the prevalence of a utilitarian approach and the lack of a critical distance towards AI. However, after targeted educational activities - such as practical testing of AI tools, watching educational videos on the principles of their operation, analyzing typical AI errors, as well as discussing cases related to the incorrect use of AI in education - students began to form more substantiated ideas about the capabilities and limitations of AI technologies.

By the end of the third week, 83.34% of students (n = 30 out of 36) demonstrated the ability to not only list the technical characteristics of the AI, but also to identify key limitations, such as a tendency to generate unreliable information, reliance on biased or incomplete training data, the AI's lack of ethical judgment, and the risk of reducing its own cognitive effort and critical thinking. These results were recorded in both the self-assessment questionnaires and in individual reflective journal entries. One student wrote:

"I used to think that ChatGPT always gave the right answers. Now I realize that it often makes things up, and I have to check every sentence it makes. I began to treat it as an assistant, and not as a source of truth.”

b) *Analysis of own AI use strategies.* At the initial stage, most students completed tasks using AI tools intuitively, without examining the functions they used, why they were used, or how justified their actions were. The lack of metacognitive support manifested itself in a weak awareness of their own preferences, dependence on AI, and uncritical acceptance of its suggestions. To overcome this deficit, special meta-reflection tools and practices were incorporated into the course, including keeping digital diaries, writing mini-essays after completing tasks, and using self-assessment checklists based on meta-literacy criteria.

By the sixth week, 72.22% of students (n = 26 out of 36) consistently used these metacognitive strategies. Reflective journals included more detailed discussions about the strengths and weaknesses of using AI, the reasons for accepting or rejecting specific decisions, and internal cognitive and ethical hesitations. At the same time, the peer review system also showed an increase in the depth of analysis. For example, one student, commenting on a classmate’s work, wrote:

“*You successfully used Grammarly to improve the structure of the text, but your reflection shows that you did not question his suggestions. Perhaps it was worth considering whether all the corrections were appropriate in the pedagogical context.”*

c) *Critical reflection on cognitive and ethical consequences.* An analysis of students’ responses to cases and situational tasks with elements of ethical dilemmas revealed progress in the depth of their reflection. In the initial phase of the course, most students viewed AI solely as a tool for increasing productivity. Their reasoning was limited to utilitarian arguments, such as “AI saves time,” “it makes it easier to write texts,” and “it helps to design a presentation faster.” However, by the seventh week of the course, a qualitative shift occurred. Students began to raise issues related to intellectual honesty, authorship, academic autonomy, and the fairness of assessment. In group discussions, participants argued their points of view, referring to possible negative effects. Cases related to algorithmic bias provoked particularly intense talks. As part of the academic debates on the topic “AI - assistant or threat?”, the participants demonstrated the ability to comprehensively analyze the consequences of introducing AI into educational practice. One of the students noted:

“*If AI automatically offers children ready-made solutions, we are not promoting the development of thinking, but its substitution. This is not just a methodological problem, it is an ethical choice*.”

d) *Formation of an internal professional position.* By the end of the course, students had become much more confident in formulating their professional views on the role of AI in education. If, at the beginning of the course, they perceived digital tools as universal and undoubtedly useful, then by the last weeks of the course, their positions included elements of critical thinking, moral responsibility, and pedagogical justification. The final reflections revealed that 86.11% (n = 31 out of 36) of students emphasized the need for a conscious balance between innovation and responsibility. One of the students expressed it this way:

"*I will definitely use AI in my future lessons, but only after I analyze whether it suppresses the creativity and critical thinking of my students*."

This internal reassessment was also reflected in the digital portfolios: in contrast to the initial stage, when brief technical comments accompanied artifacts, the final versions included detailed professional explanations.

e) *Responsible pedagogical behavior in the digital environment.* The learning simulations and final projects vividly demonstrated how students transferred metareflective skills to real-life teaching activities. The course participants not only used AI tools correctly but also clearly justified their choices in terms of pedagogical principles, methodological goals, and professional values. For example, one group of students used ChatGPT to generate test questions on the topic of “Information Security.” However, instead of blindly copying the generated questions, they revised each element according to the levels of Bloom’s taxonomy, reworked the wording, and added tasks for analysis, evaluation, and creative thinking. In their reflective comments, they explained why it is essential to encourage students to think more deeply about the topic, rather than simply testing their factual knowledge. 80.56% of the participants (n=29 out of 36) consistently integrated elements of meta-AI literacy into their final projects.

Thus, the most mature and professionally verified behavior of students manifested itself at the final stage of the course: meta-reflection ceased to be merely an educational goal and became a sustainable, practical tool for pedagogical choice in the digital environment.

E. V. DISCUSSION

The results of this study provide empirical validation of the hypothesis that developing meta-AI literacy among future teachers requires the purposeful integration of metareflective strategies into course content and pedagogy. The significant improvements across all five stages of metareflection, ranging from awareness of AI limitations to responsible pedagogical application, demonstrate the effectiveness of the proposed methodology.

A key finding is the substantial growth in students’ ability to identify the risks and boundaries of AI tools. Precourse data revealed that many students treated AI as a reliable authority; however, post-course reflections showed increased skepticism, a greater emphasis on source verification, and a stronger orientation toward human oversight. This supports previous research by Ng et al. [3] and Chiu et al. [9], who argue that a critical understanding of AI's limitations is central to literacy development.

Another significant result concerns the development of metacognitive self-awareness. Students’ reflective journals and peer assessments revealed a progression from taskoriented thinking to a more process-oriented mindset. This aligns with the foundational concept of metacognition and confirms that meta-reflection can be operationalized in teacher education through structured assignments [18].

The emergence of ethical reasoning and internal professional positioning is particularly notable. While initially focused on convenience and productivity, students evolved to express thoughtful, value-based positions on AI use in educational practice. This shift reflects the success of pedagogical interventions such as debates, case-based dilemmas, and professional reflections, methods that prompted students to engage not only cognitively but morally and professionally [19].

Finally, the translation of meta-reflective insights into practice, as evidenced by students’ lesson design projects and portfolios, suggests that the methodology succeeded not only in fostering critical awareness but also in shaping practical instructional behavior. Students demonstrated that they could articulate pedagogical justifications for AI use or rejection, simulate classroom scenarios involving AI responsibly, and reflect on the outcomes.

These results underscore a broader implication: AI literacy is insufficient without meta-literacy. In the context of teacher education, producing technically skilled users of AI is not enough. Educators must be prepared to model ethical, critical, and self-aware behavior in their own practice and to cultivate these qualities in their future learners. Without such preparation, there is a risk of delegating too much agency to AI systems - an outcome that contradicts the humanistic values at the core of education.

F. CONCLUSION

This study shows that integrating critical metareflection into the structure of digital technologies courses is not only feasible but also highly effective in enhancing future teachers’ meta-AI literacy. The developed methodology, based on sequential stages of reflection and grounded in activity-based, ethical, and reflexive learning, proved successful in transforming students from passive users of AI into critical, ethically conscious, and professionally responsible educators.

By combining practical AI exploration with structured reflective practices (journals, self-assessments, peer reviews, and ethical dilemmas), the course enabled students to understand the capabilities and limitations of AI, monitor and regulate their own AI use strategies, assess the ethical implications of technology in education, apply these insights to real pedagogical tasks, and take responsibility for solving AI problems.

The findings advocate for a paradigm shift in digital teacher education: from skills-centered training to reflectively integrated meta-literacy development. Future research may explore how this model can be adapted for different cultural or disciplinary contexts, as well as its long-term impact on teaching behavior and student outcomes in AI-rich classrooms.

G. REFERENCES

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THE USE OF NETWORK BOOMERANG TECHNOLOGY IN EDUCATION

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Abstract. The article discusses ways of increasing students' engagement, motivation and participation in higher education using "Network Boomerang" technology, as an example of pre-service IT teacher training.

Keywords: education reforms, innovative teaching, active learning, network boomerang, e-learning, computer-assisted learning, smart technology

LIII. INTRODUCTION

Today the mankind is undergoing the global process of computerization.The accomplishment of this requires every citizen to access the information resources and bring the information technologies into different sectors such as science, education, producing and so on.

The implementation of UNESCO 's digital technologies in the education system is creating a new interactive environment in which teachers are required not only to manage these technical devices , but also to have some" simple skills " like searching and selecting information,flexibility , team working skills as well as creative thinking.

The integration of information technologies among society accelerated the development of science and all fields of our life. At the same time, it created new information resources that increase the human's creative potential.

The process of integrating information technologies to education is taking the leading role .Innovations in science are considered to play a significant role in its further development.

Moreover the integration of information technology to our society can hasten scientific technologies and be a solution to most problems that we are facing in our daily lives{1}

The purpose of the study:

To enhance the system of training students being instructed professional training for innovative working environment.

Scientific news of this study includes the following:

During the implementation of information technologies in the education it intends to improve the methodology of creating scientific- pedagogical and teaching- methodological programs and teach to use them effectively to the students training for innovative working via the module of "The Network Boomerang " and " Educational Technologies " program.

Identifying the content, form, methods and means of innovative training program by adding new themes to different subjects in " The Network Boomerang " Module according to socio- psychological qualities of students.

Creating assessment system of students ' innovative readiness.

It comes up with science-based suggestions and theories about how to organize the professional training.

LIV. LITERATURE REVIEW

XXI century is defined as the era of development of technique and technologies.In this century more and more attention is being paid to the implementation of information technologies in education than ever before.

First of all let's identify the meaning of the terms of " Innovation ", " Innovative acting " and " Pedagogical Innovations ".

Research by B.M. Polanski states that the term " innovation " was first suggested by Shumpeter and given a definition to the " Innovational process " for the first time.

In dictionaries Innovation is defined as the following:

Innovation comes from English and means news, a new idea or method. Innovations are quite complex so researchers have different approaches to understanding its meaning.

D.V.Chernilevski explains it in his book called " Teaching technology at high school " as:

Innovation(introduction of something new) is creating new scientific- pedagogical techniques, acquiring them and putting them into practice.

K.Anglovski learned different studies and pointed out that most of these scientists describe innovation as something new, new modules and methods. However, he thinks that it should be explained as changes focusing on improving and developing upbringing and education[52]

R.N.Yusufbekova states the following while defining the " pedagogical news ": the matter of changes that may occur in pedagogical theories or practice (acquiring the innovation in education system and implementing it) will lead it to a particular condition that never existed before. Consequently, the theory and practice of education will develop. The new approach here is that the changes are probable, not made .

According to V A.Slastenin a d L.S.Podimov , news is a means (new method, methodological technology or program), while innovation is a process that develops step by step in a clear way.

B.Lazareva says that innovation should be defined not as a change but the necessity that should be implemented in the education system which is likely to lead to its improvements. Innovation is a materialistic idea that is a way of increasing efficiency of any education system.

classroom, quickly absorbing and delivering new knowledge, developing logical thinking, teaching their knowledge to another student. The technology allows for continuous improvement of knowledge during the course and the effective use of the new learning materials

Conclusion

[52] Ангеловски, К.мУчителя и инновации /К.ангеловски.- М.:Просвещение, 1991.-159с

According to the description of pedagogical scientific N.Jumaniyazova , the aim of the innovation is to get great results in return to all the money spent and effort put on it. Differently from other news occurring naturally,innovation makes up the system of manageable and controllable changes. Every news related to education cannot however be an innovation. That's why difference between "novation"and " innovation " should be better understood. This difference is based on the form , meaning and the amount of the reformation. If the activity lasts for a short period of time and cannot be characterized as a whole system,and intends to change a few elements in a particular direction, then this can be referred to novation. If the activity is being carried out based on a conceptual approach and if it results in the development or principal transition of a certain system , this correlates to innovation. [Jumaniyazova,19 b.].

LV. METHODOLOGY

A special program has been created to test the outcomes from the studies. The aim of experiment- testing, arranged duties, experiment- testing stages and fields have been set up in this program. While selecting the fields of experiment, current pedagogic state , its technical and information supplements have been investigated. The experiment- testing process is conducted in three stages: emphasizing (2016-2017), forming (2017-2018),completing (2018-2019) stages.TUIT (Tashkent university of information technologies) it is branch in Karshi and Fergana have been chosen as the areas of experiment. Totally, 177 students participated in experiment- testing process, 89 of whom are from TUIT, 48 students from its subsidiary in Karshi and 40 students are from TUIT' s branch in Fergana.On emphasizing stage of testing the content of the State Education Standards of educational field of" 5350400- professional education of Information communication technologies ",the curriculum of subjects,tasks based on practical and laboratory experiments of both general and specific subjects , literatures, educational manuals, the role and usage of innovative pedagogical techniques and the necessities of its improvements have been studied, several methods such as talk, testing, observing the students' learning process, assessing their basic knowledge from general and specific subjects.

When implementing "The network boomerang" technology in an e-learning environment, first a special folder should be created in the computer, with only one file (course name, index, html), which serves as an access point to the course content. The remaining files in folders are as follows:

IMG - graphics, pictures, animations and others;

CHARTER - lectures, laboratory works and their content;

TEST - tests, control tasks, exercises;

FILE - handouts related to “The network boomerang” method.

At the first stage, students are enrolled after a special folder is created.

Each student has access to the digital resources, and studying these resources both individually and in groups, they answer questions and participate in discussions, while the teachers can evaluate them based on their participation..

At the second stage, students will be explained the following guidelines / recommendations:

- ✓ Studying the assignments carefully;
- ✓ Completing the task (remembering);
- ✓ Allowing up to 10-15 minutes’ of preparation time, depending on the volume of the text,

The teacher should monitor each student through a local network or the online monitoring system.

The number of learners of pedagogical staff who took part in the experimental and control groups are given in the Table I.

TABLE I. TABLE I. NUMBER OF LEARNERS TOOK PART IN THE EXPERIMENT

Institution	Experimental groups		Control groups	
	Groups	Number of students	Groups	Number of students
TUIT	INFORMATICS	48	INFORMATICS	53
FTS	PHISICS	50	PHISICS	52
SST	MATHEMATICS	42	MATHEMATICS	48
Total:	160		153	

LVI. DISSCUSS AND RESULTS

The qualification requirements based for the development of educational institutions, the procedure for monitoring and evaluation of the quality of education as well as the teachers of "Computer Technology and Informatics", "Mathematics", "Physics" sciences. According to the syllabus for the retraining and improvement of professional skills of teachers of higher educational institutions, in Module 2.1. ("Innovative Learning Technologies and Pedagogical Competence") is presented in all directions. This module includes the essence of the psychological, methodological, informative, creative, innovative competence of the teacher, creativity as the basis of pedagogical creativity, evaluation of creative potential, creative competence, and criteria of assessing creativity Based on the above considerations, there are not enough creative methods in this module program. We have improved the content of this module. According to this conception, we create methodology of doing lecture (Table II).

A suggested planning of a lesson using “The network boomerang” method

	Type of activity

Stages of the lesson and timing	The teacher	The student
Organizational part 5 min	Greetings and marking attendance	Greetings.
Introduction 5 min	1.Presenting the material to be learned 2. Explaining the purpose and tasks of the teacher	1. Writing an outline of the material. 2. Listen.
The main part 55 min	1. Explaining the new topic, using presentations. 2. Assigning a task to be done in computers using "The network boomerang" method.	1. Listening, making notes. 2. Performing the assignment on the computer.
The closing part 15 min.	1.Summarizing the task and evaluating students. 2.Assigning hometask.	1. Listening. 2. Write down the homework.

One of the main forms of training in teacher training and retraining is lecture. Much depends on how well the lecturer works in the lecture. In our opinion, if the listener realizes that the internship is a process, he or she will actively work on the lecture and analyze the entire learning process over and over. During reflection, the listener experiences his or her creative activity and turns from a passive listener to an active listener.

Criteria for evaluating the creativity of listeners of the courses "Informatics", "Mathematics" and "Physics", which are taught in the courses of retraining and improvement of professional skills of teachers, based on the nature of creativity. The criteria for targeting, motivating, creative knowledge and skills and focusing on innovative activities were selected, with the development of high, medium and low development levels in each.

From the testing and experimenting in high education institutions, the following results can be seen:

In control groups 17,18% students showed high levels on the initial stage , while on the final stage 19,2 percent students achieved high results. In experiment- testing groups 16, 49 % students recorded high results on the initial stage and 32, 99 % on the final stage. Students with medium results in control groups 43, 43% on final stages and it reached 50, 5 % on final stages , while this trend shows 47, 42% on initial stages and 52,58% on the last stage in experiment- testing groups.

As to students at low levels, they reduced from 39,39% to 30,3 in control groups .The percentage of low level students in experiment- testing groups decreased from 36,09% to 14, 43%.

According to overall results, by recalculating mathematic- statistic way the efficiency level was 1.4.This has proved that the achieved effectiveness was statistically true.Effectiveness of the experimental work’s results, which was calculated based on the Student’s t-test (Table III).

TABLE II. TABLE III. MATHEMATICAL AND STATISTICAL DATA ACCORDING TO THE RESULTS OF EXPERIMENTAL WORK

Courses on training and retraining of teaching staff general results of the creativity of the learners		
Group	**Experimental**	**Control**
Number of learners	153	160
The arithmetic mean of the scores	2,18	2,0
Student statistics	9,3	T_{emp}= 2,58>t_{cri}= 1,96

Олий таълим муассасаларида ўтказилган тажриба-синовнинг умумий натижалари

3.2.6-жадвал

Level of Students	In experimental group n=97		Controlled group m=99	
	At the beginning of the experiment	At the end of the experiment	At the beginning of the experiment	At the end of the experiment
High	16 (16,49 %)	32 (32,99 %)	17 (17,18%)	19 (19,2%)
Medium	46 (47,42 %)	51 (52,58 %)	43 (43,43%)	50 (50,5%)
low	35 (36,09 %)	14 (14,43 %)	39 (39,39%)	30 (30,3%)

The results confirm the assumption that the methodology for the development of creativity of learners of advanced training and retraining of pedagogical staff of universities provides an increase in the effectiveness of education and creativity of learners of in the experimental group is 10% higher in comparison to learners in the control group.

LVII. CONCLUSION

After carried out experimental tests, we came to the following conclusions:

1.An experimental testing program has been worked out to train students for innovative activities in the process of integration of information technologies in the education according to the theme, aim and duties of the experiment.

2.During the experimental work a set of methods selected and created according to the aim, duty of the investigation and the program of the experiment.

3." Observing method"helped the directly understanding of the target pedagogical process and incidents by the researcher." Talk method " helped to come into contact with the focused students involved in the program.Tests were used to assess the theoretical knowledge and other features of

students, while a set of independent and individual tasks helped to check the students' readiness for innovative activities according to given norms.

3.According to the comparative analysis of the results of higher education institutions, the following can be pointed out:

The efficiency is.....% in TUIT, and this trend is .....% in TUIT's branch in Fergana and in total .....% in TUIT's branch in Karshi.

4.While mathematically- statistically analyzing all the figures above in the 3 higher education institutions it is clarified that the efficiency rate is .....%.This has proved that the created program aiming at training students for innovative working and the educational- methodological manual gas worked effectively along with integrating information technologies in education.

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RAQAMLI TEXNOLOGIYALARDA GUMANITAR FANLARNI O‘QITISHNING ROLI

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Annotatsiya

Ushbu maqolada hozirgi davrda raqamlashgan jamiyat, uning ijobiy xususiyatlari, ta’lim jarayonida raqamli texnologiyalar va uning zamonaviy usullarni joriy etish bo‘yicha tadbirlar tavsiya etilgan. Shuningdek uzluksiz hamda oliy ta’lim tizimida raqamli ta’limga bo‘layotgan talab va ehtiyojlar muhokama qilingan.

Raqamli texnologiyalarning gumanitar fanlarni o‘qitishdagi roli tahlil qilingan. Raqamli vositalardan samarali foydalanish ta’lim jarayonini interfaol va qiziqarli qiladi, talabalarning mantiqiy fikrlashini, ijodiy salohiyatini rivojlantiradi. Maqolada raqamli texnologiyalarning gumanitar fanlardagi afzalliklari, imkoniyatlari va ulardan foydalanishning amaliy usullari yoritilgan.

Demokratik tamoyillarning amal qilishi Talabailarning aql-idrokiga ishonch, ularning mustaqil fikrlashiga imkon yaratish, talabalar faoliyatidagi ijodkorligi va tashabbuskorligini rag’batlantirish tarzida namoyon bo’lishida bevosita innovatsion texnologiyalarning o’rni va uning rivoji haqida fikr yuritiladi.

Kalit so‘zlar: Raqamlashgan jamiyat, raqamli ta’lim, raqamli texnologiya, modernizatsiya, taraqqiyot strategiyasi, axborot makoni, axborot texnologiyasi, ma’naviyat, ijtimoiy taraqqiyot.

Аннотация

В данной статье рекомендуются цифровое общество, его положительные черты, цифровые технологии в образовательном процессе и меры по внедрению современных методов. Также были обсуждены требования и потребности в цифровом образовании в системе непрерывного и высшего образования.

В статье анализируется роль цифровых технологий в преподавании гуманитарных наук. Эффективное использование цифровых инструментов делает образовательный процесс более интерактивным и увлекательным, развивает логическое мышление и творческие способности студентов. Рассмотрены преимущества, возможности и практические методы применения цифровых технологий в гуманитарных науках.

В статье речь идет о роли инновационных технологий и их развития в реализации демократических принципов в процессе непрерывного образования в виде уверенности в интеллекте учащихся, создания возможностей для их самостоятельного мышления, поощрения их творчества и инициативы на уроках и внеклассная деятельность. Ключевые слова: Образование, непрерывное, инновационное, технологическое, техническое, реальное, интерактивный метод, обучение.

Ключевые слова: цифровое общество, цифровое образование, цифровые технологии, модернизация, стратегия развития, информационное пространство, информационные технологии, духовность, социальное развитие.

Abstract

This article recommends the digital society, its positive features, digital technologies in the educational process and measures to introduce modern methods. The requirements and needs for digital education in the system of continuous and higher education were also discussed.

This article analyzes the role of digital technologies in teaching humanities. Effective use of digital tools makes the educational process more interactive and engaging, fostering

students' logical thinking and creative potential. The article highlights the advantages, opportunities, and practical methods of applying digital technologies in humanities education.

The article deals with the role of innovative technologies and their development in the implementation of democratic principles in the process of lifelong education in the form of confidence in the intellect of students, creating opportunities for their independent thinking, encouraging their creativity and initiative in the classroom and extracurricular activities. Key words: Education, continuous, innovative, technological, technical, real, interactive method, training.

Basic concepts: digital society, digital education, digital technology, modernization, development strategy, information space, information technology, spirituality, social development.

Kirish

Keyingi paytlarda raqamlashgan jamiyat, raqamlashgan iqtisodiyot, raqamlashtirilgan ta’lim kabi iboralar ko‘p ishlatilmoqda. Xo‘sh, raqamlashgan jamiyatning qanday afzallik tomonlari bor? Raqamlashgan jamiyatda insonning o‘rni va ahamiyati nimalardan iborat? Raqamlashtirish bugungi yangi taraqqiy qilayotgan O‘zbekiston uchun qanday zaruriyatga ega? O‘tgan asrlardan boshlab insoniyatning postindustrial jamiyatga o‘tishi globallashuvning keskin darajada oshishiga, inson faoliyatining barcha sohalarida axborotning rolini oshirish bilan bog‘liq jarayonlarda namoyon bo‘ldi. Axborot texnologiyalarining keskin rivojlanishi nafaqat ishlab chiqarishda, balki insonning kundalik hayotida ham muhim ahamiyatga ega bo‘ldi.

Raqamli texnologiyalari kishilar hayotining ko‘p jabhalarida axborot mahsulotlari va kommunikatsiyalar sohasiga o‘tishga imkon yaratib berdi. O‘zbekistonda shu munosabat bilan jamiyat nafaqat axborotlashgan, balki raqamli jamiyat bo‘lib qoldi. Jamiyatni yanada modernizatsiya qilish va milliy iqtisodiyotning raqobatbardoshligini oshirish borasida raqamli transformatsiya alohida ahamiyatga ega. Buni anglab yetgan Prezidentimiz Sh.Mirziyoev raqamlashtirish siyosatiga e’tibor qaratib, amalga oshirilayotgan islohotlarda haqiqiy axborotlashgan jamiyatni barpo etishga alohida e’tibor qaratmoqda.

Tadqiqot metodologiyasi.

O‘zbekistonda axborot-kommunikatsiya texnologiyalari (AKT)ni rivojlantirish va raqamlashtirishga 2000 yillarning boshlaridanoq ahamiyat berila boshlandi. Bu borada hukumat qarorlari va Farmonlar, chora-tadbirlar rejalari ishlab chiqildi. Jumladan, “2013-2020 yillarda O‘zbekiston Respublikasi Milliy axborot-kommunikatsiya tizimini rivojlantirish kompleks dasturi”, “2017-2021 yillarda O‘zbekiston Respublikasini rivojlantirishning beshta ustuvor yo‘nalishi bo‘yicha Harakatlar strategiyasi” hamda “Raqamli O‘zbekiston – 2030” va “2022-2026 yillarga mo‘ljallangan Yangi O‘zbekistonning Taraqqiyot strategiyasi” kabi normativ hujjatlar qabul qilinib, ularda milliy iqtisodiyot, sanoat, ijtimoiy soha, ta’lim va umuman jamiyatda raqamli transformatsiyani amalga oshirishga qaratilgan bir qator chora-tadbirlar ko‘zda tutilgan.

Tahlil va natijalar.

Jamiyatni raqamlashtirish fuqarolarga qanday yengilliklar olib keladi? Birinchidan, ijtimoiy-iqtisodiy va ilmiy-texnikaviy jarayonlarni tezlashtiradi; fuqarolarning hokimiyat organlari va boshqa tashkilotlar bilan uchrashuvlari va murojaatlarida yengilliklar yaratadi; uchinchidan, hayot sifatini yaxshilaydi; to‘rtinchidan, ish unumdorligini oshirish va mehnat sharoitlarini yengillashtirishga muvaffaq bo‘ladi. Raqamlashgan jamiyatning yana eng muhim xususiyatlaridan biri shuki, bu korrupsiyaga qarshi kurashishning eng samarali usulidir. Chunki, raqamlar hamma narsani aniq ko‘rsatadi, xotirada saqlaydi, kerak paytda ma’lumotlarni taqdim eta oladi. Bunday sharoitda biron ma’lumotni yashirish, yashirin bitimlar tuzish(kelishish), u yoki bu faoliyat haqida to‘liq axborot bermaslik(kamchiliklarni yashirish)ning iloji yo‘q, kompyuter hammasini namoyon qilib qo‘yadi. Ma’lumotlarning tizimliligi yolg‘on va qing‘ir ishlarga yo‘l bermaydi, chunki tizimni aldashning imkoni yo‘q. Natijada poraxo‘rlik, mablag‘larni samarasiz va maqsadsiz sarflash, oshirib yo yashirib ko‘rsatish imkoni qolmaydi. Bu esa jamiyatning barcha sohasida shaffoflik bo‘lishiga olib keladi, misol uchun, ijtimoiy sohaga yo‘naltirilgan mablag‘lar o‘g‘irlanmaydi,

maktablar, kasalxonalar, yo‘llarga ajratilgan pullar to‘liq yetib boradi va hokazo.

Bundan tashqari hozirgi kunda jahonda yuz berayotgan global o‘zgarishlar, axborot texnologiyalarning jadallashuvi kelgusida mexanik hamda jismoniy mehnat o‘rnini robototexnika egallashi mumkinligidan darak bermoqda. Shuning uchun raqamli texnologiya bo‘yicha strategiya ishlab chiqish, raqamli ko‘nikmalarni ommaviy shakllantirishni ta’minlash dolzarb masalalaridan biri sanaladi. Yoshlar yangi kasblar, turli texnologiyalardan foydalanish, kompyuterlar, internet, katta miqdordagi raqamli ma’lumotlarga ishlov berishga tayyor turishi kerak. Odamlar o‘z faoliyatida zamonaviy texnologiyalardan foydalanishga tayyor turishlari lozim, bularning barchasi esa bilimni talab etadi.

Xo‘sh, raqamli texnologiyalar shiddat bilan rivojlanib borayotan, axborot olish va foydalanish tezligi juda yiriklashgan hozirgi davrda ta’lim tizimida o‘qitish jarayoni qanday tashkil qilinmoqda?

Oliy ta’lim tizimida raqamli texnologiyalardan foydalanish ta’lim sifatini oshirish va ijtimoiy faol yoshlarni tarbiyalashda katta ahamyatga ega. Chunki, o‘qitish jarayonini sifat jihatidan yangi bosqichga ko‘tarish, yuqori malakali kadrlar tayyorlash tizimini yo‘lga qo‘yish va keng dunyoqarash va yuksak ma’naviyatli barkamol avlodni tarbiyalash borasida raqamli texnologiyalar va zamonaviy usullardan foydalanish bugungi kun talabidir.

2020 yil 5 oktabrdagi PF-6079-sonli “Raqamli O‘zbekiston - 2030” strategiyasini tasdiqlash va uni samarali amalga oshirish chora-tadbirlari to‘g‘risida”gi Farmonda aynan shu raqamli texnologiyani rivojlantirish va masofaviy ta’limni rivojlantirish masalalari ko‘rib chiqildi. O‘zbekiston Respublikasida uzluksiz ta’lim tizimini yanada takomillashtirish, ta’lim samaradorligi imkoniyatlarini rivojlantirish, mehnat bozorida yuqori malakali kadrlar tayyorlash siyosatini davom ettirish vazifalari ilgari surildi. Bu borada bir qancha amaliy islohotlar olib borildi va bugungi kunga qadar olib borilmoqda.

Ta’lim jarayoniga raqamli texnologiyalar va zamonaviy usullarni joriy etish bo‘yicha quyidagi tadbirlarni amalga oshirish lozim:

Raqamli ta’limni tushunadigan yuqori malakali kadrlar tayyorlash tizimini tashkil etish va bu borada pedagog kadrlarning kasbiy mahoratini uzluksiz rivojlantirib borish uchun qo‘shimcha shart-sharoit hamda imkoniyatlar yaratish;

Oliy ta’lim muassasasining konferensiya materiallari, bitiruvmalakaviy ishlar, magistrlik va doktorlik (PhD, ScD) dissertatsiyalaridan iborat ilmiy–texnik ma’lumotlar elektron bazasini yaratish;

Masofaviy o‘qitishning didaktik imkoniyatlarini nazariy-metodik asoslash; Zamonaviy axborot-kommuniksiya texnologiyalari va ta’lim texnologiyalarining mustahkam integratsiyasini ta’minlash;

Ta’lim jarayonlarini raqamli texnologiyalar asosida individuallashtirish, masofaviy ta’lim xizmatlarini rivojlantirish, vebinar, onlayn, “flipped classroom” texnologiyalarini amaliyotga keng joriy etish

Tinglovchilar ham kamida kompyuter va internet bilimlaridan xabardor bo‘lishini ta’minlash.

Ta’lim tizimiga raqamlashtirish jarayonining kirib kelishi ya’ni, noan’anaviy ta’lim texnologiyalarining kengayishi ta’lim jarayonining samarali bo‘lishiga olib kelmoqda. Ta’lim oluvchining bilimlarni o‘zlashtirishi an’anaviy texnologiyalarga qaraganda ancha tezdir. Ushbu texnologiyalar bilimlarni rivojlantirish, egallash va tarqatish xarakterini o‘zgartiradi, o‘rganilayotgan fanlarning mazmunini chuqurlashtirish va kengaytirish, uni tezda yangilash, samaraliroq o‘qitish usullarini qo‘llash, shuningdek, har bir kishi uchun ta’lim olish imkoniyatini sezilarli darajada kengaytirish imkonini beradi. ,

Raqamli texnologiyalar orqali talabaga ta’lim berilganda ta’lim oluvchiga ham, o‘qituvchiga ham darsni tashkil qilish usullari osonlashadi. Bunda esa ta’lim tizimi vositalari rolini multimediyalar, proektorlar, telefon liniyalar, smart doska, kodoskop, kompyuter, noutbuk, internetga ulangan televizorlar, bajarib beradi. O‘qituvchilarga bunday vositalar bilan dars mashg‘ulotlar o‘tkazish ta’lim sifatini oshirishni ta’minlaydi.

Agarda raqamli ta’limda samarali foydalanilganda qanday yutuqlarni qo‘lga kiritish mumkin?

Talaba xohlagan joyida va xohlagan vaqtida ta’lim olish imkoniga ega bo‘ladi;

Vaqt va mablag‘ sarfini keskin kamaytiradi

Internetdan axborot olish va undan foydalanish madaniyati shakllanadi;

Ta’lim tizimini yangi bosqichga ko‘taradi;

O‘qituvchilarga internet orqali turli ochiq kurslar tashkil etish imkoniyati tug‘iladi;

Ta’lim beruvchilarni o‘z ustida ko‘proq ishlashi va raqobat tufayli ta’lim sifatini yanada ortishiga xizmat qiladi va boshqalar; Raqamli texnologiyalarni o‘zlashtirish insoniyat tarixidagi boshqa innovatsiyalarga qaraganda tezroq sodir bo‘lmoqda: masalan, ta’lim sohasida virtual o‘quv muhiti va masofaviy ta’limning ta’minlanishi talabalarga boshqa imkoniyatga ega bo‘lmagan dasturlarda qatnashish imkonini berdi.

Xulosa va takliflar.

Xulosa sifatida aytish mumkinki raqamli texnologiyalarni turli sohalarga nafaqat ta’lim tizimiga joriy etilishi mamlakat ta’lim tizimini modernizatsiya qilishga, zamonaviy ta’limni tashkil etish va ta’lim samaradorligini ortishiga xizmat qiladi, bu birinchidan.

Ikkinchidan, raqamli ta’lim ta’lim samaradorligini oshirishga, onlayn ta’lim orqali mavjud vaqt va budjetning tejalishiga xizmat qiladi.

Uchinchidan, ta’lim muassasalarida o‘quv faoliyatini boshqarishda shaffoflikka erishishga, interfaol kontentlar yaratishga olib keladi.

To‘rtinchidan, o‘quvchi va talabalarda o‘qishga, izlanishga bo‘lgan motivatsiyaning oshishiga sabab bo‘ladi. Umuman olganda, uchinchi Renessans ostonasida turgan Yangi O‘zbekiston uchun, unda faoliyat olib borayotgan fuqarolari uchun raqamli jamiyat judayam zarur. Faqatgina buning uchun barcha korxona va tashkilotlarda Internet tezligini oshirish, uning narxini pasaytirish hamda axborot xavfsizligini ta’minlash masalalarini ham tahlil qilib ko‘rish lozim. Aksincha esa mazkur yo‘nalishda amalga oshiriladigan islohotlar katta samara bermasligi mumkin.

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GUMANITAR FANLARNI O‘QITISHDA RAQAMLI INNOVATSIYALARNI QO‘LLASH USULLARI

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Annotatsiya: mazkur maqolada bugungi kunda respublikamizda ijtimoiy-gumanitar fanlarni o‘qitishga qanchalik zarurat borligi xususan O‘zbekistonning eng yangi tarixini oliy o‘quv yurtlarida o‘qitilishiga oid mazkur maqola muallifi hamda O‘zbekiston Respublikasi Prezidentining bu boradagi fikrlari yoritilgan.

Kalit so‘zlar: ijtimoiy, gumanitar, ta’lim, yo‘nalish, fan, O‘zbekistonning eng yangi tarixi, tendensiya, rivojlanish, qaror, strategiya, o‘tmish, siyosiy.

Аннотация: в данной статье изложены мнения автора данной статьи и Президента Республики Узбекистан о преподавании социальных и гуманитарных наук в нашей республике сегодня, в частности, относительно преподавания новейшей истории Узбекистана в высших учебных заведениях. выделены.

Ключевые слова: социальное, гуманитарное, образование, направление, наука, новейшая история Узбекистана, тенденция, развитие, решение, стратегия, прошлое, политическое.

Abstract: in this article, the author of this article and the President of the Republic of Uzbekistan's opinions on the teaching of social and humanitarian sciences in our republic today, in particular, regarding the teaching of the latest history of Uzbekistan in higher educational institutions, are highlighted.

Key words: social, humanitarian, education, direction, science, latest history of Uzbekistan, trend, development, decision, strategy, past, political.

Kirish: Tarix fani ijtimoiy taraqqiyot va o‘tmishga oid turli xil voqelik hamda hodisalarning izchil rivojlanishi, ularning qachon, qayerda, qanday holatda yuz bergani, insoniyatning paydo bo‘lishi va uning tadrijiy-evolyutsion rivojlanishi, ijtimoiy-siyosiy, iqtisodiy jarayonlar hamda madaniy-ma’naviy hayot jabhasi va boshqalarni o‘rganadi. Shuningdek, O‘zbekiston tarixi umumjahon-insoniyattarixining ajralmas qismi hisoblanib, o‘z navbatida, ahamiyatga molik voqeliklargajuda boydir. O‘zbekiston tarixi fani mana shu voqeliklarni boshidan kechirgan qadim va yaqin ajdodlarimizning hayoti qanday bo‘lganini, jahon tarixi taraqqiyotiga qo‘shgan ulkan hissalarini xolisona va haqqoniy tarzda o‘rganadi[1].

Adabiyotlar tahlili va metodlar: Zamonaviy ta’lim texnologiyalari qo‘yilgan maqsadlarga erishishga yordam beradi, masalan: ta’lim darajasini farqlash texnologiyasi; guruh texnologiyalari; kompyuter o‘qitish texnologiyalari; o‘yin texnologiyalari; muammoli va tadqiqot o‘rganish texnologiyasi; o‘quv materialining sxematik va ramziy modellari asosida o‘qitishni intensivlashtirish texnologiyalari hamkorlik pedagogikasi. Zamonaviy texnologiyalar hissiy qulay muhitda o‘quvchilarning faol ko‘p bosqichli kognitiv faoliyati jarayonida fan va o‘quv bilim va ko‘nikmalarini shakllantirish va rivojlantirish, o’rganish uchun ijobiy motivatsiyani rivojlantirish imkonini beradi. Hozirgi bosqichda pedagogik texnologiya tushunchasidan pedagogik amaliyotda faol foydalanilmoqda. Biroq, uni tushunish va qo’llashda katta tafovutlar mavjud, shuningdek, turli olimlar tomonidan berilgan ko’plab ta’riflar mavjud, masalan, B.T.Lixachev, V.P.Bespalko, I.P.Volkov, V.M. tushunish pedagogik texnologiyani barcha ta’riflarning ma’nolarini o‘zida mujassam etgan mazmunli umumlashtirishdir[2].

Turli mualliflar. G.K.Selevkoning fikricha, “pedagogik texnologiya” tushunchasini uch jihat bilan ifodalash mumkin: 1) ilmiy: pedagogik texnologiyalar – pedagogika fanining maqsadlari, mazmuni va o’qitish usullarini o’rganuvchi va ishlab chiqadigan hamda pedagogik jarayonlarni loyihalashtiruvchi qismi; 2) protsessual va tavsifiy: jarayonning tavsifi (algoritmi), rejalashtirilgan o’quv natijalariga erishish uchun maqsadlar, mazmun, usullar va vositalar majmuasi; 3) protsessual jihatdan samarali: texnologik (pedagogik) jarayonni amalga oshirish, barcha shaxsiy, instrumental va uslubiy pedagogik vositalarning ishlashi. Shunday qilib, pedagogik texnologiya o‘qitishning eng oqilona usullarini o’rganuvchi fan sifatida ham, o’qitishda qo’llaniladigan usullar, tamoyillar va tartibga soluvchilar tizimi sifatida ham, real o‘quv jarayoni sifatida ham faoliyat yuritadi. Albatta, har bir o‘qituvchi o‘z faniga talabalarda chuqur qiziqish uyg’otishini, ular nafaqat o‘ylanmasdan ma’ruza yozishni, balki aytilayotgan gaplarni tushunib yetishlarini, mantiqiy fikr yurita olishlarini, har bir dars yuk bo‘lmasligini, balki har bir darsning o‘ziga yuk bo‘lmasligini xohlaydi. Talabalar va o‘qituvchi uchun quvonch[3].

Birinchidan, O‘zbekistonning eng yangi tarixi fani boshqa ijtimoiy fanlarga nisbatan ancha aniq fandir. U matematika usulidan ham keng foydalanadi. Tarixiy voqea va hodisalar qat’iy aniqlikda, davriy ketma-ketlik – xronologik asosda o‘rganiladi. Shuningdek, tarixiy voqea va hodisalar, hujjat va dalillarning haqiqiy va haqiqiy emasligi, ular qachon, qayerda, qanday tarixiy muhit va sharoitlarda tarixan voqe’ bo‘lgani aniqlanadi. Va nihoyat, bo‘lib o‘tgan voqeliklarning aniq sabab va oqibatlari, shu bilan birga, ularning aniq shakl-shamoyillari va holati aniqlanadi.

Ikkinchidan, O‘zbekistonning eng yangi tarixi fani mamlakatimiz yaqin o‘tmishidagi siyosiy-ijtimoiy, iqtisodiy hayotining ahvoli, holatini o‘rganadi, ulardan kelajak uchun saboq va xulosa chiqaradi. Mustaqillikka erishishidagi murakkab siyosiy ahvol tahlil etilgan holda istiqlolning qanchalik ulug‘ ne’mat ekanligi ko‘rsatib beriladi. Bu esa kelajak avlod uchun dasturilamal sifatida xizmatqiladi.

Uchinchidan, O‘zbekistonning eng yangi tarixi fani ko‘p qirralik va xilma- xillik xususiyatiga ega. U jamiyat taraqqiyotining va inqirozlarining faqat bir tomoninigina emas, balki jamiyatning hamma tomonlarini uzviy, o‘zaro bog‘liqlikda, bir butunlikda o‘rganadi. O‘zbekistonning eng yangi tarixi fani mamlakatning yaqin o‘tmishdagi voqeliklari, insoniyat hayoti, jamiyat taraqqiyotini tahlil qiladi. Uning o‘rganish predmetiga esa mana shu makondagi jamiki voqelik va jarayonlar, ulardagi umumiy aloqadorlik va yaxlit birlik hamda qonuniyatlar hodisasi va jarayonlar, umuman, xalq va insonning yaratuvchanlik faoliyati kiradi[4].

Zamonaviy o‘qituvchi o‘z faoliyatida o‘quvchilarning faolligi va mustaqilligini rag‘batlantiradigan turli shakllar, usullar, o‘qitish vositalarini birlashtirgan holda faollashtirishning turli usullaridan foydalanishi, ta’lim jarayoniga innovatsion pedagogik texnologiyalarni joriy etishi kerak. O‘rta maxsus kasb-hunar ta’limi muassasalari bitiruvchilariga oliy ta’lim muassasalariga kirish yoki ishga joylashish uchun yuqori talablar qo’yiladi. Ular murakkab zamonaviy dunyoga moslasha olishlari kerak: ularga nafaqat olgan bilimlari, balki ularni o‘zlari topish, hayotda o‘zini muvaffaqiyatli o‘rnatish uchun har qanday sohada o‘zini qobiliyatli odamlar sifatida his qilish, ijodiy fikrlash qobiliyati kerak.

O‘qituvchi o‘z faniga qiziqishini oshirish orqaligina bilim olishda yaxshi muvaffaqiyatlarga erisha oladi. Buning uchun talabalar tomonidan tayyor bilimlarni taqdim etish, ularni yodlash va takrorlash uchun emas, balki faol bilish jarayonida o‘quvchilar tomonidan bilim va ko‘nikmalarni mustaqil ravishda o‘zlashtirishga qaratilgan usullar tizimidan foydalanish kerak. faoliyat. Ba’zi an’anaviy o‘qitish texnikasi va usullari bu qiziqishning yo‘qolishining sabablaridan biridir. Talabalarning fanni o’rganishga bo’lgan qiziqishini rivojlantirish uchun talabalarni amaliy va aqliy faoliyatga undashga hissa qo’shadigan usullardan foydalangan holda o’qitishning an’anaviy usullaridan ham foydalanish zarur; kognitiv qiziqish va qobiliyatlarni shakllantirish va rivojlantirish; ijodiy fikrlashni rivojlantirish, shuningdek, innovatsion texnologiyalar elementlari (muammolarga asoslangan, o‘quvchilarga yo‘naltirilgan ta’lim elementlari, axborot-kommunikatsiya texnologiyalari va boshqalar)[5].

Mashg’ulotning muvaffaqiyati va bilimning mustahkamligi o‘quvchilarning fanga bo’lgan kognitiv qiziqishlarining rivojlanish darajasiga to‘g‘ridan-to‘g‘ri mutanosibdir. Talaba uchun darsning muhim jihatlaridan biri bu bilim olishda shaxsiy qiziqish zarurligini tushunishdir, shunda talabalar nafaqat natijada, balki butun o‘quv jarayoni davomida o‘z kompetentsiyalarini his qilishlari mumkin. ta’limning o‘quvchi shaxsiga rivojlanishiga ta’siri. Shuning uchun zamonaviy dars maxsus tashkil etilgan mashg’ulotlar va oddiy shaxslararo aloqalar uyg’unligida qurilishi kerak, shuning uchun darsda shaxsiy muloqot rejasi orqali o‘quvchilarning yoshi, psixologik xususiyatlari hisobga olinadi: ularning doirasini kengaytirishga tayyorligi. muloqot,kattalar muammolariga hamdardlik, o‘zini-o‘zi tasdiqlash istagi.

Zamonaviy ta’lim texnologiyalari qo‘yilgan maqsadlarga erishishga yordam beradi, masalan: ta’lim darajasini farqlash texnologiyasi; guruh texnologiyalari; kompyuter o‘qitish texnologiyalari; o‘yin texnologiyalari; muammoli va tadqiqot o‘rganish texnologiyasi; o’quv materialining sxematik va ramziy modellari asosida o‘qitishni intensivlashtirish texnologiyalari; hamkorlik pedagogikasi. Zamonaviy texnologiyalar hissiy qulay muhitda o‘quvchilarning faol ko’p bosqichli kognitiv faoliyati jarayonida fan va o‘quv bilim va ko’nikmalarini shakllantirish va rivojlantirish, o‘rganish uchun ijobiy motivatsiyani rivojlantirish imkonini beradi. Hozirgi bosqichda pedagogik texnologiya tushunchasidan pedagogik amaliyotda faol foydalanilmoqda. Biroq, uni tushunish va qo‘llashda katta tafovutlar mavjud, shuningdek, turli olimlar tomonidan berilgan ko‘plab ta’riflar mavjud, masalan, B.T.Lixachev, V.P.Bespalko, I.P.Volkov, V.M. tushunish pedagogik texnologiyani barcha ta’riflarning ma’nolarini o‘zida mujassam etgan mazmunli umumlashtirishdir[6].

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O‘qituvchi gapiradi, o’quvchi esa tinglaydi va o‘rganadi, lekin tayyor ma’lumotni tinglash o‘qitishning eng samarasiz usullaridan biri hisoblanadi. Bilimni mexanik ravishda boshdan boshga o‘tkazib bo‘lmaydi (eshitilgan – o‘rganilgan). Shuning uchun o‘quvchini ta’lim jarayonining faol ishtirokchisiga aylantirish zarur. Talaba fanga qiziqish bilan faqat o‘z faoliyatida ma’lumotni o‘zlashtira oladi. Binobarin, o‘qituvchi informator rolini unutishi, u o‘quvchining bilish faoliyatining tashkilotchisi, muvofiqlashtiruvchisi rolini o‘ynashi, o‘quvchi uchun darsda barcha turdagi o’quv va

bilish faoliyatini tashkil qilishi kerak. Talabaning o‘quv va kognitiv faoliyati o‘zlashtirilishi kerak bo‘lgan o‘quv materialiga mos kelishi kerak. Faoliyatnatijasida talaba mustaqil ravishda har qanday xulosaga kelishi, o‘zi uchun bilim olishi kerak[8].

Didaktikaning eng muhim tamoyili – bilimlarni mustaqil yaratish tamoyili bo‘lib, u bilimni o‘quvchi tomonidan tayyor shaklda emas, balki o‘qituvchi tomonidan tashkil etilgan ma’lum bir bilish faoliyati natijasida yaratilishidan iborat.

Binobarin, har xil turdagi pedagogik texnologiyalar talabalarning bilim va ijodiy qiziqishlarini rivojlantirishga yordam beradi. Innovatsion pedagogik texnologiyalardan faol foydalangan holda tizimli ishlar o‘quvchilarning fanga bo‘lgan qiziqishini, o‘quv faolligini oshiradi, bilimlarni chuqur va doimiy o‘zlashtirishni ta’minlaydi, o‘quvchilarning tafakkuri, xotirasi va nutqini rivojlantiradi, halollik, mehnatsevarlik va vijdonli munosabatni tarbiyalashga xizmat qiladi. tarbiyaviy ishlar, shuningdek, asosan talabalarning reproduktiv faoliyatini faollashtiradi[9].

O‘qitishning muhim xususiyati – bilimlardan foydalanish, ularni umumlashtirish va tizimlashtirishda samarali faoliyat uchun sharoit yaratishdir. Ta’lim jarayonini bunday tashkil etish o‘quvchilarning fikrlash qobiliyatini rivojlantiradi, ularni diqqatli bo’lishga majbur qiladi, ularni tahlil qilishga, taqqoslashga, asosiy narsani ajratib ko‘rsatishga o‘rgatadi, ularni sinfdagi passiv tinglovchilardan faol ishtirokchiga aylantiradi. Zero, pedagogik texnologiya – bu o‘rganish nazariyasiga asoslangan va rejalashtirilgan natijalarni ta’minlovchi ta’lim faoliyatini tashkil etish usullari, uslubiy texnikasi, shakllari yig‘indisidir[10].

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INTERDEPARTMENTAL COLLABORATION AS A TOOL FOR DEVELOPING PROFESSIONALLY-ORIENTED FOREIGN LANGUAGE TEXTBOOKS AT TUIT

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Abstract. This paper explores the collaborative development of professionally-oriented English language textbooks at the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi (TUIT), highlighting interdepartmental cooperation between the Foreign Languages Department and technical faculties. Over the past three years, this collaboration has produced instructional materials tailored to IT-related fields, incorporating digital tools and subject-specific content. The process also serves as a practice-oriented project for linguistics master’s students, enhancing their pedagogical and curriculum design skills. Challenges in interdisciplinary communication are acknowledged, but the initiative ultimately strengthens the quality of language education in alignment with industry needs.

Keywords: Professionally-oriented textbooks, English for Specific Purposes, interdepartmental collaboration, foreign language teaching, technical education, linguodidactic design, digital learning tools, interdisciplinary projects.

Introduction. The article discusses the development of professionally-oriented textbooks for foreign language instruction through the collaboration between the Department of Foreign Languages and specialized departments of a technical university. Interdepartmental cooperation is viewed as an institutional resource for enhancing the quality of higher education. The article provides examples of successful interdepartmental collaboration at the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi. It is demonstrated that a distinctive feature of the new generation of professionally-oriented textbooks, developed jointly by language and subject-matter departments, is the extensive use of terminology related to students’ future professional fields. This approach contributes to more effective acquisition of subject-specific content. A list of English language textbooks developed as a result of such interdepartmental collaboration is also presented.

Intra-university cooperation in creating professionally-oriented textbooks in a foreign language not only enhances the quality of educational resources but also fosters a culture of collaboration among faculty and departments. By leveraging diverse expertise, conducting thorough needs assessments, and implementing continuous feedback loops, universities can produce effective learning materials that meet both academic standards and industry requirements.

In an increasingly globalized world, the ability to communicate effectively in a foreign language is essential for professional success across various fields. Recognizing this need, universities are increasingly focusing on developing professionally-oriented textbooks that equip students with the language skills necessary to thrive in their chosen careers. This article explores the experience of intra-university cooperation in the creation of such textbooks, highlighting the collaborative efforts among faculty members, departments, and industry stakeholders. [1]

The process of designing these educational resources involves more than just translating technical jargon; it requires a comprehensive understanding of both the language and the specific professional contexts in which it will be used. By fostering interdisciplinary collaboration, universities can ensure that the content is not only linguistically accurate but also relevant and applicable to real-world scenarios. This article will delve into the strategies employed, challenges encountered, and best practices identified through various case studies, illustrating how cooperative efforts can lead to the development of high-quality, professionally-oriented language materials.[]

Through this exploration, we aim to shed light on the importance of collaboration in higher education

and its impact on enhancing the learning experience for students. Ultimately, our findings underscore the value of creating resources that bridge the gap between language learning and professional application, preparing graduates to meet the demands of an evolving job market. Modern scientific and technological advancements demand that future specialists, particularly in technical fields, possess strong foreign language skills, especially in English for accessing up-to-date information, reading scholarly publications in the original, and presenting their research internationally. At the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi (TUIT), this need has led to a strategic shift from using general technical English textbooks to developing specialized, professionally-oriented teaching materials aligned with specific academic programs. The Foreign Languages Department at TUIT has recognized that the creation of such targeted resources requires collaboration with technical faculty, as language instructors may lack detailed subject knowledge. As a result, interdepartmental cooperation has emerged as a vital approach to designing effective foreign language instruction that meets the evolving demands of technical education. In the context of developing specialized English-language teaching materials for the diverse fields of a technical university, the Foreign Languages Department at the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi (TUIT) has engaged talented students in linguistics (pedagogical profile) as active participants in the creation process. This initiative serves as valuable linguodidactic practice for these students and exemplifies internal university collaboration between three key stakeholder groups: language instructors, subject-matter faculty, and talented students. The aim of the study is to analyze both interdepartmental and intradepartmental collaboration in the development of specialized English textbooks for non-linguistic students. While such cooperation is recognized as a means of enhancing the quality of instructional materials, it remains an underexplored area in methodological research. Despite growing interest in interdepartmental collaboration across universities, existing studies are few and often general in scope. At TUIT, as in many other technical institutions, cooperation between language and technical departments is often limited to the formal alignment of course syllabi and rarely extends to deeper joint curriculum development. This highlights the need for more structured and meaningful academic partnerships to improve language education in technical contexts. Analysis of international literature reveals that this issue receives limited attention at the global level, despite its recognized importance among researchers. It is noted that insufficient collaboration between language departments and specialized faculties is a weakness in projects and studies conducted within the well-established methodological frameworks of English for Specific Purposes (ESP) and English for Academic Purposes (EAP) across various countries [3, 4].

Analysis of international literature shows that this issue receives limited attention globally, despite researchers recognizing its relevance. Insufficient collaboration between language departments and specialized faculties remains a weak point in projects and studies conducted within the widely recognized frameworks of English for Specific Purposes (ESP) and English for Academic Purposes (EAP) in various countries.

At the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi (TUIT), interdepartmental cooperation between technical and language departments has become increasingly important in recent years. Since the 2018/2019 academic year, TUIT and its branches have implemented a credit-based system for training personnel in the fields of information technologies and communications. This reform aligns with the university’s strategic goal of internationalization, which includes increasing the number of international students, delivering lectures in English for senior students, and raising the research publication output of academic staff with a focus on international indexing databases such as Scopus and Web of Science. These strategic developments have heightened the demand for effective collaboration between language and specialized departments at TUIT, making such cooperation a critical factor in improving the quality of foreign language education tailored to the needs of technical students.

Due to the increasing mobility of international students enrolling in core programs, the Foreign Languages Department at the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi (TUIT) has taken on additional responsibilities. To meet these demands, the department has organized intensive English courses to prepare technical faculty for delivering lectures in English. Furthermore, language centers for German, English, and French have been established to support student participation in academic mobility programs with partner universities abroad through language clubs and preparatory activities.

Since TUIT has also implemented a credit-based training system as part of its broader internationalization strategy. The university actively

engages in dual degree programs with institutions such as Kookmin University (South Korea) and participates in Erasmus+ projects aimed at curriculum modernization. Collaborations with European universities like the University of Klagenfurt (Austria) promote joint research and student exchanges. Additionally, partnerships with industry leaders, including ZTE, facilitate the integration of cutting-edge digital technologies into the educational process. Through these initiatives, along with regional academic exchanges across Central Asia, TUIT continues to strengthen its global academic presence and enhance the quality of its education. The study of lexical, grammatical, and stylistic aspects of business correspondence, official and colloquial styles, as well as the analysis of tables and charts based on illustrative material, linguistic formulas for describing similarities and differences between graphs and figures, and the description of statistical data, are all seamlessly integrated into the curriculum of the specified discipline. A crucial factor in the quality education of students at a technical university has also been the availability of well-developed teaching and methodological support. However, the collaboration between academic staff of specialized and language departments has extended beyond these aspects. In light of changes in the graduate education concept, one of the most important directions of interdepartmental cooperation has become the joint development of interdisciplinary English-language teaching materials.

Next-generation textbooks resulting from such collaboration are characterized, according to leading international methodologists, by a comprehensive linguodidactic framework that facilitates productive mastery of subject content. Whereas traditional professionally-oriented foreign language textbooks involve the interaction of two cognitive componentsthe generalized professional and the foreign language componentsthe new generation of interdisciplinary textbooks integrates additional interdisciplinary elements to better support the learning process. Given that integrating subject-specific content with language instruction is a key trend in modern foreign language teaching methodology, it is logical to incorporate this approach in the creation of new-generation professionally-oriented textbooks. The model of such a textbook can be described as follows: professional subject matter + foreign language + interdisciplinary integration.[5]

Table 1.

English language textbooks and manuals created as a result of interdepartmental collaboration

	Textbook and Manual Titles	Authors	Department in a Specialized Field
1.	Guide to the world of television	Safarova F.I	Television technologies
2.	English for wireless communication	Shakhakimova M.T	Telecommunicatio n technologies
3.	English in E-Commerce	Sharipova A. A.	E-commerce
4.	Business Principles and Practices	Ibragimova S.T.	Economics and management in ICT sphere
5.	Programmble mobile systems	.Nigmatova H.A	Radio and mobile communication
6.	English for Computer Engineering	.Razzakova G.R	Computer Engeneering
7.	English for IT students manual	Sharipova A.A.	Programmimng Engeneering
8.	Digital English	Atashikova N.A	Digital economics
9.	Cybersecurity Basics	Abulkasimovs Yu.S	Cybersecurity
10	English for Mechatronics and Robototechnics	Saydaliyeva G.A	Mechatronics and Robototechnics
11	English for Artificial Intelligence specialists	Muxitdinova M	Artificial Intelligence
12	High Level Languages	Barnoyeva N.	Programmimng Engeneering

As shown in Table 1, which was developed within the framework of the interdepartmental cooperation program, specialized textual materials were provided by faculty members of the profile departments, while all linguistic exercises and assignments were prepared by instructors from the Foreign Languages Department in collaboration with talented students, who have demonstrated advanced competence in both their chosen fields of study and in foreign language proficiency, enabling them to actively contribute to the development of specialized educational materials by bridging subject-specific knowledge with effective linguistic expression.

The partnership between language departments and specialized departments proved overall to be highly productive, though it initially faced several challenges, particularly, concerning the selection of source materials for the specialized texts. Some professors from the specialized departments believed that their own research articles, published in international journals, should serve as the main content for the teaching materials. However, throughout the collaborative process, they were provided with clear explanations regarding the preference for authentic texts authored by native English speakers.

Another significant challenge was the initial lack of awareness among specialized faculty

regarding the necessity of dividing selected professionally-oriented content from foreign journals and monographs into manageable didactic segments. Many co-authors from technical departments submitted excessively large blocks of text and were surprised when language instructors requested their assistance in breaking down the material and selecting appropriate illustrations.

In general, cooperation with specialized departments at TUIT in the development of teaching manuals has been an enlightening experience for foreign language instructors, particularly in terms of understanding the evolving nature of educational and cognitive activity among students in technical fields. For instance, in the field of robotics, the Department of Artificial Intelligence recommends that students engage with and translate robot maintenance manuals rather than scientific literature , despite, the latter often being considered more intellectually stimulating and academically relevant by language educators. [4]

Furthermore, in terms of content organization, foreign language instructors often found themselves needing to align with the structure preferred by the specialized departments, who aimed to ensure that the instructional content logically followed the progression of the professional course. As a result, the typical linguistic progression from simple lexical and grammatical structures to more complex ones was often not prioritized. To compensate for this challenge, many texts were supplemented with glossaries or translations of general technical glossary and field-specific terminology.

In summarizing our experience of co-developing professionally oriented textbooks with specialized departments, it can be concluded that the resulting materials align more closely with the principles of Content and Language Integrated Learning (CLIL), a methodological framework commonly used in introductory courses for professional specialization. With regard to the methodology of English for Specific Purposes (ESP), it tends to take a secondary role compared to Content and Language Integrated Learning (CLIL) in our context. Within the ESP framework, the logic of presenting professionally oriented material is subordinated to the structure of language instruction, which typically progresses from simpler to more complex lexical and grammatical constructions. In contrast, CLIL prioritizes the logic and structure of professional content delivery, integrating language learning into the subject matter. The correlation between CLIL and ESP, however, remains approximate in our case and requires further exploration through detailed analysis and practical examples. Textbook Development as an Interdisciplinary, Practice-Oriented Project for Linguistically Inclined Students. [5]

According to national educational standards, project-based learning is a required component of contemporary university curricula. Such projects are designed to develop a range of general cultural (universal), professional, and field-specific competencies that cannot be fully cultivated through traditional instructional methods alone. Project activities may be integrated within academic disciplines, program modules, or practical internships.

Practice-oriented projects are a core feature of professionally focused master's programs. They are aimed at equipping students with applied professional competencies through hands-on, real-world experience. The outcome of such project work is typically a tangible product that reflects practical, analytical, or creative efforts undertaken by the student.

In our case, the development of professionally oriented English-language teaching materials for students in non-linguistic specialties constitutes a practice-oriented interdisciplinary project. It is grounded in the synthesis of content and process-oriented elements of the course “Interdisciplinary Connections in Higher Education” and students’ pedagogical internships. This integration is viewed as methodologically sound, as it not only enhances the quality of instructional materials but also provides students with a meaningful opportunity to apply linguistic and methodological skills in a real-world academic setting. Interdisciplinary Approach and Its Role in Higher Education Textbook Design. [6]

The interdisciplinary approach to organizing the educational process in higher education, as embodied in the next-generation textbook model, enables the fulfillment of both national educational standards and the internal educational quality standards of TUIT. This approach helps students develop the ability to recognize interdisciplinary connections between the subjects (modules) they study and to understand their relevance to future professional activities. Specifically, students learn to establish meaningful links between the course “Foreign Language” and the professional disciplines within their academic programs and instructional materials.

As part of this initiative, the practical development of linguistic exercises for technical, interdisciplinary textbooks was integrated into the pedagogical internship program of linguistically inclined students. These activities were assigned as

individual tasks aimed at fostering their linguodidactic professional competence. The tasks required students to simulate the initial lessons from the textbooks under development by foreign language instructors. Each student was assigned a lesson from the forthcoming textbook, which they used as a foundation to design targeted exercises.

The majority of participating students completed the assignments with enthusiasm and demonstrated a deep understanding of the tasks. Several students expressed gratitude to their instructors for the opportunity to “immerse themselves” in their future professional domain in a new and meaningful way.

Conclusion

Intra-university cooperation in the creation of professionally-oriented textbooks in a foreign language can be a multifaceted process that involves collaboration among various departments and teachers. Interdepartmental cooperation between foreign language departments and specialized (profile) departments serves as a strategic resource for improving the quality of education in multidisciplinary universities. Based on the experience of the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi (TUIT), it has been demonstrated that the educational needs and expectations of technical departments are increasingly taken into account in language instruction, including in programs for international students.

Foreign Languages Departments at TUIT and its branches have engaged in meaningful collaboration with technical faculties, not only in delivering subject-specific language instruction, but also in organizing intensive English language training courses for faculty members to enhance their readiness to teach technical subjects in English. An additional area of cooperation is the establishment of language centers and language clubs (German, English, French), aimed at supporting students preparing for academic mobility programs with TUIT’s international partner universities.

One of the most significant outcomes of interdepartmental collaboration is the joint development of interdisciplinary foreign language textbooks. These next-generation instructional materials are tailored to specific academic disciplines and incorporate authentic, subject-relevant content. Although challenges initially arose, such as disagreements over source material and differing expectations about the structure and segmentation of the content ongoing dialogue between departments resulted in productive solutions. For instance, the preference for authentic, native-speaker sources was explained and accepted, and adjustments were made to ensure that technical content could be adapted into didactic portions suitable for language learning.

To date, seven co-authored English-language teaching manuals have been developed, reflecting the collective expertise of language instructors, technical faculty, and highly capable students. These students recognized for their advanced knowledge in both their future professional fields and in foreign languages played an active role in this interdisciplinary project. Their contributions, particularly in the development of linguistic and didactic exercises, were integrated into their pedagogical practicum and aligned with the national educational standards for the Linguistics specialization, as well as with TUIT’s internal educational quality framework .

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TA’LIM TIZIMIDA INNOVATSIYALARDAN FOYDALANISH XUSUSIYATLARI

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Anotatsiya **— Mazkur maqolada ta‘lim tizimidagi innovatsiyalar va yangicha innovatsion yondashuvlar asosida ta’lim sifatini oshirishga qaratilgan tadqiqotlarning tahlili hamda hukumatimiz tomonidan innovatsion ta’lim texnologiyalarini joriy etishga qaratilgan qonun va qarorlar keltirilgan. Raqamli texnologiyalarning gumanitar fanlarni o‘qitishdagi roli tahlil qilingan. Raqamli vositalardan samarali foydalanish ta’lim jarayonini interfaol va qiziqarli qiladi, talabalarning mantiqiy fikrlashini, ijodiy salohiyatini rivojlantiradi. Maqolada raqamli texnologiyalarning gumanitar fanlardagi afzalliklari, imkoniyatlari va ulardan foydalanishning amaliy usullari yoritilgan. Demokratik tamoyillarning amal qilishi Talabailarning aql-idrokiga ishonch, ularning mustaqil fikrlashiga imkon yaratish, talabalar faoliyatidagi ijodkorligi va tashabbuskorligini rag’batlantirish tarzida namoyon bo’lishida bevosita innovatsion texnologiyalarning o’rni va uning rivoji haqida fikr yuritiladi.**

KALIT SO‘ZLAR: RAQAMLI TEXNOLOGIYALAR, AXBOROT KOMMUNIKATSIYA TEXNOLOGIYALARI, RAQAMLI TA’LIM,

Bugungi kunda raqamli texnologiyalar har bir sohani, jumladan, ta’lim tizimini ham tubdan o‘zgartirmoqda. Insoniyat bilim va axborotga bo‘lgan talabini qondirish uchun zamonaviy texnologiyalarni yanada kengroq qo‘llashga intilayapti. Xususan, gumanitar fanlarni o‘qitish jarayonida raqamli texnologiyalarni joriy qilish ta’lim sifatini oshirish va talabalarning bilimlarni chuqurroq o‘zlashtirishlariga zamin yaratadi.

Gumanitar fanlar – inson ma’naviyati, madaniyati, tarixi va ijtimoiy munosabatlarini tadqiq qiladigan fanlar bo‘lib, ular jamiyatning ma’naviy rivojlanishida muhim ahamiyatga ega. Ushbu fanlarni raqamli texnologiyalar asosida o‘qitish nafaqat an’anaviy bilim berish uslublarini takomillashtirish, balki ularning samaradorligini oshirishda muhim ahamiyat kasb etadi.

Bugungi kunda yurtimizda ta‘lim sohalarida olib borilayotgan tub islohotlar O‘zbekiston Respublikasining yangi tahrirdagi “Ta‘lim to‘g‘risida”gi Qonuni va O‘zbekiston Respublikasi Prezidenti Sh.Mirziyoevning qator Qaror va Farmonlari talablari asosida mavjud ta‘lim-tarbiya tizimini tubdan isloh qilish, uzluksiz ta‘lim tizimini shakllantirish orqali ta‘lim muassasalari rivojini ta‘minlovchi yangi konsepsiyaning yaratilishi uchun zamin bo‘ldi. Mazkur ta‘limga oid me‘yoriy-huquqiy hujjatlar barkamol shaxsni tarbiyalash, uni yetuk mutaxassis sifatida innovatsion pedagogik faoliyatga tayyorlashni nazarda tutadi.

Innovatsion pedagogik faoliyatga tayyorlash muammosini tadqiq qilishning ustuvor metodologik asoslari bo‘lib, shu muammoni keng ko‘lamdagi tadqiqotlar konteksti doirasida har tomonlama tahlil qilish imkonini beruvchi tamoyillar xizmat qiladi.

Hozirgi davrda insoniyat yangi axborot asriga kirdi. Bu shuni anglatadiki, mahalliy va xorijiy tadqiqotchilarning fikriga ko‘ra (J.Delor, N. D. Nikandrov, A. I. Subetto va boshqalar.), jamiyat shakllanmoqda, uning asosiy ustuvor yo‘nalishlari axborot, bilim, ta‘limdir. Ushbu fikirni tasdiqlashda tadqiqotchilar, mutafakkirlar, davlat arboblari va ommaviy xalqaro tashkilotlar kelajakning kaliti butun aholining ta‘limida va ularning ta‘lim darajasini doimiy ravishda yaxshilashda yotadi, deb hisoblashadi Yuneskoning ta‘lim bo‘yicha Jahon hisobotida “biz keyingi asrni shaxslar va dunyo bo‘ylab davlat organlari ko‘rib chiqadi nafaqat bilimlarni chuqurlashtirishning davomi maqsadga yerishish demakdir, balki o‘z-o‘zidan tugaydi. Har bir insonning hayoti davomida bilim olishga qaratilgan sa‘y-harakatlari rag‘batlantiriladi va unga shunday imkoniyat beriladi" [2].

Ilm-fan, texnika, ishlab chiqarish va texnologiyaning jadal rivojlanishi jamiyat hayotining barcha sohalarida taraqqiyotining yangi istiqbollarini ochib berdi. Insoniyatning davlat va jamiyat qurilishiga doir asriy tajribalari ijtimoiy munosabatlarni yangicha yondashuvlar asosida tartibga solish borasidagi ilg‘or yondashuvlarning qaror toptirilishiga olib keldi. Mazkur yondashuvlarning mohiyati so‘nggi yillarda umumiy tarzda “innovatsiya” tushunchasi yordamida ifodalanib kelinmoqda. Xo‘sh, “innovatsiya” tushunchasi lug‘aviy jihatdan qanday ma‘noni anglatadi? Ushbu tushuncha negizida qanday holat tavsiflanadi?

Innovatsiya – inson ehtiyojlarini qondirish uchun yangi amaliy vosita, tushuncha, usul-yangilik yaratish, tarqatish, joriy etish va undan foydalanishning murakkab jarayonidir.

Odatda innovatsiya jarayonida mashinalar, dastgohlar, ishlab chiqarish qurollari hamda

texnologik jarayonlariga yangiliklar kiritiladi. Biroq, ilm-fan, texnika, ishlab chiqarish va texnologiyalarning rivoji tufayli jamiyat ham rivojlanishning muayyan bosqichidan yanada takomillashgan bosqichga o‘tadi. Xususan, gumanitar fanlarni o‘qitish jarayonida raqamli texnologiyalarni joriy qilish ta’lim sifatini oshirish va talabalarning bilimlarni chuqurroq o‘zlashtirishlariga zamin yaratadi.

O‘zbekiston mustaqillika erishgach, hayotimizda ro‘y berayotgan yuksalish jarayonlari o‘zini barcha sohalarda namoyon etmoqda. Ayniqsa ta’lim tizimida ham tub islohotlar olib borilmoqda. Bu borada o‘nlab muhim farmon, qaror va dasturlar qabul qilingani bizga yaxshi ma’lum.Qaerda “Raqamli iqtisodiyot” va “Elektron hukumat”ga o‘tilgan bo‘lsa, odamlarning og‘iri yengil bo‘layotgani, davlatning sarf-xarajatlari tejalayotgani, korrupsiyaning oldi olinayotgani yaqqol namoyon bo‘lmoqda.

Mamlakatimizda raqamli iqtisodiyotni faol rivojlantirish, barcha tarmoqlar va sohalarda, eng avvalo, davlat boshqaruvi, ta’lim, sog‘liqni saqlash va qishloq xo‘jaligida zamonaviy axborot-kommunikatsiya texnologiyalarini keng joriy etish bo‘yicha kompleks chora-tadbirlar amalga oshirilmoqda. Xususan, elektron hukumat tizimini takomillashtirish, dasturiy mahsulotlar va axborot texnologiyalarining mahalliy bozorini yanada rivojlantirish, respublikaning barcha hududlarida IT-parklarni tashkil etish, shuningdek, sohani malakali kadrlar bilan ta’minlashni ko‘zda tutuvchi 220 dan ortiq ustuvor loyihalarni amalga oshirish boshlangan.

Bundan tashqari, 40 dan ortiq axborot tizimlari bilan integratsiyalashgan geoportalni ishga tushirish, jamoat transporti va kommunal infratuzilmani boshqarishning axborot tizimini yaratish, ijtimoiy sohani raqamlashtirish va keyinchalik ushbu tajribani boshqa hududlarda joriy qilishni nazarda tutuvchi «Raqamli O‘zbekiston» kompleks dasturi amalga oshirilmoqda.

Bu kabi ustuvor vazifalarni amalga oshirishda birinchi galda, hozirgi holatni ijobiy yo‘nalishga solish va ushbu vaziyatni bir imkoniyat sifatida qabul qilishi kerak.

Raqamli ta’lim masofa va makon to‘siqlarini olib tashlaydi. Hozirgi sharoitda O‘zbekiston ta’lim tizimi qaysi yo‘ldan ketishi to‘g‘risida bir qator savollar turibdi. Xususan, u hozirgi an’anaviy tizimni rivojlantirilgan bosqichiga o‘tadimi yoki raqamli ta’lim tizimiga o‘tadimi? Savollar ko‘p. Ushbu savollarga qaramasdan ta’lim tizimida hech qachon o‘zgarmaydigan asos, ya’ni ustunlar mavjud. Bu “ta’lim oluvchi” va “ta’lim beruvchi” ya’ni “talaba” va “o‘qituvchi”dir. Agar ta’limda ana shu ikki tomonning dunyoqarashini o‘zgartira olsak, ya’ni o‘quvchini mustaqil ta’lim olishga, bilim olish yo‘llarni mustaqil izlashga, o‘qituvchini esa yangi bilimlar bilan raqamli texnologiyalar asosida qurollantirib talabaga bilim olish yo‘llarini o‘rgatishini yo‘lga qo‘ya olsak, ta’lim tizimi qaysi shaklga o‘tishidan qat’iy nazar ta’limda sifat paydo bo‘ladi. Ana shu masala mamlakatimiz ta’lim tizimining eng og‘riqli va zaif nuqtasi hisoblanadi.

Bu masalalar bo‘yicha oliy ta’lim tizimi dunyoning yetakchi universitetlaridan o‘rganadigan, o‘zlashtiradigan jihatlar nihoyatda ko‘p. Ta’lim tizimi rivojlangan dunyoning qator davlatlarida muayyan kurs bo‘yicha darslar Google Classroom platformasidan foydalangan holda amalga oshirilmoqda. Odatda, keng omma “Google” tizimini asosan qidiruv va elektron tarjimon sifatida taniydi. Biroq ushbu tizimning ilm-fan, ta’lim uchun foydali imkoniyatlari nihoyatda keng. “Google” tizimi ta’limdagi masofa va makon tushunchasini yo‘qqa chiqaradi. Sababi uning dasturlari dunyoning qay chekkasida bo‘lmasin talaba va pedagogni bir vaqtda ishlash imkoniyatini yaratadi. Bu uchun “gmail”dan elektron pochta ochishning o‘zi kifoya qiladi. “Google classroom”, “Google doc”, “Google disk” dasturlari bunda yordamga keladi. “Google classroom”- dasturi sinfxona vazifasini bajaradi. Bunda O‘zbekiston Respublikasi Prezidentining 2020 yil 5 oktabrdagi PF-6079-sonli “Raqamli O‘zbekiston -2030” strategiyasini tasdiqlash va uni amalga oshirish chora – tadbirlari to‘g‘risida”gi Farmoni. pedagog talabalarni ro‘yxatini tayyorlash, vazifa berish, topshiriq bajarilishi muddatini belgilash, baholash, fanga oid qo‘shimcha ma’lumot berish, turli xil mavzuga doir bahslar uyushtirish va talabalar fikrini bilishga erishishi mumkin. Bunda talaba “Google doc” dasturida elektron hujjat yaratadi va ilmiy rahbari bilan “gmail” orqali aloqaga chiqadi. Ushbu dasturning imkoniyati shundaki, bir paytning o‘zida ham talaba, ham pedagog tahrir qilish, qo‘shimchalar kiritish imkoniyatiga ega bo‘ladi. Hammualliflikda ilmiy maqolalar yozishda ham juda qo‘l keladi. Ayniqsa, hozirgi kezda chet ellik hamkorlar bilan yoxud ilmiy rahbar bilan bevosita ko‘rishish imkoniyati cheklangan sharoitda bu dastur katta qulaylik yaratadi. “Google disk” dasturi ma’lumot saqlash uchun xizmat qiladi. Dastur katta hajmdagi ma’lumotni saqlash imkoniyatiga ega. Bu dastur barchaga birdek qulay. Foydalanuvchilar yozilgan matnlarni yo‘qotish va og‘ir kitoblarni ko‘tarib yurishdan ozod qiladi. Kutubxonada ishlab

turib kerakli ma’lumotlar “Google disk”da saqlanadi va zarurat tug‘ilganda istalgan yerdan internet vositasida yuklab olish mumkin buladi.

Yuqorida keltirilgan barcha dasturlardan foydalanilgandan so‘ng, talabalarni amalga oshirgan vazifalarining natijasini “E-Portfolio” sahifasida ko‘rsatish mumkin bo‘ladi. “E-Portfolio” ham “Google” imkoniyatlaridan kelib chiqqan holda yaratiladi. “Google”da veb-sayt yaratish dasturi ishlab chiqilgan bo‘lib, u juda qulay. Hozirgi informatsion texnologiyalar rivojlanib, jadallashib borayotgan bir paytda, har bir shaxs o‘zining har sohadagi fikrlari, qarashlari va yutuqlarini o‘rtoqlashish maqsadida shu turdagi “E-Portfolio” yaratsa, uning ilmiy, ijtimoiy, falsafiy faoliyatidan barcha birdek bahramand bo‘lishi mumkin. Shu o‘rinda yozuvchi, qator ta’limiy saytlar muallifi Mark Prenskining “Digital Natives, Digital Immigrants” (“Raqamli dunyo sohiblari, raqamli dunyo muhojirlari”) nomli maqolasida bugungi kun talabalariga quyidagi ta’rifni beradi: “Hozirda talabalarimiz batamom o‘zgargan. Zamonaviy talabalar endilikda biz ishlab chiqqan ta’lim tizimimizga ko‘ra o‘qitiladigan kishilar emas”. Maqolada bugunning talabalari “Digital Natives” – “Raqamli dunyo sohiblari”– bugungi kunda kompyuter, video o‘yinlari va internetning raqamli tilida o‘z ona tiliday so‘zlashuvchi yoshlar sifatida ta’rif beriladi. Ta’lim sohasi vakillari o‘qituvchilarga esa “Digital Immigrants” – “raqamli dunyo muhojirlari” – raqamli, elektron dunyoga moslashayotgan, yangi texnologiyalarning ko‘pgina qirralarini endi qabul qilayotgan kishilar sifatida baho beriladi. \

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DIGITAL TRANSFORMATION OF UNIVERSITY LIBRARIES OF THE REPUBLIC OF KAZAKHSTAN

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***Abstract*—This article delineates the phased digital transformation of university libraries in the Republic of Kazakhstan from the early 1990s to the present. The analysis identifies five distinct stages of evolution: initial automation of internal processes and the creation of electronic catalogs; connectivity to the global internet and the adoption of network-integrated library systems; a strategic shift towards full-text electronic resources facilitated by national and international consortia; the integration of RFID technologies to enable user self-service and smart library functions; and the current migration to cloud-based automated library platforms. The study highlights key milestones, including the formation of the national library consortium, the development of major national digital libraries, and the growing adoption of institutional repositories. The transformation has been driven by technological advancements, strategic national projects, and increasing integration into the global library community, fundamentally reshaping information services in Kazakhstani higher education.**

Keywords—Digital Transformation, University Libraries, Kazakhstan, Library Automation, Electronic Resources, Library Consortia, RFID, Cloud Technologies, Institutional Repositories.

LVIII. INTRODUCTION

The digital transformation of libraries is a global imperative, fundamentally altering how information is managed, accessed, and delivered. In the context of higher education, this transformation is critical for supporting research, teaching, and learning. For the Republic of Kazakhstan, this process is a stated national priority. The Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023–2029, approved by the Government Decree No. 248 dated March 28, 2023, explicitly notes the digital transformation of libraries as a key task for transitioning universities to a "smart university" model with an integrated digital ecosystem [1].

Digital transformation is distinct from mere automation or digitization. Following Borovinsky's definition, it is understood as a profound reorganization of business processes through the extensive use of digital tools, leading to a significant improvement in efficiency (e.g., reduced execution time, resource savings) and/or the emergence of fundamentally new qualities and services [2]. In academic libraries, this shift extends beyond technology to enhance the overall efficiency and effectiveness of services [3]. Libraries globally are leveraging this transformation to expand virtual services, create customized user experiences through AI, improve data security with blockchain, promote digital literacy, foster open access, ensure access to up-to-date information, and support environmental sustainability [4]. Key trends shaping future strategies include the wider adoption of low-code platforms, cloud migration, AI and machine learning, intelligent search, automation, blockchain, virtual collaboration, IoT, and the XaaS model [5].

While the drivers of digital transformation are universal, their implementation is shaped by local contexts. This article analyzes the specific evolutionary path of digital transformation within the university libraries of Kazakhstan, tracing its distinct phases from initial automation to the current adoption of cloud-based platforms, as detailed in Chapter II.

LIX. EVOLUTION OF DIGITAL TRANSFORMATION OF UNIVERSITY LIBRARIES IN KAZAKHSTAN

The **initial stage** of digital transformation for university libraries in the Republic of Kazakhstan began in the early 1990s, when libraries started using personal computers to automate both internal library processes and user services. Automation typically began with the creation of an electronic catalog, often carried out by staff from the university to which the library belonged. The Scientific Library of the Kazakh State University (now Al-Farabi Kazakh National University), the country's leading university, began maintaining its electronic catalog in 1992. That same year, the National Library of the Republic of Kazakhstan, the nation's main library, began its own automation [6]. In 1994, the first republican conference on the automation of university libraries was held at the Scientific Library of Kazakh State University. From 1995–1998, the higher library education system was modernized, its content updated, and the first Kazakh educational standards were approved [7].

This stage was characterized by a lack of knowledge about international formats for storing and exchanging bibliographic information (USMARC and UNIMARC), an absence of international connections (outside the CIS) that would allow the use of international experience in library automation, and software installed on standalone PCs used primarily for creating and editing bibliographic records. A positive development was the creation of specialized automation departments (sectors) and the introduction of positions for Deputy Library Director for Automation into the

organizational structures of libraries. This allowed for the hiring of IT specialists, including programmers, which undoubtedly accelerated the automation of library and information processes.

In the second half of the 1990s, Kazakhstani universities, and consequently their libraries, connected to the global Internet. This period can be considered the **second stage** of digital transformation, as the adoption of email for communication at global, national, and local levels, access to external information resources via the Internet, and the implementation of library websites as entirely new tools for library and information services brought qualitative changes to the activities of the country's university libraries. The library of Kazakh State University opened its first Internet hall for students in 1998 (https://edu.kaznu.kz/about.html).

This stage is also characterized by the implementation of networked integrated library automation systems, both domestic (KABIS, RABIS) and foreign (Russian) (IRBIS, MARK-SQL, Biblioteka 4.0). The National Library initiated the creation of a union electronic catalog for the country's public libraries based on the RABIS software (Republican Automated Library Information System), implemented in more than 50 libraries nationwide [6]. During this time, university library websites were actively created, though they offered a limited range of virtual services (information about library resources and events, electronic catalog search, asynchronous and synchronous virtual reference service).

Kazakhstani libraries began integrating into the international library community. In 1995, the Scientific Library of Kazakh State University became a member of the International Federation of Library Associations and Institutions (IFLA). In 1996, on the initiative of the National Library of the Republic of Kazakhstan, the Library Association of the Republic of Kazakhstan (BARK) was founded for the first time in the country's history and became an IFLA association member.

The **third stage** of digital transformation for university libraries in Kazakhstan is associated with a shift in focus from bibliographic information to full-text resources, typically represented in licensed databases accessible by subscription. This occurred in the early 2000s and was marked by the creation of the country's first information consortium, the "Association for Cooperation with International, State and Other Organizations of the Information Consortium of Libraries of Kazakhstan," officially registered on November 14, 2001 [8]. The consortium's founders were the Republican Scientific and Technical Library of Kazakhstan and the Central Scientific Library of the Ministry of Education and Science of the Republic of Kazakhstan. The idea was to improve and develop information technologies in libraries and other organizations in Kazakhstan, and to enhance the completeness, quality, and timeliness of bibliographic and information services for users regardless of their location. Ultimately, 50 leading Kazakhstani libraries from various systems and departments across all regions of the country became members.

The national consortium became a member of the international library consortium Electronic Information for Libraries (EIFL.net). The first international information resource accessed by consortium members in Kazakhstan was EBSCO databases on CD/DVD-ROMs, a choice dictated by the low speed of full-text information transmission in the computer networks available to university and public libraries at the time. Subsequently, members were provided with remote access to licensed databases from various international providers, to which the consortium subscribed either independently or as a member of EIFL.net.

During this period, university libraries also began creating their own full-text digital libraries from the works of university teachers and researchers or digitized public domain books. Projects to accumulate full-text content at the national level were also implemented. In December 2007, the Kazakh National Electronic Library (KAZNEB), created on the basis of the National Academic Library of the Republic of Kazakhstan in Astana, became accessible on the Internet at: http://www.kazneb.kz. The goal of KAZNEB is to preserve the historical and cultural heritage of Kazakhstan and provide access to it through modern information and communication technologies. In 2009, the Republican Inter-University Electronic Library (RMEB) was created at https://rmebrk.kz/ to provide faculty, students, master's and doctoral students with interactive multimedia educational resources by combining the electronic educational resources of higher education institutions. Currently, 94 universities in the country are participants in RMEB.

University libraries in Kazakhstan participate in creating their universities' institutional repositories (IRs), populating them with content and conducting self-archiving workshops for faculty, researchers, and students. The first IR was created at L.N. Gumilyov Eurasian National University in 2013, followed by IRs at 7 other Kazakhstani universities [9].

The **fourth stage** of digital transformation is associated with the implementation of RFID technologies in libraries, starting in the 2010s. This innovation enabled user self-service in library reading rooms, provided open access to shelves, improved statistical reporting, etc. The range of international licensed databases to which libraries subscribed, as well as the virtual services offered to users, also expanded. In 2014, university libraries were given the opportunity to benefit from a national subscription to the international databases Web of Science, Scopus, and ScienceDirect, and later to Wiley databases. To improve the efficiency of library processes and user service quality, Springshare products like LibCal, LibGuides, and LibAnswers were implemented at Nazarbayev University Library. Reference managers—EndNote, Mendeley, and Zotero—began to be actively used in Kazakhstani universities. The libraries of Nazarbayev University, Narxoz University, Maqsut Narikbayev University, Demirel University, and the Kazakh National Women's Teacher Training University transitioned from UDC to the Library of Congress Classification for organizing their collections.

The **fifth stage** of digital transformation involves the implementation of cloud-based automated library systems, which began in the 2020s. The first such system in Kazakhstan was the MegaPro system from Data Express LLC (Russia). It is currently installed in 17 universities (https://data-express.ru/mir-megapro/Kazakhstan/). The platform elibra.kz (online electronic library), developed in Kazakhstan, is gradually gaining popularity among the country's academic libraries. It provides cloud data storage, supports Kazakh and Russian languages, the MARC21 format and Z39.50 protocol, and integration with RFID and SIP2. In 2023, the Ex Libris (Clarivate) Alma library services platform was implemented at Nazarbayev University Library. Another distinctive feature of this stage has been the creation of assistive technology rooms for users with visual and hearing impairments at libraries, driven by the government's signing of international conventions and subsequent inclusion legislation.

LX. CONCLUSION

The digital transformation of university libraries in Kazakhstan has followed a clear and phased evolutionary path, as detailed in Chapter II. The journey began with basic automation and the creation of electronic catalogs in the early 1990s, progressed through connectivity and networking in the late 1990s, and was significantly advanced by the strategic, consortia-led acquisition of full-text electronic resources in the 2000s. The 2010s introduced RFID technologies for smart services and self-service, while the current decade is defined by a strategic migration to cloud-based platforms like elibra.kz, MegaPro and Alma, promising greater agility, scalability, and interoperability.

This evolution has been propelled by key national initiatives such as the formation of the library consortium, the development of KAZNEB and RMEB, and integration into global networks like IFLA and EIFL. These efforts have collectively transformed libraries from passive repositories of print materials into dynamic, user-centric hubs for digital information and innovative services.

Looking forward, the trajectory points towards the continued development of sophisticated Library Services Platforms (LSPs), the expansion of institutional repositories and research data management services, and the integration of artificial intelligence for personalized content discovery and advanced analytics. However, future success depends on overcoming significant barriers. These include securing sufficient funding for technology modernization and staff development, justifying ROI in the language of ICT, and, most crucially, ensuring that library staff are sufficiently motivated and possess the necessary modern skills to be active drivers of their libraries' ongoing digital transformation. Overcoming these challenges is paramount for university libraries to fully support the research and educational goals of Kazakhstani universities in the 21st century.

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МОДЕЛЬ ОЦЕНКИ ЭФФЕКТИВНОСТИ МОДУЛЯЦИОННО-КОДОВОЙ КОНСТРУЦИИ В СЕТЯХ 5G

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Аннотация **—Рассматриваются модели и методы оценки помехоустойчивости кода LDPC (Low-density parity-check code). Предложен простой метод оценки корректирующей способности кода LDPC. Определена вероятность неправильного приема кодового слова при различных скоростях кодирования и уровнях помех в радиоканале. Выбор эффективных модуляционно - кодовой конструкции (MCS- Modulation and Coding Scheme) сети 5G основан на допустимом значении вероятности ошибки кодового слова.**

Ключевые слова — код LDPC, помехоустойчивый код, код с корректирующей способностью, скорость кодирования, сеть 5G, модуляционно-кодовая конструкция (MCS), эффективность MCS.

LXI. Введение

В рекомендациях ITU-T излагаются различные аспекты применения и оценки эффективности функционирования сети телекоммуникации [1-4]. Наряду с этим, в Республике Узбекистан разработаны государственные стандарты и нормативные документы по показателям и нормам качества услуг передачи данных [5].

В рекомендации ITU-T Y.1540 приведена многоуровневая модель показателей эффективности (производительности) IP-сети (Network performance - NP) [1].

IP-сети состоят из следующих уровней:

нижележащие уровни (Lower Layer), которые обеспечивают (через звенья передачи данных) транспорт, ориентированный на соединения и поддерживающий уровень IP;

уровень IP (IP Layer), который обеспечивает транспортировку IP-дейтаграмм (то есть IP-пакетов) без организации соединений;

более высокие уровни (Higher Layer), которые поддерживаются протоколом IP и обеспечивают дальнейшие связи "от конца до конца".

Нижележащие уровни (звено передачи данных) соответствуют физическим и канальным уровням, уровень IP – сетевому уровню, высокие уровни - транспортным, сеансовым и прикладным уровням OSI.

В рекомендации ITU-T X.149 дается отображение характеристик звена передачи данных (LL) и IP [4]. Указанное отображение характеристик рассматривается как дополнение к Рекомендации МСЭ-Т Y.1541, поскольку Рекомендация МСЭ-Т Y.1541 не зависит от технологий обеспечения уровня звена передачи данных. Соответственно, Рекомендация ITU-T X.149 не определяет нормы на характеристики “от конца до конца”, но иллюстрирует путь, дающий возможность поддержать нормы ITU-T Y.1541.

Звено передачи данных 5G, отличается от звена LTE тем, что в протоколе HARQ (Hybrid Automatic Repeat reques)__реализуется код с малой плотностью проверки на четность – LDPC [6].

Производительность протокола HARQ существенно зависит от помехоустойчивости LDPC кода. Оценка количества исправляемых битовых ошибок в кодовом слове LDPC кода необходима для выбора оптимальных MCS и параметров протокола HARQ. Поэтому задача оценки исправляющей способности LDPC кода и выбора оптимального MCS является актуальной.

В данной работе на основе обработки известных результатов имитационного моделирования предлагается модель аналитической оценки исправляющей способности LDPC кода и эффективности MCS.

LXII. Определение исправляющей способности LDPC-кода

Алгоритмы кодирования и декодирования LDPC-кода подробно описаны в работах [6,7]. В теории помехоустойчивого кодирования скорость кодирования r_k определяется по формуле [6]:

$$r_k = \frac{k}{n} \qquad (1)$$

где k - число информационных битов в кодовом слове, n - длина кодового слова.

Для LDPC кодов не существует точного аналитического выражения для определения их исправляющей способности t как функции длины кодового слова n и скорости кодирования r_k. В работах [8-10] проведены множество численных экспериментов для исследования помехоустойчивости

LDPC кода с проверочными матрицами для кода с длинами n (50,100,200,500,1000 бит) и алгоритмом жесткого декодирования с числом итераций 50. На основе аппроксимации результатов имитационного моделирования предложена следующая эмпирическая формула для определения исправляющей способности кода [10]:

$$t = \frac{n(r_k - 0.0342 \ln n - 0.7101)}{-0.73 \ln n - 0.2951} \quad (2)$$

Формула (2) достоверна только для рассмотренных длин кода, а для остальных длин кода результаты расчета не совпадают с результатами имитационного моделирования, полученных для больших длин кода $(n > 1000)$.

Проведенный анализ известных результатов экспериментальных исследований показывает, что существует закономерность зависимости исправляющей способности кода t от скорости кодирования r_k независимо от длины кода n. Эта закономерность приведена на рисунке 1.

Из рисунка 1 следует, что доля исправленных битов от длины кода при различных скоростях кодирования является почти постоянной величиной. Результаты имитационного моделирования, полученных для максимальной длины LDPC кода 64800 бит, также подтверждают выявленную закономерность.

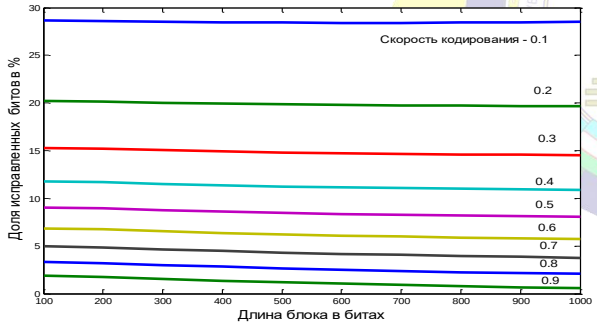


Рис.1. Зависимость исправляющей способности LDPC кода от длины кода и скорости кодирования.

На основе рисунка 1 в таблице 1 приведены средние доли исправляемых ошибок от длины кода при различных скоростях кодирования.

ТАБЛИЦА I. ИСПРАВЛЯЮЩАЯ СПОСОБНОСТЬ LDPC КОДА

Скорость кодирования	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
Средняя доля исправляемых битов от длины кода, %	28	20	15	12	8	6	4	3	2

LXIII. ОПРЕДЕЛЕНИЕ ОПТИМАЛЬНОЙ MCS

Если исправляющая способность кода t известна, то вероятность ошибочного приема кодового слова определяется по формуле:

$$P_c = \sum_{i=t+1}^{n} C_n^i P_b^i (1 - P_b)^{n-i} \quad (3)$$

Вероятность правильного приема кодового слова равна:

$$Q_c = 1 - P_c \quad (4)$$

Вероятность битовой ошибки после реализации MCS определяется в виде:

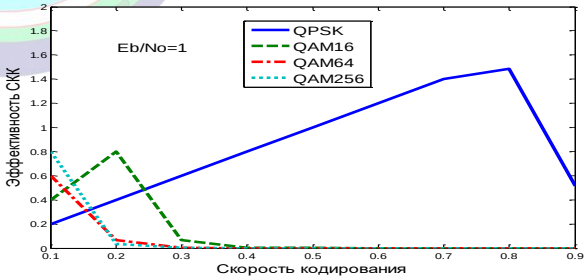
$$p_1 = \frac{P_c}{n} \quad (5)$$

К MCS предъявляются следующие требования к ее показателям: большая скорость кодирования r_k, высокая вероятность правильного приема кодового слова Q_c и высокая спектральная эффективность метода модуляции $log_2 M$.

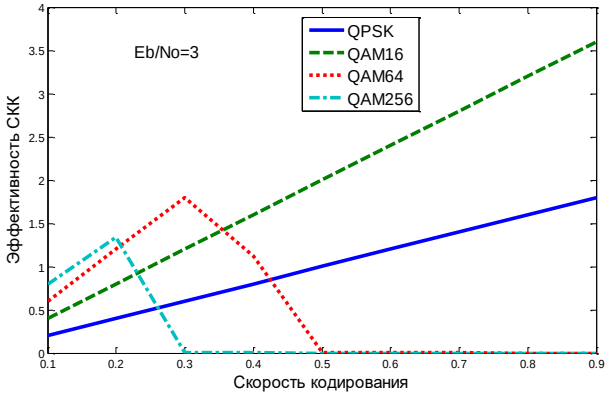
Все перечисленные требования являются противоречивыми, т.к. улучшение одного показателя эффективности приводит к ухудшению другого показателя. Поэтому эффективность MCS следует оценивать по следующему критерию, представляющему произведения всех показателей эффективности:

$$E = r_k Q_c \log_2 M \quad (6)$$

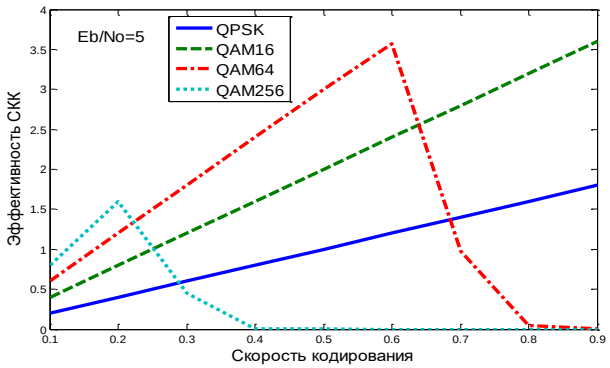
Для примера на рисунках 2 приведены значения E при нескольких отношениях E_b/N_0.



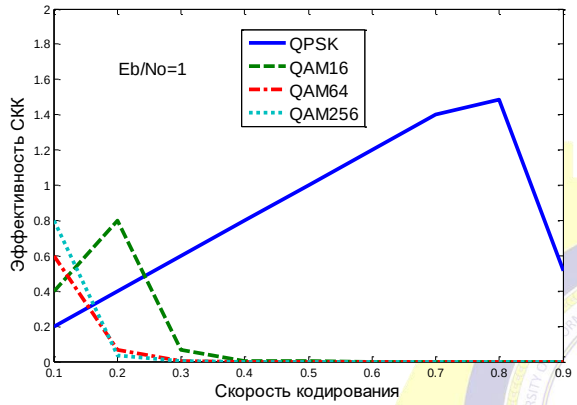
(a)



(б)



(с)



(д)

Рис.2. (а), (б), (с) и (д) графики зависимости эффективности MCS от скорости кодирования при различных значениях E_b/N_0.

Необходимо выбирать MCS с максимальным значением E в зависимости от показателя качестве радиоканала E_b/N_0.

В некоторых приложениях задаются ограничения на вероятность правильного (или ошибочного) приема кодового слова. Допустим, вероятность правильного приема кодового слова Q_c должна быть равна и больше, чем допустимое значение Q_c^* ($Q_c \geq Q_c^*$). Тогда из множества вариантов MCS, удовлетворяющих условию $Q_c \geq Q_c^*$, выбирается вариант MCS с максимальной эффективностью.

В таблицу 2 сведены результаты выбора варианта MCS при некоторых отношениях E_b/N_0 и $Q_c^* = 0.999$.

ТАБЛИЦА II. ВАРИАНТЫ СКК С МАКСИМАЛЬНОЙ ЭФФЕКТИВНОСТЬЮ И УДОВЛЕТВОРЯЮЩИЕ УСЛОВИЮ $Q_c \geq 0.999$

E_b/N_0 dB	Параметры MCS	
	Метод модуляции	*Скорость кодирования LDPC*
1	QPSK	0.7
2	QAM16	0.5
3	QAM16	0.7
4	QAM16	0.8
5	QAM16	0.9
6	QAM64	0.5
7	QAM64	0.6
8	QAM64	0.7
9	QAM64	0.8
10	QAM64	0.9
15	QAM256	0.6
20	QAM256	0.8

LXIV. ЗАКЛЮЧЕНИЕ

На основе анализа результатов имитационного моделирования определена закономерность исправляющей способности LDPC кода в зависимости от скорости кодирования. Это позволило аналитически оценить помехоустойчивость LDPC кода и эффективность MCS.

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HIGH AVAILABILITY OF CORPORATE NETWORK SERVICES WITH PROXMOX VE AND CEPH

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***Abstract*—This paper presents the design, deployment, and evaluation of a cost-efficient, open-source high-availability (HA) cluster for corporate IT services using Proxmox VE and Ceph. Motivated by national digital-transformation priorities, we implement a three-node Proxmox VE cluster with distributed Ceph storage, network segmentation for management/ replication/ client traffic, and HA orchestration via Proxmox HA-manager. On this platform we provision mission-critical services – file sharing, a replicated database tier, web hosting, and mail – and assess failure behavior under node and service fault scenarios. Measurements show automatic service recovery after a physical-node outage in ~120 s and VM-level recovery after process/guest failures in ~10 s, corresponding to effective annual availability up to "five nines" while eliminating single points of failure at compute, storage, and network layers. We further analyze reliability risks, describe mitigation, and provide a brief cost/benefit view highlighting the viability of open technologies for organizations with constrained budgets. Results indicate the proposed architecture is reproducible, scalable, and suitable for medium-to-large enterprises seeking HA without proprietary licensing overhead.**

Keywords—Proxmox VE; high availability (HA); Ceph; failover clustering; virtualization (KVM/LXC); Galera replication; quorum/Corosync; cost-effectiveness.

LXV. INTRODUCTION

In the context of rapid digitalization and growing business dependence on IT infrastructure, ensuring the continuous operation of key corporate services is of strategic importance. According to the Strategy of the President of the Republic of Uzbekistan "Digital Uzbekistan – 2030", one of the priority areas is the implementation of reliable digital solutions in the public and private sectors, which requires ensuring high availability of information systems [1]. File servers, databases, web applications and other critical services must be protected from failures and ensure the continuous operation of business processes. Even short-term interruptions can lead to significant losses and undermine the trust of partners and customers. According to the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated March 15, 2021 No. RCM-134 "On the Strategy for Ensuring Information Security", special attention should be paid to building a fault-tolerant infrastructure that minimizes the risks of downtime and disruptions in the functioning of digital systems [2]. One of the effective approaches to solving this problem is clustering server resources, which provides automatic service recovery in case of node failure, as well as flexible load distribution between them.

Virtualization technologies and open software platforms, such as Proxmox Virtual Environment (Proxmox VE), are becoming popular tools for building an available and fault-tolerant infrastructure. Proxmox VE provides the ability to build full-featured high-availability clusters based on open software, supporting both virtual machines (KVM) and containers (LXC), as well as built-in distributed Ceph storage. This is especially relevant for organizations seeking to optimize costs without losing the reliability and flexibility of solutions.

This work is aimed at the analysis and practical implementation of a cluster architecture based on Proxmox VE in the context of ensuring high availability of corporate IT services. The study considers both the theoretical foundations of building an HA environment and the practical aspects of cluster configuration and operation: from architecture design and service configuration to monitoring and cost-effectiveness assessment. This approach is in line with the priorities of the state digital transformation and meets the requirements of the national information security strategy.

The purpose of the work is to analyze and implement a failover cluster using Proxmox VE, as well as evaluate its effectiveness in ensuring high availability of corporate network services. To achieve this goal, the following tasks are solved in the work:

- designing a test bench architecture taking into account the requirements for failover;
- installing and configuring a Proxmox VE cluster with Ceph storage integration;
- deploying highly available services: file server, database server, web server, and mail service;
- conducting failover tests and recovery time analysis; assessing the reliability of the solution and the economic effect of implementation.

The practical significance of the work lies in the possibility of using the obtained results to create a reliable and failover IT infrastructure with minimal costs, using open source software solutions, which is especially important for organizations with a limited budget.

LXVI. METHODOLOGY

LXVII. Rationale for Choosing Proxmox VE Platform for Clustering

Selecting a hardware and software platform for implementing a highly available cluster is a key step in designing a solution. In the context of our task (ensuring high availability of corporate network services through clustering), it makes sense to use Proxmox VE for a number of reasons:

LXVIII. No licensing costs and openness;

LXIX. Full-fledged high availability capabilities;

LXX. Flexibility in working with data storage;

LXXI. Support for containerization and various OS;

LXXII. Ease of management and community.

Taking into account all of the above, the choice of Proxmox VE for clustering is justified economically and technically. This platform provides a full set of tools for building a highly available cluster: from fault tolerance of virtual machines to flexible storage management, with zero license cost and reliance on proven open technologies (KVM, Linux, Ceph, etc.). As part of the work, this choice will allow us to implement an HA cluster for corporate services and conduct its analysis, demonstrating the advantages of Proxmox in practice in comparison with analogues (VMware, Hyper-V). The following sections will be devoted to the practical implementation and testing of such a cluster on Proxmox VE.

LXXIII. Architecture and requirements for the test cluster

To ensure fault tolerance of corporate services, a cluster of several physical nodes running Proxmox VE is built. Virtualization significantly simplifies the task of high availability, removing dependencies on physical hardware and providing the ability to quickly restart the service on another node in the event of a failure. A typical Proxmox VE cluster is based on Corosync for transmitting service messages and on the pmxcfs distributed configuration file system, which replicates settings between all nodes. According to the requirements, at least three nodes are required for a reliable quorum. The selected servers have the same hardware characteristics (dual-processor systems with 16-32 cores, 64-128 GB of RAM, several SSD drives and 10GbE network adapters). It is recommended to separate the cluster and storage traffic: for example, allocate a separate network for Corosync (1Gbps), one for internal Ceph traffic (25+ Gbps) and one for public VM networks (10+ Gbps). This avoids mutual influence of Ceph and Corosync traffic. The general network diagram of the test cluster is shown in Figure 1. The nodes are connected via a dedicated management switch (Management) and direct Ceph cluster channels (ens3f0/ens3f1). Corosync/pmxcfs daemons and Ceph components (monitors and OSD) are running on each node.

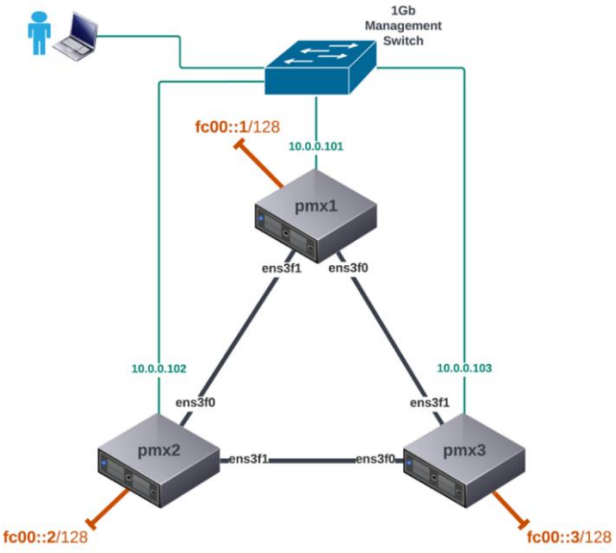

Fig. 3. Proxmox VE test cluster network topology (example)

Important hardware requirements include the use of server components with no single point of failure: RAID controller with redundant disks, redundant power supply, ECC memory, two network interfaces in a bond or two ports on different switches. For a Ceph cluster in a small deployment, it is better to use SSD drives, since they speed up recovery after failure and reduce the risk of data loss during cluster degradation. Below is a summary table of the test cluster configuration (Table I).

TABLE III. TEST CLUSTER CONFIGURATION SUMMARY TABLE

Component	Description / Test cluster selection
Number of nodes	3 (minimum for stable quorum)
Processor	2× Intel Xeon (16 cores, ~3GHz)
RAM	64 GB DDR4 per node
Storage	4× 1 TB NVMe SSD per node (OSD Ceph)
Network	2×10 Gbps (for Ceph cluster and VM traffic), 1×1 Gbps (for Corosync)
OS	Proxmox VE 8 (based on Debian 12 “Bookworm”)
Software	Ceph (Quincy), Samba/NFS, MariaDB/Galera, Apache/Nginx, Postfix/Dovecot

Architectural features of nodes and resource planning. Cluster nodes are dual-processor servers with ECC memory support, redundant power supplies, and duplicated network ports (bond). On such servers, processors and memory are distributed across NUMA nodes (each processor has its own set of local memory). For optimal performance of virtual machines, it is important that the resources of one VM are located mainly within one NUMA node, without excessive movement across nodes – Proxmox VE and KVM support NUMA-Aware VM configuration. This allows reducing memory access delays and improving the performance of multi-threaded applications.

Storage configuration and redundancy. The Proxmox VE operating system is installed on RAID1 (e.g. software ZFS or mdadm RAID) for fault tolerance of the system disk. A distributed Ceph pool is used to store virtual machine data. Each node contains four NVMe SSDs (1 TB), which act as

separate OSD disks (JBOD) in Ceph. According to Ceph recommendations, a hardware RAID controller is not required - on the contrary, it can increase latency; instead, JBOD mode or software mirroring is used for system disks. The distributed Ceph storage is configured with a replication factor of “size=3” (three copies of objects) and “min_size=2”, which allows writing to continue if one node fails. This approach eliminates a single point of failure in the data: the loss of a disk or an entire server does not lead to its inaccessibility, since the remaining nodes store two copies of each fragment. OSD failure recovery is accelerated by SSD drives: high-speed drives reduce data synchronization time and reduce the risk of data loss during cluster degradation.

Network partitioning and traffic isolation. The cluster has separate networks for management, storage, and client traffic. A 1-Gbps network labeled Management is used for Corosync and cluster management. Ceph traffic is divided into public (for client IO) and private (for replication) channels. Although Ceph can operate in a single network segment at speeds of ≥25Gbps, our solution physically allocates two 10-Gbps networks: one for Ceph and the other for the virtual machine load. All interfaces are combined into an active bond (LACP) connected to redundant switches - this ensures load balancing and fault tolerance at the network level. This segregation eliminates the mutual influence of Ceph and Corosync networks (management), increasing the predictability of cluster performance.

Node failure scenario and load redistribution. When one node is disconnected, the others maintain quorum (2 out of 3) and continue to work. Corosync and pmxcfs daemons on the remaining servers record the absence of the node by heartbeat. The web interface and pvecm status immediately show the "Out-of-Cluster" state for the failed node. If the virtual machine was turned on and configured as HA, ha-manager will automatically start it on one of the remaining nodes. Thanks to Ceph replication, the VM disk image is available on other OSDs, and the machine will continue to work with intact data. At the same time, Ceph detects the unavailability of the OSD and automatically rebuilds the missing replicas: at size=3, min_size=2, the cluster allows working with one missing disk and shares data with copies on active nodes. After the node returns, the data is partially resynchronized back, restoring the balance. In total, this ensures service continuity: although the detection and restart time of the VM takes several tens of seconds, the OS itself and applications do not actually lose critical data (see the overview of Proxmox HA capabilities).

Comparison with traditional shared storage (iSCSI/NFS). The Ceph cluster architecture is fundamentally different from the classic scheme of a single network storage. In the case of NFS or iSCSI, one or more separate storage source servers are usually used. One NFS server can provide a shared resource to all nodes, but it itself is a point of failure (if the server fails, the virtual machines lose access to the disks). iSCSI provides block access, but one target in a standard configuration is “mounted” by only one client and does not allow simultaneous connection of several nodes without special cluster mechanisms. For HA with iSCSI/NFS, it would be necessary to organize additional replication or clustering (for example, NFS-HA on OCFS2/GFS2, iSCSI with DRBD and multiple paths), which complicates the infrastructure. Ceph is initially distributed: thanks to storing three copies and the CRUSH algorithm, the load is automatically distributed, and new copies are built without external management. In addition, access via Ceph RBD (the Linux kernel) is more efficient: tests show that the performance of RBD modules is 4-10 times higher than using an iSCSI gateway under equal conditions. RBD clients communicate directly with OSD daemons without gateway bottlenecks. As a result, the Ceph approach provides more uniform I/O and scalability by adding nodes, which is difficult to achieve with "monolithic" iSCSI/NFS solutions.

Justification of key parameters. For a failover cluster, a three-node minimum solution was chosen (3 nodes provide a guaranteed quorum in the event of one failure). The number of NVMe disks (4 pcs. per node) is due to the desire to increase Ceph parallelism: more OSD streams - higher storage throughput. A capacity of 1 TB is minimal for efficient use of OSD (less than 100 GB is inefficient). 10Gbps networks are used based on Ceph's need for high-speed replication and disk traffic servicing; under modern workloads, 1Gbps would be a bottleneck. The use of server-class components (ECC memory, PSU redundancy, dually bonded NIC) meets the recommendations for eliminating single points of failure. All these solutions together provide a balance between performance, fault tolerance, and scalability: the selected architecture allows for node failure without service downtime, fast data recovery, and flexible cluster resource expansion if necessary. This section substantiates the choice of architecture and technical requirements for building a fault-tolerant cluster based on Proxmox VE. The key components were defined: the minimum number of nodes (at least three to ensure quorum), types of network connections (management network, Ceph network, client network), storage structure (distributed using Ceph), and hardware requirements for nodes (server-class with power backup, ECC memory, and SSD drives for Ceph OSD). The architecture design takes into account the elimination of a single point of failure at all levels: from the network to storage and computing resources. The proposed cluster configuration ensures high scalability, flexibility and stability, being a reliable basis for hosting critical corporate services with high availability support.

LXXIV. Deploying and Configuring a Proxmox VE Cluster

The cluster deployment process begins with installing the Proxmox VE operating system on each physical node. For this, the official ISO image provided on the developer's website is used. The installation is performed in bare-metal mode and takes less than 15 minutes on a standard configuration server.

After installation, each node is given:

- a unique host name (hostnamectl set-hostname node1);
- a static IP address for the management network (for example, 192.168.100.1/24);
- correct DNS settings and default gateway;
- time synchronization via an NTP server to avoid desynchronization of timestamps, which is critical for quorum and Ceph.

On the first node, the cluster is created using the pvecm command:

```
# apt update && apt full-upgrade -y
# pvecm create ha-cluster
```

On the remaining nodes, execute the command to add to the cluster, specifying the IP of the first node:

```
# pvecm add 192.168.100.1

After merging, check the cluster status:

# pvecm status

Cluster information

~~~~~~~~~~~~~~~~~~~~
Name:             ha-cluster
...
Quorum information
~~~~~~~~~~~~~~~~~~~~
Date:             Fri May 15 12:00:00 2025
Quorate:          Yes
...
```

At this stage, the basic cluster configuration is formed: the nodes are combined into a Corosync ring, providing distributed synchronization and configuration coordination. Message exchange between nodes occurs with minimal delay, which is critical for fault tolerance. Under the hood, pmxcfs works – a configuration file system synchronized between cluster nodes via RAM (RAMFS).

After starting the monitors and OSD, the ceph status command is executed on all nodes to check health (HEALTH_OK). In Proxmox VE, RBD (Ceph block device) or CephFS storage is configured via the Datacenter → Storage interface. All virtual disks of future VMs are placed in this fault-tolerant storage so that the data is available from any node upon restart.

LXXV. Organization of fault-tolerant services

For each service, a virtual machine (KVM) or container (LXC) is created and its monitoring is enabled via the HA manager. This allows the service to be automatically brought up on another available node if a node fails. Let's look at the main server roles:

- *File server.* It is implemented on the basis of Samba (or NFS) inside a separate VM. User data is stored on CephFS or RBD partitions, which ensures their availability when migrating a VM. A VM with a file server is marked as an HA resource (using a command like ha-manager add vm:<ID>). If the current node fails, ha-manager will automatically start this VM on the remaining node.
- *Database server.* The test cluster uses MariaDB with Galera replication support. Each node contains one DB cluster node, united by a Galera cluster. If a node fails, Galera ensures data consistency on the remaining nodes. In addition, the DB server VM itself is included in HA: it can be restarted on another node if the container/virtual machine itself crashes. Using Galera allows you to achieve virtually continuous operation even if one database node is turned off.
- *Web server.* For example, Nginx or Apache is used as a frontend. You can deploy two web servers as separate VMs with a replica of static content, and put a virtual IP or balancer in front of them. In the simplest version, one VM with a web server is launched, the site data is stored on a common Ceph storage. The VM is marked as an HA resource, so if a node fails, the web server will be automatically raised on another node.
- *Mail server.* Organized on the basis of Postfix + Dovecot in a virtual machine. Mailboxes are stored on CephFS / RBD, which also ensures general data availability. To prevent loss of emails, you can set up replication of mail agent accounts and queues between nodes (for example, use a common LDAP or DRBD for /var/mail). The mail server VM is also added to the HA cluster.

For example, after creating all the necessary VMs, register them in the HA manager:

```
# ha-manager add vm:110 # File server
# ha-manager add vm:120 # Database server
# ha-manager add vm:130 # Web server
# ha-manager add vm:140 # Mail server
```

In the Proxmox GUI, this corresponds to enabling the HA option in the virtual machine properties. After that, ha-manager starts monitoring the state of these resources. Each HA resource is included in a group if it is necessary to ensure the order of starting interdependent VMs, but there are no special dependencies for the services considered.

LXXVI. Results and Discussion

LXXVII. Failure Testing and Availability Analysis

Targeted tests were conducted to validate fault tolerance. The test cases simulated node and service failures, and then measured the downtime of user services (via ping, HTTP requests, attempts to access the file server, etc.).

For example, during an emergency shutdown of one of the nodes (simulation of a hardware failure), the HA manager determined the loss of quorum and automatically restarted all HA resources running on the failed node on the remaining node. The measured downtime of the web service showed about 120 s (2 minutes) until full availability on the new node. This corresponds to an availability level of approximately 99.999%: when converted to an annual period, 2 minutes of downtime is negligible (Table II shows typical values of availability and acceptable downtime).

TABLE IV. Typical values of availability and acceptable downtime

Failure Scenario	Downtime Estimated	Availability
Physical Node Emergency Shutdown	~120 sec	~99.999%
Virtual Machine Soft Restart	~10 sec	~99.9999%

The second scenario is a process crash in a VM: we simulated a sudden termination of the guest OS (for example, kill -9 of the main web server process). In this case, Proxmox itself quickly restarted the virtual machine according to the specified policy; the service was back online in about 10 seconds. Such a short downtime has virtually no impact on annual availability (about 99.9999%).

The results confirm that high service availability is achieved thanks to Proxmox VE HA and properly selected cluster hardware. Regular failure testing allows you to evaluate recovery metrics and confirm that the service recovery time meets enterprise-level requirements (<99.99%). Additional tools are available if necessary – for example, manually launching ha-manager migrate to perform scheduled migrations, as well as detailed logs (/var/log/pve-ha.log, GUI

Tasks/Logs), allowing you to analyze the behavior of the cluster during failures.

A cluster with three nodes designed and deployed on the basis of Proxmox VE provides automatic switching of virtual services in case of equipment failures. Architectural solutions (network separation, distributed Ceph storage, database replication) and built-in monitoring mechanisms allow achieving the required fault tolerance of corporate services.

LXXVIII. Assessing the reliability, risks and sustainability of the system

A Proxmox VE cluster with Ceph distributed storage provides high reliability by eliminating single points of failure and using a redundant architecture. Every piece of software and hardware in the cluster must be designed for fault tolerance. Key measures to improve reliability include the use of UPSs, redundant power supplies in servers, ECC memory, and redundant communication channels. Figure 2 shows an example of a typical design for a fault-tolerant cluster: two servers are connected to two independent networks and two SAN switches for access to storage; heartbeat communication is established between the nodes to detect failures.

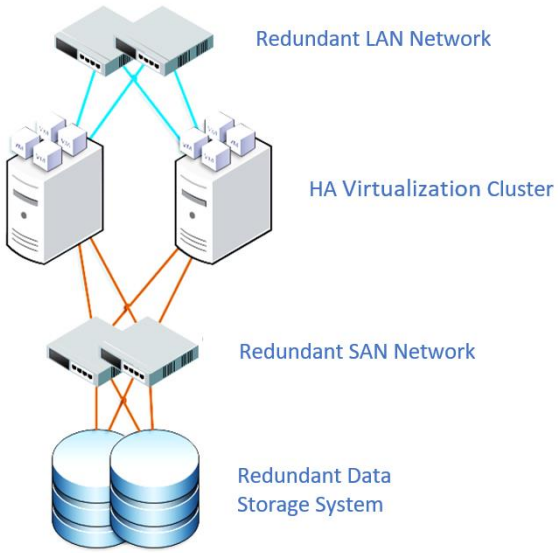

Fig. 4. 2-node failover cluster diagram (redundant networks and storage)

Each component of the system introduces its own risks and requires measures to mitigate them. Let's consider them by category:

Network infrastructure. A cable or switch failure can lead to loss of communication between nodes or split-brain of the cluster. To reduce the risk, network channel duplication (bonding), backup switches and separation of management and storage traffic on different VLANs/segments are used. It is also important to ensure stable network connectivity between Ceph nodes and networks, since network separation can lead to the inaccessibility of some data.

Ceph storage. Ceph is initially designed without a single point of failure: the CRUSH mechanism is used to store data, distributing objects across multiple OSD disks. If one disk (OSD) fails, the system automatically rebuilds the data on other nodes to maintain the specified replication level. An important requirement is the presence of at least three monitors (monitoring daemons) to ensure quorum - this allows maintaining control over the cluster if one MON node fails. If the majority of monitors fail or the quorum is lost, data access will be impossible. Therefore, it is recommended to have three (or an odd number more) monitor nodes, each on a separate physical server. It is also important to use a sufficient number of OSD daemons and correctly configure crush rules to withstand multiple failures (for example, with replication in 3 copies, the system will survive the failure of up to two OSDs). Virtualization nodes (Proxmox VE). Transparent failure of one cluster server leads to automatic migration of virtual machines to backup nodes thanks to the built-in ha-manager. However, this requires compliance with the quorum conditions: at least three nodes are recommended in a Proxmox cluster. If one node fails, the remaining two will keep the cluster running; the failure of the second node will lead to loss of data access. In addition, it is necessary to provide hardware self-fencing (watchdog) and a cluster configuration replication scheme so that if a node hangs or suffers a hardware failure, it is automatically rebooted and "drops out" of the cluster without the risk of a corrupt state. Proxmox has a typical failure and failover detection time of about 2 minutes; therefore, the maximum availability is limited to about 99.999% (up to 5 minutes of downtime per year in total). For clarity, a comparative analysis of risks and mitigations is provided in Table III.

TABLE V. RISK ANALYSIS FOR CLUSTER SOLUTION COMPONENTS

Component	Possible refusal	Consequences	Risk reduction measures
Networking Equipment	Switch, cable, LAN failure	Loss of communication between nodes or with Ceph; split-brain	Redundancy of switches and cables; channel bonding; UPS
Storage Modules (Ceph OSD)	Ceph disk/node failure	Loss of availability of some data, cluster degradation	Data replication (min 3 copies); hot-spare disks; status monitoring; regular check (scrub)
Ceph Monitors	≥2 of 3 monitors failure	Loss of quorum; storage unavailable	At least 3 monitors on different nodes; network for monitors via a dedicated channel
Proxmox VE Node	Server failure (power, hard crash)	Restarting VM on backup nodes; short-term downtime	≥3 nodes in a cluster for quorum; redundant power supplies, UPS; ECC-RAM
Software Failures (SW)	Hypervisor, kernel failure	Hanging of service, possible failover	Self-healing mechanisms (ha-manager); testing updates; service monitoring

Thus, the cluster reliability is ensured by the redundancy of all critical components. The standard Proxmox and Ceph tools provide automatic fault balancing: for example, Ceph does not have a single point of failure and can continue to operate even in a “degraded” state, rebuilding the data placement in real time. The applied quorum algorithm eliminates the occurrence of split-brain: the cluster remains operational as long as more than half of the monitors (and nodes) are available. The economic feasibility of the requirements for fault tolerance is also emphasized by the developers: when designing a cluster, all critical elements should be “doubled”, although this increases the cost of the system, but significantly increases availability.

LXXIX. CONCLUSION

This article provides a comprehensive theoretical and practical study of the issue of building a highly available IT infrastructure based on the open Proxmox VE platform. The main concepts and criteria of high availability were studied, fault tolerance implementation methods were analyzed, cluster types were classified, and comparative characteristics of popular virtualization solutions were given – VMware vSphere, Microsoft Hyper-V and Proxmox VE. The analysis results showed that Proxmox VE has all the necessary capabilities to create a full-fledged HA cluster, while not requiring licensing costs and providing broad support for open standards and tools.

In the work, a test bench was designed and implemented, including a cluster of three nodes with the integration of the distributed Ceph storage. Fault-tolerant virtual services were deployed and configured: file server, database, web server and mail server. Node and service failure tolerance tests were conducted, the recovery time was recorded and the availability level corresponding to 99.999% was confirmed. Automatic recovery mechanisms (ha-manager, Ceph replication, watchdog) worked correctly, demonstrating the system's ability to ensure continuous operation of services even in the event of equipment failure.

At the end of the article, an assessment of the economic efficiency of cluster implementation was given: calculations of estimated costs for equipment and software were made, and the payback level was determined taking into account the prevention of losses from downtime. Potential risks at the network, Ceph and hypervisor levels were assessed, and practical recommendations for implementing the solution in a corporate environment were formulated.

Based on the conducted research, the following main conclusions can be made:

- Building a fault-tolerant cluster using Proxmox VE and Ceph is an effective way to ensure high availability of corporate IT services;
- The proposed solution has a high degree of stability, scalability flexibility and economic feasibility;
- The use of open technologies allows you to reduce licensing and operating costs without losing functionality and reliability;
- The developed architecture and practical implementation demonstrate the applicability of the solution for both medium and large companies, as well as for organizations with a limited budget.

The practical significance of the work is that the developed solution can be applied in the real IT infrastructure of enterprises to improve the reliability and availability of business-critical services, and can also serve as a basis for further scaling, development and integration with modern IT infrastructure management technologies (including containerization and orchestration). Thus, the goals set in the work were achieved, all tasks were successfully solved, and the results obtained have both theoretical and applied value.

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THROUGHPUT ANALYSIS OF WIRELESS NETWORKS IN HIGH SENSOR DENSITY ENVIRONMENTS

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***Abstract*— The paper is devoted to the analysis of wireless network throughput in conditions of high sensor density. The features of IoT network scalability are considered, a comparative analysis of data transmission technologies (Wi-Fi, Zigbee, BLE Mesh, NB-IoT, LoRaWAN, 5G) is performed, and modeling is carried out in the OMNeT++ environment to assess the impact of device density on network performance, as well as aspects of life safety.**

***Keywords*— Zigbee, Wi-Fi, LoRaWAN, OMNeT, NB-IoT**

LXXX. INTRODUCTION

Modern progress in the field of the Internet of Things is associated with a constant increase in the number of connected devices. This creates new challenges for specialists, it is necessary to ensure stable and trouble-free operation of networks [1]. The issue of competent resource allocation and maintaining high data transfer rates in conditions of dense clusters of sensors is especially acute - this is often the case in industrial enterprises, smart cities and monitoring systems. Therefore, today it is especially important to carefully study available wireless technologies, compare them by key parameters and choose the best solutions for specific tasks. The Internet of Things has turned from a technological innovation into a necessity - it allows you to work with huge amounts of data that need to be collected, analyzed and responded to without delay [2]. The complexity of infrastructures, growing demands for energy saving, information security and automation have led to the fact that classical approaches to management and control have become insufficiently effective. IoT makes it possible to build adaptive and self-learning systems, where devices independently communicate with each other, make decisions and adapt to changes in the external environment [3]. This is not just a trendy trend, but a natural stage of digital evolution, without which sustainable development in key areas is impossible as Industrie 4.0, smart cities, next-generation medicine and intelligent transport [4].

As the number of IoT devices increases and their areas of application expand, issues related to network scaling and high deployment density become increasingly important. These factors directly determine the performance, fault tolerance and level of security of systems - especially in urban areas, at production sites or in agricultural complexes, where the number of nodes can reach many thousands [5].

Scalability is understood as the ability of a network to grow without a serious loss in efficiency and stability. In fact, achieving it is associated with a number of technical and organizational limitations.

Firstly, as the network increases, the load on communication channels increases - this is especially noticeable in wireless technologies, where bandwidth is initially limited. Protocols such as Zigbee, Wi-Fi and LoRaWAN do not always cope with the simultaneous operation of multiple devices. This results in delays, lost data packets, and overall poor connection quality. In addition, addressing and routing management becomes more complex, the system must process millions of unique identifiers and routes, avoiding conflicts and failures.

Secondly, scaling requires a fault-tolerant system for processing and storing information. Centralized cloud solutions often cannot cope with the sharp increase in traffic, which forces a transition to distributed architectures. Edge computing methods, as well as local caching and data pre-processing, are increasingly being used - this helps to unload central nodes.

Another difficulty is mass firmware updates and configuration management. If there are thousands of devices on the network, it is critical to have tools for centralized and secure implementation of updates - this is the only way to

quickly fix vulnerabilities and improve functionality. Without this, the system becomes unmanageable and vulnerable to threats [6].

An equally important aspect is energy efficiency. This problem is especially acute for battery-powered devices. As the number of nodes increases, the total power consumption increases, so it is necessary to optimize the data transfer frequency, sleep modes and rationally distribute tasks between devices.

High node density is a separate serious challenge. This refers to a situation where a large number of connected devices are concentrated in a limited area, exchanging data via wireless channels. Such scenarios are typical for smart cities, industrial zones, agricultural complexes, logistics centers, residential buildings with automation systems - anywhere where hundreds or even tens of thousands of sensors and actuators can operate in a small area [7]. It is high density that makes IoT systems detailed and valuable in terms of data, but at the same time creates difficulties in organizing communications, management, and energy consumption.

LXXXI. USE OF TECHNOLOGIES IN CONDITIONS OF HIGH DEVICE DENSITY

Modern wireless networks are facing an unprecedented growth in the number of connected devices in areas such as smart cities, industrial Internet of Things, and distributed sensor systems. In these conditions, the ability of technologies to scale and maintain stability at high connection density is of particular importance. When choosing a suitable solution, it is necessary to consider not only the maximum number of supported devices, but also the efficiency of using the radio frequency spectrum, resistance to transmission conflicts, the level of delays, energy consumption, and the architectural features of the network infrastructure. Zigbee, built on the IEEE 802.15.4 standard, is actively used in building automation, industrial systems, and smart homes due to its low power consumption, adaptability, and support for mesh topology. An important advantage of the technology is its ability to function in dense environments with a large number of sensors, actuators, and controllers located in a limited area. Support for multi-hop architecture plays a key role in maintaining operability in conditions of high node density. Zigbee devices can act as routers, transmitting data through intermediate nodes, which reduces the load on coordination centers and distributes traffic more evenly. This reduces the likelihood of collisions and data loss even when many devices are actively operating. In addition, the mesh network allows you to bypass faulty or overloaded areas, increasing fault tolerance.

However, Zigbee has a limited bandwidth - up to 250 kbps in the 2.4 GHz range, which requires careful planning of air access. The CSMA / CA mechanism is used to reduce conflicts, but in conditions of ultra-high device density, delays may occur and the overall efficiency of the radio interface may decrease.

To improve operation in such environments, network segmentation into clusters is used, each of which is served by a separate coordinator. This reduces the number of devices simultaneously competing for the channel and increases overall scalability. The choice of frequency channels is also important - Zigbee supports 16 channels in the 2.4 GHz range, which minimizes interference with other networks, such as Wi-Fi.

In extremely dense environments (thousands of devices in a small area), hybrid approaches like logical division into subnets, increasing the number of routers, using repeaters can be used. Sometimes it is effective to use several channels or control systems for load balancing.

Thus, Zigbee demonstrates high flexibility and reliability in conditions of dense device placement, provided that the network is designed well. Thanks to the mesh architecture, retransmission, multi-channel and energy efficiency, it remains one of the most popular solutions for deploying scalable and fault-tolerant IoT networks.

Wi-Fi technology (IEEE 802.11 standards) is widely used in offices, homes, public spaces and in production due to its versatility. However, with the widespread use of the Internet of Things in smart cities, corporate and educational networks, Wi-Fi is faced with increasingly stringent requirements for operation in conditions of high connection density. Stability, low latency, high throughput and efficient distribution of resources between devices are of particular importance.

In traditional Wi-Fi versions (such as 802.11b/g/n), the increase in the number of connected clients often entailed a decrease in overall performance. This is due to an increase in collisions when accessing the data transmission medium - all devices compete for one channel using the CSMA/CA mechanism. The more active nodes, the higher the risk of packet collisions, which leads to increased latency, instability and a drop in throughput. Modern standards - 802.11ac (Wi-Fi 5), 802.11ax (Wi-Fi 6) and 802.11be (Wi-Fi 7) - were developed with high load conditions in mind. For example, Wi-Fi 6 introduced technologies such as OFDMA, MU-MIMO, TWT and BSS Coloring, which significantly increase the efficiency of airtime use and reduce contention between devices. Thanks to these improvements, Wi-Fi 6 and Wi-Fi 7 are able to provide a stable connection with low latency even in congested airspaces - at stadiums, airports, shopping malls and large offices.

Proper design and configuration play an important role in ensuring the scalability of Wi-Fi networks:

• using multiple SSIDs and VLANs to separate traffic between devices (IoT, users, guests);

• optimizing the placement of access points to minimize interference and overlapping coverage areas;

• distributing devices across bands (2.4 GHz, 5 GHz and 6 GHz in Wi-Fi 6E), which reduces the load on individual channels.

However, even modern versions of Wi-Fi have limitations related to channel throughput and the number of MU-MIMO streams. In scenarios with mass connection of IoT devices generating low traffic, Wi-Fi may be inferior to specialized LPWAN technologies such as NB-IoT or LoRaWAN [8].

Thus, although the latest versions of Wi-Fi (6 and 6E) demonstrate high efficiency in densely populated environments, a thoughtful approach to network design, selection of equipment and configuration of its parameters is required to achieve the best results.

As for LoRaWAN, it uses a star topology - multiple end devices transmit data to gateways, which forward them to a network server via an IP network. The key feature of LoRaWAN is asynchronous data transmission where devices spend most of their time in sleep mode and wake up only to

send data on a schedule or when an event occurs. This ensures low power consumption, but in conditions of high node density, its own challenges arise [9].

Since LoRaWAN operates in unlicensed bands (433, 868, 915 MHz) and uses a channel access mechanism similar to Aloha, the main problem is the increase in collisions when transmitting data from multiple devices at the same time. To reduce the likelihood of collisions, LoRaWAN uses the following mechanisms [10]:

- Adaptive selection of the spreading factor (SF). Different SF values are used (from SF7 to SF12), the higher the factor, the lower the transmission rate, but the higher the resistance to interference. Signals with different SF are orthogonal, which allows for simultaneous data transmission without mutual interference.
- Duty Cycle and Time-on-Air limitations. In the European frequency range, LoRaWAN has strict Duty Cycle standards (e.g. 1%), which limit the time a device transmits data during a certain period. This reduces the overall load on the network, but also limits the frequency of sending messages. Time-on-Air (the time it takes to transmit one packet) calculation allows optimizing airtime and minimizing collisions.
- Adaptive Data Rate (ADR). This mechanism allows dynamically adjusting the transmission parameters for each device depending on communication conditions. Devices with a stable signal automatically switch to higher transmission rates (lower SF) and reduce the transmit power, which reduces the channel occupation time and reduces the overall load on the network.
- Multi-channel gateways. Modern LoRaWAN gateways support simultaneous operation on several channels (usually 8-16), which significantly increases network throughput. This allows receiving data from many devices on different frequencies without mutual interference, which is especially important in conditions of high node density.
- Classification of devices. LoRaWAN defines three classes of devices (A, B, C), each with different operating modes [11]:
  - Class A - devices with minimal power consumption that transmit data only on initiative and then briefly open a window for reception. The least load on the network.
  - Class B - devices with synchronized reception windows, which allows them to receive commands from the server at a certain time. Moderate load on the network.
  - Class C - devices with a constant reception window (except for transmission time). Most demanding on network resources, but provide minimal latency when transmitting commands.

These mechanisms together allow LoRaWAN to scale efficiently and support thousands of devices in a limited area, although the technology remains primarily focused on applications with low data rates and low power consumption.

To achieve optimal performance in high-density conditions, it is important to carefully plan the network, place gateways taking into account coverage areas, configure ADR, distribute devices across channels and classes depending on their latency and power consumption requirements.

Thus, LoRaWAN offers a balanced solution for scenarios where communication range, energy efficiency, and the ability to work with a large number of devices are important, but high throughput is not required.

Thus, LoRaWAN demonstrates high efficiency in dense device placement conditions due to a set of technological solutions: the use of various spreading factors, duty cycle limitation, adaptive data rate regulation (ADR), and multi-channel gateways. However, maximum network performance is achieved only with proper infrastructure design, optimal selection of transmission parameters, and compliance with architectural recommendations. When configured correctly, LoRaWAN remains one of the most promising technologies for organizing mass connectivity of energy-efficient IoT devices with low data transfer rate requirements.

5G technology, developed within the framework of 3GPP standards, is initially focused on operation in conditions of high connection density and service diversity. The key aspect is the support of mMTC (massive Machine-Type Communications) scenarios, providing connection of up to 1 million devices per square kilometer. This feature is especially in demand in smart cities, industrial IoT networks and transport systems, where simultaneous operation of multiple sensors and actuators in a limited area is required. Thanks to the use of massive MIMO, beamforming and OFDMA, 5G ensures efficient distribution of radio resources even with extreme connection density.

An important advantage of 5G is the possibility of network slicing, which allows creating virtual network segments with individual performance, latency and reliability characteristics for different types of services. This ensures that mobile users, critical industrial connections, and mass IoT devices can be served simultaneously within a single infrastructure without degradation of service quality.

Implementation of 5G networks in high-density conditions requires careful architecture design, including optimal placement of base stations, use of sub-6 GHz and mmWave bands, and implementation of self-configuring network (SON) mechanisms. Combining different frequency bands allows achieving high performance, reliability, and energy efficiency in the most demanding scenarios.

NB-IoT (Narrowband Internet of Things) is a specialized cellular communication technology designed to connect a large number of IoT devices with small amounts of data. Thanks to narrowband architecture (channel width of 180 kHz) and operation in a licensed spectrum, NB-IoT ensures high noise immunity and communication reliability even with tens of thousands of devices operating simultaneously in one cell. Centralized network management allows operators to flexibly allocate resources and prevent collisions. Additional energy-saving mechanisms (Power Saving Mode and eDRX) allow devices to remain in sleep mode longer, reducing the load on the network. High reception sensitivity and the ability to deeply penetrate the signal provide a stable connection in difficult conditions. However, NB-IoT is optimal only for transmitting small amounts of data and is not suitable for applications that require high transmission speeds. Table 1 presents a final comparison of the considered technologies by their applicability in high-density scenarios, taking into

account key parameters like throughput, energy efficiency, scalability and implementation features in various operating conditions.

The analysis shows that the choice of the optimal technology for high-density IoT scenarios is determined by the specific requirements of the application:

- 5G and NB-IoT provide maximum scalability and communication stability for mass device connections within the public infrastructure.
- Wi-Fi 6/6E is the preferred solution for local networks with intensive data exchange and high bandwidth requirements.
- LoRaWAN, Zigbee and BLE Mesh remain optimal for energy-efficient decentralized networks with moderate traffic and strict energy consumption restrictions.

TABLE VI. FINAL COMPARISON OF APPLICABILITY IN HIGH-DENSITY SCENARIOS

Technology	Applicability in High-Density Environments	Main Scalability Mechanisms	Limitations
5G	Very high	mMTC, massive MIMO, beamforming, network slicing	High deployment cost
NB-IoT	High	Licensed spectrum, centralized management	Low speed, narrowband
LoRa WAN	Medium	Different SFs, duty cycle limitations	Collision probability in unlicensed spectrum
Wi-Fi 6/6E	High	OFDMA, MU-MIMO, TWT	Medium range, high power consumption
Zigbee	Medium	Mesh topology, packet relaying	Limited data rate
BLE	Medium (in BLE Mesh)	Advertising channels, frequency hopping, mesh	Limited number of active connections

The correct choice and design of a network based on these technologies allows achieving high reliability and stability even in conditions of extreme connection density.

LXXXII. SELECTING A SIMULATION ENVIRONMENT AND SIMULATION SCENARIO

Accurate simulation modeling is required to assess the throughput and behavior of wireless technologies in high-density sensor environments. This is especially critical for designing industrial monitoring systems, where hundreds and thousands of devices operate in a limited space, placing high demands on reliability, delays, and efficient use of radio resources.

The key criteria for selecting a simulation platform are:

1. Accuracy of PHY/MAC level emulation. Support for multiple access methods (CSMA/CA, OFDMA, ALOHA), scheduling mechanisms, and radio resource management.

2. Ability to simulate dense networks. Tools for specifying high node density, complex topology (mesh, star, hybrid), and realistic radio channel models.

3. Availability of implemented models of specific technologies.

Based on these criteria, the following simulators were selected:

- For Wi-Fi 6/6E - NS-3 with support for the 802.11ax standard (OFDMA, MU-MIMO, TWT), which allows for detailed modeling of channel sharing between multiple devices.
- For Zigbee and BLE Mesh - OMNeT++ with the INET and Castalia frameworks, providing emulation of IEEE 802.15.4 protocols, mesh routing (RPL) and BLE channel operation.

A. Description of the simulation scenario

For a comprehensive study, a scenario of a virtualized IoT network in a cloud environment was developed using OMNeT++. The model includes a hybrid infrastructure, where physical devices interact via virtual objects (VOs) in the cloud.

The model architecture includes four types of nodes (Figure 1):

1. IoT devices (sensors and actuators) to generate data and execute commands.

2. Access points (gateways) to support various technologies (Wi-Fi, Zigbee, BLE Mesh) and are an interface between the physical and virtual networks.

3. Virtualization server to stores device profiles, creates and manages virtual objects (VOs) that represent physical devices in the cloud, and provides logical communication between them according to a specified topology.

4. Client devices to used to configure a virtual network, select devices and set their interaction parameters.

Data from sensors is transmitted through gateways to the virtualization server. The server creates a virtual twin (VO) for each physical device, which processes the data and provides logical interaction with other VOs according to a specified configuration, after which commands are transmitted to target actuators. This allows abstraction from the physical topology and organization of interaction between devices from different network domains.

B. Experimental Methodology

To evaluate the performance in detail, a scenario with direct virtual one-to-one connections between sensors and actuators was implemented. In each experimental run, five sensor-actuator pairs located in two different physical network domains communicated exclusively through their virtual objects (VOs) on the cloud server.

Workload parameters:

- Packet generation rate. Varied across simulation runs and was 80, 100, and 120 packets per second (pps) per sensor.
- Packet size was fixed at 1000 bytes (8000 bits) per packet.

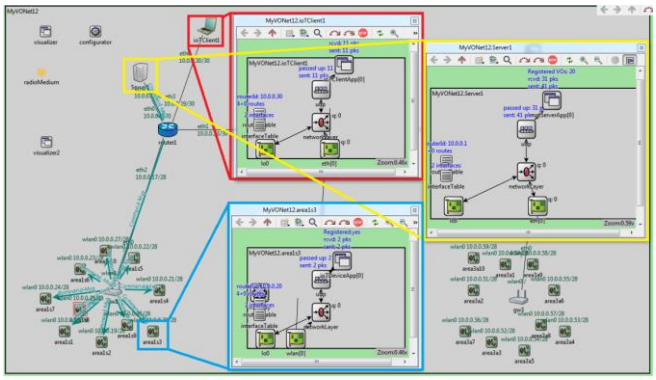

Fig. 5. Virtualized IoT Network in a Cloud Environment

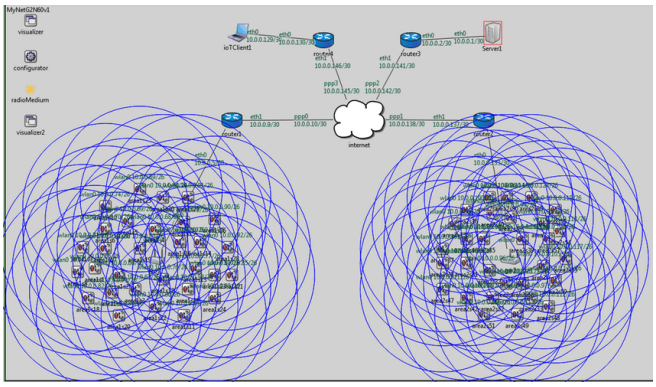

Fig. 6. Simulation process

For each tested technology (Wi-Fi, Zigbee, BLE Mesh), two key performance metrics were evaluated:

- End-to-End Delay - the time between the moment a packet is generated by a sensor and the moment it is fully received by the target actuator. Calculated as the difference between the t_received (actuator) and t_sent (sensor) timestamps.
- Throughput - the total amount of useful data successfully delivered to all actuators per unit of time (usually in bits per second, bps). Calculated using the formula (total number of delivered bits / total simulation time).

Experiment execution sequence:

- Network initialization. Physical IoT devices send registration requests to the virtualization server. The server creates a virtual object (VO) for each device and sends a confirmation of successful registration.
- Virtual network configuration. The client device sends a command to the server to form a virtual network, specifying the composition of sensor-actuator pairs and setting the traffic generation parameters (speed and packet size).
- Data generation and transmission. Sensors start generating and sending packets at a specified rate. Packets are routed through their VOs on the server to the VOs of the corresponding actuators, which then forward the data to the physical devices.
- Data collection. During the simulation, the sending and receiving timestamps are recorded for each packet.
- Result analysis. Once the simulation is complete, the collected data is used to calculate the final end-to-end latency and throughput values for each run.

A visual representation of the simulation run process is shown in Figure 2.

LXXXIII. Simulation Results and Their Interpretation

Results of the simulations given in figure 3 shows the dynamics of end-to-end latency for Wi-Fi, Zigbee and BLE Mesh technologies under conditions of significantly increased sensor density (from 50 to 500 devices).

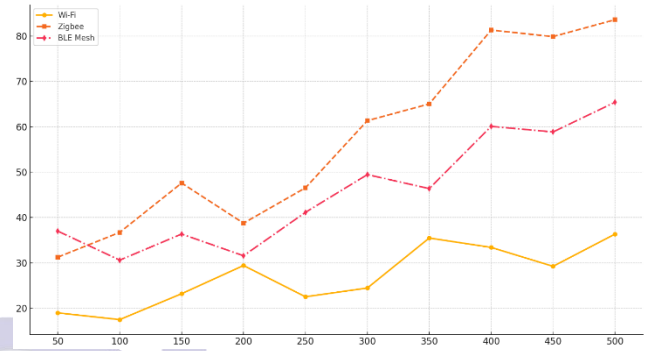

Fig. 7. End-to-End Latency under High Sensor Density

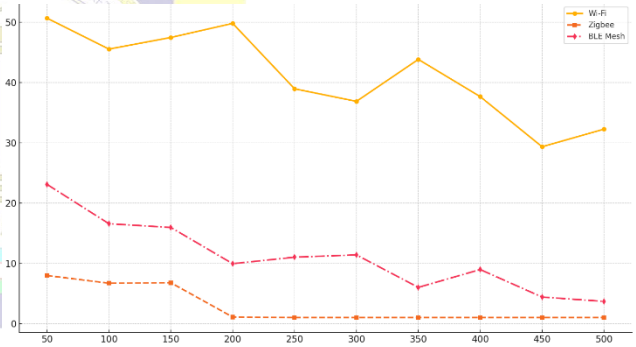

Fig. 8. Throughput under High Sensor Density

Analysis of Figure 4 shows different scalability profiles of technologies with increasing device density from 50 to 500 nodes. Wi-Fi (probably 802.11ax) demonstrates the highest throughput with steady growth due to OFDMA and MU-MIMO, which allow efficient aggregation of traffic from many devices. Zigbee shows peak performance at 150-200 nodes, followed by a sharp drop due to the limitations of a narrow 2 MHz bandwidth and overload of the CSMA channel with service traffic. BLE Mesh demonstrates the worst scalability with a monotonic drop in performance due to an avalanche-like growth of flooding traffic, approaching zero throughput at high density. The choice of technology is determined by the target metrics, Wi-Fi - for high performance, Zigbee - for energy efficiency at moderate density, BLE Mesh - only for low-intensity networks.

Data analysis shows a clear division of technologies in terms of performance in high-density environments. Wi-Fi provides the highest throughput with moderate degradation as the load increases due to OFDMA/MU-MIMO mechanisms. Zigbee demonstrates low throughput and a sharp drop in performance due to narrow bandwidth and CSMA/CA

collisions. BLE Mesh occupies an intermediate position, but significantly loses efficiency when scaling due to the flooding architecture, which makes it applicable only for networks with low traffic intensity.

CONCLUSION

Based on the conducted research, a comprehensive evaluation of the throughput performance of Wi-Fi, Zigbee, and BLE Mesh technologies has been completed under high sensor density conditions for industrial monitoring scenarios. The obtained simulation data from the OMNeT++ environment revealed key advantages and limitations of each technology. Wi-Fi demonstrated the best throughput performance and minimal latency, making it the optimal choice for applications requiring high-speed and reliable data transmission. Zigbee confirmed the effectiveness of its mesh architecture, providing stable and energy-efficient operation under high loads, though with noticeable throughput degradation when significantly increasing the number of devices. BLE Mesh occupied an intermediate position, offering a balance between energy efficiency and acceptable latency and throughput metrics.

Thus, the selection of an appropriate technology should be based on specific requirements of the particular scenario: for latency-sensitive applications with high data volumes, Wi-Fi is recommended; in cases where energy efficiency and longevity of autonomous devices are crucial, Zigbee or BLE Mesh are preferable. The presented results and modeling methodology can be used for designing and deploying industrial IoT systems, ensuring their stable and efficient operation in high-density connected device environments.

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IOT SIMSIZ TEXNOLOGIYALARDAN FOYDALANISH BILAN LIFTLARNING XAVFSIZLIGINI OSHIRISH

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Абстракт - **Liftlarni dispetcherlashtirish uchun IoT simsiz texnologiyalardan foydalanishni tashkil etish masalalari lift tuzilmalarining xavfsizligini ta'minlash va texnik holatini kuzatishning muhim shartlaridan biri sifatida ko'rib chiqiladi. Bu usul va tizim liftni ishlatish xavfsizligini oshirish, liftlar tuzilmalari holatini javobgar tashkilotlar va nazorat organlar tomonidan tezkor nazoratni ta'minlash va inson omilining xavfsizligiga salbiy ta'sirni kamaytirish imkonini beradi**.

Kalit so'zlar - **lift, avariya darajasi, xavfsizlik, inson omili, simsiz texnologiyalar, IoT, LTE, Wi-Fi, ZigBee**

I. Kirish

A. *liftlarning xavfsizligi tavsifi*

Har qanday o'rta va yirik shahar infratuzilmasining muhim elementi lift tizimi hisoblandi. Bu element uy-joy kommunal xo'jaligi va qurilish sanoati o'rtasidagi chegarada mavjud. Hozirgi vaqtda lift sanoati global miqyosda faoliyat yuritadigan mustaqil sanoatga aylandi va lift va tegishli qurilmalarni ishlab chiqaruvchilar, liftlarga texnik xizmat ko'rsatish va ulardan foydalanishni ta'minlaydigan tashkilotlar va tizim integratorlarini o'z ichiga oladi.

Lift qurilmasining xavfsiz ishlashi uchun bir qator chora-tadbirlarni amalga oshirish talab etiladi:

- liftlarni ishga tushirish va hisobga olishni tartibga solish tizimini yaratish, foydalanishning barcha bosqichlarida ularning texnik holatini baholash;
- dispetcherlashtirish tizimlarini joriy etish orqali boshqarish-nazorat qilish faoliyatini axborotlashtirish va avtomatlashtirishni ta'minlash;
- inson omili xavfini hisobga olgan holda boshqarish-nazorat qilish faoliyatida xavfga asoslangan yondashuvni qo'llash [2,3,5].

B. Lift qurilmalarini dispetcherlashtirish.

Lift qurilmalarini dispetcherlashtirish tizimlarining asosiy vazifalari qurilmaning ishlashini operativ monitoring qilish, liftlarning ishlashi bo'yicha ma'lumotlar bazasini shakllantirish va ma'lumotlarni tahlil qilish, liftni boshqarishni ta'minlash, xatolar, nosozliklar va baxtsiz hodisalar haqida ma'lumotlarni avtomatik qabul qilish orqali operatsion xarajatlarni kamaytirish va uning ishlashi xavfsizligini ta'minlashdan iborat.

Liftlar parametrlarini uzatish maxsus dispetcherlik aloqa liniyasi orqali, mobil texnologiyalari tarmoqlarining kanallari orqali yoki boshqa tarmoqlar infratuzilmasi (telefon yoki TCP/IP) yordamida amalga oshiriladi.

Simsiz va simli aloqa liniyalari uchun asosiy talab - ishonchli ishlash, shovqinga chidamlilik, buzilish va shikastlanishdan himoya qilishdan iborat.

Dispetcherlashtirish tizimi liftlarning xavfsiz ishlashini ta'minlaydigan zarur shartlardan biri hisoblanadi, chunki bu ularga texnik xizmat ko'rsatish samaradorligi va sifatini oshirishga imkon beradi [5-9].

C. Dispetcherlashtirishdagi IoT simsiz texnologiyalar.

Umuman olganda, lift konstruksiyalarini ishlatish xavfsizligini oshirish, xususan, inson omilining salbiy ta'sirini kamaytirish yo'llaridan biri mobil texnologiyalar - mobil qurilmalar (smartfonlar) asosidagi ilovani ishlab chiqish hisoblanadi. iOS va Android tizimlarida va simsiz Internetda quyidagilarga imkon beradi:

- xodimlarning mehnat va ishlab chiqarish funksiyalarini bajarish samaradorligini oshirish;
- liftlar qurilmalarining joriy holatini kuzatish;
- davlat nazorati tashkilotlar uchun obyekt holati to'g'risidagi ma'lumotlarning ochiqligini ta'minlash;
- liftlarni texnik sertifikatlash va ko'rikdan o'tkazish bo'yicha ishlarning o'z vaqtida bajarilishini ta'minlash.

Shunga o'xshash ishlanmalar minora kranlari kabi ko'taradigan tuzilmalar uchun ham mavjud [11,12]. Biroq, onlayn rejimda barcha obyektlarda ma'lumotlarni uzatish, obyektni tekshirish va masofadan boshqarish uchun lift qurilmalarini mobil qurilmalardan foydalanish bilan birlashtirish lift kabi bunday turdagi xavfli obyektlar uchun qo'llanilmagan. Taklif qilingan texnologiya va mavjud liftlarni dispetcherlashtirish tizimlari o'rtasidagi asosiy farq hisoblanadi.

II. liftlarning xavfsizligini monitoring qilish tizimining arxitekturasi va elementlari

Liftlar xavfsizligini monitoring qilish tizimlari asosan real vaqt rejimida ularning bir qator xarakterli parametrlarini kuzatish uchun mo'ljallangan. Bunday ko'rsatkichlarga tortishish, trosning tarangligi, masofa,

tezlik, muvozanat koeffitsiyenti, tezlanish va sekinlanish, kabinaning sifati, saqlash mexanizmining xarakteristikalari, xavfsizlik mexanizmi xususiyatlari, lift eshiklarining yopilishi, kinetik energiya va tezlik, lift gidravlik bosimi, elektromagnit halaqitlardan himoya qilish qobiliyati va shkafning haroratini nazorat qilish qobiliyati, liftni boshqarish va liftning xavfsiz ishlashiga bevosita ta'sir qiladigan boshqalar omillar kiradi.

So'nggi paytlarda ZigBee texnologiyasi paydo bo'lishi bilan unda IP-protokol asosida ma'lumotlarni uzatish mumkin bo'ldi [11].

ZigBee va boshqa 802.15.4 asosidagi texnologiyalar qishloq xo'jaligini monitoring qilish [12-15] va inshoatlarning holatini monitoring qilish [16] kabi ilovalarda muvaffaqiyatli qo'llaniladi. Ko'pincha, bunday turdagi past tezlikli tarmoqlar uchun ilovalar faqat uzlukli yoki real vaqtda bo'lmagan ma'lumotlarni uzatilishini talab qiladi, bu esa datchiklarning juda kichik ish siklini ta'minlaydi. Shunday qilib, datchiklar tugunlari vaqtning katta qismida o'chirilishi mumkin va kamdan-kam hollarda bitta qiymatni uzatadi. Bunday ish siklining sxemasi ma'lumotlarni uzatish tezligi cheklanganligi sababli batareyaning ishlash muddatini bir necha yillarga oshirishi mumkin. Past tezlikda ishlaydigan tarmoqlar uchun real vaqtda ilovalar ko'p emas.

Aloqa liniyalari uchun asosiy talab - ishonchli ishlash, halaqitbardoshlik, xakerlik va shikastlanishdan himoya qilish hisoblanadi. Internet-resurslardan foydalanish bilan simsiz texnologiyalardan foydalanganda obyektning holati haqidagi barcha ma'lumotlar nazorat qilish organlari uchun ochiq bo'ladi va xavfli obyektni boshqarish osonroq bo'ladi.

Shunday qilib, ZigBee texnologiyasiga asoslangan simsiz lift xavfsizligi monitoringi buyumlar Internetiga (IoT) o'tish talablariga javob berishi mumkin.

Ko'p qavatli binolarda liftlarning tarmoqqa ulanishini ta'minlash videokuzatuv va raqamli tablo kabi ilovalar uchun juda muhim bo'lishi mumkin:

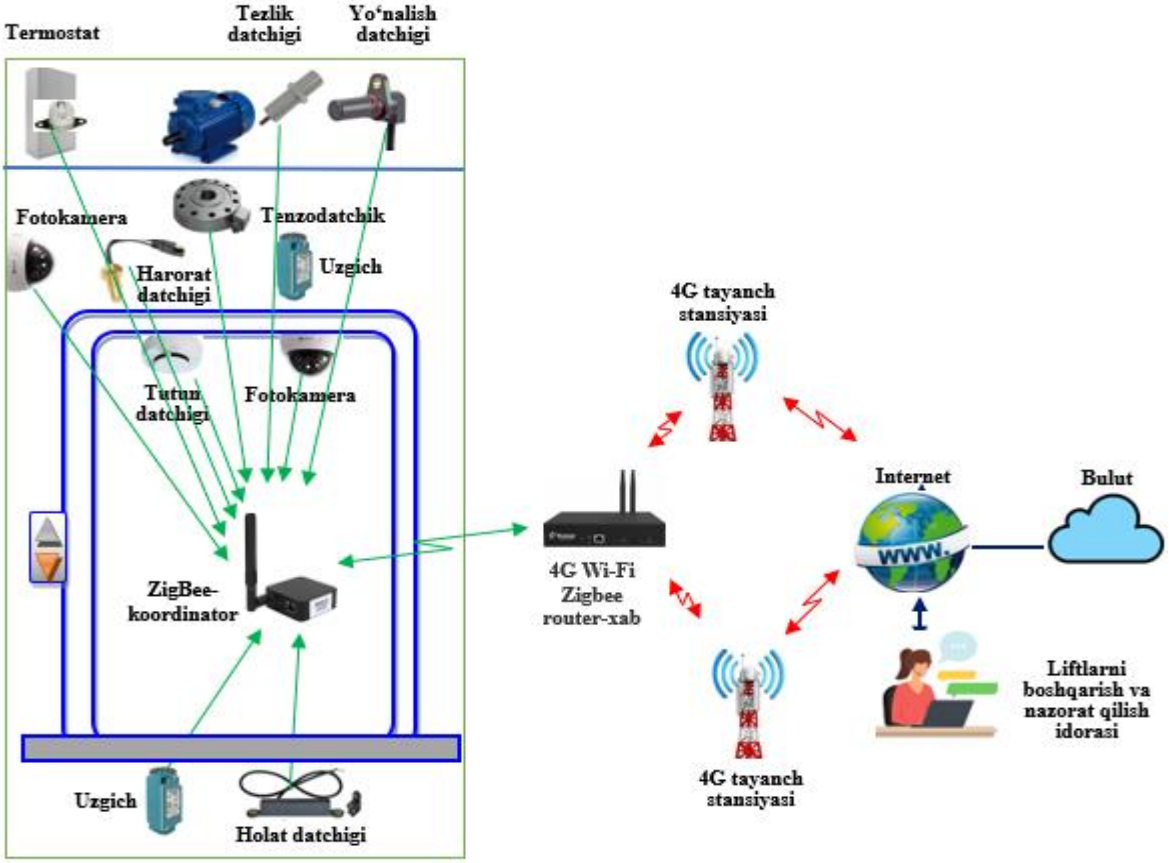
An'anaviy ravishda buning uchun lift shaftalarining tepasida yoki ostida yotqizilgan Ethernet kabellari kabi yechimlar qo'llaniladi. Ammo bu usul quyidagi sezilarli kamchiliklarga ega:

- Qurilish shu kabellardan foydalanish mumkin bo'lgan tarzda amalga oshirilishi kerak.
- Murakkab o'rnatish
- Kabellar doimiy eskirish tufayli shikastlanishi mumkin.

Bu muammolarni yechsh uchun simsiz texnologiyalar qo'llaniladi. Simsiz qamrab olish butun shaxta bo'ylab tarqaladi, bu esa kuzatuv kameralarini yoki boshqa datchiklarni tarmoqqa ulash imkonini beradi.

1-rasmda liftlar xavfsizlini monitoring qilish tizimining tarmoq arxitekturasi tasvirlangan

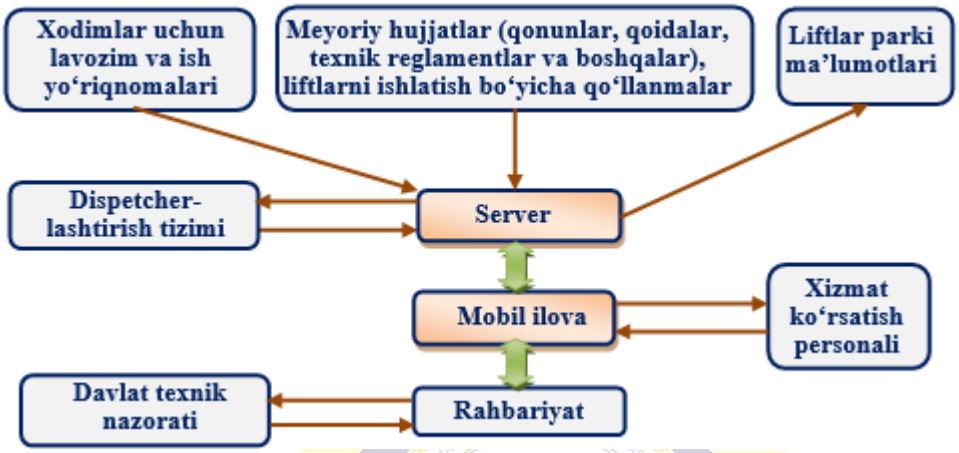
Kamera trosning holatidagi o'zgarishlarni belgilangan davrlarda qayd tetadi, bir vaqtning o'zida tasvirlarni o'rnatilgan xotira qurilmasiga saqlaydi va ularni ZigBee koordinatori orqali tarmoqqa uzatadi [1].



1-rasm. Liftlarning xavfsizlini monitoring qilish tizimining tarmoq arxitekturasi

Koordinator-tugun lift shaxtasining yuqori yoki pastki qismiga o‘rnatiladi, boshqa tugunlar esa lift kabinasi va shaftining yuqori yoki pastki qismidagi tugunlardir. Liftlar uchun simsiz tarmoq uchun bitta tugun lift kabinasi va shaxtasining yuqori qismida kameraga yoki boshqa datchiklarga ulangan mobil kulanish nuqtasi sifatida o‘rnatiladi va u lift kabinasi bilan birga harakatlanadi. Shu bilan bir vaqtda boshqa tugun (ZigBee-koordinator) lift shaxtasining yuqori qismida serverga yoki asosiy tarmoqqa ulangan statsionar ulanish nuqtasi sifatida o‘rnatiladi [1].

Ma’lumotlarni turli organlarlar va bo‘limlar orasida uzatish va ularga ishlov berish mobil ilova orqali amalga oshiriladi. Ilovaning ishlash prinsipi quyidagicha (2-rasm): liftlar parki, meyoriy hujjatlar (qonunlar, qoidalar, texnik reglamentlar va boshqalar), liftlarni ishlatish bo‘yicha qo‘llanmalar (yo‘riqnomalar), xodimlar uchun ish va ishlab chiqarish yo‘riqnomalari, shuningdek liftni dispetcherlashtirish tizimlaridan olingan ma’lumotlar to‘g‘risidagi ma’lumotlar (javobgar tashkilot doirasida - ish haqi fondi, kattaroq miqyosda - Yagona Lift axborot-tahlil tizimining ma’lumotlar bazalaridan markaziy serverga yuklanadi [17].



1-rasm. Mobil ilovaning ishlash prinsipi

Mobil ilova orqali xodim o‘z lavozimi va vakolatlariga muvofiq liftlarning holati to‘g‘risida ma’lumot oladi; ularga texnik xizmat ko‘rsatish yoki ta’mirlash bo‘yicha har qanday ishni bajarish zarurati; liftlarni tekshirish, texnik xizmat ko‘rsatish va sertifikatlash muddatlari va ko‘rilgan choralar; meyoriy hujjatlarning nomenklaturasi va mazmuni va liftlarni ishlatish yo‘riqnomalari to‘g‘risida. Bundan tashqari, qo‘shimcha hujjatlarni to‘ldirish va tegishli xizmat yoki organga yuborish mumkin.

Xodimlar shaxsiy login va paroldan foydalangan holda tizimga kiradi. Ma’lumotlarni kiritishda ilova ma’lumotlarni xodimga faqat uning ish majburiyatlariga muvofiq uzatadi. Har bir xodim faqat shaxsiy ma’lumotlarni olishi mumkin bo‘ladi.

Shuningdek, agar telefonda elektron o‘tish kartalarini birlashtirish orqali NFC texnologiyasi mavjud bo‘lsa, mobil telefondan obyektlarga elektron o‘tish vositasi sifatida foydalanish imkoniyati mavjud bo‘ladi. Tizimda ro‘yxatdan o‘tish obyektning xavfsiz ishlashi uchun mas’ul shaxs tomonidan amalga oshiriladi [18].

III. LIFTLARNING XAVFSIZLIGINI TA‘MINLASHDAGI MUAMMOLAR

Liftlarning xavfsizligini ta‘minlashda ma’lumotlarni uzatishdagi muammolarni yechishda ko‘plab IoT simsiz texnologiyalari qo‘llanishi mumkin. Ulardan ayrimlarini quyida ko‘rib chiqamiz.

[1] ishda ZigBee texnologiyasi asosida liftlarning xavfsizligini monitoring qilish tizimi ko‘rib chiqilgan. Unda liftlarning xavfsizligini monitoring qilish tizimining arxitekturasi ishlab chiqilgan, elementlarining tavsiflari berilgan, apparaktlar ta’minoti asoslangan, lekin real eksperimental sinovlari berilmagan. Shuningdek, ko‘p qavatli binolar temir-beton konstruksiyalari va lift kabinalarining temir-faner korpuslaridan ZigBee texnologiyasi signallarini o‘tishi qiyin va mumkin bo‘lmasligi mumkin.

[10] ishda WiMAX texnologiyasi asosida liftlarning xavfsizligini monitoring qilish tizimi ko‘rib чиқилган. IP-protokol asosida video va audiosignallarni uzatishni ta’minlaydi[4], bu 3G/4G va WLAN taqchilligini kompensatsiyalaydi. Shu sababli, WiMAX asosidagi simsiz liftlarni monitoring qilish IoT talablariga javob berishi mumkin. WiMAX ochiq standartlarga asoslangan shahar tarmoq texnologiyasi sifatida Wi-Fi texnologiyasiga nisbatan kengroq geografik diapazonda simsiz keng polosali ulanishni ta’minlay oladi. Simsiz ulanishlar bilan simsiz lokal tarmoqlarning yuqori o‘tkazish qobiliyatiga erishish uchun zarur bo‘lgan kilometrgacha bo‘lgan ko‘rinmas diapazonda hech narsa bu afzallik bilan taqqoslanmaydi.

IV. LIFTLARNING XAVFSIZLIGINI TA‘MINLASHDAGI RIVOJLANISH YO‘NALISHLARI

IoT (Internet of Things) texnologiyalarinijadal rivojlanishi va mamlakat tomonidan kuchli qo‘llab-

quvvatlanishi bilan IoT texnologiyalari turli sohalarda tobora ko‘proq qo‘llanilmoqda [19]. IoT texnologiyalarining odatiy qo‘llanilishi sifatida liftlarning xavfsizligini monitoringi tizimi yanada samarali boshqarish modelini taqdim etishi mumkin. IoT texnologiyalaridan foydalanish bilan liftlarni monitoring qilish tizimidan foydalanishda liftlardagi avariyalarini muvaffaqiyatli bashoratlash va nosozliklarni samarali bartaraf etish, liftlarning xavfsizligini ta’minlash va avariya darajasi va yo‘qotishlarni kamaytirish mumkin.

Yo‘lovchilarni tashish liftlarini monitoring qilish tizimlarida buyumlar interneti va LTE va Wi-Fi kabi simsiz texnologiyalardan foydalanish boshqarish samaradorligi va ishlash xavfsizligini oshirish uchun katta imkoniyatlar yaratadi. Ushbu texnologiyalarni joriy etish real vaqt rejimida liftlarning holatini kuzatish, yuzaga kelishi mumkin bo‘lgan nosozliklar va avariyalarni bashoratlash imkonini beradi. Bunday tizimlar uchun IoT simsiz tarmoqlarini loyihalashda qurilish arxitekturasi, liftlar turi va ulanish nuqtalarining strategik joylashishi kabi omillarni hisobga olish kerak. Bu, ayniqsa, ko‘plab liftlar eskirgan va modernizatsiyalashni talab qiladigan O‘zbekiston sharoitlari uchun mos keladi. Tizim, shuningdek, liftlarning xavfsiz ishlashini ta’minlash va texnik xizmat ko‘rsatuvchi xodimlarni yoki mas’ul tashkilotni tezkor xabardor qilish uchun muhim bo‘lgan elektr ta’minotidagi uzilishlar kabi avariya vaziyatlarini nazorat qilish (avariya haqidagi ma’lumotlarni uzatish bilan) imkonini beradi.

XULOSA

Simsiz texnologiyalarning rivojlanishi yangi talablarni qo‘yadi va texnik tizimlar holatini onlayn monitoring qilish tizimlarini yaratish imkoniyatlarini beradi. Lift sanoati bunday sharoitlarda istisno bo‘lmasligi kerak. Takliq etilgan yondashuv lift sanoati obyektlarining texnik holatini operativ monitoring qilish imkonini beradi va shu bilan ularning ishlashi xavfsizligini oshiradi.

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TARMOQNI SEGMENTLASH MODELLARI VA USULLARINING QIYOSIY TAHLILI

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Annotatsiya **— 5G tarmoqlari allaqachon keng qo'llanilgan va zamonaviy aloqa tizimlarida amaliy foydalanish va amalga oshirish uchun ishlab chiqilgan. Ushbu tarmoqlarning asosiy texnologiyalaridan biri tarmoqni segmentlash (Network Slicing) texnologiyasi bo'lib, butun tarmoqni taqsimlash, optimallashtirish va ishlashini yaxshilash imkonini beradi. Tarmoqni segmentlashning ko'plab nazariy va amaliy echimlari mavjud. Ushbu maqolada biz telekommunikatsiya tarmoqlarida amalga oshirish uchun ishlatilishi mumkin bo'lgan segmentlash modellari va usullarini ko'rib chiqamiz. Ko'rib chiqilgan modellarning har biri ham afzalliklarga, ham cheklovlarga ega. Ushbu ishda ilmiy yondashuv bilan bir qatorda tizimli va institutsional yondashuvlar, grafik va algebraik usullar hamda kompleks tahlil usullaridan foydalaniladi. Tarmoqni segmentlash mavzusiga oid ochiq manbalardan olingan ilmiy nashrlar tahlil qilinadi, xususiyatlar va farqlar aniqlanadi, ularning qiyosiy bahosi beriladi.**

Keywords—Tarmoqni segmentlash, Dasturiy konfiguratsiyalanadigan tarmoq, 5G, Tarmoq funktsiyalari virtualizatsiyasi

KIRISH

Hozirgi kunda Internetga kirish uchun foydalanadigan qurilmalar soni bilan bir qatorda Internet foydalanuvchilari soni ham tez o‘sib bormoqda. Tarmoq xizmatlarining ko‘payib borayotgani, xizmat ko‘rsatish sifati hamda statsionar va mobil Internetga ulanish tezligiga qo‘yilayotgan qat’iy talablar tarmoq arxitekturasini yangi talablar, standartlar va tavsiyalar asosida modernizatsiya qilishga sabab bo‘ldi. Narsalar Interneti kontsepsiyasining faol rivojlanishi tufayli internetga ulangan qurilmalar katta hajmdagi tarmoq trafigini hosil qiladi, bu esa faqat marshrutizatorlar va kalitlarga o‘rnatilgan tarmoqlardan keyingi foydalanishni qiyinlashtiradi.

Bu beshinchi avlod tarmoq kontseptsiyasining ajralmas elementlari bo'lgan dasturiy konfiguratsiyalanadigan tarmoqlar (DKT) va tarmoq funktsiyalarini virtualizatsiyalash xizmatlarini faol rivojlanishining eng muhim sabablaridan biriga aylanadi [1].

Ushbu texnologiyalar yordamida 5G tarmoqlari infratuzilma platformasini o‘zgartirmasdan, muayyan turdagi vazifa uchun turli mantiqiy (virtual) tarmoqlarni qurish uchun zarur bo‘lgan zarur dasturlash, moslashuvchanlik, masshtablilik va hokazolarni ta’minlashi mumkin. Umumiy resurslarga ega bu mantiqiy tarmoqlar tarmoq bo'laklaridir. Ushbu ishning maqsadi zamonaviy telekommunikatsiya tarmoqlarida tarmoqni kesishning hozirgi modellari va usullarini tahlil qilish va ularni amalga oshirishdir.

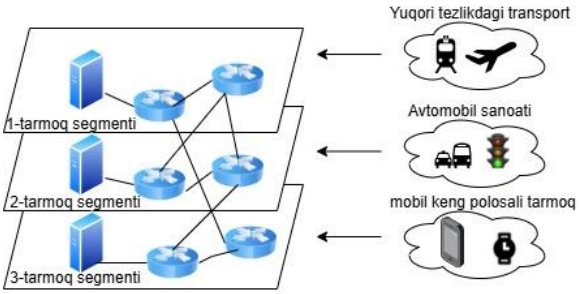
TARMOQNI SEGMENTLASH TUSHUNCHASI

Tarmoqni segmentlash operatorga moslashtirilgan tarmoqlarni taqdim etish imkonini beradi. Masalan, funksionallik (ustuvorlik, siyosat nazorati, xavfsizlik va hokazo), ishlash talablaridagi farqlar (masalan, kechikish, harakatchanlik, mavjudlik, ishonchlilik va ma’lumotlar tezligi) bo‘yicha turli talablar bo‘lishi mumkin yoki ular faqat ma’lum foydalanuvchilarga (Multimedia ustuvor xizmati foydalanuvchilari, Jamoat xavfsizligi foydalanuvchilari, korporativ mijozlar va boshqalar) xizmat qilishi mumkin[2]. Shu maqsadda 5G/IMT-2020 aloqa tarmoqlarida tarmoq segmentatsiyasi texnologiyasi joriy etilgan.

Aslida tarmoqni segmentlash virtualizatsiyaga tayangani uchun oldin ham Overlay, VLAN/PlanetLab, VPN va boshqa shakllarda mavjud bo’lgan[3]. Aloqa tarmoqlarida tarmoq segmentatsiyasi kontsepsiyasi ilgari taqsimlangan xizmatlar va ilovalar arxitekturasi kontekstida taklif qilingan. Lekin ular moslashuvchan, avtomatlashtirilgan va/yoki egiluvchan emas. OpenFlow protokoli va DKT paydo bo’lishi 5G tarmoqlarini segmentlash imkoniyatini berdi. 5G kontekstida tarmoqni segmentlash NGMN (Keyingi avlod mobil tarmog‘i) tomonidan kiritilgan[4].

Tarmoqni segmentlash umumiy jismoniy infratuzilma platformasi ustidagi bir nechta mantiqiy mustaqil tarmoqlarni osonlashtiradi, bu jismoniy va/yoki mantiqiy tarmoq va bulut resurslarini dasturlashtiriladigan, ochiq dasturiy ta’minotga yo‘naltirilgan ko‘p ijarachili tarmoq muhitiga integratsiyalashgan texnik va biznes innovatsiyalariga imkon beruvchi moslashuvchan manfaatdor tomonlar ekotizimini ta’minlaydi.

Uyali aloqa operatori nuqtai nazaridan, tarmoq segmentatsiyasi - foydalanuvchi ehtiyojlariga ko‘ra, umumiy jismoniy infratuzilmada joylashgan mantiqiy mustaqil tarmoqlar (tarmoq segmentlari) to‘plamini yaratish jarayoni, ularning har biri maxsus belgilangan tarmoq xizmatlarini taqdim etish uchun tuzilgan (1-rasm).



1-rasm. 5G aloqa tarmoqlarida tarmoq segmentatsiyasi arxitekturasi

DKT kontekstida tarmoq segmentini jismoniy infratuzilma tarmog‘idan mustaqil ravishda ishlaydigan virtual tarmoq sifatida ko‘rish mumkin. Masalan, virtual tarmoq tugunlari va uning jismoniy tugunlari o‘rtasidagi virtual tarmoq ko‘prigi. Virtual tarmoq tugunlari oddiy jismoniy tarmoq tugunlari (router, xavfsizlik devori yoki tarmoq xizmati serveri) kabi maxsus tarmoq xizmatlarini amalga oshirishi mumkin. Virtual tarmoq ko‘priklarini o‘rnatish PCC kaliti orqali amalga oshirilishi mumkin. Dasturiy konfiguratsiyalanadigan tarmoq texnologiyasi tarmoq ma’muriga yaratilgan tarmoq segmentiga zarur resurslarni ajratish uchun jismoniy tarmoqni boshqarish imkonini beradi. Va virtual tarmoq tugunini tarmoq funksiyasini virtualizatsiya texnologiyasi yordamida o‘rnatish mumkin. Dasturiy konfiguratsiyalanadigan tarmoq va tarmoq funksiyalarini virtualizatsiya qilish texnologiyalari tarmoqning yuqori moslashuvchanligi talablariga javob beradigan aloqa tarmoqlarida segmentatsiyani amalga oshirish imkonini beradi [5].

TARMOQ SEGMENTATSIYASINING YAGONA ETALON VA MODELLARI VA USULLARINI QIYOSIY TAHLIL QILISH

Birinchidan, biz asosiy jismoniy tarmoq infratuzilmasini yo‘naltirilgan ko‘p grafik $G = (N, L)$ sifatida ifodalaymiz, bu erda N - tarmoq tugunlari to‘plami va L - tugunlar orasidagi aloqa kanallari to‘plami. Tugun $n \in N$ hisoblash quvvati p bilan tavsiflanadi, flop/s bilan o‘lchanadi; aloqa kanali $l \in L$ o‘tkazish qobiliyati $b > 0$ bilan tavsiflanadi va bit/s bilan o‘lchanadi. Ijobiy hisoblash quvvati $p > 0$ bo‘lgan tugun virtual tarmoq funksiyalarini bajarish qobiliyatiga ega bulutli joylashuvni ifodalaydi, nol hisoblash quvvati $p = 0$ bo‘lgan tugun esa faqat DKT tarmoqda router vazifasini bajaradi [6].

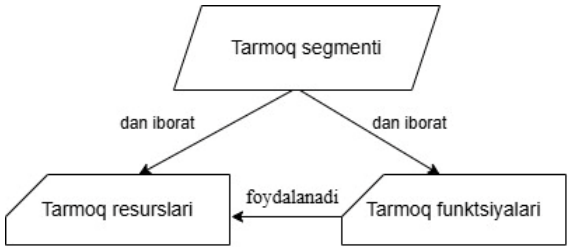
Modellashtirish nuqtai nazaridan tarmoq segmentlari o‘zaro bog‘langan virtual tarmoq funksiyalari to‘plami sifatida taqdim etilishi mumkin. Adabiyotda eng keng tarqalgan yondashuv virtual tarmoq funksiyalarini hisoblash birligi sifatida ko‘rib chiqishdir [6].

Yagona etalon modeli

Yagona etalon modelida (bazi manbalarda “Yagona mos yozuvlar modeli” deb ham uchraydi) tarmoq segmenti ma’lum bir vaqtda tarmoq resurslari va virtual tarmoq funksiyalarining kichik to‘plamlari birlashmasi sifatida qaraladi [7; 8].

Tarmoq segmentatsiyasi bu holda jismoniy tarmoq infratuzilmasi ustidagi bunday segmentlarni yaratish va boshqarishdir.

Ushbu model sxematik tarzda 2-rasmda ko‘rsatilgan.



2-rasm. Tarmoq segmentining mos yozuvlar modeli

Matematik jihatdan birlashtirilgan mos yozuvlar modelining segmenti quyidagi ifoda bilan tavsiflanadi:

$$s = \langle NR, NF, R \rangle$$

bu yerda s - tarmoq segmenti;
NR – tarmoq resurslari to‘plami;
NF – tarmoq funksiyalari to‘plami;
R - bu tarmoq resurslari va tarmoq funktsiyalarini bir-biriga bog‘laydigan munosabatlar to‘plami.

Ushbu modelda tarmoq funksiyasi ma’lum tarmoq resursidan foydalanishini aniqlaydigan “foydalanishlar” munosabati mavjud. Agar nol “funksiya resursdan foydalanmaydi” va bittasi “funksiya resursdan foydalanadi” ga to‘g‘ri kelishini qabul qilsak, u holda matematik belgilarda munosabat biz quyidagi xaritani olamiz:

$$\text{“foydalanadi”: } NF \times NR \to \{0,1\}.$$

Tarmoq resursining segment ishida ishtirok etish darajasini statistik tahlil qilish yoki ma’lum bir tarmoq funksiyasi yoki boshqa narsa bilan bog‘liq tarmoq resurslarini hisobga olish uchun “foydalanishlar” munosabati quyidagi ikki o‘lchovli matritsa bilan ifodalanishi mumkin. Yaxshiyamki, tarmoq resurslari va tarmoq funksiyalari soni cheklangan. Matritsada qatorlar tarmoq funksiyalariga, ustunlar esa tarmoq resurslariga mos keladi. Matritsaning katakchasiga (i, j) i -tarmoq funksiyasi tomonidan j-tarmoq resursidan foydalanilgan yoki foydalanilmasligiga qarab 1 yoki 0 ni yozamiz.

Biz quyidagi turdagi matritsani olamiz:

$$U = \begin{bmatrix} b_{1,1} & \cdots & b_{1,n} \\ \vdots & \ddots & \vdots \\ b_{m,1} & \cdots & b_{m,n} \end{bmatrix}$$

bu yerda m - tarmoq funksiyalari soni;
n - tarmoq resurslari soni,
$b_{i,j} \in \{0,1\}, i = \overline{1,m}, j = \overline{1,n}.$

U - matritsadagi har bir i - qator tarmoq funksiyasiga mos vektor bo‘lib, u tarmoq resurslaridan qanday foydalanishini aks ettiradi:

$$R_i^T = [b_{i,1} \cdots b_{i,n}].$$

Xuddi shunday, har bir j-inchi ustun tarmoq resursiga mos keladigan va undan tarmoq funktsiyalari tomonidan qanday ishlatilishini aks ettiruvchi vektordir:

$$C_j = \begin{bmatrix} b_{1,j} \\ \vdots \\ b_{m,j} \end{bmatrix}$$

$R_i^T R_k$ mahsuloti segment ishlayotgan paytda ushbu tarmoq funksiyalarining korrelyatsiyasini beradi. Matritsa mahsuloti UU^T tarmoq funksiyasi vektorlarining barcha ana shunday mahsulotlarini o‘z ichiga oladi. Element (i,k)((k,i) element bilan bir xil) $R_i^T R_k$ (= $R_k^T R_i$) ko‘paytmani o‘z ichiga oladi. Matritsa $U^T U$ tarmoq resurs vektorlarining barcha mahsulotlarini o‘z ichiga oladi, ularni ta’minlaydi, tarmoq funktsiyalari bo‘yicha korrelyatsiya: $C_j^T C_l (= C_l^T C_j)$.

U ning singulyar qiymatli dekompozitsiyasi (SVD) [26] bor, shundayki, W va V ortogonal matritsalar, Σ diagonal matritsadir. Ya’ni:

$$U = W\Sigma V^T.$$

Keyin matritsa mahsulotlari bo‘ladi:

$$UU^T = (W\Sigma V^T)(W\Sigma V^T)^T = (W\Sigma V^T)(V^T W^T \Sigma^T) = W\Sigma V^T V W^T \Sigma^T = W\Sigma W^T \Sigma^T,$$

$$U^T U = (W\Sigma V^T)^T (W\Sigma V^T) = (V^{TT} W^T \Sigma)(W\Sigma V^T) = VW^T \Sigma^T W\Sigma V^T = V\Sigma^T \Sigma V^T.$$

$\Sigma\Sigma^T$ va $\Sigma^T\Sigma$ diagonal bo‘lganligi sababli, W da UU^T ning xos vektorlari , V esa $U^T U$ ning xos vektorlarini o‘z ichiga olishi kerakligini ko‘ramiz. Ikkala mahsulot ham nolga teng bo‘lmagan $\Sigma\Sigma^T$ yozuvlari yoki teng ravishda $\Sigma^T\Sigma$ nolga teng bo‘lmagan yozuvlar bilan berilgan nolga teng bo‘lmagan o‘z qiymatlariga ega . Endi yagona qiymat parchalanishi quyidagicha bo‘ladi:

$$\begin{matrix} & & U & & \\ & & (C_j) & & \\ & & \downarrow & & \end{matrix}$$
$$(R_i^T) \rightarrow \begin{bmatrix} b_{1,1} & \cdots & b_{1,n} \\ \vdots & \ddots & \vdots \\ b_{m,1} & \cdots & b_{m,n} \end{bmatrix} =$$

$$\begin{matrix} & W & & \Sigma & & V^T \\ & \downarrow & & \downarrow & & (D_j) \\ & & & & & \downarrow \end{matrix}$$
$$= (S_i^T) \rightarrow [[w_1] \cdots [w_i]] \cdot \begin{bmatrix} \delta_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \delta_l \end{bmatrix} \cdot \begin{bmatrix} [v_1] \\ \vdots \\ [v_l] \end{bmatrix}$$

$\delta_1, \cdots, \delta_l$ qiymatlari yakka qiymatlar deb ataladi va $w_1, \cdots, w_l$ va $v_1, \cdots, v_l$ mos ravishda chap va o‘ng yakka vektorlardir. E’tibor bering, W ning R_i ga hissa qo‘shadigan yagona qismi i- qatordir. Bu chiziq S_i bo‘lsin. Xuddi shunday, V^T ning C_j ga hissa qo‘shadigan yagona qismi D_j ning j- ustunidir . Ular xos vektorlar emas, balki barcha xos vektorlarga bog‘liq. Ma’lum bo‘lishicha, biz k eng katta singulyar qiymatlarni va ularning mos singular vektorlarini W va V dan tanlaganimizda, eng kichik xato bilan (Frobenius normasi) U ga k darajali yaqinlashuvni olamiz . Ushbu yondashuv minimal xatolikka ega. Endi biz tarmoq funksiyasi vektorlari va tarmoq resurs vektorlarini “elementlar maydoni” sifatida ko‘rib chiqishimiz mumkin. Keyin S_i vektori k ta yozuvga ega bo‘lib, ularning har biri k elementdan birida i -tarmoq funksiyasining paydo bo‘lishini tavsiflaydi. Xuddi shunday, D_j vektori j-tarmoq resursi va har bir element o'rtasidagi munosabatni tavsiflaydi. Bu yaqinlik quyidagicha aniqlanadi:

$$U_k = W_k \Sigma_k V_k^T.$$

Endi biz quyidagilarni amalga oshirishimiz mumkin:

1) D_j va D_q vektorlarini solishtirish orqali j va q tarmoq resurslari o‘rtasidagi munosabatlarni ko‘rib chiqish. Bu tarmoq resurslarining avtomatik klasterlanishini ta’minlaydi;

2) tarmoq funksiyalarini avtomatik klasterlashni ta’minlovchi S_i va S_p vektorlarini solishtirish orqali i va p tarmoq funksiyalarini solishtirish;

3) tarmoq resurslaridan foydalanish reytinglari va samaradorligini baholash;

4) tarmoq funktsiyalari va resurslarni element maydonida qidirish.

Qidiruvni amalga oshirish uchun avval so‘rovni element bo‘shlig‘iga tarjima qilishingiz kerak, so‘ngra avvalgidek amallarni bajaring:

$$C_j = W_k \Sigma_k D_j, \quad D_j = \Sigma_k^{-1} W_k^T C_j.$$

ğ so‘rov vektoriga ega bo‘lsak , biz ushbu so‘rovni element maydonidagi tarmoq resursi vektorlari bilan solishtirishdan oldin ğ $= \Sigma_k^{-1} W_k^T g$ tarjimasini bajarishimiz kerak. Xuddi shu narsani tarmoq funktsiyalarining psevdovektorlari uchun qilish mumkin:

$$R_i^T = S_i^T \Sigma_k V_k^T, S_i^T = R_i^T V_k^{-T} \Sigma_k^{-1} = R_i^T V_k \Sigma_k^{-1},$$

$$S_i = R_i V_k^T \Sigma_k^{-1}$$

Modelning asosiy afzalliklari:

– modelni o‘rganish oson,
– amalga oshirish va joylashtirish qulayligi,
– ko‘p qirralilik,
– juda ko‘p turli xil xizmatlar ko‘rsatilishi mumkin,
– ehtimol ko‘p sonli yo‘l harakati ishtirokchilari,
– trafik ishtirokchilari o‘rtasida bir nechta aloqa yo‘llari,
– har qanday turdagi trafikni qo‘llab-quvvatlaydi,
– yuqori moslashuvchanlik,
– yuqori miqyoslilik,
– model transport talablaridagi noaniqliklarga chidamli.
– model ham semantik, ham matematik tasvirga ega, segmentlarni har tomonlama nazorat qilish va monitoring qilish uchun modelga komponentlar o‘rtasidagi turli munosabatlarni kiritish mumkin.

va kamchiliklari:

– tarmoq xizmatlari qatlami aniq ko‘rsatilmagan,

– boshqaruv va transport sathlarida aniq bo‘linish yo‘q,
– ko‘pgina parametrlarni optimallashtirishning aniq usullari ko‘rsatilmagan,
– Keling, o‘zgartirilgan mos yozuvlar modelini ko‘rib chiqishga o‘tamiz.

Keling, modifikatsiyalangan etalon modelini ko‘rib chiqishga o‘tamiz.

Modifikatsiyalangan etalon modeli

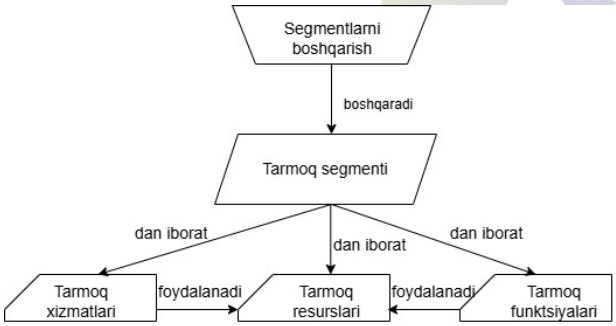
Ushbu model tarmoq xizmatlarini ajratish orqali mos yozuvlar modelini kengaytiradi. Ya’ni, segment ma’lum bir vaqtda tarmoq resurslari, virtual tarmoq funksiyalari va tarmoq xizmatlarining kichik to‘plamlari birlashmasi sifatida qaraladi. Har bir segment o‘z boshqaruviga ega [9; 10].

Bu holda tarmoq segmentatsiyasi jismoniy tarmoq infratuzilmasi tepasida ushbu kengaytirilgan segmentlarni yaratish va boshqarish jarayonidir. Ushbu model sxematik tarzda 3-rasmda ko‘rsatilgan.

Matematik jihatdan o‘zgartirilgan mos yozuvlar modelining tarmoq segmenti quyidagi kortej bilan tavsiflanadi:

$$s = \langle MF, NR, NF, NS, R \rangle,$$

bu yerda s - tarmoq segmenti;
MF – boshqaruv funksiyalari to‘plami;
NR – tarmoq resurslari to‘plami;
NF – tarmoq funksiyalari to‘plami;
NS – tarmoq xizmatlari to‘plami;
R - tarmoq resurslari va tarmoq funktsiyalarini, shuningdek, tarmoq resurslari va tarmoq xizmatlarini bog‘laydigan munosabatlar to‘plami.



3-rasm. Modifikatsiyalangan etalon segment modeli

Modelning asosiy afzalliklari:
– amalga oshirish va joylashtirish qulayligi,
– yuqori tezlik,
– turli manfaatdor tomonlarga nisbatan tabiiy ajralish imkonini beradi,
– model transport talablaridagi noaniqliklarga chidamli,
– model ham semantik, ham matematik tasvirga ega, segmentlarni har tomonlama nazorat qilish va monitoring qilish uchun modelga komponentlar o‘rtasidagi turli munosabatlarni kiritish mumkin.

va kamchiliklari:
– ko‘pgina parametrlarni optimallashtirishning aniq usullari ko‘rsatilmagan.

XULOSA

Yuqorida muhokama qilingan modellar va yondashuvlarning asosiy kamchiliklari va afzalliklari ko‘rsatib o’tildi. Ushbu taqqoslash modellar va yondashuvlarning kamchiliklari va afzalliklarini taqqoslashga asoslangan.

Etalon modeli haqiqatan ham o‘z nomiga loyiqdir, chunki uning mos yozuvlar tabiati uning murakkabligi va ko‘p qirraliligi bilan tasdiqlangan.

Etalon modeli o‘rganish osonligi, qulayligi, juda ko‘p turli xil xizmatlar ko‘rsatilishi mumkinligi, yuqori moslashuvchanlik, miqyoslilik, chidamlilik, ham semantik, ham matematik tasvirga egaligi foydalanuvchiga ko‘plab qulayliklar tug‘diradi. Lekin avtomatlashtirishdagi muammolar borligi, suniy intelekt bilan integratsiya qilishdagi muammolar borligi bois katta tarmoqlarda kam qo‘llaniladi. Shunday bo‘lsada, dastlabgi o‘rganuvchilar, laboratoriya muhitida qo‘llash uchun juda qulay hisoblanadi.

LXXXIV. FOYDALANILGAN ADABIYOTLAR RO‘YXATI

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ANALYSIS OF NETWORK TECHNOLOGIES FOR DELIVERING MULTIMEDIA CONTENT IN CLOUD INFRASTRUCTURE

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Abstract – The article examines the significance of network architecture, the role and development trends of telecommunication infrastructure, and its interrelation with informatization. The study analyzes the key factors limiting the existing network architecture, particularly in the context of content delivery within cloud infrastructures. Furthermore, network architectures and the functional capabilities of CDN, NDN, and SDN/NFV technologies are presented.

Keywords – Telecommunication infrastructure, informatization, cloud computing, multimedia, cloud technologies, TCP/IP, CDN, NDN, SDN/NFV

International practice demonstrates that a strategic objective of a developed country is the establishment of a national information infrastructure, which comprises two fundamental components: telecommunication and information [1–3].

The telecommunication component of the modern information infrastructure represents data transmission networks with packet switching based on the IP protocol, serving as the transport foundation of the entire information infrastructure.

The modern telecommunication sector has evolved into a high-technology industry that requires substantial investment and continuous support for innovation. Its technical systems are highly knowledge-intensive, while manufacturers update their product lines every 3–5 years, thereby reducing the lifecycle of equipment [1–3].

Historically, the driving force behind the development of telecommunications has been the user's desire to access information in a form as close as possible to face-to-face communication—anywhere, at any time, in any format, and even while in motion—across distances far greater than those achievable through direct interaction.

Findings from international research on the informational capabilities of various types of telecommunications have made it possible to determine the relative volumes of information transmitted through different modes of communication [2]. Table 1 presents the informational capacity of telecommunication media.

TABLE 1. INFORMATION CAPACITY OF TELECOMMUNICATION SYSTEMS

Direct (face-to-face) communication – 100%	
Environmental factors (light, smell, taste, etc.)	2-5%
Multimedia-based communication – 95-98%	
Transfer through gestures and facial expressions	52-55%
Telephone communication – 45%	
Voice features (timbre, intonation, volume, pauses)	38%
Text-based communication – 7%	

An analysis of the evolution of telecommunication technologies shows that, once the possibility emerged to convert textual messages into electrical signals and to reverse the process at the receiver, telegraph communication appeared. However, such communication transmitted only about 7% of the information available in face-to-face interaction.

With the advent of methods and devices for converting sound waves into electrical signals and back at the receiver, speech transmission became possible. This increased the volume of transmitted information from 7% to 45%, due to the inclusion of voice timbre, intonation, and other acoustic features. Subsequently, the development of techniques and devices for converting static and moving images, and their reproduction at the receiver, enabled the transmission of drawings, images, and video, further increasing the amount of conveyed information by an additional 50%.

The data presented in Table 1 indicate that the final stage of this progression is the creation of multimedia technologies, which combine text, audio, and video transmission, thereby providing up to 95–98% of the information available in direct interpersonal communication.

At the same time, the only type of information not yet captured remains that perceived through human senses of smell, taste, and touch, for which various companies are actively seeking solutions. Each type of telecommunication, by gradually incorporating the latest achievements of scientific and technological progress—

such as increasing microprocessor performance, the emergence of powerful digital signal processors, the development of high-speed compression methods, advances in fiber-optic communication systems, and the advent of high-speed data transmission technologies—has reached a qualitatively new level. As a result, these technologies have become increasingly homogeneous in terms of their underlying technical principles, thereby ensuring both the technical feasibility and economic viability of their integration into a unified system [1–3].

The informational component of the national information infrastructure consists of tools for searching, processing, and storing information, including data centers and standalone servers. It is particularly important to emphasize that, historically, telecommunications and informatization developed almost independently of each other. For many decades, the disproportionate advancement of telecommunications led to a lag in the development of informatization [1–3].

In the context of their integration, a terminological convergence has also taken place. The ITU introduced the new term *infocommunication*, which functions as an umbrella concept. The synthetic origin of this term is illustrative: it derives from the words “information” and “telecommunication”—with “info” coming from “information” and “communication” from “telecommunication” [2,3]. Under market conditions, operators and providers act as commercial entities, with content and services as their core products, while network technologies are merely tools for delivering these services. In today’s environment, the most profitable business models are tied directly to content and services, which are generated and created beyond the boundaries of traditional transport (network) infrastructure. International practice in developed countries shows that a three-tier model of infocommunications has been adopted as the standard [2,3]:

– Content level (responsible for the substance of content);

– Service level (service infrastructure responsible for the creation and provision of services);

– Transport level (network infrastructure responsible for traffic delivery).

In this regard, operators and providers are restructuring their business strategies, shifting from the “pipe” model toward a content- and service-oriented business model. At present, telecommunications are increasingly becoming a subsystem of informatization, the functioning of which largely depends on the performance of the informatization subsystem. Consequently, forecasting the development of telecommunications must be closely aligned with the strategic objectives of informatization.

Analysis shows that the emergence of modern multimedia services is mainly driven by two factors: (1) the growing demand for diverse multimedia applications; and (2) the availability of appropriate technological and technical capabilities for providing multimedia services. Existing telecommunication networks can be classified by the number of services provided into monoservice networks, designed for the organization of a single telecommunication service, and multiservice networks, intended for the provision of two or more services. In turn, telecommunication services can be divided by the type of transmitted messages into monomedia services, designed for transmitting messages of a single type, and multimedia services, designed for transmitting messages of two or more types.

Thus, the rapid development of telecommunication and information technologies currently enables the provision of a wide range of multimedia services. As a result of ongoing transformations in the fields of telecommunications and informatization, demand for multimedia services has significantly expanded, leading to the continuous growth and diversification of multimedia applications [1–3]. The rapid increase in memory capacity, processing speed, and performance of modern information terminals has enabled the transition toward integrated multimedia services, where text, data, graphics, audio, and video are combined and displayed within a single terminal. This process is achieved through the interaction of broadband transmission methods with powerful operating systems of modern information terminals [4]. Initially, the IP protocol was designed solely for data transmission services, but with further advancements it has become applicable for real-time services such as voice, graphics, video, and multimedia. However, the rapid growth of diverse multimedia applications with large volumes of data, along with the active use of cloud services, requires significant resources for the storage, processing, and transmission of such applications (see Table 2).

TABLE 2. AVERAGE VOLUMES FOR DIFFERENT TYPES OF MESSAGES

Message Type	Typical Size
e-mail	2,2 kB
Long documents (~20 pages)	44 kB
Graphic image	330 kB
1 minute of audio	475 kB
1 minute of video	2400 kB

In this context, there has been a rapid increase in video traffic, accompanied by profound changes in both the structure and nature of traffic transmitted over IP networks, including real-time multimedia applications [4]. The primary factors necessitating changes to the existing data transmission architecture based on the TCP/IP protocol stack include:

– the exponential growth of traffic volumes, along with changes in its structure and characteristics (most notably, the explosive increase in mobile and video traffic driven by the widespread adoption of smartphones and tablets);

– the extensive deployment of cloud technologies, big data, the Internet of Things, and related innovations;

– the challenges of network scalability and the limited flexibility of current systems for managing network resources and services.

Within the modern network architecture based on the TCP/IP protocol stack and the “host-to-host” model (Figure 1), the network layer constitutes the primary bottleneck. Consequently, the limitations of existing networks, their insufficient flexibility, growing user demands, and the active use of cloud technologies have underscored the urgent need for new network architectures and technologies capable of enhancing the efficiency of resource utilization.

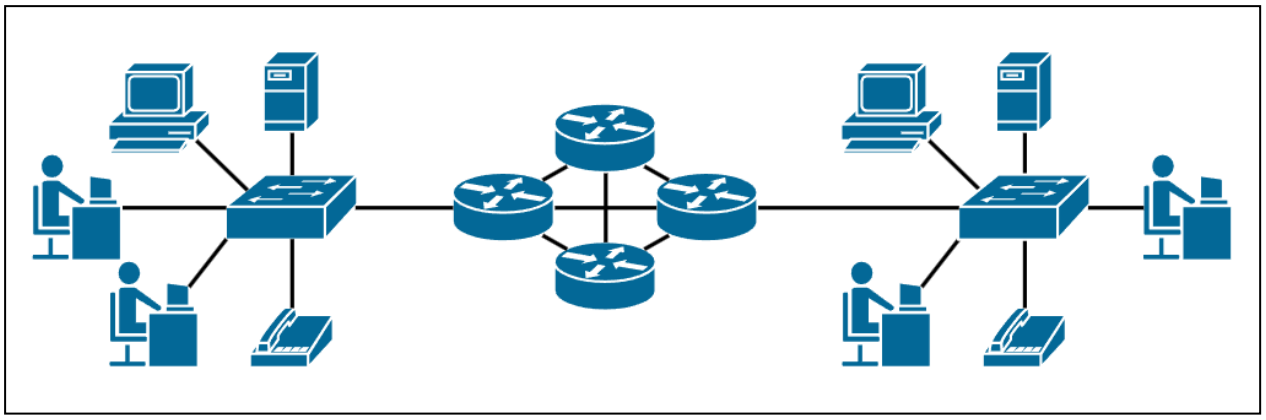

Fig. 1. TCP/IP-Based Network

International practice in developed countries shows that, for the first time in several decades, the field of telecommunications is undergoing a fundamental transformation driven by new network architectures and emerging technologies such as CDN, NDN, and SDN/NFV.

Content Delivery Networks (CDN) represent a network architecture that emerged in the late 1990s with the primary objective of enabling efficient and timely content delivery over the Internet [6,7]. With the rapid growth of video traffic, CDNs have become the dominant channel for delivering content to end users. According to Cisco forecasts, in 2016, 57% of all Internet video traffic was transmitted through CDNs, and by 2019 this figure had already reached 72% [8].

A CDN is a geographically distributed network composed of a central node and caching nodes, where information is stored on servers located in close proximity to users (Figure 2) [9].

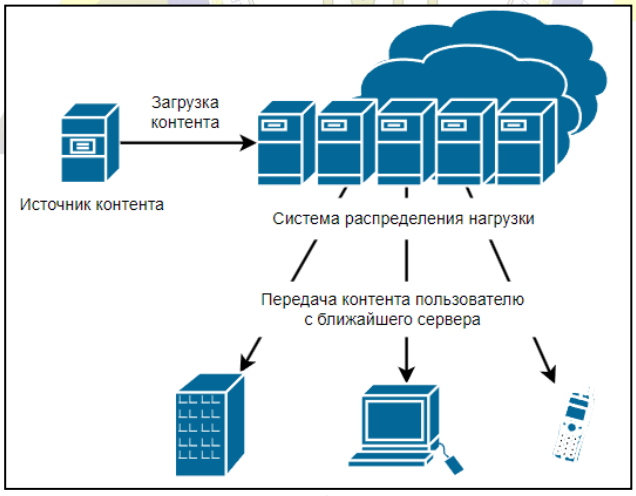

Fig. 2. Principle of CDN Operation

A CDN may be owned by a single company providing data—such as Google, which distributes videos and other content through its YouTube service—or shared by multiple providers, as in the case of Akamai, which supplies CDN services for numerous platforms including Netflix and Hulu [9]. According to international experts and analysts, the use of CDNs can reduce the load on the central server by up to 95% and decrease network latency between the user and the server by a factor of up to five [8]. Despite being a specialized solution for the problem of content distribution, CDNs still face significant challenges, such as complex control planes and the bottlenecks inherent in the TCP/IP protocol, which are not fully addressed by CDN deployment [10].

In search of a solution to these limitations, Van Jacobson introduced a new Internet architecture in 2006—Named Data Networking (NDN). Unlike traditional architectures that identify content by its location, NDN names the data itself, potentially shifting the Internet paradigm from the current focus on “where” (addresses and hosts) to “what”

(content). NDN represents an evolution of the IP architecture, moving away from endpoint-centric communication toward a model in which packets contain the names of data objects rather than only the identifiers of communication endpoints [11].

NDN is based on named content, which eliminates the notion of a host at the lowest level and does not rely on source or destination addresses. Each content packet is assigned a unique name and is forwarded through the network based on a lookup of that name. The NDN network architecture (Figure 3) incorporates content delivery functions directly at the network layer. Its routing and stateful forwarding mechanisms can efficiently detect and adapt to the dynamic and continuously changing Internet environment [11–12].

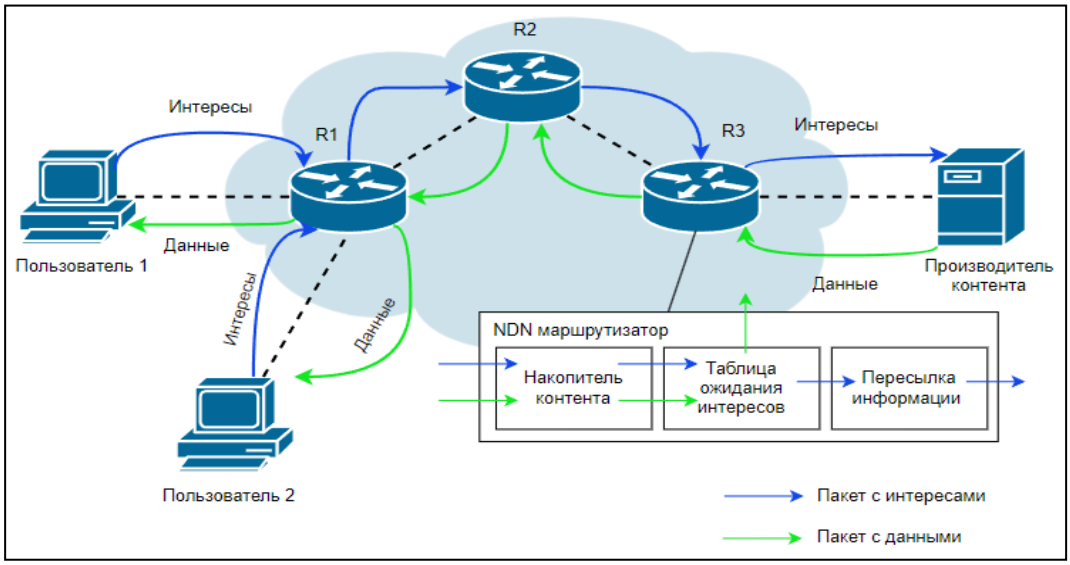

Fig. 3. Architecture of the NDN Network

Each NDN router maintains three key tables: the Content Store (CS), the Pending Interest Table (PIT), and the Forwarding Information Base (FIB) used for packet forwarding. When an interest packet arrives at an NDN router, it first checks the CS to determine whether any cached data matches the requested name. If a copy exists, the router immediately returns the data to the consumer. Otherwise, the router consults the PIT to verify whether an outgoing interface already has a pending request for the same content. If a match is found, the PIT is updated with the new interface, and the duplicate interest is discarded. If no match exists, the new interface is added to the PIT. The interest packet is then forwarded to the FIB, where names and their corresponding interfaces are stored for forwarding to the content producer [10]. After these processes, the requested data is delivered back to the consumer, as illustrated in Figure 3.

NDN also offers advantages across multiple dimensions, including security, scalability, and Quality of Service (QoS). Both CDN and NDN are designed to optimize content delivery. While CDNs use named content in the form of HTTP URLs, NDN employs named content not only for data delivery but also for intra-network operations such as routing and forwarding.

As traffic volumes generated by cloud service providers continue to grow, the need for more efficient solutions has become evident. The most relevant technologies for data transmission are now Software-Defined Networking (SDN) and Network Function Virtualization (NFV), which introduce a transition toward centralized control of data transmission networks. SDN/NFV represent another novel network architecture: SDN refers to software-defined networks, while NFV refers to the virtualization of network functions. SDN introduces a fundamentally new paradigm for designing, deploying, and operating data transmission networks and data centers, whereas NFV focuses on leveraging virtualization technologies to virtualize the functions of network nodes [13,16].

The most critical distinction between NFV and SDN lies in their ultimate objectives. NFV is primarily concerned with implementing specific network functions in software and managing them as software objects, while SDN embodies an ideology for the operation of the entire network, in which all control and decision-making (e.g., routing, switching) are delegated to a centralized layer [14,17]. At present, the integration of SDN and NFV technologies is driving a shift in approaches to building data transmission networks (Figure 4) [15]. This integration enables reduced network complexity, enhanced scalability, automated management, infrastructure virtualization, and significant reductions in both capital expenditures (CAPEX) and operational expenditures (OPEX) [16,17].

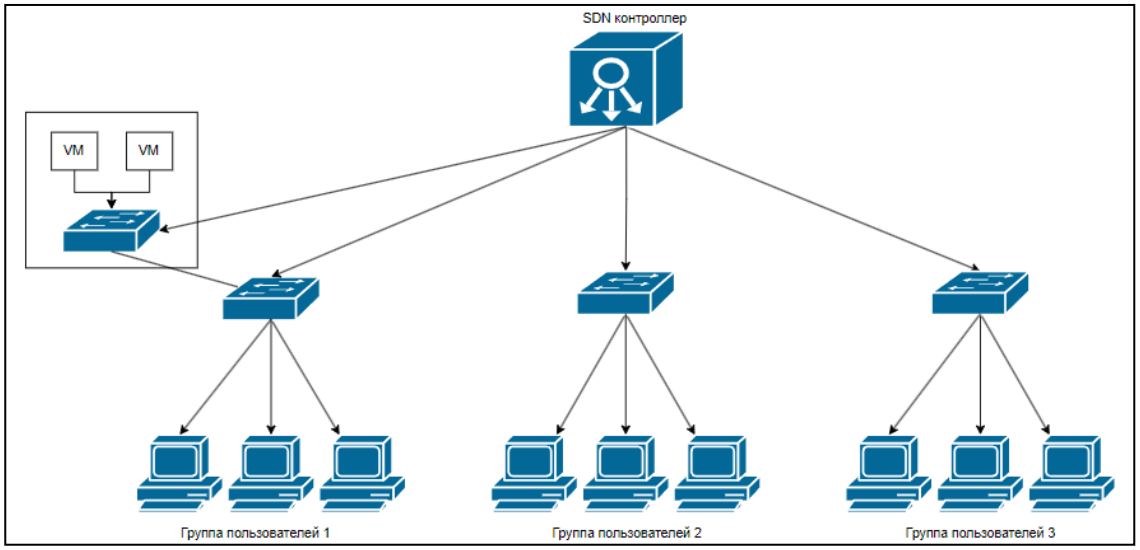

Fig. 4. Architecture of the SDN/NFV Network

According to international experts and analysts, the integration of SDN and NFV will make it possible to [13–15]:

– fundamentally transform the physical and virtual infrastructure of data transmission networks;

– implement an innovative approach to the delivery of both traditional and emerging services through open platforms;

– significantly reduce the time between the emergence of demand for a service and its availability on the market;

– simplify configuration, improve scalability, and automate network management;

– reduce capital expenditures (CAPEX) and operational expenditures (OPEX).

Given the rapid growth of network traffic, the expansion of cloud technologies, big data, and the Internet of Things, as well as the scalability challenges of existing networks, the development of these technologies is inevitable [16,17]. At the same time, considering the volumes of traffic being generated, many modern network services cannot function without the use of content delivery networks (CDNs). CDNs make it possible to significantly reduce the costs of transmitting data across the network, improve solution scalability, and ensure timely data delivery to end-user devices, thereby guaranteeing an adequate Quality of Experience (QoE). However, existing CDNs also suffer from a number of shortcomings, including:

– inefficient use of network infrastructure;

– inability to personalize content in accordance with user requests;

– excessive load on content providers.

TABLE 3. ANALYSIS OF NETWORK TECHNOLOGIES FOR MULTIMEDIA CONTENT DELIVERY IN CLOUD INFRASTRUCTURE

Parameter / Technology	TCP/IP	SDN	CDN	NDN
Reliability of delivery	High, but delays occur under heavy load	Flexible routing, increased reliability	High due to distributed nodes	High thanks to caching at each node
Transmission delay	Medium, depends on routing	Low due to route optimization	Low, as data is closer to the user	Minimal due to decentralized caching
Scalability	Limited by architecture	High, centralized management	High, easily expanded by adding nodes	High, built-in scalability support
Implementation cost	Low (widely adopted)	Medium (requires SDN controllers)	Medium/High (depends on infrastructure)	Medium (emerging technology, requires adaptation)
Bandwidth	Medium, limited by routing and congestion	High due to dynamic resource allocation	High, optimized for multimedia	Very high, as requests are served by nearest nodes
Key advantages	Simplicity and universality	Centralized control, flexible routing	Optimized multimedia delivery, reduced latency	Efficient caching, reduced network load
Limitations	Scalability issues, congestion	Requires additional controllers and infrastructure	Dependent on number and location of nodes	Still not fully standardized, complex deployment

It should also be emphasized that the advancement of technologies such as NDN and SDN/NFV will inevitably affect content delivery networks in the near future. The transition to SDN/NFV is being implemented gradually; at present, these technologies are actively deployed in data centers and are widely used by providers to deliver cloud services. However, considering the operational lifecycles of existing network technologies, as well as the limited practical experience of network operators and service

providers in deploying and utilizing SDN/NFV, this transition will occur progressively, depending on financial, technical, organizational, and human resource capabilities.

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IMPROVING BIG DATA TRANSFER IN CLOUD INFRASTRUCTURE THROUGH SDN TECHNOLOGY

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***Abstract* - The article explores approaches to the transfer and analysis of Big Data, with particular emphasis on the fundamental challenges arising in cloud infrastructures. A simulation model of a cloud environment has been developed to investigate Big Data transfer employing SDN and TCP/IP technologies. The study provides a comparative evaluation of the efficiency of the applied data transmission mechanisms.**

Keywords – Cloud Computing, Big Data, SDN, TCP/IP, Simulation.

I. INTRODUCTION.

Nowadays, more and more organizations and enterprises are turning to cloud computing to store and process their data. Cloud infrastructure offers flexibility, scalability and ease of use, allowing you to efficiently manage and access information from anywhere in the world [1].

As characteristics for big data, the concept of Big Data is defined as a technology in the field of hardware and software that integrates, organizes, manages and analyzes data characterized by the "3 V's": Volume, Variety and Velocity. Below are the characteristics of big data in more detail [2, 3]:

Volume: Big data is usually huge in size and requires special infrastructure solutions for storage and processing.

Variety: Big data can be structured, such as data from databases, as well as semi-structured and unstructured data, such as text documents, videos, images, logs and social media.

Velocity: Big data can arrive at significant speed and requires fast processing in real time.

The cloud infrastructure provides an efficient and flexible solution for processing and storing big data. It allows organizations to distribute and process bulk data on remote servers rather than on local computers or servers [1,3].

But a large volume of data requires large computing power, which is concentrated in data processing centers that ensure guaranteed trouble-free operation of the information system with specified levels of availability, reliability, security and controllability. The use of technology for creating data processing centers makes it possible to create backup headquarters of enterprises while maintaining the maximum possible functionality of the information system in emergency circumstances [4].

But data centers, which play a key role in modern information infrastructure, sometimes encounter problems in transmitting data. Traditional network architectures based on physical switches and routers can limit flexibility and scalability, making it difficult to manage and maintain efficient network operations.

To overcome these problems, the implementation of software-defined network concepts has become relevant, allowing to ensure security [5], increase network throughput [6], increase fault tolerance [7], reduce latency, etc [8].

SDN (Software-Defined Networking) is an approach to network management that separates the management of network equipment (switches, routers) from data transmission [9].

NFV (Network Functions Virtualization) is an approach to virtualizing the functions of network devices and services that typically run on specialized hardware such as routers, firewalls, load balancers, etc [10].

SDN and NFV are often used together to create flexible, software-driven, and virtualized networks. SDN provides centralized management and control of network infrastructure, while NFV allows network functions to run and scale virtually on shared hardware. This makes it easier to deploy new network services, manage load, provide flexibility, and quickly adapt to changing network requirements [11].

SDN solves the problem of optimizing the transfer of large amounts of data, due to the fact that all control logic is placed in controllers based on the OpenFlow protocol, capable of monitoring the operation of the entire network. OpenFlow is the first standardized open interface responsible for the interaction between the control plane and the communication plane. OpenFlow provides access, information exchange and delivery of control commands to network infrastructure elements.

The SDN controller [12] acts as a single centralized control point that interacts with the application layer through an open API interface, and also monitors and manages physical network devices through an open interface - the OpenFlow protocol.

II. MAIN (EXPERIMENTAL RESULT)

In article [8], a comparative analysis of channel throughput was carried out, based on SDN technology and traditional TCP/IP technology.

In this work, an experiment was conducted to test the latency indicators for data transmission using the TCP/IP

protocol and SDN technology. Table 1 lists the topology parameters that will be used in the simulation [13,14].

TABLE I. CONFIGURATION OPTIONS

Parameter	Configuration #1	Configuration #2
Data transfer technology	TCP	SDN
Number of hosts	10	10
Number of switches	6	6
Number of Routers	4	SDN Controller

Configuration #1 is a network that transmits data using the TCP/IP protocol. This standard approach involves transmitting data over a network using a set of protocols. The device that distributes packets in the network is the router, which operates on the basis of the routing table.

On the other hand, configuration #2 is a network that uses Software Defined Networking (SDN) principles for data transmission. SDN differs from TCP/IP technology by the principle of network management, in which control is concentrated on a single device - a controller using the OpenFlow protocol.

For the purity of the experiment, identical topologies were built for both configurations, but when transmitting data using traditional technology, 4 routers were used in the network, and when transmitting data using SDN technology, 1 controller was used.

The results of the work carried out are shown in Figures 1 and 2. To analyze the effectiveness of data transmission technologies, we used data on delay (ms) obtained during the transmission of the first packet, based on when the first packet is transmitted from one host to another.

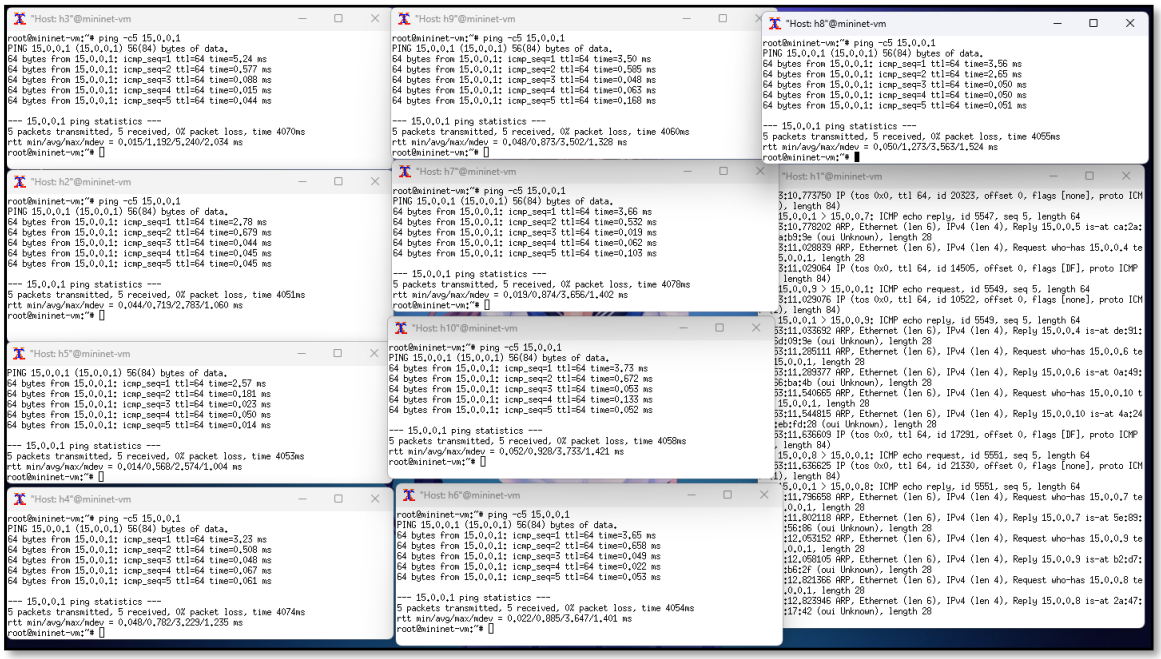

Fig. 1. Data transfer using TCP / IP technology (Configuration № 1).

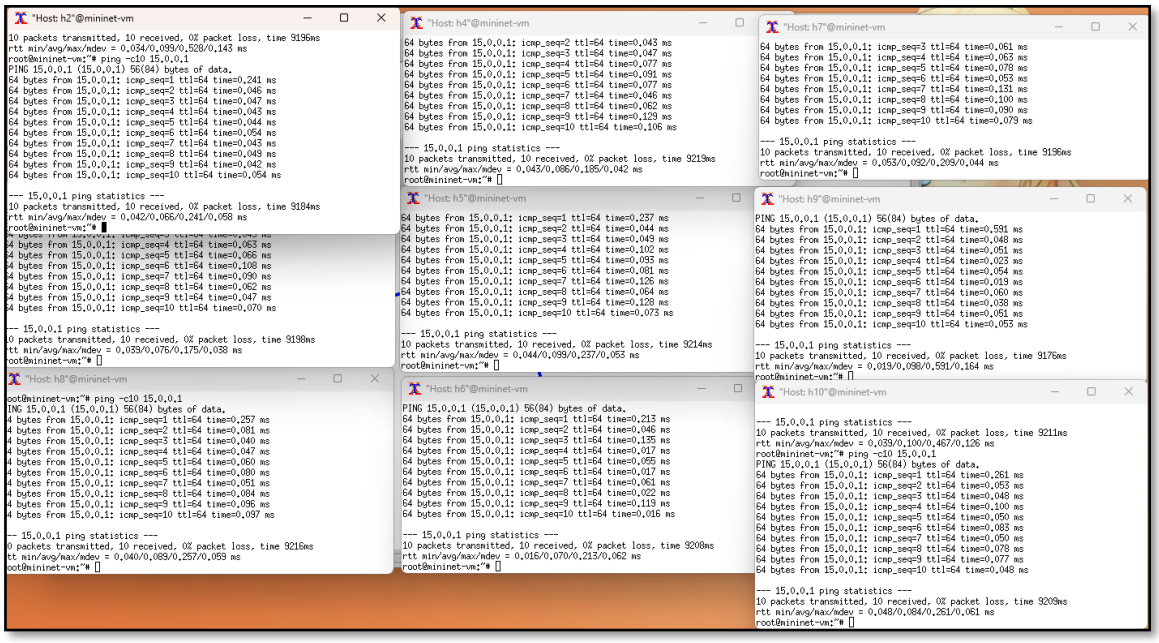

Fig. 2. Data transfer using SDN technology (Configuration № 2).

The data obtained are summarized in Table 2.

TABLE II. DATA FROM EXPERIMENTS 1 AND 2

Parameter	Configuration #1 TCP	Configuration #2 SDN
Host 2	2.78	0.241
Host 3	5.24	0.175
Host 4	3.23	0.185
Host 5	2.57	0.237
Host 6	3.65	0.213
Host 7	3.66	0.209
Host 8	3.56	0.591
Host 9	3.5	0.261
Host 10	3.73	0.257
Total transfer time	31.92	2.369

Based on the table, it can be seen that the total packet transfer time with TCP/IP is 13.18 times slower than with SDN. Table 2 data is shown in Figure 3.

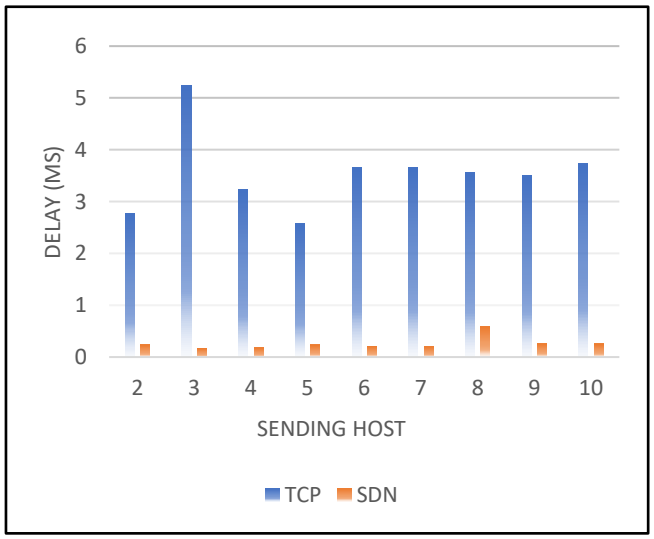

Fig. 3. Delays in the transmission of the first packet.

Since the routing process is carried out at the expense of the routing table, each router on the path of the first IP packet processes information about the routing tables to lay the best route, while generating a delay in the transmission of the IP packet.

At the same time, thanks to SDN technology, packets can be immediately directed to the end device, since the route is laid by a centralized controller [12]. As a result of this process, the initial delay is reduced, resulting in faster data delivery and improved transmission efficiency.

For a detailed analysis of the transmission parameters of all packets in a given system, you can use the Wireshark program. With Wireshark, you can examine the contents and properties of each packet, analyze protocols, and identify possible network communication problems.

Figure 4 and 5 show a graph of transmitted packets for 1 (ms).

From figures 4 and 5, it can be seen that the network using SDN is more stable and does not exceed a delay of 70ms, while TCP / IP transmits data with a delay of more than 80ms.

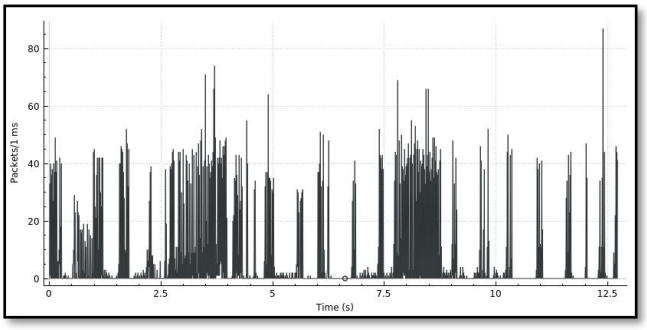

Fig. 4. Graph of transmitted packets using TCP/IP technology.

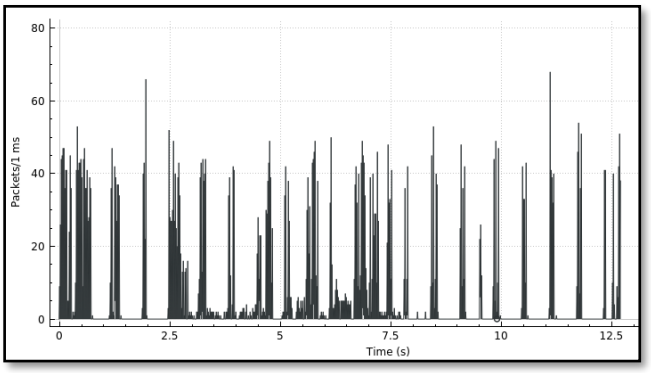

Fig. 5. Graph of transmitted packets when using SND technology.

Analyzing the data provided, we can conclude that the use of SDN technology for transferring big data allows you to transfer data with minimal delay, due to the lack of routers that process information from the IP header. Compared to TCP / IP technology, the use of SDN reduces the delay time by 10-15 times on average. This is achieved through an innovative approach where network resources are controlled and managed in software rather than through traditional hard-coded network devices.

III. Conclusion

SDN offers a flexible and dynamic architecture that allows you to manage network traffic, resources, and policies through a centralized controller. As a result, data can be transmitted over the network with lower latency, as traffic is routed and handled in software, optimizing transmission paths to avoid unnecessary delays.

This is essential in today's networks where low latency is critical to achieving high performance and reliability.

The use of SDN makes it easy to configure network rules and policies, administrators can change them on the controller and apply changes to all devices. It also provides easy scalability of the network infrastructure and the possibility of network virtualization. SDN represents an evolution in network management, providing a more controlled and efficient network infrastructure, improving performance and security. With the increase in data volume, SDN is becoming an increasingly important factor in the development of network technologies and the improvement of user experience. At the moment, SDN is being actively implemented in the work of data centers that ensure the operation of the cloud infrastructure.

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SOME ISSUES OF MOBILE EQUIPMENT IDENTIFICATION BY IMEI IN MULTI - SIM / ESIM SCENARIOS

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Abstract - The paper considers technical aspects of user equipment identification in modern next-generation telecommunication systems using international IMEI and IMEISV identifiers. Particular attention is paid to the scenarios of operation of devices with multi - SIM (DSDS/DSDA) and eSIM (eUICC) support, which are becoming dominant in the mobile ecosystem. The analysis shows that parallel registration processes for two SIM cards, as well as frequent switching between eSIM profiles, lead to identification errors: saving outdated records and rebinding IMEI to the wrong NAS context. The use of a probabilistic model describing the total risk of identification errors is proposed. It takes into account the probability of outdated records ( ) and the probability of rebinding contexts ( ). In addition, a set of metrics has been formed that allow quantitatively assessing the reliability of the identification process: the proportion of correct matches, the delay in updating IMEI, the false negative rate (FNR) and false positive rate (FPR), as well as the integral stability index.

Keywords— IMEI, IMEISV, multi - SIM, eSIM, identification, LTE, 5G, EIR, reliability, trustworthiness

I). INTRODUCTION

Modern mobile networks (4G LTE and especially 5G NR) are characterized by high dynamics of subscriber device registration processes, multivariance of radio access topologies and a variety of user terminals. One of the key elements for ensuring the correct operation of network procedures is the identification of mobile equipment, which is carried out on the basis of the international identifier of mobile equipment - IMEI (International Mobile Equipment Identity).

IMEI is a unique 15-digit number, the structure of which is regulated by 3 GPP standards TS 23.003 and includes:

- TAC (Type Allocation Code) — 8 digits that define the device model and manufacturer;
- SNR (Serial Number) — 6 digits, individual serial number of the device;
- Check Digit - 1 digit calculated using the Luhn algorithm to check the correctness.

The IMEI is used in the NAS signaling chain to perform registration procedures, access control, and interaction with equipment registries (EIRs).

II. Multi- SIM and eSIM scenarios

However, the development of subscriber equipment technologies leads to the emergence of new scenarios that complicate the unambiguous identification of the device. In particular, Multi- SIM scenarios and eSIM (embedded SIM) - scenarios:

1) Multi- SIM-scenarios (DSDS, DSDA) assume the operation of several SIM cards in one terminal, which leads to the emergence of parallel or quasi-joint registration contexts in the network. In this case, one device can have two IMEI (IMEI1 and IMEI2), and the system must correctly correlate them with the corresponding NAS sessions.

2) eSIM-scenarios provides storage and remote management of several profiles on a single module. Frequent switching between profiles, typical for eSIM, creates a risk of desynchronization: the IMEI registered in the network may not match the profile actually active in the device.

These scenarios are superimposed on the features of the 5G network architecture, where interaction with distributed core elements (AMF, SMF) and with the EIR function (Equipment Identity Register), responsible for checking the admissibility of using equipment in the network. In conditions of parallel handover, TAU/RAU procedures and transition from NSA to SA mode, the probability of errors in IMEI matching and device registration increases.

To provide additional accuracy in 4G and 5G networks, IMEISV (IMEI Software Version), which is an extended 16-digit identifier containing, in addition to the basic IMEI, also 2 digits of the device software version (SV). This allows operators to take into account the features of the terminal firmware and distinguish identical devices by their software version.

NAS procedures in LTE and 5G are described in 3 GPP standards TS 24.301 and 3 GPP TS 24.501. According to these specifications:

- IMEI/IMEISV can be transmitted when performing the Attach/Registration procedure in response to Identity Request from the network;
- in the early stages before encryption is established (Security Mode) IMEI is transmitted in clear text, after enabling protection it is preferable to use IMEISV;
- IMEI is used when interacting with Equipment Identity Register (EIR), where the network checks the status of the device (authorized, stolen, blocked, etc.).

In 5G, in addition to IMEI, SUPI and SUCI identifiers are also used. SUPI (Subscription Permanent Identifier) is a unique subscription identifier (usually IMSI), SUCI (Subscription Concealed Identifier) is an encrypted version of SUPI, used to protect subscriber privacy.

Thus, IMEI/IMEISV characterizes the equipment, and SUPI/SUCI - the subscription, which is important to consider in multi - SIM and eSIM scenarios.

Table 1 shows the features of key identifiers and where they appear.

Key identifiers and where they appear. Table 1

No.	Identifier	Purpose	Length / structure	Alarm level	Source / standard
1	**IMEI**	Device identification	15 digits (TAC + SNR + CD)	NAS (Identity Response to Security Mode)	3GPP TS 23.003, TS 24.301
2	**IMEISV**	Identifying a device with a software version	16 digits (IMEI + SV)	NAS (Identity Response, more common in 5G)	3GPP TS 23.003, TS 24.501
3	**SUPI (IMSI)**	Subscription identification	up to 15 digits	NAS (Registration, hidden in SUCI)	3GPP TS 23.003
4	**SUCI**	Protected form SUPI	Depends on the encryption algorithm	NAS (Registration, to protect privacy)	3GPP TS 23.003
5	**TAC**	Identifies the model and manufacturer	8 digits	Extracted from IMEI	GSMA TS.06

Thus, the existing regulatory framework provides clear regulation of the IMEI and IMEISV structure, and also describes the procedures for their use in NAS signaling. It is important that in multi - SIM and eSIM scenarios, the need to maintain the relevance of these identifiers leads to new technical challenges.

II .1. Features of multi - SIM scenario (DSDS, DSDA)

Modern smartphones increasingly support dual SIM cards (Dual SIM Dual Standby, DSDS; Dual SIM Dual Active, DSDA). In such devices, each SIM card has its own IMEI (IMEI1 and IMEI2). Ideally, each NAS context (Attach / Registration) should be clearly associated with a specific IMEI.

However, in practice the following problems are possible:

- simultaneous registration. With DSDA, the device initiates two parallel registration processes in different networks (or in different PLMNs). In this case, the network may have difficulties in correctly matching the IMEI with the corresponding SIM context.

- quasi-joint registration (DSDS). In DSDS mode SIM cards are activated in turn in a common radio modem. This leads to a situation where IMEI1 and IMEI2 "intersect" in time, and information about them in the network core may become outdated or erased.

handover and TAU/RAU procedures. When changing the registration zone, especially in EN - DC/NR - DC scenarios, IMEI inconsistency in MME/AMF caches is possible if registration was performed in parallel for two SIM cards.

This results in the possibility that the network will store IMEI1 instead of IMEI2 (or vice versa), which reduces the reliability of equipment identification.

II.2. Features of the eSIM scenario

eSIM is fundamentally different from a classic SIM card in that it can contain several profiles, between which the user or operator switches remotely. Unlike two physical SIM cards, it uses one hardware module, but several subscription profiles.

IMEI identification for eSIM are as follows:

- frequent profile switching. When changing a profile, desynchronization occurs - the network may still store the IMEI associated with the previous profile, while the new one is already active.

- Delay in IMEI update. NAS procedures (Identity Request / Response) are not executed instantly on every profile switch, which creates the possibility of stale entries.

IMEI and IMEISV mismatch. When activating a profile with a different firmware version, it may be necessary to request IMEISV, but the network does not always initiate such a request, which reduces the accuracy of identification.

Thus, even with one physical device, a situation is possible when the “old” IMEI is recorded in the network core, which leads to errors when working with the equipment register (EIR).

Both multi - SIM and eSIM scenarios create potential sources of ambiguity when identifying equipment by IMEI. In the first case, the main risk factor is the parallelism and overlapping of registrations for two SIMs. In the second case, it is the dynamics of profile switching and delays in updating information. In both cases, this requires the introduction of additional mechanisms for synchronization and updating IMEI / IMEISV in the network.

Identification of equipment by IMEI in multi - SIM and eSIM scenarios is subject to a number of technical failures. The main types of errors can be divided into two categories:

I) Stale errors. These types of errors occur when an "old" IMEI remains in the network core, associated with a previous eSIM profile or with a SIM context that has already been deactivated.

II) Context rebinding errors (P_{mix} **).** Such errors are related to the situation when the IMEI of one SIM or profile is mistakenly associated with the NAS context of another SIM or profile.

Then the total probability of identification errors can be described by the model:

$$P_{\text{error}} = P_{\text{stale}} + P_{\text{mix}}, \quad (1)$$

where P_{stale} - increases with the frequency of switching eSIM profiles (or TAU / RAU procedures in DSDS);

P_{mix} - depends on the number of parallel registrations in DSDA and the probability of overlapping NAS contexts.

Thus, model (1) shows that with an increase in the intensity of switching and simultaneous registrations, the total probability of errors can reach significant values, which makes it relevant to implement corrective mechanisms (conditional NAS requests IMEISV, TTL for EIR caches, etc.).

In order to quantitatively assess how correctly and reliably the system matches the IMEI with the active context of the device in LTE / 5G networks, special metrics are used. They allow operators and developers of telecommunications equipment to objectively compare different algorithms and identify risk points. For engineering practice, the following metrics for assessing the reliability of identification can be distinguished:

1) The proportion of correct matches - an indicator that reflects what proportion of all registrations took place with the correct binding of IMEI and NAS context:

$$R = \frac{N_{\text{correct}}}{N_{\text{total}}}, \quad (2)$$

where N_{correct} - is the number of registrations with the correct IMEI ;

N_{total} - total number of registrations.

The closer the R value is to 1, the higher the stability of the identification.

2) Average delay in updating IMEI - characterizes the time between the actual profile switch and the new IMEI being recorded in the network core.

$$D = \frac{1}{N}\sum_{i=1}^{N}\left(t_{\text{fix},i} - t_{\text{switchi},i}\right), \quad (3)$$

where $t_{\text{switchi},i}$ - time of profile or SIM switching;

$t_{\text{fix},i}$ - time of registration of the correct IMEI in the network core.

Large *D* values mean that the network is running with outdated records, which can lead to errors in the EIR or during equipment checks.

3) *FNR* (*False Negative Rate*) - characterizes the probability of missing an error when the IMEI in the network no longer corresponds to the actually active profile, but the system did not record this discrepancy.

$$FNR = \frac{N_{\text{missed errors}}}{N_{\text{errors total}}}. \quad (4)$$

Such cases are the most dangerous, as they lead to **invisible errors** that distort the network performance statistics.

4) *FPR* (*False Positive Rate*) – characterizes the probability of a false alarm of the control system, when the IMEI is mistakenly recognized as inconsistent, although in fact it is correct.

$$FPR = \frac{N_{\text{false alarms}}}{N_{\text{checks total}}}. \quad (5)$$

High *FPR* results in unnecessary repeated NAS IMEI/IMEISV query procedures and increased signaling traffic load.

4) The coefficient of identification stability (Stability Index, S) is also an integral metric that takes into account both the probability of errors and the delay in updating:

$$S = \frac{R}{1 + D \cdot (FNR + FPR)}. \quad (6)$$

This metric allows to reduce the stability of the identification system to one number. The higher the value of *S*, the more reliably and quickly the network synchronizes IMEI.

III. CONCLUSION

Identification of mobile equipment by IMEI/IMEISV in multi - SIM and eSIM conditions is associated with the risks of outdated records and context rebinding, which reduces the reliability of network procedures. The proposed error model and proposed metrics allow quantitatively assessing the reliability of identification, and the implementation of engineering measures - conditional NAS IMEISV requests, optimization of the EIR architecture and correlation of IMEI with TAC and UE parameters - ensures increased stability and consistency of identification processes in LTE/5G networks, which contributes to the growth of reliability of new-generation telecommunication systems..

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FEATURES OF RELIABILITY ASSESSMENT OF THE SYSTEM “GROUND STATION - LEO SATELLITE”

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Abstract - This paper examines the reliability features of a satellite communication system based on low-orbit satellites (LEO) in the context of interaction with a ground station. It is emphasized that LEO systems are highly dynamic, have short communication times, and require stable radio channel management in the presence of frequent handover processes. A structural diagram of the ground station - LEO satellite complex is presented, describing its key hardware and software components. The main groups of parameters affecting reliability are identified: fault tolerance of the ground segment and satellite equipment, radio channel, orbital dynamics, software stability, and the impact of external factors. Particular attention is paid to risks such as synchronization failure, the influence of ionospheric and weather conditions, space debris, micrometeorites, as well as radiation and cyber impact. The paper emphasizes the need for an integrated approach to ensuring reliability through redundancy, robust tracking algorithms, secure telemetry, and monitoring.

Key words – LEO, satellite, ground station, reliability, handover, radio channel, synchronization, space risks, telemetry, equipment failure

I. INTRODUCTION

Modern satellite communication systems, especially those based on low-orbit satellites (LEO - Low Earth Orbit), are actively developing and are widely used in various fields: from the global Internet (Starlink, OneWeb) to monitoring, telemedicine and defense. Unlike geostationary satellites, LEO systems have a number of advantages - low signal latency, higher throughput and the ability to cover hard-to-reach regions. However, the high density of satellites and the constant dynamics of orbits are accompanied by new challenges in ensuring their reliability.

One of the key links in the satellite infrastructure is the interaction between the ground station and the satellite. This radio communication is critically important for both the transmission of useful data and for command control, telemetry, and synchronization.

II. STRUCTURE OF THE GROUND STATION - LEO SATELLITE SYSTEM

The ground station - LEO satellite communication system is a complex integration infrastructure that ensures the establishment, maintenance and termination of radio communications between earth users and space objects in low orbits (at altitudes from 500 to 2000 km). Fig.1 shows a simplified structural diagram of the communication system.

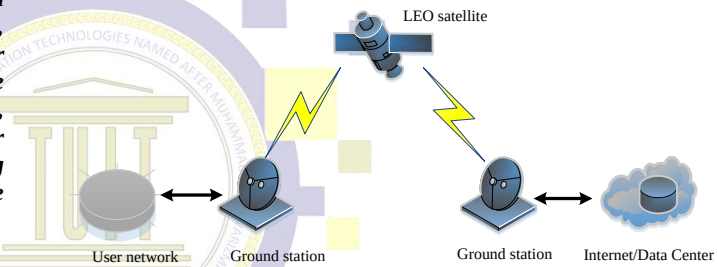

Fig.1. Simplified structural diagram of the satellite communication system

Each side of the interaction includes hardware, software and channel components.

The ground communication station includes an antenna system (with a satellite tracking mechanism), radio frequency units (transmitters/receivers, power amplifiers), signal processing modules (DSP, demodulation, decoding), a control and monitoring system (including telemetry and telecommands), and an interface for connecting to the transport network (IP network, fiber optics, etc.).

LEO satellite includes antennas and repeaters (or active data transmission equipment), an onboard computing system, a power supply system (solar panels, batteries), an onboard transceiver (usually Ka-, Ku-, S-bands), an orientation and stabilization system, and handover mechanisms (transfer of communication sessions between satellites).

LEO system are high speed of movement, frequent handover sessions, and limited visibility of one station.

In LEO systems it is possible to organize the following types of communication:

- direct connection (ground station ↔ LEO satellite);

- fraternal communication (LEO satellite ↔ ground station);

- cross-link (inter-satellite) (if Inter - Satellite Links (ISL) is available).

Inter-satellite connections improve reliability and reduce latency, but add complexity to the system architecture.

The features of ground stations include:

- the need to ensure automatic tracking of satellites;

- work in conditions of frequent orbit changes and a small communication window;

- may have backup channels and mechanisms for switching to other satellites;

- Gateway stations are often used to connect to the global network.

III. PARAMETERS AFFECTING SYSTEM RELIABILITY

The reliability of the "ground station - LEO satellite" system is determined by many factors, including hardware, radio channel, software and orbital dynamics. At the same time, the failure of any of the elements can lead to a disruption of stable communication and data loss. Let's consider the key groups of parameters that affect reliability.

1) Reliability of the hardware components of the ground station.

The ground station consists of a large number of electronic, electromechanical and computing units, the reliability of which directly affects the ability to establish and maintain communication.

The main parameters that influence the reliability of the hardware components of the ground station are:

- mean time between failures (MTBF) of equipment;

- availability of backup units (power supply, antennas, radio modules);

- the condition of tracking antennas and drive mechanisms;

- operating conditions (humidity, dust, temperature, corrosion);

- reliability of monitoring and control software.

For example, failure of the antenna's rotating mechanism makes it impossible to track the satellite and results in the loss of the communication session.

2) Reliability of the satellite segment.

Despite advances in technology, satellites remain complex technical devices that are susceptible to failure, especially in conditions of radiation, vacuum, and temperature changes.

The main factors influencing the reliability of the satellite segment are:

- the active life span (ALS) of the satellite (usually 3–7 years);

- quality and radiation resistance of components;

- orientation and stabilization system;

- power supply system (degradation of solar panels, battery failures);

- thermal conditions and degradation of materials;

- reliability of relay equipment.

According to statistics, up to 5–8% of LEO satellites experience failure of one or more onboard components in the first 3 years of operation.

3) Radio communication channel (RF link).

Signal transmission between a ground station and a LEO satellite is subject to a number of physical influences that affect the reliability and integrity of the transmitted information.

Parameters affecting RF link, are:

- free space attenuation (FSPL)

$$FSPL = \left(\frac{4\pi df}{c}\right)^2, \quad [\text{dB}] \tag{1}$$

where d - distance (km);

f - frequency (GHz);

c - speed of light;

- weather conditions (rain, snow, clouds (especially in the Ka-band), for example, when using the Ka-band (26-40 GHz), precipitation can reduce the signal level by 10–15 dB);

- distortions due to the ionosphere and troposphere;

- noise and interference from other systems (interference);

- Doppler effect (LEO satellite moves at a speed of ~7.5 km/s).

4) Orbital dynamics and time parameters.

LEO satellites move quickly in orbit (1 revolution ~90–100 minutes), therefore the duration of a communication session is limited (5–15 minutes), frequent reinstallation of the antenna is required, handover occurs (transition from one satellite to another), "dead zones" are possible when the satellite is temporarily unavailable.

In this case, the critical parameters affecting reliability are the visibility change rate, the density of satellites in the orbital plane, the delay in the ground station's response to the appearance of a satellite, and the algorithms for trajectory planning and redundancy.

5) Software reliability.

The software, both on board the satellite and at the ground station, is one of the most critical components of the system:

- errors in the satellite firmware can lead to failure of navigation and orientation;

- problems with the antenna control software may result in lost communication sessions;

- insufficient monitoring of the equipment condition may lead to an increased probability of equipment failures and loss of stability of the communication channel between the satellite and the ground station;

- disruption of data synchronization between segments can lead to errors in packet decoding, high **level bit error rate (BER),** telemetry loss (downlink), errors in inter-satellite routing, etc.

6) External influences and risks.

External influences and risks that affect the reliability of the satellite communication system include space debris and micrometeorites, the Earth's radiation belts (Van Allen belts), battles due to space weather (solar flares), and cyber threats (hacking control channels, spoofing telemetry).

IV. CONCLUSION

The satellite communication system "ground station - LEO satellite" is a complex and vulnerable complex, the reliability

of which depends on many interrelated factors. High orbital dynamics, limited communication time windows and exposure to external influences require not only high reliability of hardware and software, but also the implementation of intelligent prediction and backup mechanisms. To improve the stability of the LEO segment, it is necessary to take into account both technical parameters (MTBF, RF - link, handover errors, software errors) and the impact of environmental factors - from solar activity to cyber threats. The use of monitoring systems, automatic tracking, radiation and cyber protection, as well as inter-satellite connection links (ISL) allows us to minimize risks and ensure stable operation of satellite communications in a constantly changing orbital environment.

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SOME DESIGN FEATURES OF ANTENNAS FOR D2D SCENARIOS IN SATELLITE COMMUNICATIONS

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***Abstract* – The development of Device-to-Device (D2D) technology via satellite channels requires the creation of specialized antennas adapted to the strict constraints of mobile and IoT devices. This paper examines the key aspects of antenna design for D2D scenarios in satellite communications, including requirements for miniaturization, energy efficiency, viewing angles, electromagnetic compatibility, and compliance with modern mobile communication standards. Particular attention is given to interference protection, safety regulations, and ensuring cyber resilience when using phased array antennas. The paper also highlights the high cost factor and the prospects for cost reduction through technology scaling. The necessity of a comprehensive design approach combining engineering, regulatory, and user aspects is demonstrated.**

***Keywords* – antenna, D2D, satellite communication, miniaturization, energy efficiency, phased array antennas, SAR, electromagnetic compatibility.**

Direct Device-to-Device (D2D) communication via satellites is moving from concept to reality, integrating into modern communication standards. Antennas are one of the key elements determining the successful development of such systems. Despite the progress achieved, there remain certain issues that need to be addressed in the design of antennas for satellite D2D scenarios.

1. *Size, weight, and power constraints*. For portable devices, every additional millimeter and gram is critical. An antenna integrated into a device competes for space with the battery, camera, and speakers. Designing a compact antenna often requires a trade-off in gain. Weight is especially important for IoT sensors, where each gram increases transportation costs. Power is the strictest limitation for IoT devices, as they may have only a couple of watt-hours of energy for a year of operation, while satellite transmission is a very energy-intensive process. Therefore, antenna systems must be highly efficient. This, in turn, leads to a conflict with miniaturization requirements. The balance must be found in materials and circuitry, for example, by using high quality resonators, matching networks with minimal losses, and sleep modes where the antenna is off most of the time.

2. *Viewing angles and "blind zones"*. Small antennas usually have directions in which radiation/reception is significantly weakened. For example, in a phone's built-in antenna, the lower hemisphere is often blocked by the circuit board, the hand, or the body. This means that if the satellite is low above the horizon and the phone is held vertically, the signal may not pass (e.g., head shadowing). "Blind zones" also occur when using narrow-beam antennas. Such antennas maintain a stable link while the satellite is in their beam, but once the satellite moves out of the beam, the connection drops. A possible solution is to use wide beam patterns (with a loss in gain) or multi-antenna modules covering different sectors, but this increases complexity and cost.

3. *Compatibility with mobile protocols and power-saving modes*. Devices cannot maintain constant satellite communication, as this would quickly drain the battery and potentially interfere with terrestrial operation. Therefore, NTN (Non-Terrestrial Networks) protocols are configured so that the device turns on the receiver periodically (e.g., listens to the downlink at set intervals, similar to how a phone listens to paging in a cellular network). In this case, the antenna system must be ready to instantly switch from sleep mode to active mode. For phased array antennas, time is required for calibration and phase alignment, which complicates fast wake-ups. Another factor is coexistence with other radio systems. A device may simultaneously use Wi-Fi or Bluetooth, so interference must be avoided. One solution is to disable them during a satellite session. Antennas should be designed and placed to minimize mutual influence.

4. *Electromagnetic compatibility (EMC) and interference protection*. Apart from internal coexistence, there is the external electromagnetic environment. A device with a powerful satellite antenna could interfere with other devices. For example, if a phone transmits at 1610 MHz and a nearby receiver operates at 1600 MHz, there must be no harmful emissions that disrupt its operation. Regulatory authorities monitor such cases. L/S bands used for NTN are licensed and coordinated, often allocated on a secondary basis, meaning they must not interfere with the primary service; geofencing restrictions may also apply. The antenna system itself should have strong out-of-band emission suppression. The reverse task is protecting the antenna system from interference. If there is a source of radio noise, say in the L-band, it may disrupt the device's receiver. In urban areas, terrestrial satellite terminals may face high noise levels (e.g., due to reflections in dense development). Therefore, antennas should be designed with spatial selectivity in mind—for example, using null-steering to form radiation nulls towards the interference source. The antenna system can spatially filter such interference, thus improving link resilience.

5. *Safety standards*. SAR (Specific Absorption Rate) measures the amount of RF energy absorbed by the human body during mobile phone use. SAR limits restrict the intensity of the electromagnetic field near the body. Prolonged satellite transmission must not cause tissue heating. Solutions include external antennas or headsets to keep the phone away from the head.

6. *Security and cyber resilience*. This is not a direct antenna problem but must be considered. If the antenna is phased and software-controlled, there is a risk of cyber interference. In theory, an attacker could alter parameters to degrade the link or cause data leakage. This may require secure controllers and software verification.

7. *Cost factor*. Many new technologies are expensive, including new metamaterials and advanced control systems for smart antennas with complex software. The current NTN market is relatively small, keeping prices high. Scaling up production, standardizing solutions, and expanding NTN networks and devices will help reduce unit costs in the future.

CONCLUSION

The design of antennas for D2D scenarios is a complex task that requires consideration of radio physics, network topology, user behavior, and regulatory requirements. At times, it is necessary to sacrifice ideal radio performance in favor of ergonomics or cost. Currently, the personal gadget segment is only taking its first steps in this area. The market has seen the emergence of smartphones and messengers with basic satellite connectivity (text messaging), using miniature antennas and existing satellite infrastructure (Globalstar, Iridium). This has demonstrated the fundamental feasibility of integrating a satellite antenna even into a thin smartphone, albeit still with operational limitations.

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COMPARATIVE ANALYSIS OF TEST PATTERNS FOR ASSESSING SIDE ELECTROMAGNETIC RADIATIONS OF VIDEO PATH OF COMPUTING EQUIPMENT

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***Abstract*— The article presents the results of an experimental study of six typical visual test patterns from the position of the formation of side electromagnetic radiation (SER) of video paths of computing equipment computer equipment (CE). Using an SDR receiver and the RSP-Spectrum Analyzer software package, the levels and spectrum band of radiation were measured. It was found that the greatest spectrum width is observed when displaying a checkerboard pattern and vertical stripes, while uniform fields (white and black screens), as well as a gradient, are characterized by a narrow-band spectrum structure.**

Keywords — Side electromagnetic radiation, TEMPEST, video path, test patterns, information security, computing equipment.

INTRODUCTION

Today, computing equipment is an integral part of the infrastructure of government, defense, finance, science and industry. During the processing, transmission and visualization of information, computing systems unintentionally emit electromagnetic radiation that can be intercepted by intruders and used to extract confidential data[1-3].

Particularly vulnerable to this type of threat are video paths of computer systems containing visualized information in open form.

In [4] the authors managed to receive and restore information displayed on the monitor screen at a distance of 80 meters

The information displayed by the monitor is transmitted in the form of digital or analog signals from the video card (video adapter) to the monitor via video interfaces(cable). The combination of these three elements is the video path of the CE (see Fig. 1).

Video paths, especially those built on video data transmission interfaces such as VGA, HDMI, DVI, are characterized by an increased tendency to form side electromagnetic radiation containing visually significant information[5-.7].

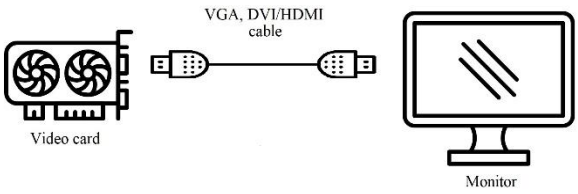

Fig. 1. Video paths of CE

MAIN PART

To protect information from leakage and interception through the SER of the video path of the CE, special methods and means of protection are used [8-12]. The choice and effectiveness of the method and means of protection depend on the level of signal radiation, the width and location of the SER in the frequency.

In this regard, there is a need to study the side electromagnetic radiation of the CE in order to measure the radiation level, determine the width of the EM radiation and its location in the frequency axis.

One approach to studying and assessing SER is the use of visual test patterns - images displayed on a monitor screen.

Test patterns are specially prepared images reproduced on the monitor screen to study the parameters of the SER video paths of CE. The test patterns themselves differ from each other in the structure of spatial brightness transitions [13-15].

Test patterns are needed for targeted excitation of the video path TEMP and allow solving several key problems:

1. Evaluation of the leakage level. Using patterns, the maximum signal level and spectral width of the SER are measured.

2. Calibration of receiving equipment. Stable repeating patterns (horizontal stripes) ensure receiver synchronization by frame or line frequency, and gradients - verification of the linearity of the frequency response.

3. Comparative analysis. By combining a single-color field (white or black screen) as a background control and contrast patterns, relative estimates of the effectiveness of shielding and filtering are obtained.

4. Development of countermeasures. Based on the distribution of SER by frequency and amplitude, the type and configuration of filters are selected, "Soft TEMPEST" algorithms are designed to suppress high-frequency components of the video signal.

Comparative analysis of visual patterns allows us to determine how the image structure affects the spectral characteristics of side electromagnetic emissions of the video path. Based on the data obtained, we can identify the most vulnerable display modes that generate informative emissions and formulate recommendations for reducing the risk of information leakage through side electromagnetic channels.

There are many visual test patterns used to analyze the characteristics of the SER video paths of the CE. Among them, we can highlight standard images such as a single-color field, checkerboard patterns, stripes of different orientations, gradients, zonal plates, and others [13-17].

In this work, six of the most typical patterns were selected for analysis, which are used in practice in TEMPEST experiments and are characterized in the literature as critical from the point of view of the formation of SER (see Fig. 2).

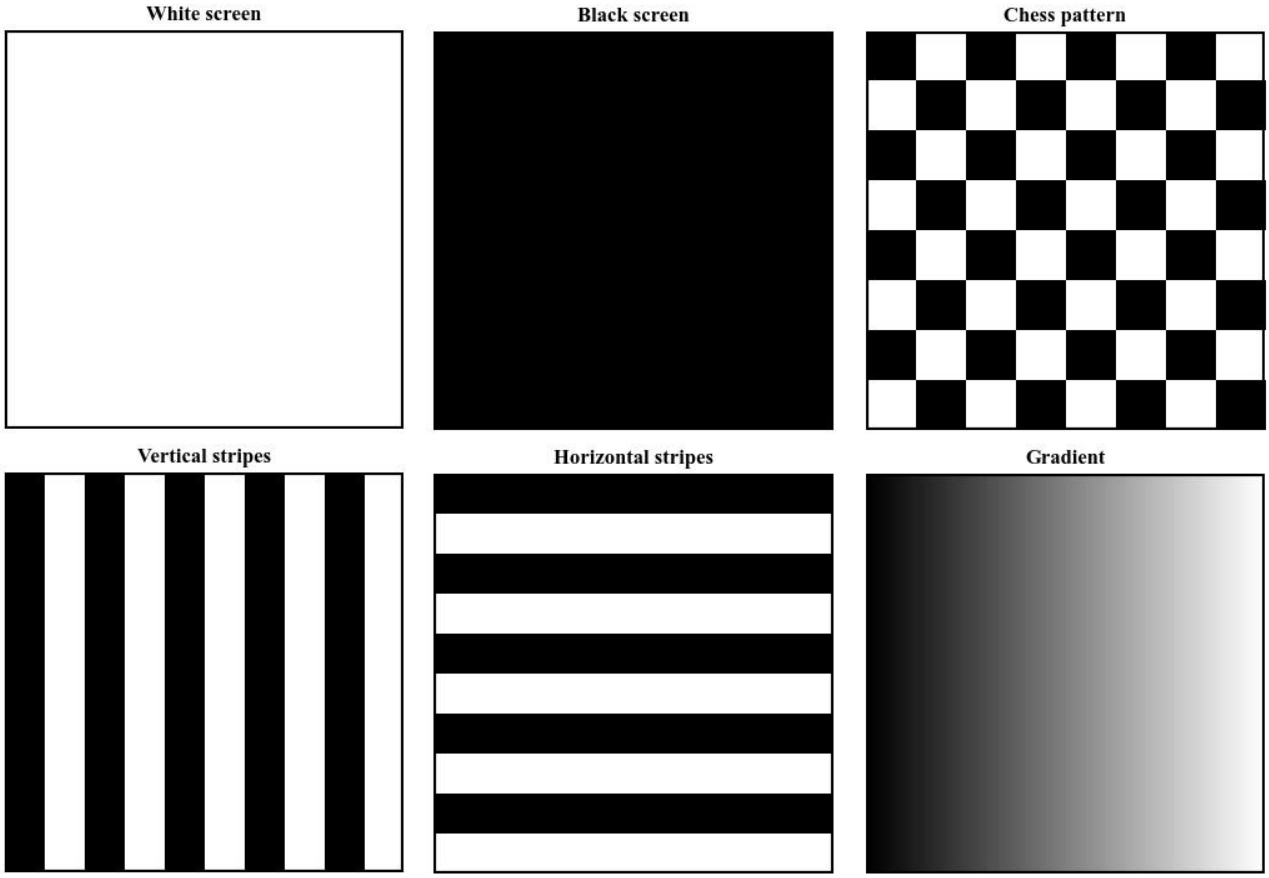

Fig. 2. A set of visual test patterns for analyzing SER video paths

• a single-color (White or black screen)—as a basic background;

• vertical stripes — to identify pixel frequency signals;

• horizontal stripes — to analyze frame scanning;

• Chess pattern— as an example of the worst case in terms of EM radiation level.

• Gradient (smooth transition of brightness from dark to light) — these patterns allow us to cover the key modes of video signal formation, from minimal brightness changes to maximum frequency transitions, and accordingly study the nature of their electromagnetic radiation.

The study was conducted as follows: six test patterns were displayed one after another on the monitor screen. Using the SDRplay RSPdx [18] receiver, the SA7000 measuring antenna and the RSP-Spectrum Analyzer [19] program, the emissions were recorded, the signal band of the TEM video path of the SVT, as well as the signal level were determined. Figure 3 shows the spectrum of the SER video path of the CE.

The measurement results are presented in Table 1.

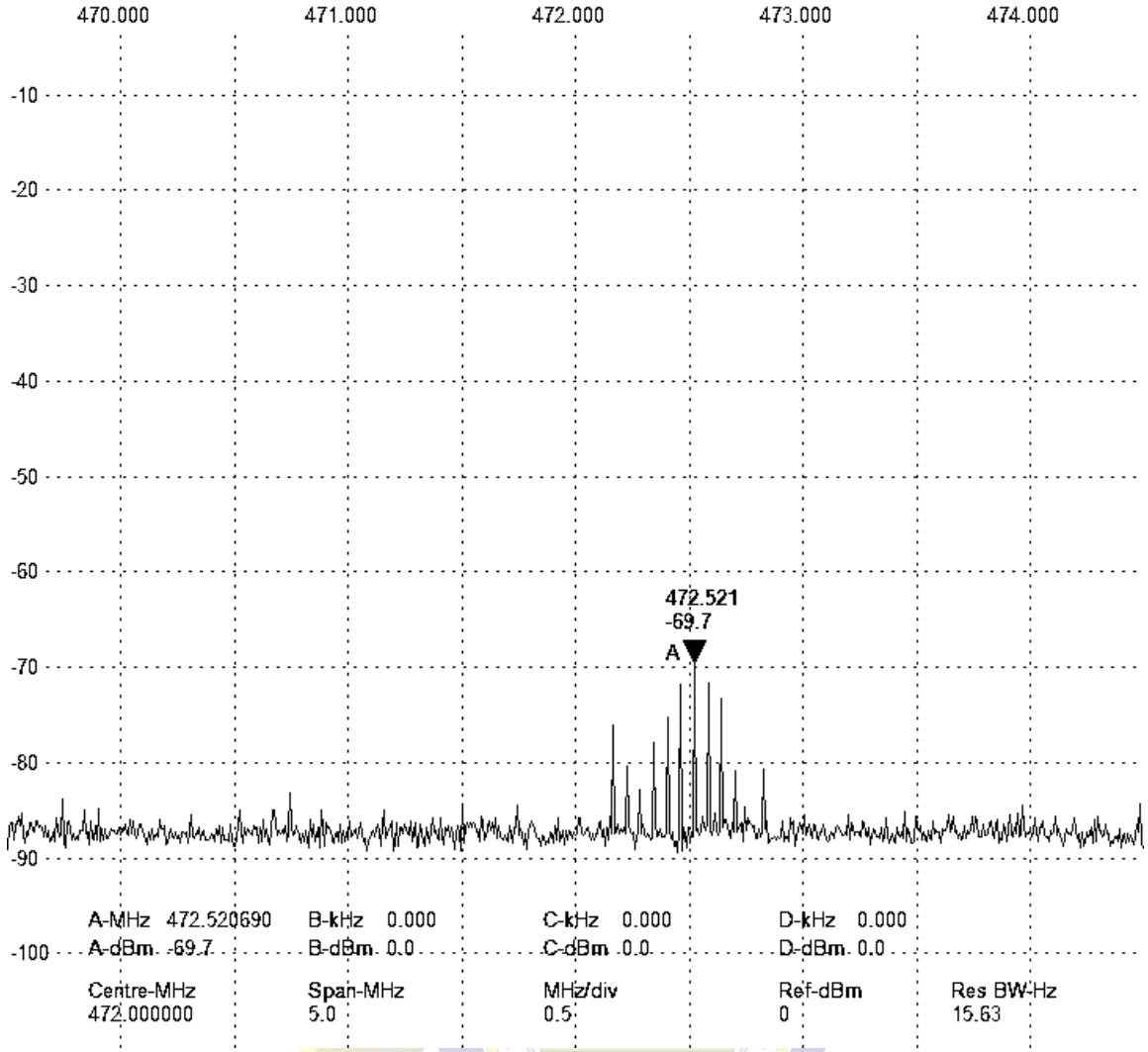

Fig. 3. the spectrum of the SER video path of the CE

SPECTRAL PARAMETERS OF THE TEST PATTERNS OF THE SVT VIDEO PATH.

Pattern	Peak level (dBm)	3 dB bandwidth (MHz)	SER signal width (MHz)
White screen	–71.3	~0.5	~1.0
Black screen	–74.2	~0.3	~0.6
vertical stripes	–69.7	~0.6	~1.2
horizontal stripes	–70.8	~0.5	~1.0
Chess pattern	–67.1	~0.7	~1.4
Gradient	–68.6	~0.4	~0.8

Peak level is the maximum measured level of the SER on the carrier (~472.521MHz).

3 dB bandwidth is the width of the band around the peak where the level does not drop more than 3dB from the maximum.

DISCUSSION

Comparative analysis of the results presented in Table 1 shows a clear dependence of the SER level and spectral width on the visual pattern structure. The checkerboard pattern and vertical stripes demonstrate the highest peak levels (–71.3 and –69.7 dBm) and the largest signal width (≈1.4 and ≈1.2 MHz). The white screen and black screen form minimal background emissions (–67.1 and –74.2

dBm) with a narrow-band spectrum (≈0.5 and ≈0.3 MHz), and therefore serve as a standard for basic testing. Horizontal stripes (–70.8 dBm, ≈1.0 MHz) and gradient (–68.6 dBm, ≈0.8 MHz) occupy intermediate positions, providing a balance between intensity and spectrum width.

CONCLUSION

Thus, the choice of pattern should be determined by the purpose of the tests. For testing the extreme shielding conditions - a checkerboard pattern and vertical stripes; for reception calibration and "Soft TEMPEST" - horizontal stripes and gradient; for background level assessment - white and black screens.

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ALGORITHM FOR CALCULATING GROUND STATION RECEIVER PARAMETERS OF A SATELLITE COMMUNICATION LINK

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Abstract **- This paper presents an algoritm for calculating the principal parameters of the ground station receiver chain in satellite communication systems. The algorithm sequentially determines the receiver noise temperature, the total system noise temperature, the noise power, the interference-corrected noise power, the signal power at the receiver input, and the maximum channel capacity. The final stage performs an automatic selection among digital television standards according to the computed capacity. The approach unifies fundamental equations into a single, transparent framework that enables comprehensive assessment of link performance and clarifies the impact of internal hardware characteristics and external disturbances. The structure of the algorithm makes it suitable for software implementation to support real-time analysis and engineering decision-making.**

Keywords - satellite communication; ground station; receiver chain; noise temperature; signal-to-noise ratio; channel capacity; digital television standards

INTRODUCTION

Modern satellite communication systems impose increasingly stringent requirements on the accurate calculation of ground station parameters, since these directly determine the stability of the transmission channel and compliance with the required digital broadcasting standards. With the continuous growth of network throughput and the adoption of new data transmission formats, the formalization of methods for evaluating receiver chain characteristics, including noise parameters, gain coefficients, and channel capacity, has become a priority. These parameters not only define the quality of signal reception but also determine the feasibility of implementing specific standards for digital television content delivery [4,6].

The development of algorithms for analyzing ground station receivers provides a systematic approach to investigating critical characteristics. In particular, the calculation of receiver noise temperature and its integration into the total system noise temperature makes it possible to adequately assess operating conditions under diverse scenarios, including the effects of external interference and atmospheric factors [1, 7]. This approach is consistent with modern radio wave propagation models and with international recommendations, thus increasing the reliability of the obtained results [2, 3].

A key aspect of the methodology is the determination of channel capacity based on Shannon's formula. The incorporation of this parameter into the algorithm enables the identification of system limitations and their comparison with the requirements of various digital television standards [9]. The selection between the 4:1:1, 4:2:2, and 4:4:4 formats is directly related to the available channel capacity and the signal-to-noise ratio [10]. Automating this decision-making process within a unified algorithm eliminates subjective errors and improves the efficiency of analysis.

It should be emphasized that the proposed algorithm has strong practical significance both for engineering calculations and for subsequent software implementation. Its structure ensures transparency of computations and clearly demonstrates the interrelation between individual receiver parameters and the final channel characteristics. Thus, the development of an algorithm for calculating ground station receiver parameters and determining the digital broadcasting standard forms a foundation for creating practical tools that support the design and optimization of satellite communication systems [5, 8].

PROBLEM IDENTIFICATION

In practice, the evaluation of a ground station's receiver chain remains a fragmented and labor-intensive process. Engineers must separately calculate key performance metrics such as the receiver noise figure (and its equivalent noise temperature), the total system noise temperature, the signal power at the receiver input, the resultant signal-to-noise ratio, and ultimately the maximum

achievable channel capacity. Each of these parameters is typically addressed through separate formulas or dedicated tools [11], [12]. While software tools exist for the calculation of specific characteristics, such as noise figure or link budgets, they are rarely integrated into a single framework. As a result, analysis becomes cumbersome and error-prone, with intermediate results requiring manual conversion and insertion into subsequent stages.

For example, converting a receiver's noise figure (specified in decibels) into an equivalent noise temperature (in kelvins) is an essential step for quantifying the internal noise of the receiver. Similarly, accounting for antenna noise contributions and feedline losses in order to determine the total system noise temperature requires another set of computations. Each intermediate result must then be carried forward into the calculation of the overall signal-to-noise ratio, which may be performed in yet another tool or spreadsheet. Managing these interconnected calculations without a unified method not only slows the process but also increases the likelihood of inconsistencies in units or assumptions [13].

This lack of integration becomes a serious limitation when verifying whether a receiver chain complies with digital television standards. Formats such as 4:1:1, 4:2:2, and 4:4:4 impose progressively stricter requirements on both the signal-to-noise ratio and channel capacity [14], [15]. In practice, this verification requires the calculation of the maximum achievable channel capacity (via Shannon's theorem) from the estimated SNR, and comparison of the result against the data-rate thresholds of the respective format. Without an automated algorithm, such verification turns into a laborious process of cross-checking separate link calculations with standard requirements, which is time-consuming and prone to omissions.

Another drawback of fragmented analysis is the difficulty of tracing how individual receiver components influence overall link quality. Each element of the chain—low-noise amplifiers, frequency converters, filters—contributes to the cumulative noise figure, affects the total system noise temperature, and thus determines the final SNR. In a disjointed approach, it is challenging to identify how a change in one component's performance (such as the noise figure of an LNA or additional feeder losses) cascades to degrade the final signal quality and achievable channel capacity. For instance, even a seemingly minor 1 dB increase in amplifier noise figure can significantly reduce the link margin, yet such an effect may remain hidden until late in the design process if calculations are not unified [16]. This makes it difficult to detect the true bottlenecks of the system and complicates optimization efforts.

These practical challenges highlight the need for a systematic solution. The key issue is the absence of an integrated tool for holistic evaluation of receiver chain parameters. Therefore, there is a pressing need for an algorithm that consolidates noise parameter analysis, system noise temperature computation, and SNR estimation into one coherent sequence. A unified and transparent structure would simplify the evaluation process and reduce the probability of human error. It would also allow engineers to clearly observe the interdependence of receiver components and performance metrics, enabling reliable design of the entire link in compliance with strict standards and ensuring robust operation in real-world conditions [17]. Addressing this gap is thus essential to improving ground station design efficiency and ensuring the reliability of satellite communication links.

METHODOLOGY

The algorithm for calculating the parameters of the ground station receiver is based on the sequential application of fundamental equations of communication theory. During the analysis, the noise characteristics of the system, the noise and signal power, as well as the maximum channel capacity are determined. This approach allows for a comprehensive assessment of reception quality and identification of the factors that limit link performance.

The first step is the calculation of the receiver noise temperature. The receiver noise temperature is one of the key characteristics that determine the sensitivity of a satellite receiving system. It describes the equivalent temperature at which the internal noise of the receiver can be represented as thermal noise. This parameter is directly related to the noise figure of the receiving chain: the higher the noise figure, the greater the internal noise power and, consequently, the lower the quality of the received signal [8]. The value T_r is used in the subsequent calculation of the total system noise temperature and has a critical impact on the overall link budget:

$$T_r = T_0 \cdot (K_n - 1)$$

Where T_r – receiver noise temperature, K; $T_0 = 290$ K – standard noise temperature; K_n – receiver noise figure.

The next stage is the determination of the total noise temperature of the system. The total noise temperature of the system accounts not only for the receiver noise but also for the noise contribution of the antenna and the losses associated with its non-ideal efficiency. This parameter represents the entire receiving system as an equivalent source of thermal noise. The higher the value of T_Σ, the lower the signal-to-noise ratio at the receiver input, which directly affects the capacity of the channel. Accurate evaluation of this value is essential for determining the ultimate performance limits of any satellite communication link:

$$T_\Sigma = T_a + T_0 \cdot \frac{1-\eta}{\eta} + \frac{T_r}{\eta}$$

Where: T_Σ – total noise temperature, K; T_a – antenna noise temperature, K; η – antenna efficiency.

After this, the noise power at the receiver input is calculated. Once the noise temperature has been calculated, the next step is to determine the amount of noise power within the given bandwidth. The noise power P_n is directly proportional to both the total noise temperature of the system and the channel bandwidth. This parameter defines the lower limit for the received signal level: if the useful signal falls below the noise threshold, it cannot be detected. Therefore, the calculation of noise power is a fundamental

step for evaluating the real signal-to-noise ratio and assessing the reliability of the satellite communication link [1]:

$$P_n = k \cdot T_\Sigma \cdot \Delta f \quad (3)$$

where: P_n – noise power at the input, W; $k = 1.38 \cdot 10^{-23}$ – Boltzmann's constant, J/K; Δf – transponder bandwidth, Hz.

In real operational conditions, the noise power is influenced not only by the internal properties of the system but also by external interference from other radio services and electromagnetic sources. To account for this effect, the calculated noise power is commonly increased by a fixed margin, for instance by 20%. This adjustment ensures that the obtained value more realistically reflects the actual operating conditions of the link and provides a conservative estimate of system performance. The corrected noise power P_n' is therefore better suited for use in subsequent calculations:

$$P_n' = P_n \cdot 1.2 \quad (4)$$

where: P_n' – corrected noise power, W.

For convenience in further calculations, the power is expressed in logarithmic scale. In satellite engineering, power levels are almost always expressed in a logarithmic scale because the values may differ by several orders of magnitude. Converting to decibel watts (dBW) simplifies arithmetic operations such as additions and subtractions of power terms, which are frequent in link budget calculations. This representation also provides a standardized unit for comparison of systems with very different parameters. The conversion to dBW is therefore an indispensable step, ensuring that all subsequent calculations are consistent and easier to interpret:

$$P[dBW] = 10 \cdot \lg\left(\frac{P_n'}{1W}\right)$$

The next step is the determination of the useful signal power at the receiver input. This parameter is derived by adding the required signal-to-noise ratio (SNR) to the noise level already calculated in logarithmic form. In satellite communication systems, the SNR is typically assumed to be in the range of 10–12 dB. Knowing the noise floor, one can evaluate how much stronger the signal must be to ensure error-free reception. The signal power at the receiver input is thus a key factor that determines the feasibility of data transmission and the compliance with the requirements of modern digital standards:

$$P_{s,in} = P + \frac{P_s}{P_n}$$

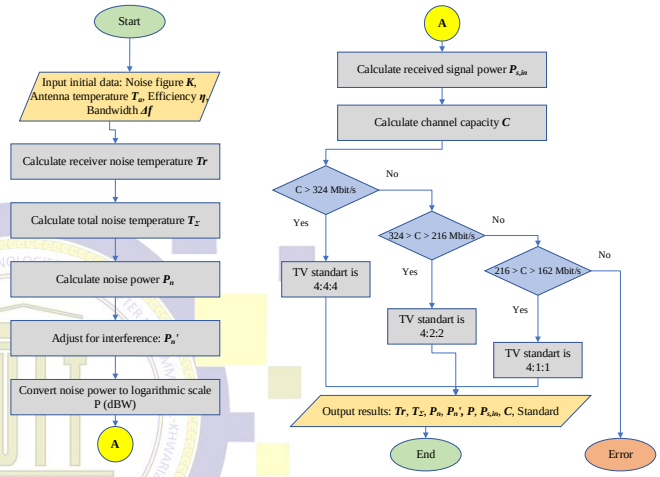
where: $P_{s,in}$ – signal power at the receiver input, dBW; P – noise power in dBW; P_s/P_n – signal-to-noise ratio, dB.

The final step is the determination of the maximum achievable channel capacity, derived from Shannon's theorem [9]. This formula links the channel bandwidth and the signal-to-noise ratio, thus allowing the estimation of the maximum error-free data rate that can be supported by the link. The larger the bandwidth and the higher the SNR, the greater the throughput of the channel. This value serves as a benchmark for evaluating whether the given communication link can support specific digital television standards, which have fixed requirements in terms of bit rates:

$$C = \Delta f \cdot \log_2\left(1 + \frac{P_s}{P_n}\right)$$

where: C – maximum channel capacity, bit/s.

On the basis of these expressions, an algorithm (Fig.1) was developed that integrates all stages into a single logical sequence.



Algorithm for calculating Ground station receiver parameters of a satellite communication link

The algorithm begins with the input of initial data, including the noise figure, antenna noise temperature, antenna efficiency, and the channel bandwidth. It then calculates the receiver noise temperature and the total noise temperature of the system. After that, the noise power is determined, adjusted to account for external interference, and converted into logarithmic scale. The next stage consists in calculating the signal power at the receiver input, followed by the determination of the maximum channel capacity. Finally, the algorithm provides an automatic selection of a digital television standard depending on the obtained channel capacity.

It should be emphasized that the algorithm incorporates the automatic selection of one of the three digital television standards: 4:1:1, 4:2:2, or 4:4:4. These notations reflect the chroma subsampling ratios of the digital video signal. The 4:1:1 standard requires the lowest channel capacity but comes at the expense of reduced color accuracy, making it suitable for links with limited bandwidth. The 4:2:2 standard represents a balance between video quality and data rate and is widely applied in professional broadcasting systems. The 4:4:4 standard is the most demanding in terms of capacity but preserves full color information, ensuring maximum image quality. This

option is typically used in studio production, digital cinema, and other applications where uncompromised fidelity is critical.

Results and Discussion

The proposed algorithm makes it possible to systematize the process of calculating the characteristics of the ground station receiver chain and to trace the influence of key parameters on the final performance of the communication channel. The sequential execution of the stages - from the calculation of the receiver noise temperature to the determination of the maximum channel capacity - ensures transparency of the computations and consistency with the fundamental principles of communication theory.

Particular attention should be paid to the receiver noise figure and the antenna efficiency. These parameters have the greatest impact on the total system noise temperature, which ultimately defines the noise power level. Even a small increase in the noise figure leads to a noticeable rise in noise temperature, reducing the signal-to-noise ratio and limiting the information throughput of the link. Similarly, a reduction in antenna efficiency increases its equivalent noise contribution and worsens the link budget [7].

An important result of the algorithm is the calculation of the maximum achievable channel capacity. The integration of Shannon's formula into the algorithm enables not only the evaluation of the current receiver parameters but also the identification of the system's limits and possibilities for modernization. Variation of the bandwidth directly affects the capacity: an expanded spectrum allows higher data rates but also increases noise power. Hence, the algorithm reflects the fundamental trade-off between channel bandwidth and reception reliability.

In general, the obtained dependencies are consistent with theoretical models of modern satellite communication systems. The algorithm captures the essential physical relationships and can be applied for comparative analysis of different receiver configurations. Its advantage lies in unifying all critical calculation stages into a single logical framework, enabling comprehensive assessment without the need for complex simulation tools.

Conclusion

In this study, a structured algorithm was developed for the calculation of key parameters of the ground station receiver chain. The algorithm integrates the sequential determination of the receiver noise temperature, the total system noise temperature, the noise power, the adjusted noise power considering external interference, the signal power at the receiver input, and the maximum channel capacity. The step-by-step structure of the algorithm ensures both transparency of the calculations and consistency with the theoretical foundations of satellite communication.

The results confirm that the proposed algorithm makes it possible to clearly identify the influence of receiver characteristics such as noise figure, antenna noise temperature, and efficiency on the overall quality of the communication link. By combining the fundamental analytical expressions into a single logical scheme, the algorithm enables comprehensive evaluation of link performance and provides reliable benchmarks for comparison of alternative receiver designs.

A significant practical implication of this work lies in its potential software implementation. The algorithm can be integrated into a dedicated application, which would allow the automation of calculations, minimize the probability of human error, and enable real-time assessment of receiver parameters under varying operating conditions. Such a tool would be of particular value for research purposes as well as for the design and optimization of satellite ground stations.

Furthermore, the inclusion of automatic selection between three digital television standards - 4:1:1, 4:2:2, and 4:4:4 - extends the applicability of the algorithm to practical broadcasting scenarios. By correlating the calculated channel capacity with the requirements of each standard, the algorithm ensures that the most appropriate configuration can be chosen for a given system. This feature enhances its relevance not only as a theoretical framework but also as a practical decision-support tool in modern satellite communications.

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АНАЛИЗ АРХИТЕКТУРЫ И ОСОБЕННОСТЕЙ ТЕХНОЛОГИИ 5G, ИСПОЛЬЗУЕМОЙ В ТЕЛЕКОММУНИКАЦИЛОННЫХ СЕТЯХ

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Аннотация - в данной статье проводится анализ архитектуры и особенностей технологии 5G, которая представляет собой новое поколение мобильной связи с расширенными возможностями. Технология 5G обеспечивает высокую скорость передачи данных (до 20 Гбит/с), минимальную задержку (до 0,5 мс), а также массовое подключение устройств интернета вещей (до 1 миллиона на км²). Архитектура 5G построена на принципах виртуализации сетевых функций (NFV), программно-определяемых сетей (SDN) и разделения сети на логические сегменты (Network Slicing), что позволяет адаптировать ресурсы под конкретные задачи и сервисы. Рассмотрены ключевые сетевые функции, такие как AMF, SMF, UPF, PCF и NWDAF, обеспечивающие гибкость, масштабируемость и аналитическую обработку данных. Отдельное внимание уделяется поддержке ультранадежной связи, облачным и пограничным вычислениям, а также обеспечению сквозной мобильности и непрерывности сессий. В заключении подчеркивается стратегическая роль 5G в цифровой трансформации экономики, развитии умных городов, телемедицины и автоматизации.

Keywords— Сеть пятого поколения, архитектура 5G, network Slicing, интернет вещей (IoT), низкая задержка (URLLC), виртуализация сетевых функций (NFV)

Введение

5G (от англ. fifth generation — пятое поколение) — поколение мобильной связи, действующее на основе стандартов телекоммуникаций, следующих за существующей технологией 4G-LTE. Начало стандартизации сетей 5G положил семинар 3GPP, прошедший в сентября 2015 года в США, где были определены планы по подготовке спецификаций. В соответствии с этими планами 1-ая фаза спецификаций должна быть завершена до второй половины 2018 г. (в рамках релиза 15 3GPP), 2-я фаза – до декабря 2019 г. (в рамках релиза 16 3GPP). С тех пор в соответствии с требованиями участников рынка планы были скорректированы и в декабре 2017 года была завершена стандартизация так называемой None-Stand-Alone архитектуры построения 5G.

Постановка задачи

Основными "фишками", характеризующими сети мобильной связи пятого поколения являются:

- сверх-широкополосный мобильный доступ (enhanced Mobile Broadband, eMBB),
- ультранадежная связь с низкими задержками (Ultra-Reliable and Low Latency Communications, URLLC),
- массовое подключение различных датчиков и устройств из мира "Интернета вещей" (massive Machine Type Communications, mMTC).

Рекомендация 3GPP TR 38.913 определяет следующие ключевые показатели сетей 5G:

- пиковая скорость передачи данных на линии вниз (Downlink) 20 Гбит/с (спектральная эффективность 30 бит/с/Гц);
- пиковая скорость передачи данных на линии вверх (Uplink) 10 Гбит/с (спектральная эффективность 15 бит/с/Гц);
- минимальная задержка в подсистеме радиодоступа для сервисов URLLC - 0,5 мс, для сервисов eMBB - 4 мс;
- максимальная плотность подключенных к сети в городских условиях устройств из мира "Интернета вещей" - 1 000 000 устройств/км2;
- автономная работа устройств из мира "Интернета вещей" без подзарядки аккумулятора в течение 10 лет;
- поддержка мобильности при максимальной скорости передвижения объектов 500 км/ч.

Данные показатели являются порой несовместимыми и даже взаимоисключающими. Поэтому различным устройствам в различные моменты времени будут доступны только определенные сервисы с определенными показателями (в рамках концепции Network Slicing).

Ключевые принципы архитектуры сети 5G заключаются в следующем:

- Разделение сетевых узлов на элементы, обеспечивающие работу протоколов «плоскости пользователя» (UP - User Plane) и элементы, обеспечивающие работу протоколов «плоскости управления» (CP - Control Plane), что значительно

увеличивает гибкость в части масштабирования и развертывания (допуская централизованное и децентрализованное размещение отдельных составляющих сетевых узлов).

- Разделение сетевых элементов на сетевые слои (Network Slicing), основываясь на услугах, предоставляемых конкретным группам конечных пользователей.
- Реализация сетевых элементов в виде виртуальных сетеый функций - VNF (Virtual Network Functions).
- Поддержка одновременного доступа к централизованным и локальным службам, что позволяет реализовывать концепции облачных (fog computing) и пограничных (edge computing) вычислений.
- Определение конвергентной архитектуры, объединяющей различные типы сетей доступа (AN - Access Network) - 3GPP (New Radio - NR) и не 3GPP (WiFi и пр.) с единой опорной сетью (CN - Core Network).
- Поддержка единых алгоритмов и процедур аутентификации (в не зависимости от типа сети доступа).
- Поддержка сетевых функций без сохранения состояния (stateless), где вычислительный ресурс отделен от ресурса хранения.
- Поддержка роуминга с маршрутизацией трафика как через домашнюю сеть (Home routed), так и с локальным приземлением (Local breakout) в гостевой сети (VPLMN).

МЕТОДЫ РЕШЕНИЯ

В архитектуре 5G взаимодействие между сетевыми функциями представлено двумя способами:

- сервис-ориентированное, когда одни сетевые функции (например, AMF) позволяют другим авторизованным сетевым функциям получать доступ к их сервисам.
- интерфейсное, которое показывает какое взаимодействие существует между сервисами сетевых функций, описанных как взаимодействие точка-точка (например, интерфейс N11) между любыми двумя сетевыми функциями (например, AMF и SMF).

Сетевые функции на плоскости управления 5G должны использовать только сервис-ориентированные интерфейсы для их взаимодействия. Сеть 5G включает в себя следующие основные программные модули и сетевые функции (NF):

- функция управления доступом и мобильностью (AMF - Access and Mobility Management Function);
- функция управления сессиями (SMF - Session Management Function);
- функция передачи данных пользователей (UPF - User Plane Function);
- модуль управления данными пользователей (UDM - Unified Data Management);
- унифицированная база данных (UDR - Unified Data Repository);
- система хранения неструктурированных данных (UDSF - Unstructured Data Storage Function);
- функция выбора сетевого слоя (NSSF - Network Slice Selection Function);
- функция управления политиками (PCF - Policy Control Function);
- функция обеспечения взаимодействия с внешними приложениями (NEF - Network Exposure Function);
- хранилище сетевых функций (NRF - NF Repository Function);
- прикладная функция (AF - Application Function);
- функция поддержки обмена короткими текстовыми сообщениями посредством протокола NAS (SMSF - SMS Function);
- функция взаимодействия с не-3GPP сетью доступа (N3IWF - Non-3GPP InterWorking Function);

Функция выбора сетевого слоя (NSSF) обеспечивает:

- выбор необходимого набора сетевых слоев (Network Slices) в процессе регистрации пользовательского терминала в сети (в зависимости от типа предоставляемой услуги, типа оборудования абонентского терминала, его местоположения и т.д.);
- определение модулей AMF, которые будут использоваться для обслуживания пользовательского терминала или, на основе конфигурации, определение списка модулей AMF, путем запроса в NRF;
- хранение информации о досупных сетевых слоях (NSSAI - Network Slice Selection Assistance Information).

Функция управления политиками (PCF - Policy Control Function)

Функция управления политиками (PCF) в реальном времени формирует и назначает пользовательским терминалам те или иные политики, включая параметры качества обслуживания (QoS) и правила тарифкации. Так, для передачи того или иного типа трафика могут динамически создаваться виртуальные каналы с различными характеристиками. При этом во внимание могут приниматься требования сервиса, запрашиваемого абонентом, его профиль, местоположение, уровень загрузки сети, объем потребленного трафика и т.д.

Функция поддержки привязки (BSF) обеспечивает привязку PDU сессии к конкретному экземпляру функции управления политиками (PCF). Является обязательным сетевым элементом при развертывании на сети 2-х и более узлов PCF. Таким образом, с одной стороны BSF позволяет узлам PCF регистрировать, обновлять и удалять в локальной базе

данных BSF информацию привязки, с другой - предоставляет различным сетевым (NF) и прикладным (AF) функциям информацию о PCF, обслуживающим ту или иную PDU сессию.

Вторая задача, возлагаемая на BSF, и присущая конвергентным сетям - это роль Diameter proxy agent или diameter redirect agent, обеспечивающего перенаправление Diameter запросов по Rx интерфейсу (например, от P-CSCF сети IMS) на соответствующий узел PCF.

Результаты и их обсуждение

Функция аналитики сетевых данных (NWDAF - Network Data Analytics Function) NWDAF предоставляет функцию аналитики сети. Обеспечивает сбор информации с сетевых функций 5GC, подписку пользователей на услуги NWDAF и предоставление пользователям метаданных, включая статистические данные о событиях, имевших место быть и предиктивную или прогнозную аналитику. Пользователями данной информации выступают PCF, NSSF, AMF, SMF, NEF, UDM, AF, OAM.

На Рис.1. показано место функции аналитики сетевых данных в структуре 5GC.

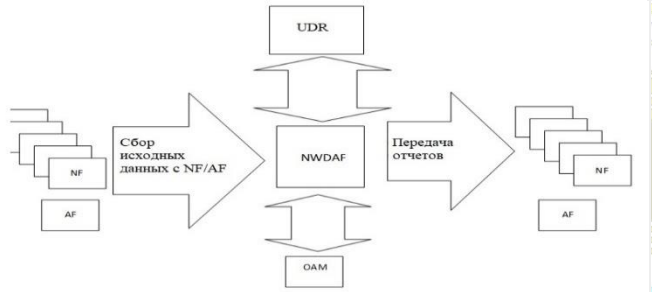

Рис.1. Функции аналитики сетевых данных в структуре 5GC

В 5GC могут присутствовать несколько экземпляров NWDAF, специализированные на разных типах аналитики. Данная информация о специализации (в виде списка идентификаторов Analytics ID) хранится в NRF профилях NWDAF.

NWDAF является исключительно внутрисетевой функцией. Он не имеет информации о логике функционирования сетевых функций, но собирает данные исключительно в статистических и аналитических целях.

Полученные результаты

В качестве возможных видов аналитики, подготавливаемой в т.ч. с использованием алгоритмов машинного обучения являются:

1. Аналитика в части загрузки сетевых слоев;
2. аналитика в части загрузки сетевых элементов;
3. Аналитика в части уровня клиентского опыта;
4. аналитика в части отдельных групп пользовательских терминалов, в т.ч. формирование отчетов, связанных с мобильностью (mobility management), соединением с сетью (communication management), детектирование аномального поведения UE;
- Аналитика в части производительности сети (network performance);
- Аналитика в части перегрузки и метрик качества (QoS).

Более детальную информацию можно получить в рекомендациях 3GPP TS 29.520, 23.288, 23.791.

Прикладная функция (AF) сети 5G взаимодействует с опорной сетью и, как пример, может решать следующие задачи:

- управление маршрутизацией трафика;
- предоставление доступа к модулю обеспечения взаимодействия с элементов сети (NEF);
- взаимодействие с функцией управления политиками.

В зависимости от конкретного внедрения на сети оператора связи, отдельным внешним платформам и приложениям может быть разрешен прямой (непосредственный) доступ к сетевыми функциями 5GC. Другие системы будут осуществлять доступ к сетевым функциям 5GC через прикладные программные интерфейсы API, предоставляемые модулем обеспечения взаимодействия сетевых функций.

В соответствии с архитектурой SDN для сетей 5G определено разделение шлюза пакетной передачи данных на две составляющие - плоскость управления (SMF) и плоскость пользовательского трафика (UPF) - control and user planes separation (CUPS). При этом ради объективности стоит отметить, что концепция CUPS релизом 14 3GPP определена и для сетей 4G-LTE, где предусмотрено разделение SGW на C-SGW (control plane) и U-SGW (user plane), а PGW соответственно - на C-PGW и U-PGW.

Упрощение архитектуры UPF по сравнению с PGW сети 4G-LTE позволяет снизить как стоимость разработки и производства самих узлов, так и затраты на их эксплуатацию. В конечном счете, это открывает путь к "пограничным вычислениям" (edge computing) за счет возможности устанавливать на сети большое кол-во шлюзов, размещая их в непосредственной близости к сети доступа. Однако такой подход создает проблему мобильности, поскольку перемещение пользовательского терминала с активной сессией передачи данных будет сопровождаться частой сменой UPF. 3GPP решает данную проблему путем введения новой функциональности - бесшовности абонентских сессией и услуг - SSC (Session and Service Continuity).

Network Slicing подразумевает разделение физической архитектуры 5G на множество виртуальных сетей или слоёв. Каждый сетевой слой включает в себя функции уровня управления, функции уровня пользовательского трафика и сеть радиодоступа (5G-NR, либо non-3GPP). Базируясь на архитектуре NFV/SDN, каждый слой обладает своими

характеристиками и нацелен на решение той или иной бизнес-задачи. 3GPP определяет три стандартных сетевых слоя:

- сверх-широкополосный доступ (eMBB, Enhanced Mobile Broadband) - пользователи глобальной сети Интернет, камеры видеонаблюдения,...
- ультра-надежность и низкие задержки (URLLC, Ultra Reliable Low Latency Communication) - транспорт без водителя, дополненная и виртуальная реальность;
- интернет вещей (IoT, Internet of Things) - миллионы устройств, передающие малые объёмы данных от случая к случаю.

Назначается каждому абоненту сети 5G и хранится в унифицированной базе данных UDM и USIM модуле пользователя. В качестве идентификатора SUPI может выступать международный идентификатор мобильного абонента – IMSI (International Mobile Subscriber Identity), либо идентификатор доступа к сети – NAI (Network Access Identifier), формат которого определен RFC 4282.

В настоящее время 3GPP определяет только один возможный формат PEI - это IMEI (International Mobile Station Equipment Identity). IMEI представляет собой уникальную цифровую последовательность, и должен назначаться всем пользовательским терминалам (UE), поддерживающим 3GPP технологию радиодоступа, при их производстве. TAC назначается ассоциацией GSMA в соответствии с рекомендацией GSMA TS.06 и определяет код конкретной модели пользовательского терминала.

Выводы

Современные телекоммуникационные технологии прошли путь от аналоговых систем передачи голоса до сложных цифровых платформ, способных обеспечивать высокоскоростной обмен данными, масштабируемость и интеграцию с другими отраслями. Эволюция сотовых технологий от 1G до 5G открыла новые горизонты, позволив перейти от простой мобильной связи к интеллектуальным сетям, поддерживающим Интернет вещей, автоматизацию производства и умные города. Пятое поколение связи стало основой для формирования единой цифровой экосистемы, где каждое устройство может взаимодействовать с другими в реальном времени, обеспечивая максимальную эффективность и надежность коммуникаций.

Таким образом, телекоммуникации перестали быть лишь средством передачи информации и превратились в стратегическую инфраструктуру, от которой напрямую зависят развитие экономики, науки, образования и социальной сферы. Именно современные телекоммуникационные решения определяют темпы цифровой трансформации, создают условия для появления новых сервисов и становятся ключевым драйвером глобального технологического прогресса.

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Статья на **Habr** о принципах архитектуры 5G — разделение на UP/CP, Network Slicing, виртуализация сетевых функций и др. Habr.

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ФОРМУЛИРОВАНИЕ ПРИНЦИПОВ ПРОЕКТИРОВАНИЯ АВТОМАТИЗИРОВАННЫХ ИНТЕГРИРОВАННЫХ ДИСПЕТЧЕРСКИХ СИСТЕМ УПРАВЛЕНИЯ ПОЛЁТАМИ ВОЗДУШНЫХ СУДОВ

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Аннотация

В условиях активной цифровой трансформации авиационной отрасли автоматизированные интегрированные диспетчерские системы (АИДС) становятся ключевым элементом управления воздушным движением. Цель статьи заключается в формулировании проектных принципов построения АИДС, обеспечивающих безопасность, масштабируемость, адаптивность и совместимость с международными стандартами. Представлены актуальные подходы к интеграции модулей обработки данных, прогнозирования конфликтов и поддержки четырёхмерных (4D) траекторий. Результаты работы ориентированы на практическое применение при модернизации диспетчерских центров Узбекистана и могут быть адаптированы для других регионов.

Ключевые слова: автоматизация, АИДС, управление полётами, диспетчеризация, 4D-траектории, цифровая трансформация

I. Введение

Мировая авиация переживает этап интенсивной модернизации, связанной с внедрением цифровых технологий, автоматизации и искусственного интеллекта. Системы SESAR (Европа) и NextGen (США) формируют новую архитектуру управления воздушным движением (ATM), включая поддержку 4D-траекторий, автоматизированные интерфейсы диспетчерских центров и интеллектуальные алгоритмы предотвращения конфликтов. В Узбекистане, где интенсивность авиаперевозок ежегодно растёт, модернизация диспетчерских систем является приоритетной задачей, требующей внедрения автоматизированных решений с открытой архитектурой.

II. Современные подходы и вызовы в проектировании АИДС

Современные системы управления воздушным движением, такие как европейская SESAR и американская инициатива NextGen, внедряют принцип Trajectory-Based Operations (TBO), который заключается в управлении воздушным судном на основе четырёхмерной траектории — широты, долготы, высоты и времени (ICAO, SESAR, 2024; EUROCONTROL, 2024). SESAR строится вокруг концепции TBO, направленной на повышение предсказуемости полётов, улучшение эффективности маршрутов и пропускной способности авиационной системы (Córdova et al., 2024; SKYbrary, 2025). В свою очередь, NextGen стремится к аналогичной модели управления трафиком, опираясь на спутниковое наблюдение, цифровую связь и централизованное распространение информации через SWIM, что переводит ATM от реактивного управления к стратегическому (FAA, 2024; Wikipedia, 2025).

Ключевой технологией, используемой в обоих подходах, является ADS-B — система автоматического зависимого наблюдения, при которой воздушное судно определяет своё положение через GPS и передаёт эти данные приёмо-передающим средствам (Wikipedia, 2025). ADS-B позволяет улучшить осведомлённость диспетчеров и пилотов, уменьшить задержки и повысить экологичность полётов (Wikipedia, 2025; AOPA, 2018). Помимо этого, системам характерна связь по каналам CPDLC и обмен информацией через SWIM, создающий общую информационную инфраструктуру для всех участников воздушного движения (ICAO, 2024; FAA, NextGen Today, 2025).

Несмотря на высокую эффективность SESAR и NextGen в условиях развитой навигационной инфраструктуры, их внедрение в Узбекистане и странах СНГ сопряжено с рядом технических и организационных вызовов. Необходимость стандартизации архитектуры, обеспечение

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безопасности, отказоустойчивости и открытости систем, а также интеграция с локальными навигационными средствами — все это требует значительных инвестиций и модернизации (дискуссии на уровне национальных программ АИДС, СНГ, 2025).

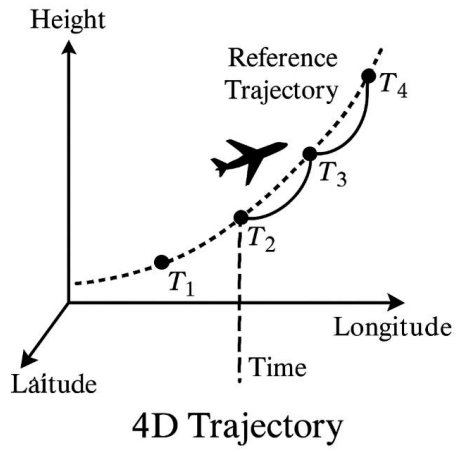
Концепция 4D-TBO открывает дополнительные возможности: управление траекторией в пространстве и времени способствует улучшению прогнозирования конфликтов, повышению плотности и эффективности маршрутизации. В пилотных исследованиях, проведённых в рамках проекта Airbus/SESAR, улучшение точности предсказания траекторий составило 30-40 %, что существенно снизило необходимость вмешательства диспетчера и оптимизировало использование топлива (Dumont, Airbus/SESAR, 2020). Аналогичные выводы делает Skybrary — концепция TBO способствует снижению реактивности в управлении, оптимизирует загрузку воздушного пространства и повышает оперативную предсказуемость (SKYbrary, TBO, 2025).

Таким образом, внедрение технологий SESAR и NextGen в авиасистему Узбекистана позволит существенно повысить безопасность полётов, пропускную способность воздушного пространства и энергоэффективность операций. Однако успешная реализация требует разработки локальных стандартов, создания гибкой, отказоустойчивой архитектуры и подготовки специалистов, способных работать с 4D-TBO, ADS-B, SWIM и другими компонентами современной ATM-экосистемы.

Поддержка 4D-траекторий

Концепция 4D-TBO позволяет управлять полётами в реальном времени, учитывая пространственные координаты и временные параметры. Внедрение этой технологии требует:

- автоматизированного прогнозирования конфликтов,
- визуализации зон допустимых отклонений,
- интеграции GPU-ускоренных вычислений для анализа больших массивов данных (рис.1).



4D Trajectory

Рис. 1. Схема 4D-траектории

III. Принципы проектирования автоматизированных интегрированных диспетчерских систем

На основе анализа действующих систем управления воздушным движением и современных требований к построению автоматизированных диспетчерских платформ были сформулированы базовые принципы проектирования интеллектуальных ATM-систем нового поколения. Одним из ключевых направлений является обеспечение модульности и масштабируемости архитектуры, что предполагает построение системы из взаимозаменяемых функциональных блоков, включающих модули связи, навигации, обработки данных и визуализации. Подобный подход обеспечивает возможность как горизонтального, так и вертикального расширения, позволяя гибко адаптировать систему под рост объёмов воздушного трафика или интеграцию новых технологических решений (EUROCONTROL, 2024; ICAO, 2024).

Следующим принципом является адаптивность и интеллектуальность платформы, что подразумевает интеграцию модулей прогнозирования и автоматического принятия решений на основе алгоритмов искусственного интеллекта и машинного обучения. Это обеспечивает повышение точности оценки воздушной обстановки, улучшение качества предсказания конфликтных ситуаций и минимизацию ошибок, связанных с человеческим фактором (Córdova et al., 2024; FAA, 2024). Подобные решения уже активно применяются в рамках инициатив SESAR и NextGen, которые демонстрируют эффективность применения интеллектуальных систем для динамического управления воздушными потоками в реальном времени (Skybrary, 2025).

Отдельное внимание уделяется принципу отказоустойчивости и надёжности. Современные ATM-системы должны быть спроектированы с учётом необходимости резервирования критически важных каналов связи, дублирования вычислительных блоков и использования встроенных механизмов самодиагностики. Это особенно важно при управлении воздушным движением в условиях высокой плотности полётов и нестабильных метеоусловий (ICAO, 2023; Airbus, 2024). Надёжная архитектура снижает вероятность возникновения критических отказов и обеспечивает непрерывность предоставления диспетчерских услуг.

Важнейшим направлением развития является интероперабельность, предполагающая соответствие международным стандартам, включая спецификации ICAO, IATA, IEEE и ARINC. Унификация протоколов передачи данных и интерфейсов обмена информацией создаёт условия для интеграции национальных систем управления воздушным движением в глобальную навигационную экосистему. Подобная совместимость обеспечивает согласованность взаимодействия между авиационными властями, аэропортами,

авиакомпаниями и смежными службами (ICAO, 2024; ARINC, 2023).

Не менее важным принципом выступает кибербезопасность. Современные ATM-системы становятся частью глобальной цифровой экосистемы и поэтому подвергаются возрастающим рискам кибератак и несанкционированного доступа к данным. Внедрение протоколов шифрования, систем многоуровневой аутентификации, инструментов анализа аномалий и технологий защиты каналов связи в реальном времени является необходимым условием обеспечения устойчивой и безопасной работы системы (IATA, 2024; FAA, 2023).

Принцип эргономичности интерфейса также приобретает всё большее значение. Современные автоматизированные диспетчерские рабочие места требуют продуманного HMI-дизайна, обеспечивающего интуитивно понятную визуализацию навигационных данных, оптимизацию расположения элементов управления и снижение когнитивной нагрузки на диспетчеров. Исследования показали, что внедрение современных HMI-систем сокращает время реакции на нестандартные ситуации на 25–30 %, повышая общую безопасность и эффективность управления (Airbus, 2024; SESAR Human Factors Report, 2023).

Особое внимание уделяется поддержке и управлению четырёхмерными траекториями (4D-TBO). Современные системы УВД всё активнее внедряют подходы управления полётами на основе четырёхмерных траекторий, включающих широту, долготу, высоту и временной параметр. Такой подход обеспечивает возможность отслеживания траекторий полёта в реальном времени и поддержания их в пределах допустимых отклонений на протяжении всего маршрута (SESAR, 2024; Skybrary, 2025). Важным элементом концепции является управление временным компонентом полёта, что позволяет обеспечивать безопасное разделение воздушных судов даже при незначительных сбоях в системе или каналах связи. Для реализации этого подхода используются алгоритмы дискретизации воздушного пространства, которые позволяют автоматически прогнозировать потенциальные конфликты, а также интеграция GPU-ускоренных вычислений для быстрой обработки больших массивов данных в реальном времени (Dumont, 2020; Airbus Research, 2023). Дополнительно важна реализация инструментов визуализации зон допустимых отклонений и временных окон для диспетчеров, что обеспечивает своевременную корректировку траекторий и предотвращает риск опасного сближения воздушных судов.

Таким образом, формируемая архитектура ATM-систем нового поколения должна сочетать интеллектуальные алгоритмы, модульный дизайн, высокую степень отказоустойчивости, совместимость с международными стандартами и возможности работы с четырёхмерными траекториями. Только комплексное применение этих принципов позволит создать устойчивую, гибкую и безопасную платформу управления воздушным движением, соответствующую современным требованиям гражданской авиации.

IV. Перспективы и рекомендации

Предлагаемые проектные принципы могут стать методологической основой для формирования и реализации национальных программ модернизации систем управления воздушным движением, ориентированных на создание единой цифровой авиационной экосистемы. Их применение особенно актуально в условиях стремительной трансформации авиационной отрасли, когда возрастают требования к безопасности полётов, пропускной способности воздушного пространства и интеграции с международными системами. Реализация таких принципов позволит обеспечить развитие современных диспетчерских центров, способных работать в условиях высокой плотности воздушного движения и сложной сетевой инфраструктуры, а также повысить уровень автоматизации процессов мониторинга и прогнозирования потенциальных конфликтов в реальном времени.

Особое внимание следует уделить подготовке и повышению квалификации диспетчерского персонала, так как внедрение автоматизированных интегрированных диспетчерских систем требует новых компетенций в области цифровых технологий, обработки больших данных и использования интеллектуальных алгоритмов. Важным направлением станет локализация программных решений и разработка отечественных модулей, обеспечивающих совместимость с международными стандартами ICAO, SESAR и NextGen, что позволит повысить устойчивость национальной инфраструктуры и снизить зависимость от внешних поставщиков. Кроме того, перспективным направлением является интеграция беспилотных авиационных систем в существующую сеть управления воздушным движением, что потребует разработки гибких алгоритмов координации и адаптации правовой базы к новым технологическим вызовам.

Комплексное внедрение данных подходов позволит не только повысить эффективность управления полётами пилотируемых и беспилотных воздушных судов, но и сформировать основу для построения интеллектуальной системы УВД, способной работать в едином информационном пространстве, интегрированном с глобальными навигационными и диспетчерскими платформами. Это создаст условия для повышения конкурентоспособности национальной авиационной отрасли, укрепления её позиций на международном рынке и достижения стратегических целей цифровой трансформации гражданской авиации.

V. Заключение

Автоматизированные интегрированные диспетчерские системы (АИДС) становятся ключевым инструментом цифровой трансформации гражданской авиации и важнейшим элементом национальной инфраструктуры управления воздушным движением. Их внедрение обусловлено необходимостью повышения безопасности полётов, оптимизации

использования воздушного пространства и обеспечения непрерывности авиасообщений в условиях стремительного роста объёмов пассажирских и грузовых перевозок. Сформулированные в работе проектные принципы демонстрируют комплексный подход к построению современных диспетчерских систем, способных эффективно функционировать в условиях высокой динамичности воздушных потоков, интеграции пилотируемых и беспилотных платформ, а также необходимости совместимости с международными стандартами и технологиями.

Особое значение имеет способность АИДС обеспечивать масштабируемость и адаптивность к меняющимся условиям эксплуатации, что позволяет интегрировать новые технологические решения без необходимости полной перестройки инфраструктуры. Поддержка 4D-траекторий, применение интеллектуальных алгоритмов прогнозирования конфликтов, использование автоматизированных модулей координации и повышения отказоустойчивости создают условия для построения единой цифровой диспетчерской среды, ориентированной на долгосрочное развитие авиационной отрасли.

Вместе с тем успешная реализация предложенных подходов невозможна без комплексного пересмотра организационно-правовой базы, внедрения современных методик подготовки кадров и создания национальных программ по развитию интеллектуальных авиационных технологий. Системная интеграция АИДС с глобальными платформами, такими как SESAR и NextGen, станет важным шагом для повышения международной совместимости и обеспечения устойчивости воздушного пространства страны.

В результате разработанные в статье рекомендации и принципы проектирования могут служить основой для построения новой модели управления воздушным движением, отвечающей современным вызовам и создающей условия для формирования безопасной, интеллектуальной и конкурентоспособной авиационной экосистемы Узбекистана в глобальном контексте.

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ANALYSIS OF DEVICES AND TECHNOLOGIES DEVELOPED FOR THE BLIND AND VISUALLY IMPAIRED PEOPLE

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***Abstract*—The development of various devices, innovations and technologies for the blind and visually impaired people, has basically required the blind and visually impaired to use a language or script that the blind and visually impaired can "understand".**

Keywords—Braille gadgets, Braille writing machine, keyboard, Braille display, tactile

LXXXV. INTRODUCTION

Nowadays, modern information and communication technologies are widely used in almost all aspects of life. One such area is the social area. Various modern technologies, technical and innovative developments are being developed specifically for them in order to create wide opportunities for people with disabilities, including the blind and visually impaired.

Braille is a tactile writing system used by people with visual impairments, including those who are blind, deaf or visually impaired. Braille is not a language. Rather, it is a code by which many languages — such as English, Spanish, Arabic, Chinese, and dozens of others — may be written and read. Braille is used by thousands of people all over the world in their native languages, and provides a means of literacy for all [1].

Braille letters (numbers, symbols) are formed by a combination of six raised dots arranged in a 3x2 matrix called a Braille cell. The number and location of these dots distinguish one character from another. Because different braille scripts originated as print transcription codes, collations (character sets) differ from language to language and even within a language; for example, English braille has 3 levels of braille:

unabridged Braille - a letter-by-letter transcription used to teach basic literacy;

abbreviated braille - abbreviations used to save space;

3rd level - less used various non-standardized personal shorthand;

6 dots in three rows and two columns are used to represent letters and numbers. Two more dots were later added, creating an 8-dot extended Braille system. It is possible to express 64 different characters using traditional six-point Braille and 256 different characters using extended eight-point braille. The formation of Braille is a systematic and somewhat complex process. The most important thing to read is the structure of the letters. Blind people who have fully mastered the Braille alphabet will be able to read and write [2].

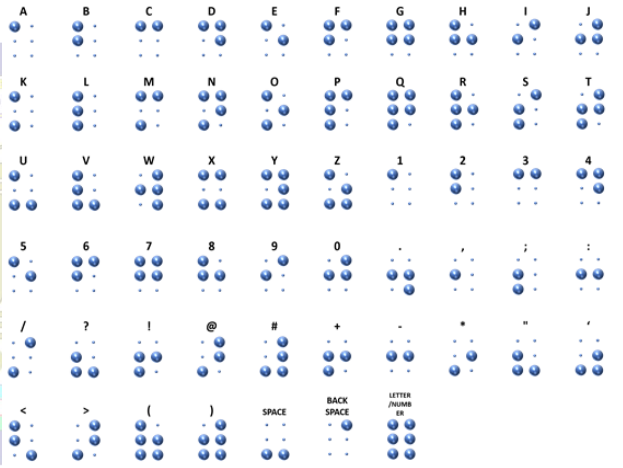

Fig. 1. Braille based on 6 points

Early education in Braille is critical to literacy, education and employment among the visually impaired. Despite the evolution of new technologies, including screen-reading software that reads information aloud, braille allows visually impaired people to access spelling, punctuation, and other aspects of written language only through audio. Although some believe that audio-based technologies reduce the need for Braille, technological advances such as Braille displays prove that Braille is more accessible and efficient [3].

8-point Braille. There are numerous examples, both historic and modern, in which the six dots of the traditional braille cell have proven inadequate for a particular task. Enterprising inventors, teachers, and braille users have sought to expand the possibilities of the braille cell by increasing the number of dots from six to eight.

These expansions have resulted in a cell that is two dots wide and four dots high [4]. In 8-dot braille, extra dots are added to the bottom of the cell, giving the matrix a height of 4 dots and a width of 2 dots. Additional points are numbered 7 (for the lower left point) and 8 (for the lower

right point). The advantages of eight-point braille are that most of an individual letter is encoded directly in the cell containing the letter, and all printable ASCII characters can be represented in a single cell. All 256 (28) possible combinations of 8 points are encoded by the Unicode standard. 6-point Braille is often stored as Braille ASCII.

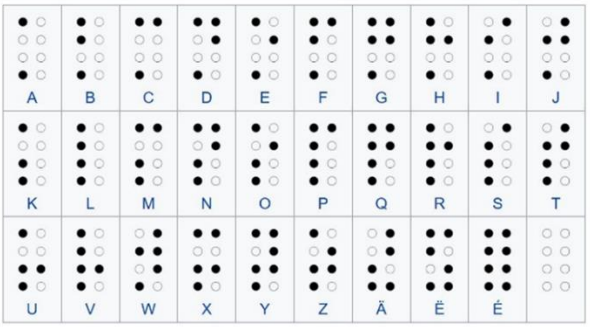

Fig. 2. Eight-dot Braille alphabet [14]

Braille writing machine. The standard Perkins Braillers typewriter, manufactured by Perkins Howe Press in 1961, is the most basic typewriter for Braille. This "braille typewriter" revolutionized communication for the blind and braille transcribers.

Although Braille was designed for people who are blind or visually impaired, prior to the advent of the Perkins braille, Braille was a labor-intensive process. Braille writers created braille with a stylus and tablet (designed by Louis Braille) or with one of the complex, expensive, and fragile braille typewriters available at the time [5].

Braille keyboard. A Braille keyboard is usually a special type of embossed dot keyboard used by visually impaired people to enter information into a computer. Unlike a standard keyboard, each point on a braille keyboard is represented by a single key.

To enter a character, letter or number using a Braille keyboard, you need to press and release the necessary keys at the same time.

In recent years, leading scientists in various regions of the world have been conducting research on the creation of Braille-based gadgets for the blind and visually impaired. Some information about these studies is provided below.

A new FPGA-based embedded power controller for Shape Memory Alloy (SMA) actuators used in refreshable Braille displays was proposed and implemented by S. Muralikrishnan Adhepalli et al [6]. According to the results of this study, the FPGA-based design outperforms the microcontroller-based design in various parameters. In addition, FPGAs provide parallelism for running several independent closed-loop controllers with a common signal, which helps to significantly reduce system response time.

Braille Pad system based on PIC16F877A microcontroller is developed by Amar Banmare et al [7] which provides information to visually impaired people through GSM, helps visually impaired people to communicate. To print the dots, the authors used six solenoid valves controlled by a microcontroller using a relay.

A study by Muna Al-Razgan et all conducted a systematic analyzed of the literature on mobile app usability for visually impaired users [8]. As a result of this study, studies effective for visually impaired users are divided into seven sections: accessibility, daily activities, assistive devices, gestures, navigation, screen allocation layout and audio instructions.

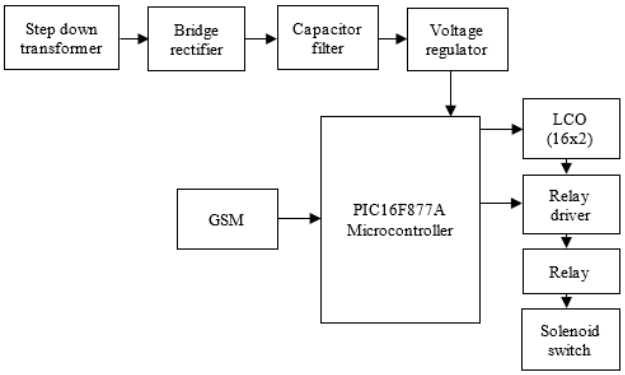

Fig. 3. Block diagram of the proposed system [7]

Another interesting study by Dennis A. Martillano et al [9] developed PINDOTS, a six-dot Braille-based assistive device for visually impaired students based on IoT technology.

Ziliang Zhou et al developed a portable Braille reading system based on electrotactile display technology [10]. The system developed by the authors consists of a six-channel electrotactile stimulator, a flexible electrode assembly for Braille display, and a graphical user interface (GUI) for monitoring and control. Based on the flexibility of the system, two reading strategies have been developed in Braille: spatial mode and sequential mode. The system was initially tested by six visually impaired subjects. The results showed that the subjects were able to recognize the Braille letters with more than 80% accuracy in less than 10 seconds on the first use. Compared to existing braille reading systems, this system has the characteristics of being portable, wearable and flexible in management.

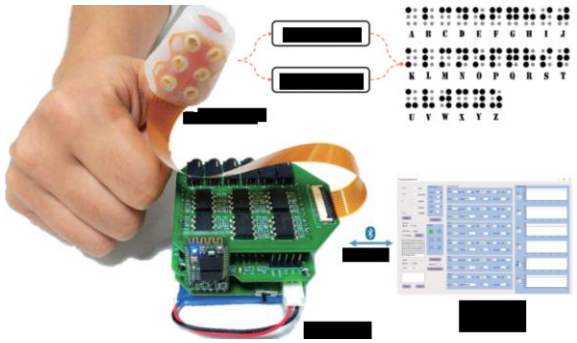

Fig. 4. Braille reading system framework: GUI and Braille controls for monitoring, stimulator for the production of impulses, electrode array for Braille display [10]

Another research work was developed by Preethi Vinnarasi et al., a Braille-based SMS system for the blind and deaf [11]. In this study, the authors developed a new methodology using Braille system intended for reading messages for blind and deaf people. In the study, GSM modem was used to receive the message, the content/letters

of the message can be easily read by blind people by feeling the vibration of the vibrator motor and the same content/letters are displayed on the LCD screen. Buzzer works as a message alert.

A smart Braille system with IoT-based full-duplex communication capability has been developed by Sravan Kumar et al [12]. This research is based on inventing a messenger for different groups of disabled people who cannot use mobile phones for messaging or other types of communication with satisfactory comfort. This system is designed to provide communication between visually impaired people using the NODE MCU module and wireless technology. Here, the user sends an SMS message to the blind person's mobile application, which can recognize the SMS message using the NODE MCU module, through the commands of the built-in Wi-Fi module, and then converts the SMS characters into Braille using the lookup table in its memory. Voice playback and OCR are the main improvements in this concept. A Raspberry combined with a camera performs the OCR process for the disabled.

Also, another interesting study is devoted to the analysis of modern renewable braille displays [13]. This study provides an overview of available upgradeable Braille displays. The study covered different types of upgradeable Braille displays, including BI 40, BraillePens, EDGE 40, Focus Blue Family, HIMS, insideONE, Orbit and QBraille XL. In the study, refreshable Braille displays were analyzed and compared.

The article describes the analysis of innovative technologies for people with visual impairments using the following methods:

1. Technologies used in the development of Braille devices (e.g. FPGAs and microprocessors).

2. Efficiency and convenience of the Braille system for reading, writing and transmitting information.

3. User convenience and speed measurements through portable and IoT-based devices.

The following table presents the results of methodological studies.

TABLE I. RESULTS OF METHODOLOGICAL STUDIES

Technology/ application	Areas of application	Advantages	Disadvantages
FPGA-based systems	Refreshable Braille displays	Fast performance, low power consumption	High price
Portable Braille reading system	Getting information on the go	Portable, convenient	Difficulty adapting for new users
IoT-based smart systems	SMS and message exchange	Availability of real-time access	Internet addiction

The analysis of technologies developed for the blind and visually impaired, in particular the Braille writing system and devices, applications, and software tools based on it, was carried out through the study of various scientific articles and technical literature. For example, FPGA-based control systems, portable Braille reading devices, and smart systems based on IoT technologies create a number of conveniences in the daily lives of blind and visually impaired individuals.

In conclusion, it can be said that a number of scientific literature and official publications were studied during the preparation of this article. Various Braille-based gadgets, mobile applications and assistive technologies developed in foreign countries for the blind and visually impaired were reviewed. As a result of the analyzed scientific and practical work, a plan was formed to create a prototype of "Braille gadget" for the blind and visually impaired in the future.

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ПРИМЕНЕНИЕ ДИНАМИЧЕСКОГО ДОСТУПА К СПЕКТРУ И КОГНИТИВНОГО РАДИО ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ИСПОЛЬЗОВАНИЯ СПЕКТРА

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Аннотация. В статье рассматривается необходимость повышения эффективности использования радиочастотного спектра в связи с внедрением новых технологий радиосвязи. Проанализированы существующие методы, уделено внимание интеллектуальным методам – динамическому доступу к спектру и когнитивному радио, их возможностям, взаимосвязи, условиям применения. Отмечена перспектива их использования с учётом будущих потребностей в спектре существующих и новых технологий радиосвязи.

Ключевые слова – эффективность использования радиочастотного спектра, помехи, методы, динамический доступ к спектру, когнитивное радио, искусственный интеллект, машинное обучение.

Введение

Эффективность использования радиочастотного спектра становится всё более значимым фактором в современных беспроводных телекоммуникационных сетях и системах в связи с возрастанием потребности в нём действующими и новыми технологиями радиосвязи. Следствием этого обстоятельства является создание более продуктивных методов планирования использования спектра по сравнению с преимущественно применяемым как на международном, так и на национальном уровнях традиционным методом.

При традиционном методе спектр распределяется государственным регулятором по фиксированным правилам и каждому пользователю или службе выделяется закреплённая полоса частот (статическое распределение частот) с обеспечением беспомеховой работы радиоэлектронных средств.

Исследования показывают, что при этом методе полосы частот используются одним пользователем, при этом - нерегулярно по времени, а также географическое использование выделенного спектра колеблется в пределах от 15% до 85%. Отмеченные обстоятельства свидетельствуют о неэффективности существующего механизма использования ограниченного частотного ресурса.

Вместе с тем, будущая массовая беспроводная связь приведёт к чрезвычайно сложной радиочастотной среде, характеризующейся различными приложениями с различными требованиями к качеству обслуживания, огромным количеством узлов, быстро меняющейся динамикой трафика, неоднородностью спектра в топологии сети и растущими помехами. Эти особенности существенно нагружают существующие беспроводные системы, особенно широкополосного доступа, мобильной связи, и, следовательно, требуют применения методов распределения спектра, обладающих интеллектуальными возможностями.

К таким методам относят когнитивное радио и динамическое распределение спектра.

Впервые понятие «когнитивное радио» было предложено в 1999 году с описанием его как радио, которое понимает контекст, в котором оно находится, и в результате может адаптировать процесс коммуникации в соответствии с этим пониманием.

В более широком определении когнитивное радио (CR - cognitive radio) — это самообучающееся интеллектуальное программно-определяемое радио (SDR, Software-Defined Radio), которое способно отслеживать окружающую среду и адаптироваться к реальным условиям, таким, как наличие базовых станций или характеристики канала радиосвязи. Наиболее важными свойствами CR являются, например, определение местоположения, осведомлённость о спектре, контроль мощности передачи или анализ радиосигнала. Адаптация к окружающей обстановке происходит посредством обучения на основе анализа изменений во внешней обстановке изменением своих собственных параметров (например, несущей частоты, мощности, способа модуляции) в реальном времени с целью увеличения эффективности использования спектрального ресурса.

Когнитивное радио позволяет использовать новые приложения и повышает

производительность существующих радиосистем (таблица 1).

Понятие «динамический доступ к спектру» (Dynamic Spectrum Access, DSA) имеет различные определения, характеризующие его свойства. К примеру следующие определения, представленные в документах международных, национальных организаций, а также научной литературе:

под динамическим доступом к спектру понимается регуляторный и технологический подход, обеспечивающий более гибкое и эффективное использование радиочастотного спектра за счёт допуска вторичных (нелицензированных) пользователей к спектру, когда он не используется первичными (лицензированными) пользователями;

Таблица 1 Приложения на основе когнитивного радио и результаты их использования

Предлагаемые новые приложения с поддержкой CR	Показатели производительности, улучшенные за счёт CR
Динамическое распределение спектра	Повышение эффективности использования спектра
Самоорганизующиеся сети	Улучшение совместимости между устаревшими и новыми системами
Когнитивные системы постановки помех	Повышение надёжности соединения
Когнитивные шлюзы / мосты	Менее дорогие радиостанции
Рынки спектра в режиме реального времени	Совершенствование методов SDR
Синтетический (кооперативный) MIMO	Увеличенное время автономной работы
Управление когнитивным спектром	Расширенное покрытие
Когнитивная маршрутизация	

динамический доступ к спектру - это метод управления спектром, при котором устройства могут динамически изменять свои параметры работы (частоту, мощность, полосу и пр.) в зависимости от доступности радиочастотных ресурсов;

динамический доступ к спектру— это механизм, позволяющий радиосистемам адаптироваться к изменениям доступности спектра и уровням помех в реальном времени для более эффективного использования частотного ресурса.

То есть, в отличие от традиционного статического распределения спектра, где каждому оператору закрепляют фиксированную полосу частот, при DSA:

первичные пользователи (Primary Users, PU) имеют приоритетное право;

вторичные пользователи (Secondary Users, SU) могут временно использовать свободные «окна» в спектре, не создавая помех PU;

система принимает решения на основе мониторинга спектра и алгоритмов когнитивного радио (теория оптимизации, искусственный интеллект, машинное обучение).

Динамический доступ к спектру, наряду с другими, является одним из методов динамического управления спектром (Dynamic Spectrum Management, DSM), при котором ресурсы спектра (частоты) распределяются динамически, в зависимости от текущей его загрузки, условий и требований по использованию спектра.

Типичные методы DSA включают:

разделение спектра на сегменты разной ширины для улучшения пропускной способности и равномерности распределения спектра;

алгоритмы распределения частот с учётом приоритетов пользователей;

централизованное или распределённое управление доступом к спектру.

Взаимосвязь DSA и CR выражается в том, что DSA - это цель (задача) сделать использование спектра гибким, эффективным и адаптивным, а CR - это инструмент (технология) для реализации DSA на практике (таблица 2).

Таблица 2 Взаимодействие DSA и CR

Характеристика	Когнитивное радио (CR)	Динамический доступ к спектру (DSA)
Суть	Технология «умного радио», адаптивное устройство	Концепция использования спектра
Основная функция	Анализ, обучение, адаптация параметров передачи	Гибкое распределение и совместное использование частот
Задачи	Мониторинг спектра, адаптация мощности, модуляции, частоты	Эффективное использование ресурса, снижение простаивания
Соотношение	Инструмент для реализации DSA	Цель, которую реализует CR

Заключение

Спрос на радиочастотный спектр стремительно растёт под влиянием наращивания беспроводных сервисов, интернета вещей, мобильных технологий 5G/6G и спутниковой связи. Традиционные методы управления спектром становятся препятствием для дальнейшего технологического прогресса.

Применение перспективных методов повышения эффективности спектра, основанных на интеллектуальных программно-определяемых системах с использованием, в том числе, динамического доступа к спектру и когнитивного радио позволит решать вызовы ограниченности спектра для внедрения новых технологий радиосвязи.

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MATLAB PAKET DASTURI YORDAMIDA OTDR REFLEKTOGRAMMALARNI VEYVLET-O‘ZGARTIRISHLAR ASOSIDA TADQIQ ETISH

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***Annotatsiya* — Maqola tolali optik aloqa liniyalarining (TOAL) ekspluatatsion holatini baholash uchun testlash, diagnostikalash yoki monitoring qilishda natijasida optik reflektometr (Optical Time Domain Reflectometer, OTDR) qurilmasi yordamida olingan reflektogrammalarni tahlil va tadqiq etishga bag‘ishlangan. Reflektogrammalarni tahlil qilish uchun qo‘llaniladigan bir nechta firmalarning dasturiy ta’minotlari taqqoslanib ularning kamchiliklari va afzalliklari keltirib o‘tilgan. Tadqiqotning eksperimental va amaliy narijalari MATLAB paket dasturi yordamida olingan. Mazkur paket dasturning Wavelet Toolbox to‘plamidan foydalanilgan bo‘lib, O‘zbekiston Respublikasining keskin kontinental hududlaridan biri bo‘lgan Qoraqalpog‘iston Respublikasi hududidagi real ekspluatatsiyadagi TOALni diagnostikalashda olingan reflektogramma ma’lumotlariga asoslangan. Tadqiqot natijalarida TOALning ekspluatatsiyasida liniya uzunligi bo‘ylab anomal nuqsonlarni aniqlanib, ular veyvlet-o‘zgartirishlari (Wavelet transformation, WT) usullar yordamida tadqiq qilingan.**

Keywords*— *TOAL, optik tola, optik reflektometr, reflektogramma, WT.

KIRISH

Tolali optik uzatish tizimlarining ishonchli ishlashini ta’minlash uchun, ayniqsa, axborot sig‘imi katta bo‘lgan TOALda nosozliklarni tezda aniqlash va bartaraf etish juda muhim hisoblanadi. Bunday turdagi aloqa tizimlarida hozirgi kunda TOALning ekspluatatsion holatini baholash maqsadida maxsus qurilmalar yordamida testlash, diagnostikalash va real vaqtda monitoring qilish orqali amalga oshiriladi. Shunday maxsus qurilmalardan biri bu OTDR qurilmalaridir. OTDR qurilmaning ishlash tamoyili radarnikiga o‘xshaydi: optik tolaning (OT) bir uchidan yorug‘lik manbaidan yuborilgan qisqa yorug‘lik signal impulslari, o‘sha toladan akslangan yorug‘lik signali qabul qiluvchi qurilma tomonidan qayta qabul qilinadi. Yorug‘lik impulsining tarqalish vaqtining funksiyasi sifatida qayd etilgan ushbu akslanuvchi yorug‘lik impulsi amplitudasi OTning har bir nuqtasidagi optik signal quvvatining susayishini va aks ettirish xususiyatlarini tavsiflaydi. Olingan narijalar qurilma ekranida reflektogramma ko‘rinishida ko‘rsatiladi. Hosil bo‘lgan tasvirda OTda aks ettirilgan yorug‘lik signal impulsining quvvat darajasining OT uzunligiga bog‘liqlik grafigi tasvirlanadi. Vertikal o‘qda logorifmik birliklarda optik signal quvvati yo‘qotishlari darajasi (nisbiy quvvat), gorizonlat o‘qi esa sinovdan o‘tkazilayotgan TOALsi uchastkasining masofasiga to‘g‘ri keladi. Odatda reflektogramma 32000 ga yaqin o‘lchangan nuqtalarni o‘z ichiga oladi va ahar bir bunday nuqtani hisoblashda bir necha ming impulslar o‘rtachasi hisoblanadi. Reflektometr ma’lumotning butun majmuasini soniyaning bir qismida qayta ishlaydi. Birlamchi o‘lchangan reflektogramma darhol displeyda ko‘rsatiladi. Keyin o‘rtacha qiymatta olngan reflektogrammalar qiya chizmasi ko‘rsatiladi.

Bunday holda, TOALdagi OTning shikastlanishlari, nosozlik turlari va sinov signali haqida ma’lumotlar sezilarli xatolar bilan olinadi. Ushbu muammolar sababli, reflektogrammadagi bunday anomal ma’lumotlarni olishning va qayta ishlashning yangi usullarini qo‘llash zaruratini talab qiladi. Ulardan biri WTni qo‘llash hisoblanadi. Buning uchun MATLAB paket dasturida Wavelet Toolbox to‘plamidan foydalanish yordamida tadqiq qilsih hozirgi kunda tadqiqotchilar tomonidan samarali usullardan biri sanaladi va keng qo‘llaniladi.

REFLEKTOGRAMMALARNI QAYTA ISHLASH UCHUN MO‘LJALLANGAN DASTURIY TA’MINOTLAR TAHLILI

OTDR qurilmasi yordamida olingan o‘lchov natijalarini shaxsiy kompyuterlar yordamida qayta ishlanadi. Dastlabki ma’lumotlarni shaxsiy kompyuterlar qayta ishlashning afzalliklari shundaki reflektogrammaning alohida qismlarini kattalashtirilgan shaklda ko‘rish, bir xil aniqlangan holatlar qiymatlarini hisoblash, ularning ro‘yxatini tuzish va hisobot shaklida olish imkoniyatlarini beradi. Har xil formatda olingan va saqlangan reflektogramma qiya chiziqlari bir xillik xususiyatlarini o‘lchash natijalarini keying qayta ishlash bosqichida kompyuter ekranida ko‘rsatilishi kerak. Shu maqsadda reflektogramma fayllarini qaytas ishlash imkonini beruvchi har xil firmalarning maxsus dasturlari mavjud. Bulardan keng tarqalganlari Anritsu firmasining Anritsu TraceView 5.0.0.0 va SORTraceViewer, EXFO firmasining FastReporter3, Yokogawa Electric Corporation firmasining

ANDO AQ7993, VeEx firmasining Fiberizer Desktop Plus dasturlarini misol qilib ko‘rsatishimiz mumkin. Quyida har bir dastur haqida qisqacha ko‘rib chiqamiz:

ANRITSU TRACEVIEW 5.0.00 DASTURI

Ushbu dastur Anritsu OTDR qurilmalari tomonidan yozilgan reflektogramma fayllarini shaxsiy kompyuterda ochish va tahlil qilish uchun ishlab chiqilgan.

Qo‘llab-quvvatlanadigan fayllar:

*.sor – Telcordia (SR-4731) / Bellcore (GR-196-CORE) fayllari (standart format).

Asosiy funksiyalari:

- OTDR reflektogrammalarini ochish va ko‘rish;
- Nosozliklarni aniqlash;
- Reflektogrammalarni kattalashtirish, markerlar bilan ishlash, yo‘qotish va refleksiya o‘lchovlarini amalga oshirish;
- Bir nechta faylni bir vaqtning o‘zida solishtirish va taqqoslash;
- Avtomatik hisobot shakllantirish (*.pdf, *.*.csv) va chop etish.

Qo‘llanishi: Windows operatsion tizimlarida ishlaydi, ko‘p tilli interfeys mavjud (ingliz, yapon, boshqa tillar).

ANRITSU SORTRACEVIEWERI DASTURI

Bu dastur Anritsu OTDR qurilmalari tomonidan yozilgan fayllarni ko‘rish uchun ishlatiladi.

Qo‘llab-quvvatlanadigan fayllar:

*.sor – Telcordia (SR-4731) / Bellcore (GR-196-CORE) formatidagi fayllar.

Asosiy funksiyalari:

- Reflektogrammalarni ochish va tahlil qilish;
- Kattalashtirish, markerlar qo‘yish, refleksiya va yo‘qotishlarni o‘lchash;
- Hisobot shakllantirish va natijalarni turli formatlarda (*.pdf, *.csv) saqlash;
- Bir nechta faylni bir vaqtda solishtirish.

Qo‘llanishi: Windows operatsion tizimida ishlaydi, foydalanuvchi interfeysi oddiy va tezkor tahlil uchun mo‘ljallangan.

EXFO FASTREPORTER 3 DASTURI

Ushbu dastur EXFO OTDR qurilmalari (FOTR seriyasi va boshqalar) tomonidan yozilgan reflektogramma fayllarini shaxsiy kompyuterda ochish va tahlil qilish uchun mo‘ljallangan.

Qo‘llab-quvvatlanadigan fayllar:

*.trc – EXFO reflektometrlari fayl formati; *.sor – Telcordia (SR-4731) / Bellcore (GR-196-CORE) standart fayllari.

Asosiy funksiyalari:

- Tahlil funksiyasi: reflektogramma fayllarini yuklash, nosozliklar joylashuvini aniqlash va tahrirlash, Bir nechta reflektogrammalarni (8 tagacha) taqqoslash, ikki xil izni solishtirish yoki ikki tomonlama o‘lchovlarni tahlil qilish mumkin;
- Hisobot yaratish: barcha yuklangan fayllar bo‘yicha umumiy jadval shaklida yoki reflektogrammalar chop etilgan ko‘rinishda hisobot tayyorlash.

Asosiy o‘lchovlar:

- yo‘qotishlarni (4 va 6 markerli metodlar yordamida) aniqlash;
- refleksiyani o‘lchash;
- ikkita ixtiyoriy nuqta orasidagi masofa va yo‘qotishni hisoblash.

YOKOGAWA AQ7933 OTDR EMULATION SOFTWARE DASTURI

Ushbu dastur Yokogawa AQ7280 va boshqa OTDR seriyalari bilan yozilgan fayllarni ochish va tahlil qilish uchun xizmat qiladi.

Qo‘llab-quvvatlanadigan fayllar: *.sor – Telcordia / Bellcore standart fayllari; *.trb – AQ7250 fayllari; *.trd – AQ7260 fayllari.

Asosiy funksiyalari:

- Reflektogrammalarni yuklash va tahlil qilish;
- Nosozliklar va g‘ayritabiiy sohalarni tahrirlash;
- Bir nechta fayllarni bir vaqtda solishtirish va taqqoslash;
- Ikki tomonlama o‘lchovlarni tekshirish va tafovutlarni ko‘rsatish.

Hisobot funksiyasi: reflektogrammalarni jadval va grafik shaklida chiqarish, *.csv formatida eksport qilish, chop etish.

VEEX FIBERIZER DESKTOP PLUS DASTURI

Ushbu dastur VeEX OTDR qurilmalari hamda boshqa ishlab chiqaruvchilar OTDR fayllarini ko‘rish va tahlil qilish uchun mo‘ljallangan.

Qo‘llab-quvvatlanadigan fayllar: *.sor – Telcordia / Bellcore fayllari; boshqa OTDR ishlab chiqaruvchilarining maxsus formatlari (ko‘p turdagi).

Asosiy funksiyalari:

- OTDR izlarini ochish va tahlil qilish;
- Reflektogramma bo‘yicha yo‘qotishlar, refleksiya va nosozliklarni aniqlash;
- Fiberizatsiya xaritasi (fiber route map) orqali tolani vizual ko‘rish;
- Hisobot yaratish va avtomatlashtirilgan hisob-kitoblarni chiqarish.

Afzalligi: Fiberizer Cloud bilan integratsiya – natijalarni masofadan saqlash va ulashish imkoniyati.

TABLE VII. OTDR REFLEKTOGRAMMALARINI TAHLIL QILISHDA QO‘LLANILADIGAN DASTURLARI

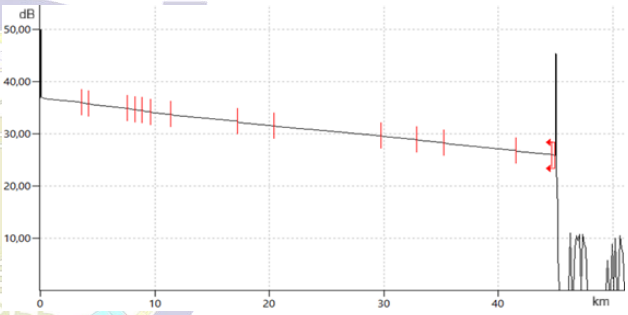
Firma nomi	Dastur nomi	Formatlar	Asosiy funksiyalari
EXFO	FastReporter 3	*.trc (EXFO), *.sor (Telcordia/Bellcore)	Reflektogrammalarni ochish va tahlil qilish, 4/6 markerli yo‘qotish o‘lchovi, ikki tomonlama izlarni solishtirish, avtomatik hisobot (*.pdf, *.csv).
Yokogawa	AQ7933	*.sor (Telcordia/Bellcore), *.trb (AQ7250), *.trd (AQ7260)	Fayllarni ochish va tahlil qilish, nosozliklarni aniqlash, bir nechta izlarni solishtirish, *.pdf, *.csv hisobot.
VeEX	Fiberizer Desktop Plus	*.sor (Telcordia/Bellcore), boshqa ko‘plab OTDR formatlari	Reflektogrammalarni tahlil qilish, yo‘qotish va refleksiya o‘lchovi, interaktiv xarita, Fiberizer Cloud bilan integratsiya, hisobotlar.
Anritsu	SORTraceViewer	*.sor (Telcordia/Bellcore)	OTDR izlarini ochish va ko‘rish, kattalashtirish, markerlar bilan ishlash, refleksiya va yo‘qotishlarni o‘lchash, hisobotlarni chop etish.
Anritsu	TraceView 5.0.00	*.sor (Telcordia/Bellcore)	Reflektogrammalarni ko‘rish va tahlil qilish, nosozliklarni aniqlash, bir nechta faylni solishtirish, avtomatik hisobot (*.pdf, *.csv).

Yuqoridagi reflektogrammalarni ko‘rish va tahlil qilishda qo‘llaniladigan dasturlardan o‘z xususiyatlariga ko‘ra qulayligi jihatdan maqbuli sifatida Anritsu firmasining SORTraceViewer dasturi tanlandi. Ushbu dastur qulay va soda interfeysi, keng funksional tahlil qilish imkoniyati bilan afzal ko‘rildi. Shuningdek, olib borilgan dastlabki tadqiqot ma’lumotlari ushbu firmaning MT9083C2-053 OTDR qurilmasida olib borilgan.

MATLAB PAKET DASTURIDA REFLEKTOGRAMMALARNI KEYING QAYTA ISHLASH JARAYONLARI

SOR Trace Viewer dasturida reflektogrammadan (joriy) diagnostika qilinayotgan TOAL ekspluatatsion holati haqida quyidagi ma’lumotlarni olish mumkin: o‘lchovda zondlangan yorug‘lik impulsining to‘lqin uzunligi; impulsning davomiyligi; belgilangan masofalar diapazoni; OTning sindirish ko‘rsatkichi; sikllar soni yoki vaqt (o‘rnatilgan o‘rtacha); faylda saqlangan masofalar oralig‘idagi o‘lchov nuqtalari. Shu bilan birga, reflektogrammadan sezilarli xatolar bilan har xil turdagi TOALdagi shikastlanishlar, nuqsonlar haqida ma’lumotlar olish mumkin. Lekin dasturning matematik qayta ishlash imkoniyati cheklanganligi uchun, ayrim anomal o‘zgarishlar e’tiborga olinmaydi. Shu sababli reflektogrammalardan bunday ma’lumotlarni olishning yangi usullarini yaratishning zarurati tug‘iladi. Ulardan biri WTdan foydalanishdir. MATLAB paket dasturi asosida matematik modellashtirishdan foydalangan holda WT tahlili yordamida reflektogrammalarni qayta ishlashni amalga oshirish mumkin. MATLABda reflektogrammalarni qayta ishlash uchun dastlab xls, pdf, jpg, png, bmp va hokazo ko‘rinishdagi formatlarga aylantirish kerak (dastur ma’lumotlarni import qilishning mumkin bo‘lgan variantlarga qarab) yoki uni jadval shaklida (CSV) ko‘rsatish kerak.

SORTrace Viewer dasturi yordamida reflektogramma ma’lumotlarini (eksport qilishda) konvertatsiya qilishni amalga oshirish jarayoni quyidagicha: grafik tasvirlar png (1-rasm), umumiy ma’lumotlar xls (2-jadval) va liniyaning holatini baholovchi ma’lumotlar CSV formatlarida olinadi (3-jadval).



1-RASM. OTDR reflektogrammasi

TABLE VIII. OTDR REFLEKTOGRAMMASINING UMUMIY MA’LUMOTLARI

Parametrlar	Qiymatlari	Parametrlar	Qiymatlari
OT uzunligi	44,963 km	Sindirish koeffitsiyenti	1,4682
Diapozon	51,085 km	Qayta akslanish	-81,5 dB
To‘qin uzunligi	1550 nm	Yo‘qotishlarning chegaraviy qiymati	0,05 dB
Impuls davomiyligi	500 ns	Akslanishning chegaraviy qiymati	-60 dB
Ulanishlar soni	14	O‘lchash vaqti	15 s
Ulanishlardagi o‘rtacha so‘nish	0,147 dB	Qaytalanishlar soni	13312
Ulanishlardagi maksimal so‘nish	0,276 dB	Kabel turi	Bir modali OT
Nuqtalar soni	25001	Versiya	Bellcore, SOR
Nuqtalar oralig‘dagi qadam	2,0433 m	OTDR	MT9083C2-053

TABLE IX. CSV FORMATDAGI OLINGAN MA’LUMOTLAR

Masofa (km)	Akslangan signal	Holat turi	So‘nish (dB)	Yo‘qotishlar (dB/km)

	quvvati (dB)			
0,00	36,829	Boshi	0,00	0,000
0,186	36,017	Yo‘qotish	0,19	0,225
4,254	35,729	Yo‘qotish	0,11	0,156
7,616	34,893	Yo‘qotish	0,17	0,217
8,300	34,653	Yo‘qotish	0,08	0,098
8,901	34,462	Yo‘qotish	0,17	0,195
9,642	34,183	Yo‘qotish	0,13	0,152
11,414	33,689	Yo‘qotish	0,10	0,208
17,26	32,421	Yo‘qotish	0,28	0,201
20,41	31,511	Yo‘qotish	0,12	0,201
29,76	29,603	Yo‘qotish	0,12	0,191
32,90	28,880	Yo‘qotish	0,14	0,193
35,29	28,281	Yo‘qotish	0,18	0,193
41,54	26,801	Yo‘qotish	0,18	0,207
44,66	26,016	Yo‘qotish	0,12	0,194
44,96	25,878	Oxiri	25,83	0,080

Grafik yoki jadval ko‘rinishidagi reflektogramma ma’lumotlari keying qayta ishlashda MATLAB paket dasturida WT yordamida amalga oshiriladi.

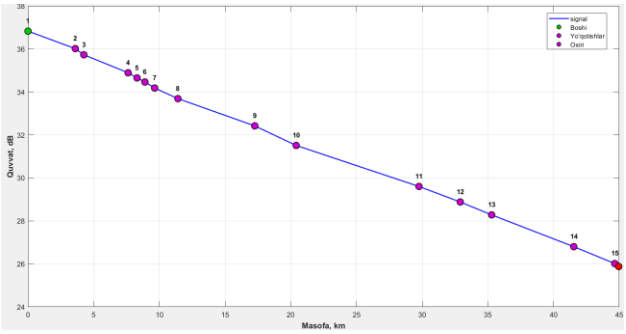
MATLAB PAKET DASTURI YORDAMIDA REFLEKTOGRAMMALARNI WT ASOSIDA TADQIQI

Veyvlet — bu bitta funksiyadan uni vaqt o‘qi bo‘ylab siljitish va yoyish orqali olinadigan funksiyalar oilasi. WT muhim ma’lumotlarni signal va vaqt qatorlari yoki tasvirning local strukturasini ajratib ko‘rsatish imkonini beradi.

Veyvlet tor yuqori chastotali bo‘limlarni ajratib ko‘rsatish uchun oynani toraytirish yoki kengaytirish orqali vaqt va chastota ma’lumotlarini olish imkonini beradi. An’anaviy ravishda WT uch o‘lchovli spektr deb hisoblash mumkin, bunda vaqt X o‘qi bo‘ylab, chastota Y o‘qi bo‘ylab, ma’lum bir vaqtdagi chastotali garmonik amplitudasi Z o‘qi bo‘ylab chiziladi.

MATLAB paket dasturidan foydalanilgan holda WT uchun 1-rasmda va 3-jadvalda ko‘rsatilgan ma’lumotlar olingan. WT tahlil qilish qulayligi uchun MATLABda ko‘p o‘lchovli statsionar bo‘lmagan hodisalarni tadqiq qilish uchun dasturning o‘rnatilgan kutubxonasi to‘plami kengaytirilgan paketga kiritilgan. Paket quyidagi signal o‘zgartirishlarini o‘z ichiga oladi: bir o‘lchovli diskret va paketli tahlil, bir o‘lchovli uzluksiz tahlil, kompleks bir o‘lchovli uzluksiz tahlil, shovqinni olib tashlash, zichlik va degradatsiyani baholash.

Dastlabki ma’lumot sifatida olingan reflektogramma MATLABga yuklanadi (2-rasm) va bir o‘lchovli uzluksiz WT yordamida tekshiriladi. Uzluksiz WT signal spektrogrammasini olish va signallardagi har qanday nosozlik, shikastlanish va anomal holatlarni aniqlash imkonini beradi. Holatlar veyvlet-spektrogrammasida ham aks etadi va veyvlet-koeffitsientlari yordamida qayd etilishi mumkin.



2-RASM. MATLB muhitidagi reflektogramma

Tadiqot OTDR reflektogrammalarini kompleks statistik usuliga asoslangan. Dastlabki ma’lumotlar qayta ishlash jarayonidan olingan ma’lumotlarni yanada qayta ishlash va masofani normallashtirish va statsionar komponentalarni ajiratish uchun eng kichik kvadratlar usuli yordamida TOALsi trassasi bo‘ylab optik signal quvvatining yo‘qotishlari tadqiq qilingan.

Umumiy optik sigan quvvati yo‘qotishlari quyidagi formula yordamida aniqlanadi

$$A_{umumiy} = |p_1|(x_n - x_1), \qquad (1)$$

bu yerda p_1 – reflektogramma qiya chizig‘ning burchak koeffitsienti , x_1 – boshlang‘ish nuqta, x_n – oxirgi nuqta.

(1) formulaga asos bir modali OT da $A_{o‘r}$ – o‘rtacha optik signal yo‘qotishlarini kuzatishlar segmenti uchun 0,18-0,35 dB qiymati oralig‘da deb hisoblanadi va degradatsiya va anomal holatlar uchun qoldiqlarni quyidagi formula yordamida ifodalaymiz.

$$r_i = y_i - (p_1 x_i - p_2), \qquad (2)$$

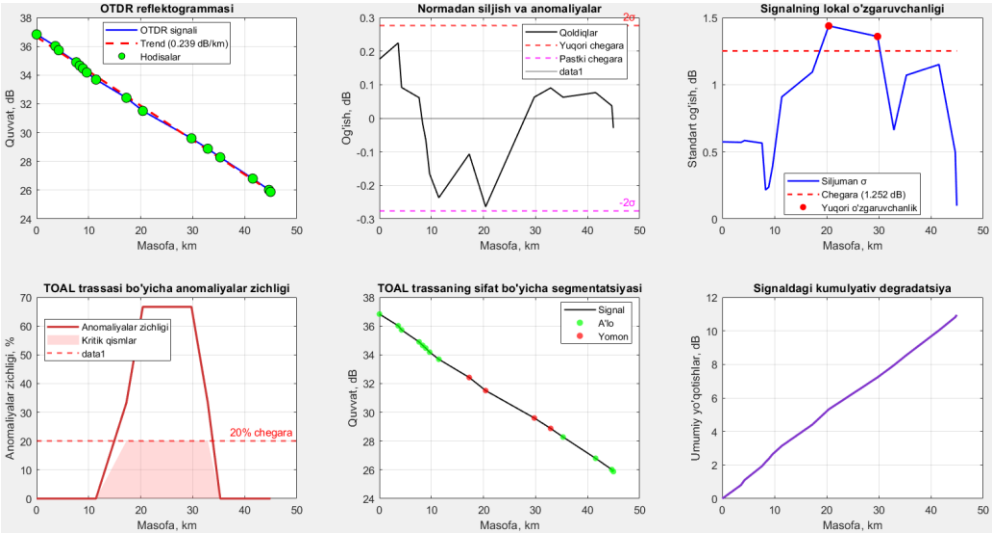
bunda y_i – i-kuzatish uchun bog‘liqlik o‘zgaruvchisining haqiqiy qiymat, $p_1 x_i - p_2$ – aproksimatsiyalanuvchi to‘g‘ri chiziq.

Qoldiqlarni orqali standart siljishlar σ hisoblab chiqiladi, u qiymatlarning yaqinlashuvchi chiziq atrofida tarqalishning o‘lchov chegaralarini belgilaydi. σ ning qiymati qancha kichik bo‘lsa, kuzatishlarni aniq tasvirlash darajasi shuncha yuqori bo‘ladi.

TOAL uchastkalaridagi lokal hududlar xususiyatlarini aniqlash uchun standart siljish tahlillaridan foydalanib $\sigma_{siljish}(i)$ va anomaliya zichligi $D(i)$ qiymatining o‘rtacha qimatini hisoblaymiz.Anomaliya zichligiga qarab bu segmentlarni to‘rtta sifat toifasiga ajiratamiz:

- $D < 5\%$ – a’lo;
- $5\% \le D < 15\%$ – yaxshi;
- $15\% \le D < 30$ – qoniqarli;
- $D \ge 30$ – qoniqarsiz.

Tanlangan usul yordamida MATLAB paket dasturida olingan natijalar 3-rasmda berilgan.



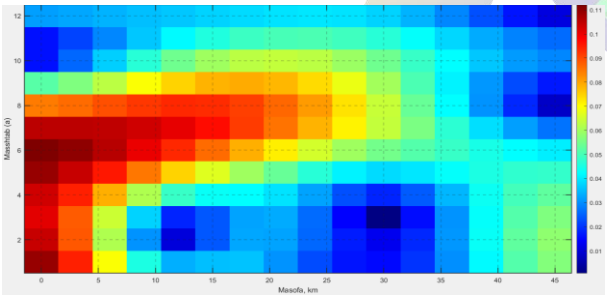
3-RASM. MATLAB dasturida TOAL trassasi uzunligda anomaliyalarni aniqlashda olingan natijalar

OTDR reflektogrammasida holatlarni aniqlash degradatsiya yoki anomal hodisalarni aniqlashni yaxshilash uchun uzluksiz WT yordamida kop masshtabli signal tahlili qo‘llaniladi. Uzliksiz WT signalni vaqt-chastota fazosiga joylashtiradi:

$$W(a,b) = \int_{-\infty}^{+\infty} x(t) \cdot \varphi^* \left(\frac{t-b}{a}\right) dt, \qquad (3)$$

bu yerda $x(t)$ – normal OTDR signali; $\varphi(t)$ – Morlet asos vevleti; a – masshtablash parametri (teskari chastota); b – siljish parametri.

MATLAB dasturida uzliksiz WT usulini qo‘llagan holda olingan tajriba natijalari quyidagi rasmda ko‘rsatilgan.



4-RASM. OTDR reflektogrammasining veyvlet-spektrogrammasi

LXXXVI. Xulosa

Olingan WT tahlil natijalari TOAL ekspluatsion holatini bahols uchun uzliksiz WT qo‘llash samarali usullaridan biri ekanligini ko‘rsatadi. Spektrogramma reflektogrammada anomal vaqtinchalik chastotali bog‘liqliklarni aniq tasvirlash imkonini beradi, bu esa vaqt sohasidagi an’anaviy tahlilda sezilmaydigan anomal xususiyatlarni ochib beradi. Olingan natijalar nafaqat testlash va diagnostikalash natijalaridan olingan dastlabki ma’lumotlarni, balki tasniflash imkoniyatiga ega bo‘lgan avtomatlashtirilgan monitoring tizimlarini ishlab chiqish qo‘llanilishi va su’niy intelekt vositalar yordamida takomillashtirish mumkin.

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МЕТОД ПРОГНОЗИРОВАНИЯ ОТКАЗОВ В ВОЛОКОННО-ОПТИЧЕСКИХ СИСТЕМАХ ПЕРЕДАЧИ ИНФОРМАЦИИ

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Аннотация **- В статье предложен метод прогнозирования отказов в волоконно-оптических системах передачи информации с использованием алгоритмов машинного обучения и функции самоанализа. Метод позволяет заблаговременно выявлять потенциальные отказы элементов, адаптироваться к изменениям сети и снижать среднеквадратичную ошибку прогноза. Основой является систематический сбор и обработка фактических данных об отказах, их анализ и динамическая корректировка модели на основе расхождений между прогнозом и фактическими данными. В рамках разработанной программной платформы реализованы модули сбора, обработки и визуализации данных. Результаты тестирования на реальных телекоммуникационных данных показали повышение точности классификации на 6–9% и снижение RMSE на 30%, подтверждая практическую применимость метода для повышения надежности волоконно-оптических систем передачи информации.**

Ключевые слова: волоконно-оптическая система передачи информации, прогнозирование отказов, машинное обучение, мониторинг.

I. ВВЕДЕНИЕ

В условиях стремительного роста объемов передаваемой информации, повышения требований к скорости и надежности связи, особое значение приобретают высокоэффективные технологии передачи данных, в том числе волоконно-оптические системы передачи информации (ВОСПИ), формирующие основу современной телекоммуникационной инфраструктуры. Отказы в ВОСПИ могут привести к потере связи, нарушению работы критически важных служб и финансовым убыткам. Наиболее частыми причинами являются механические повреждения кабеля, сбои оборудования и программные ошибки. Управление отказами в ВОСПИ включает в себя выявление, изоляцию и устранение разнообразных сетевых проблем, обеспечение стабильной работы сети и соблюдение уровня обслуживания. Для достижения этой цели применяются методы прогнозирования, обнаружения, идентификации, диагностики и локализации сбоев [1]. Метод прогнозирования отказов заранее определяет возможные неисправности оборудования на основе специфических признаков, которое позволяет предпринять активные меры для предотвращения сбоев до их возникновения. Традиционные методы управления отказами, основанные на порогах и вероятностных моделях, недостаточно эффективны в условиях сложной и изменчивой сетевой среды. Для повышения надёжности оптических сетей всё больше применяется искусственный интеллект, который способствует прогнозировать трафик, проектировать топологию, рассчитывать маршруты и управлять отказами [2].

Машинное обучение (МО) представляет собой область искусственного интеллекта, в которой системы выявляют закономерности в данных и принимают решения с минимальным участием человека [3]. Однако эффективность МО снижается при наличии неполных или искажённых данных, особенно при обнаружении сбоев в волоконно-оптических системах, где важную роль играет длительный сбор и предварительная обработка информации. Поскольку многие модели работают с ограниченными табличными данными, различия в результатах между традиционными алгоритмами и глубоким обучением остаются неочевидными. Качественный сбор данных остаётся ключевым фактором успешного управления отказами.

В настоящее время ведутся исследования по различным методам распределенного оптоволоконного мониторинга [4, 5], методов обнаружения и мониторинга событий сбоев волокна в системах оптических сетей связи [6]. Учитывая, что прогнозирование отказов является оценочной задачей, а эксплуатационные данные содержат неотъемлемые взаимосвязи, машинное обучение хорошо подходит для решения этой задачи. Использование интеллектуальных систем мониторинга в ВОСПИ значительно улучшает надёжность системы за счёт выявления возможных отказов, минимизирует время отказа и повышает эффективность технического

обслуживания [7, 8, 9]. Применение методов искусственного интеллекта обеспечивает высокую точность прогнозов и автоматизацию процессов управления сетью, что особенно важно в условиях повышенных требований к качеству телекоммуникационных услуг.

Методы прогнозирования отказов на основе алгоритмов машинного обучения [10, 11, 12] показывают высокую точность, но зависит от факторов таких как зависимость от качества журналов сигналов отказов, сложность реализации и в этих работах не рассмотрены системы самоанализа и коррекции.

II. МЕТОДЫ

В рамках данной работы исследованы задачи повышения надежности ВОСПИ, в том числе:

– прогнозирование вероятности отказа компонентов системы;
– оценка степени деградации компонентов;
– прогнозирование остаточного срока службы компонентов.

Для эффективного решения указанных задач целесообразно использовать алгоритмы регрессии и классификации, поскольку они соответствуют типу данных и постановке задачи. Регрессионные алгоритмы, позволяют строить аппроксимирующие модели, отражающие зависимости в структуре ВОСПИ. Применение этих алгоритмов обеспечивает возможность точного прогнозирования отказов, прогнозирование остаточного ресурса и оценки степени деградации компонентов. Применение моделей классификации позволяет системе оценки степени деградации компонентов, в том числе определению уровня риска отказа низкий / средний / высокий. Совместное применение моделей регрессии и классификации позволяет одновременно прогнозировать поведение системы, анализировать текущее состояние компонентов и способствует повышению их надежности, адаптивности и устойчивости к отказам.

При разработке метода прогнозирования отказов необходимо учитывать технические характеристики элементов и оптимальность самой структуры сети. Методы прогнозирования отказов, внедрённые в практическое применение, включают, в частности, метод прогнозирования рисков в сетях связи, обеспечивающий оценку вероятности отказа узлов коммуникационных сетей с использованием технологий машинного обучения [13].

Метод прогнозирования отказа системы разработанный в работе [14] основан на машинном обучении с переобучением моделей (рис.4.8), в которой система обучает несколько моделей на исходных данных, отбирает наиболее эффективные из них и затем переобучает выбранные модели на новых данных для повышения точности прогнозирования отказов.

Анализ существующих методов прогнозирования отказов показывает, что даже при использовании высокоэффективных моделей и их переобучении отсутствует механизм самоанализа и динамической настройки параметров в реальном времени. Это снижает адаптивность систем и точность прогнозов в условиях изменяющейся сетевой среды. Цель предлагаемого метода - повысить надёжность и сократить время простоя ВОСПИ за счёт раннего выявления потенциальных отказов с учётом самообучения, высокой точности и минимальных вычислительных затрат [15, 16]. Предлагаемая система анализирует результаты прогнозирования, а при расхождении прогнозированных результатов с реальными данными, выбирает другой алгоритм или производит изменение параметров раннее использованного алгоритма. Каждые определённые промежутки времени система обновляется на основе новых данных об отказах с сетей связи и самоанализа алгоритмов машинного обучения.

III. РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

Структурная схема метода прогнозирования отказов в ВОСПИ с самоанализом приведена на рис.1 [15, 16]. Сбор данных об отказах служит основой для анализа, представляя собой многомерные временные ряды. Предобработка данных значительно улучшает качество данных, облегчает процесс моделирования и повышает точность прогнозирования отказов в волоконно-оптических системах. Из отфильтрованных данных извлекаются признаки (характеристики), которые будут использоваться для построения модели прогнозирования. Обучение модели – наиболее значительный этап, где на основе выбранных признаков строится прогностическая модель, используя алгоритмы машинного обучения. В этапе прогнозирования модель используется для оценки вероятности возникновения отказов в системе на основе текущих и исторических данных.

Система самоанализа непрерывно оценивает производительность модели в реальном времени, корректируя её параметры в случае обнаружения отклонений от ожидаемых результатов. Визуализация играет важную роль в интерпретации результатов, предоставляя графики и диаграммы, которые демонстрируют взаимосвязи в данных и эффективность модели.

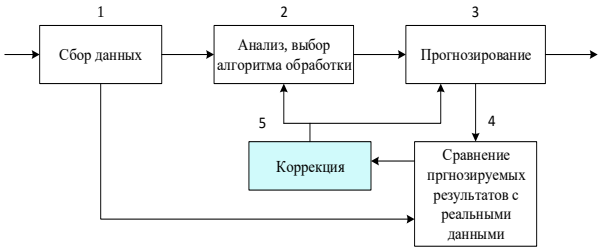

Рис.1. Структурная схема метода прогнозирования отказов с самоанализом в ВОСПИ

Для реализации предложенного метода разработана программная платформа, включающая модули для сбора данных, их предварительной обработки, анализа и визуализации результатов [16]. Тестирование метода проводилось на основе реальных данных, полученных

из телекоммуникационных компаний, и показало высокую точность прогнозирования отказов.

На этапе Коррекция производится самоанализ метода на основе расхождений между прогнозами и реальными данными. При обнаружении расхождения, система автоматически корректирует параметры алгоритма или выбирает другой алгоритм, чтобы улучшить точность.

Благодаря периодическому анализу расхождений и корректировке гиперпараметров (или смене модели) RMSE снизилась примерно на 30 % по сравнению с исходным уровнем, а F1-score вырос с 0,75 до 0,81; в свою очередь, система реже «опаздывала» с сигналом о возможном сбое, позволяя операторам сети принимать упреждающие меры; при изменении условий (добавлении новых типов устройств и повышенных нагрузок) модель быстро (в течение одного-двух циклов) переобучалась и сохраняла высокую точность (рис.2).

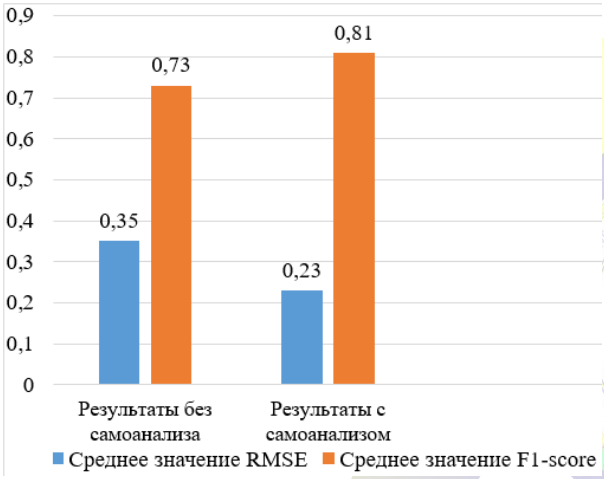

Рис.2. Показатели метрик до и после применения самоанализа

Результаты моделирования показали высокую эффективность предложенного метода прогнозирования отказов в телекоммуникационных сетях с использованием алгоритмов машинного обучения и механизма самоанализа. Модели, реализованные в среде MATLAB показали устойчивое снижение RMSE и рост F1-score после внедрения системы самоанализа. Это подтверждает, что автоматическая адаптация параметров и смена модели при снижении точности существенно повышают надёжность прогнозов. В результате система не только улучшила своевременность обнаружения отказов, но и обеспечила устойчивость к изменяющимся условиям и структурам телекоммуникационной сети, что делает её применимой для реальных эксплуатационных задач в отрасли.

IV. ЗАКЛЮЧЕНИЕ

Предложен метод прогнозирования отказов в телекоммуникационных сетях с функцией самоанализа и автоматической коррекции модели. Система в реальном времени отслеживает расхождения между прогнозом и фактом, адаптируясь к изменяющимся условиям без участия оператора. Разработанная программная платформа продемонстрировала высокую точность и устойчивость к снижению качества данных. Результаты моделирования показали прирост точности классификации на 6–9% и снижение среднеквадратичной ошибки на 30%. Метод запатентован как «Метод прогнозирования отказов с самоанализом в телекоммуникационных сетях» (№ IAP 7986, 18.03.2025).

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FEATURES OF THE ORGANIZATION OF THE EARTH-SATELLITE CHANNEL IN DIRECT COMMUNICATION SYSTEMS D2D

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Abstract - The paper considers the technical features of constructing a downlink channel in the context of direct communication between subscriber devices (Device-to-Device, D2D) using satellite segments, especially low-orbit satellites (LEO). The architecture of D2D communication via satellite is analyzed, and the advantages and limitations of different orbits (LEO, MEO, GEO) are highlighted. Attention is paid to the influence of the Doppler effect, the dynamics of orbital systems, the need for distortion compensation, and the implementation of handover protocols. It is noted that the LEO segment is best suited for the implementation of satellite D2D systems due to its low latency and high coverage density.

Keywords - D2D, satellite communication, LEO, earth-satellite channel, delay, Doppler, handover, 5G NTN, energy budget, L- band, retransmission.

INTRODUCTION

Modern developments in wireless technologies are rapidly approaching the realization of the concept of ubiquitous and continuous communication between devices regardless of their location. One of the promising areas in this area is the organization of direct communication between subscriber devices (Device-to-Device, D2D) via satellite infrastructure, which allows for stable communication in the absence or overload of terrestrial networks.

Unlike traditional schemes in which devices communicate via base stations and terrestrial gateways, D2D communication via satellite (especially using low-orbit satellites – LEO) allows direct data exchange between terminals, bypassing traditional infrastructure. This is especially relevant for scenarios such as remote areas, emergency communications in disaster areas, the Internet of Things (IoT), autonomous transport, and ensuring connectivity during terrestrial network failures.

The downlink in D2D systems is a key link that provides primary radio communication between devices and the space segment. Its efficiency directly determines the reliability, delays, throughput and stability of the channel. The organization of such a channel is associated with many issues that need to be addressed: limited energy capabilities of mobile devices, satellite movement and short visibility time (in the case of LEO), atmospheric and ionospheric interference, the need to use compact, directional antennas and adaptive modulation schemes.

An additional challenge is the need for standardization, since modern communication standards (in particular, 3 GPP Releases 17 and 18 within 5G Non-Terrestrial Networks (NTN) are just beginning to integrate satellite D2D scenarios into the overall mobile network architecture.

D2D communications in a satellite context involve the ability to directly exchange data between two subscriber terminals, with the satellite acting as a relay, without the need for a terrestrial base station or centralized switching infrastructure. This approach extends the capabilities of standard D2D communications in terrestrial mobile networks, offering global coverage, especially in hard-to-reach or isolated regions (Fig.1).

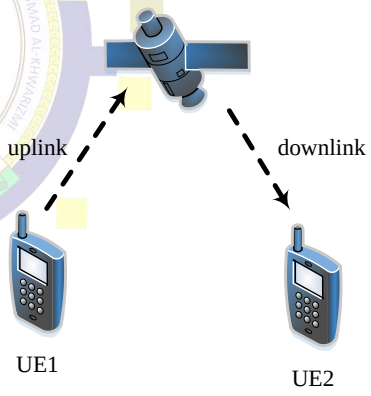

Fig.1. Basic structure of D2D communication via satellite

Modern D2D systems using satellites are formed within the Non - Terrestrial Networks (NTN) and 5G NR standards. The basic principles of operation are as follows:

- both parties (UE1 and UE2) are within the coverage area of one satellite or group of satellites;
- signal transmission is carried out via the uplink channel UE1 satellite and the downlink channel satellite UE2;
- in the case of LEO, dynamic reconnection is required when changing satellites.

Earth-satellite channel is a key link, the features of which are as follows:

- forms the basis of the energy budget for communications;

- depends on the frequency range, propagation conditions, channel geometry;
- requires real-time adaptation in the case of mobile satellites (LEO);
- causes additional delays and distortions compared to terrestrial D2D communication.

Developing effective systems for direct D2D communications via satellites requires a detailed understanding of the parameters and features of the satellites themselves, as they determine the architecture of the downlink, the throughput, the power requirements, and the stability of the communications. Satellites can be classified by their orbital characteristics, frequency ranges, and technical parameters that directly affect the quality of D2D communications (Table 1).

Table 1 Orbital classification of satellites

No.	Orbit type	Height, km	Turnaround time	Advantages	Restrictions
1	**LEO** (low orbit)	300–1500	90–120 min	Low latency, high speed, dense coverage	Short visibility time, high dynamics
2	**MEO** (medium orbit)	2000–20000	2–12 h	Tradeoff between reach and latency	Fewer satellites, higher latency
3	**GEO** (geostationary)	~35786	24 h (stationary relative to the Earth)	Continuous coverage of the area, easy tracking	High latency (~250-300ms), high power

LEO satellites, despite the need for dense constellations and complex handover logistics, are most suitable for D2D applications requiring low latency and high recontact rates.

The choice of frequency range directly affects the requirements for the antenna, power consumption and channel stability. For example, the L-band is actively used in Direct-to-Cell pilot projects due to its stability and low requirements for the antenna of the mobile device.

LEO-based systems, satellites move relative to the earth's surface at speeds of up to 7.5 km/s, which results in:

1) Doppler frequency shift - tens of kHz (especially critical for D2D with a narrow band);

2) changing the angle between the UE and the satellite - an adaptive antenna or tracking is required;

3) re-establishing the connection (handover) when the satellite goes beyond the horizon (usually after 5–10 minutes).

These features are taken into account when designing adaptive protocols and distortion compensation mechanisms.

Conclusion

The "earth-satellite" channel in direct D2D communication systems show a high degree of complexity in the construction of reliable and effective communications in this architecture. Analysis of the D2D architecture via satellite allowed us to identify key components, including the orbital characteristics of satellites, the choice of frequency ranges, as well as critical parameters of the channel itself: energy budget, attenuation, Doppler effects and dynamics.

Due to their low latency and high coverage density, LEO satellites are the most suitable for building D2D networks. However, the high mobility of satellites requires the implementation of adaptive antennas, Doppler compensation and optimization of handover protocols.

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INTEGRATION OF AI INTO VIDEO SIGNAL PROCESSING SYSTEMS

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***Abstract*— The integration of artificial intelligence (AI) into video signal processing systems opens up new opportunities for improving the quality, adaptability, and functionality of video technologies. Modern neural network models effectively address tasks such as noise reduction, super-resolution, detail restoration, compression artifact removal, and frame interpolation. This paper provides an overview of key deep learning methods applied to video streams, along with a comparative analysis of their accuracy and computational costs. Particular attention is given to the practical application of AI in fields such as telemedicine, intelligent video surveillance, autonomous transportation, and industrial visualization. The study also examines the implementation of AI models under resource-constrained conditions and in real-time systems, including edge computing and hardware acceleration. The findings confirm the high efficiency and broad potential of AI applications in modern video systems.**

Keywords*— *intelligent video processing, neural networks, noise reduction, super-resolution, frame interpolation, video surveillance, telemedicine, edge AI, image restoration, real-time processing

INTRODUCTION

Digital video has become the primary medium of visual information across diverse fields—from medicine and transportation to security and education. The quality of the video signal directly affects the accuracy of analysis, the reliability of automated decision-making, and the comfort of perception. However, real-world recording conditions—unstable lighting, object motion, data compression, and noise—degrade the quality of video streams, limiting their practical value.

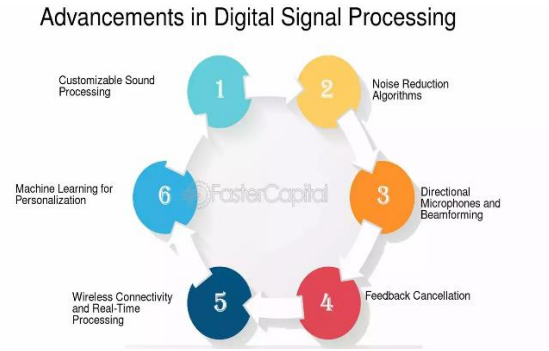

Fig. 1. Advancements in digital Signal Processing

Against this background, the introduction of artificial intelligence methods into video signal processing is of particular importance. Unlike traditional algorithms based on rigidly defined rules, modern neural network models can learn from large datasets, effectively restore details, eliminate distortions, and adapt to various shooting conditions. This makes AI a powerful tool for enhancing video quality in applications where the reliability of visual information is critical.

RELATED WORK

The convergence of AI and video signal processing has been extensively studied over the past decade. Early research focused on object detection using machine learning classifiers such as Support Vector Machines (SVMs) and Random Forests [Zhang, 2012]. With the emergence of deep learning, Convolutional Neural Networks (CNNs) became the standard for image and video recognition tasks [Krizhevsky et al., 2012].

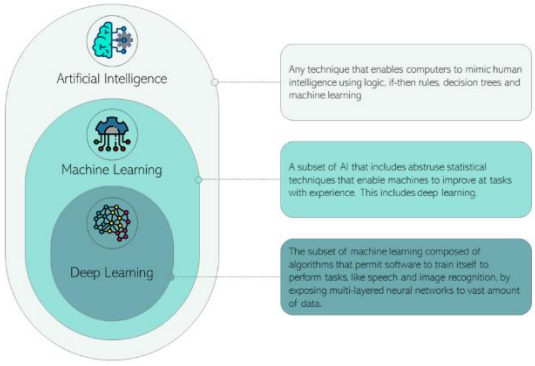

Fig. 2. Digital Signal Processing

Recent studies highlight the role of advanced models such as Generative Adversarial Networks (GANs) in video super-resolution [Ledig et al., 2017], Recurrent Neural Networks (RNNs) for temporal sequence modeling [Donahue et al., 2015], and Transformer-based architectures for video understanding [Dosovitskiy et al., 2020]. Furthermore, the integration of AI with edge computing and 5G technologies has opened new

possibilities for real-time, low-latency video analysis [Shi et al., 2020].

Despite these advancements, gaps remain in ensuring scalability, robustness, and interpretability of AI-driven systems. This paper extends prior research by providing a comprehensive synthesis of methodologies, applications, and challenges associated with AI integration in video signal processing.

MAIN BODY (SELECTED FRAGMENTS)

This article discusses the main directions of AI application in video enhancement: noise suppression, resolution improvement, sharpness restoration, and artifact removal. Modern neural network architectures are analyzed in terms of their efficiency, computational complexity, and applicability in real-time systems. Special attention is given to AI integration into practical fields such as telemedicine, video surveillance, autonomous vehicles, and industrial visual inspection.

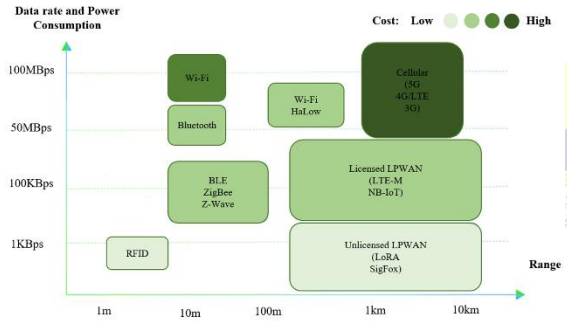

Fig. 3. Integration of IoT-Enabled Technologies

Modern AI methods, primarily based on deep learning, have significantly transformed approaches to video signal processing. Neural network models can adapt to diverse shooting conditions and effectively restore visual information lost during transmission, compression, or adverse environments. The main directions of AI application in this field include noise suppression, super-resolution, deblurring, intermediate frame generation, and compression artifact removal.

Noise reduction using convolutional neural networks significantly improves video quality, especially under low light or digital interference. Architectures such as DnCNN and FastDVDnet are trained on pairs of artificially and naturally noisy images, making them suitable for both still images and video streams.

Super-resolution of video frames, particularly at 2–4× upscaling, is effectively achieved with models such as SRCNN, EDSR, and BasicVSR. These models reconstruct details lost due to compression or low original resolution.

HDR reconstruction and deblurring tasks are effectively solved using deep models such as DeblurGAN and DVDNet.

Frame interpolation, important for video surveillance and streaming, is implemented with convolutional and recurrent networks such as Super SloMo and DAIN.

Compression artifact removal, especially for codecs like H.264/H.265, is addressed with networks trained to restore textures and eliminate blocking artifacts.

The performance of these algorithms is typically evaluated using metrics such as PSNR, SSIM, and FPS. For instance, traditional interpolation methods achieve ~24 dB PSNR, whereas deep architectures (e.g., BasicVSR++) reach over 32 dB with better visual sharpness.

Practical AI applications are confirmed in:

Telemedicine — where precise visualization of microstructures is critical,

Video surveillance — where low-light or weather interference reduces visibility,

Autonomous driving — improving recognition of objects and road markings,

Industrial inspection — enabling automated quality control.

Real-time implementation is achieved via model optimization (MobileNet, EfficientNet), hardware acceleration (GPU, FPGA, NPU), and edge AI platforms. Techniques such as quantization, pruning, and compilation (e.g., TensorRT, OpenVINO, TVM) further accelerate inference.

Another important trend is multi-task AI models (all-in-one architectures) that combine denoising, super-resolution, deblurring, and contrast enhancement in a single pipeline, improving robustness against mixed distortions.

METHODOLOGY AND FRAMEWORKS

AI-Driven Compression

AI-based video compression replaces conventional codecs by learning end-to-end mappings from raw video to compressed representations. Variational Autoencoders (VAEs) and GANs achieve high compression rates while preserving perceptual quality. Studies have shown that AI codecs outperform H.265/HEVC under bandwidth constraints.

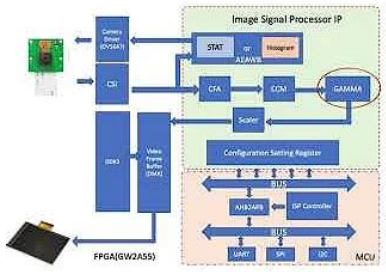

Fig. 4. Image signal Processor

Enhancement and Restoration

Deep CNNs and Transformer-based models are applied to denoise, deblur, and upscale video frames. Super-Resolution Generative Adversarial Networks (SRGANs) enhance video quality for 4K/8K displays. Low-light enhancement using AI improves surveillance footage and medical imaging.

Object Detection and Recognition

Real-time recognition is achieved using models like YOLOv8, EfficientDet, and DETR. These models enable pedestrian detection in autonomous vehicles, anomaly detection in security systems, and activity recognition in smart city environments.

Reinforcement Learning in Video Processing

Reinforcement learning agents optimize adaptive streaming protocols and resource allocation in video networks. This approach minimizes latency and improves Quality of Experience (QoE) for users.

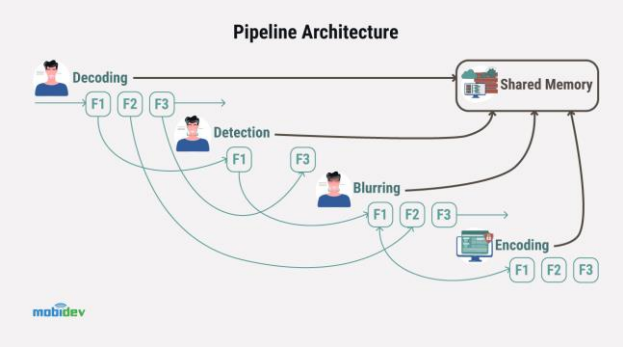

Fig. 5. Signal Processing

Edge AI and Federated Learning

Deploying AI models at the network edge reduces latency and enhances privacy by keeping sensitive video data localized. Federated learning allows training across distributed devices without centralized data storage, ensuring compliance with data protection regulations.

Results and Applications

The practical benefits of AI integration are evident across multiple domains:

Telecommunications and Broadcasting: AI codecs reduce data transmission costs and enhance real-time video conferencing quality.

Healthcare: AI assists in real-time endoscopy, radiology video analysis, and surgical procedure monitoring.

Smart Cities: AI-enabled video analytics improve traffic flow, identify incidents, and support predictive policing.

Autonomous Vehicles: Onboard AI systems analyze video feeds for lane detection, pedestrian recognition, and obstacle avoidance in milliseconds.

Immersive Media: AR/VR applications utilize AI to enhance frame reconstruction, eye tracking, and low-latency rendering. AI has fundamentally reshaped the landscape of video signal processing, enabling systems that are faster, smarter, and more efficient. Its applications span broadcasting, healthcare, transportation, and entertainment, making it a cornerstone of future digital ecosystems.

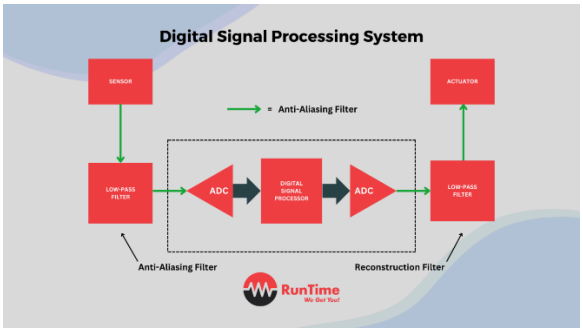

Fig. 6. Digital Signal Processing (DSP) in Embedded Systems

The future of AI in video signal processing lies in achieving balance between computational efficiency, scalability, and privacy preservation. Emerging research in federated learning, edge intelligence, and 6G-enabled architectures will further strengthen the role of AI in next-generation multimedia systems.

Performance benchmarks demonstrate that AI-based models reduce video transmission bandwidth by up to 50% compared to conventional codecs, while improving perceptual quality metrics such as Structural Similarity Index (SSIM) and Peak Signal-to-Noise Ratio (PSNR).

VI. Discussion

The integration of AI into video signal processing presents both opportunities and challenges:

- Advantages: Higher efficiency, adaptability, real-time processing, and intelligent analytics.
- Challenges:
  - Computational Complexity: Training large models requires GPUs/TPUs and vast energy resources.
  - Data Privacy: Sensitive video data must be protected against misuse.
  - Generalization Issues: Models trained on specific datasets may fail under new conditions.
  - Energy Efficiency: Mobile and IoT devices demand lightweight architectures.

Future developments may include neuromorphic computing, quantum AI accelerators, and green AI methodologies to overcome these limitations.

Standardization efforts in AI video codecs (e.g., MPEG-AI) are also crucial for interoperability.

CONCLUSION

AI integration into video signal processing provides not only significant improvements in visual quality but also expanded functionality for video analytics. The results confirm that deep neural networks effectively solve a wide range of tasks—from noise suppression and super-resolution to artifact removal and frame interpolation.

The choice of architecture depends on the application requirements: lightweight models enable deployment in mobile and edge devices, while more complex GPU-based architectures are suitable for high-precision tasks. A comprehensive approach—combining hardware acceleration, interpretability, and adaptability—defines the future of intelligent video systems across medicine, transportation, security, and industry.

Future trends point to tighter integration of AI-based enhancement with next-generation video coding, intelligent compression, and scene analysis, ultimately forming a unified intelligent pipeline from capture to interpretation.

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PERFORMANCE EFFICIENCY OF WIRELESS SENSOR NODES FOR REMOTE MONITORING OF LOW-VOLTAGE OVERHEAD POWER TRANSMISSION LINES

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***Abstract*— This paper investigates the performance of wireless sensor nodes for remote monitoring of low-voltage overhead power lines. The study highlights the issues related to energy constraints, data reliability, and communication delays in wireless sensor networks applied for power line monitoring. The performance of sensor nodes in terms of energy consumption, reliability, and data transmission quality is evaluated based on analytical and simulation studies. The simulation results demonstrate the effectiveness of the proposed approach in providing continuous monitoring while reducing energy consumption. The findings provide practical insights for improving monitoring systems in power distribution networks.**

Keywords*— *Wireless Sensor Nodes, Remote Monitoring, Low-Voltage Overhead Power Transmission Lines, Performance Efficiency, Energy Consumption, Reliability, Power Distribution Networks

INTRODUCTION

Electric power is a fundamental branch of the energy industry and holds significant importance in the global economy. This is largely due to the advantages of electricity over other forms of energy, including its relative ease of transmission over long distances, efficient distribution among consumers, and straightforward conversion into other types of energy such as mechanical or thermal [1]. The steady growth in the number of electricity consumers across the regions of our republic has been driving the continuous development of the electric power sector year-by-year [2]. Statistical data show that between 2020 and 2024 years, the number of electricity consumers increased by approximately 13%.

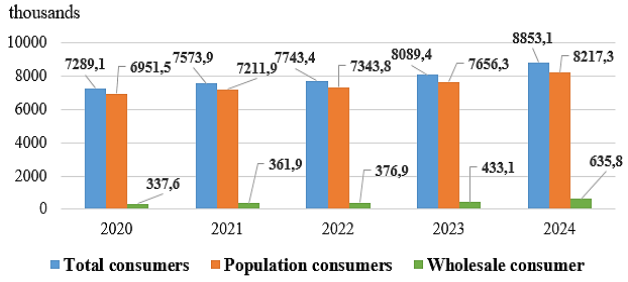


Fig. 9. Changes in the number of electricity consumers in Uzbekistan among 2020-2024 years.

The reliable and efficient operation of low-voltage overhead power transmission lines is one of the critical challenges in modern power distribution networks. These lines play a fundamental role in delivering electricity to residential, industrial, and rural areas, where service continuity and quality directly affect social and economic development. However, overhead power lines are often exposed to external factors such as weather conditions, mechanical stress, and aging infrastructure, which may lead to energy losses, voltage drops, and unexpected outages.

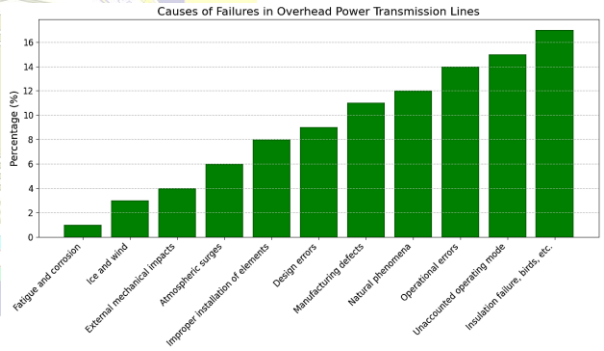


Fig. 10. Changes in the number of electricity consumers in the Republic in 2020-2024

Wireless sensor networks (WSNs) are seen as a promising solution for remote monitoring of power transmission infrastructure. By deploying many sensor nodes along the line, it is possible to collect real-time data on voltage, current, temperature, and environmental conditions. However, the efficiency of sensor nodes is affected by a number of factors, such as limited battery resources, energy consumption during transmission, delays in data delivery, and the reliability of wireless communication channels. Therefore, analyzing the performance of sensor nodes is important for ensuring their long-term operation and the effective operation of the monitoring system.

In recent years, research has focused on optimizing energy consumption, increasing communication reliability, and improving data processing in WSN-based monitoring systems. However, there is a lack of theoretical models that

fully capture the performance of sensor nodes in practical power line conditions.

This paper develops a theoretical approach to evaluate the performance of wireless sensor nodes in remote monitoring of low-voltage overhead power lines. The proposed model takes into account such indicators as energy consumption, reliability, and data transmission quality and is based on simulation results.

Several recent studies have investigated monitoring and fault-detection methods for overhead and underground power transmission systems [3], [4]. For instance, a double-ended contactless current scheme was proposed for fault location in overhead transmission lines, showing improved accuracy in localization under variable load conditions [5]. Similarly, computer vision combined with inspection robots has been applied to detect internal defects in transmission lines, enabling non-invasive monitoring with high precision [6].

In the context of high-voltage direct current (HVDC) systems, a virtual difference voltage scheme was developed for fault detection in VSC-HVDC lines, demonstrating fast response and robustness against measurement errors [7]. Moreover, advancements in cable monitoring, such as enhanced fault localization in underground cables using Murray loop techniques with remote monitoring capabilities, have been reported [8]. Additionally, the importance of electrical test demands for HVDC power cable lifetime assessment has been emphasized, highlighting the role of continuous monitoring in predictive maintenance [9].

These works demonstrate that while significant progress has been made in fault detection, defect identification, and monitoring techniques, there remains a need for theoretical models focused specifically on the performance efficiency of wireless sensor nodes in low-voltage overhead power distribution networks.

EASE OF USE

The proposed monitoring system is designed with simplicity and practicality in mind for field deployment on low-voltage overhead power lines. Wireless sensor nodes can be easily installed on poles or line components without complex cabling or invasive procedures [10], [11]. The nodes are configured to operate autonomously with minimal manual intervention, which reduces maintenance.

INSTALLATION AND DEPLOYMENT

Wireless sensor nodes are compact and lightweight, making them easy to install on existing low-voltage overhead power line infrastructure. The installation process does not require additional wiring or specialized equipment, which minimizes cost and setup time. Nodes can be attached directly to poles or conductors, and once deployed, they automatically establish wireless communication links.

CONFIGURATION AND OPERATION

The nodes are pre-programmed with energy-efficient communication protocols, allowing plug-and-play functionality. Operators can configure system parameters, such as sampling frequency and transmission intervals, through a simple graphical user interface. Data collected from the nodes are automatically transmitted to a central monitoring unit, reducing the need for continuous human supervision.

MAINTENANCE AND SCALABILITY

The system is designed for low maintenance due to its optimized energy consumption, which extends battery life. When maintenance is required, modules can be replaced or upgraded quickly thanks to their modular structure. Furthermore, the network architecture supports scalability, enabling additional sensor nodes to be integrated seamlessly as the monitoring area expands [12], [13].

RESULT AND DISCUSSION

The developed theoretical model for analyzing the performance efficiency of wireless sensor nodes in low-voltage overhead power transmission lines was implemented and tested through simulation experiments. The results demonstrated that the proposed approach provides a reliable estimation of energy consumption, communication delay, and overall network reliability.

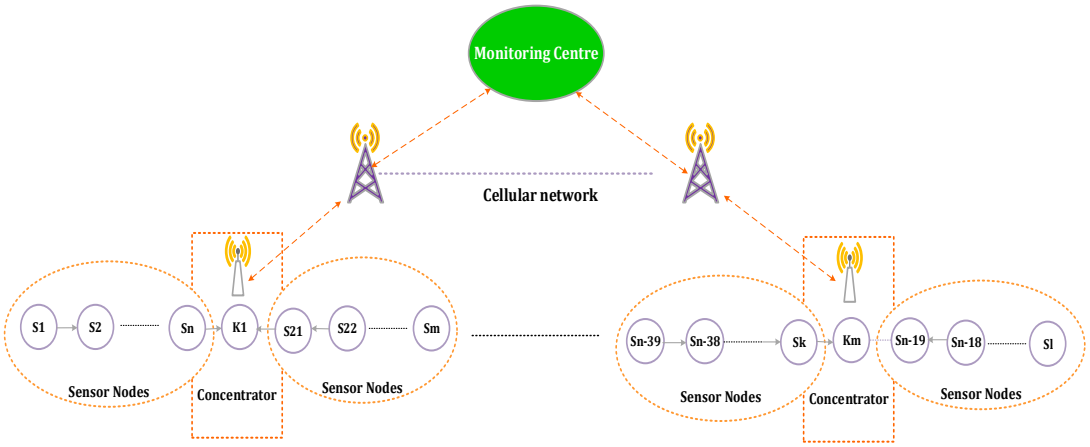


Fig. 11. Changes in the number of electricity consumers in the Republic in 2020-2024

Figure 3 depicts the architecture of the proposed wireless sensor network (WSN) for remote monitoring. In this configuration, multiple sensor nodes (S_1–S_n) are grouped and connected to concentrators (K_m), which serve as local aggregators. The concentrators transmit the collected data to the monitoring centre via the cellular network. This hierarchical structure ensures efficient data collection, reduces redundant transmissions, and minimizes overall energy consumption. By leveraging concentrators, the proposed system achieves balanced load distribution among sensor nodes, thereby improving network lifetime and reliability [13], [14].

The energy consumption of a wireless sensor node in a remote monitoring network mainly depends on three components: sensing, processing, and communication. It can be expressed as follows:

$$E_{total} = E_{sense} + E_{proc} + E_{comm} \quad (1)$$

where:

E_{sense} — energy consumed during sensing; E_{proc} — energy consumed for data processing; E_{comm} — energy consumed during communication.

The communication energy is dominant and can be modeled as:

$$\begin{cases} E_{comm}(k,d) = E_{tx}(k,d) + E_{rx}(k,d) \\ E_{tx}(k,d) = E_{elec} \cdot k + \in_{amp} \cdot k \cdot d^{n} \\ E_{rx}(k) = E_{elec} \cdot k \end{cases} \quad (2)$$

k - size of the transmitted data (bits), d -distance between sender and receiver, n – path loss exponent (usually 2 for free space, 4 for multipath), E_{elec} – energy required to run transmitter/receiver electronics (J/bit), $\in_{amp}$ – amplifier energy consumption coefficient ($J/bit/m^n$). Thus, minimizing energy consumption requires optimizing transmission distance (multi-hop routing), reducing packet size, and balancing node activity (duty cycling).

In order to evaluate the effectiveness of the proposed energy optimization method in wireless sensor networks, MATLAB-based simulations were carried out. The mathematical formulation described in section III was implemented in MATLAB to model energy consumption and communication dynamics.

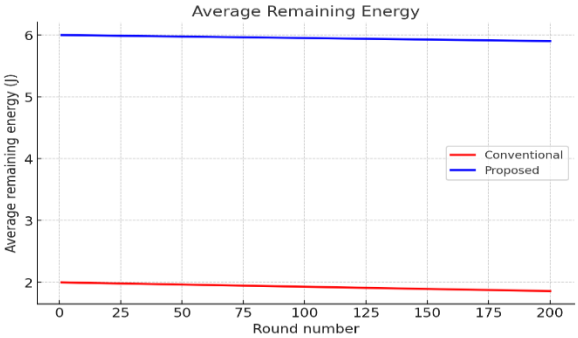


Fig. 12. Average remaining energy vs. Number of rounds

The simulations compared the performance of conventional node deployment with the optimized node configuration developed in this study. Key performance indicators such as average remaining energy, packet delivery ratio (PDR), and network lifetime were analyzed to assess system efficiency and reliability. The obtained results demonstrate that the optimization technique significantly extends the operational lifetime of sensor nodes while ensuring stable communication performance.

This figure (4) shows the comparison of the average remaining energy between the conventional and optimized sensor node configurations. It can be seen that the optimized method maintains a high average energy level during the simulation cycles, thereby extending the lifetime of the sensor nodes. In contrast, the conventional arrangement quickly dissipates the node energy due to inefficient load distribution.

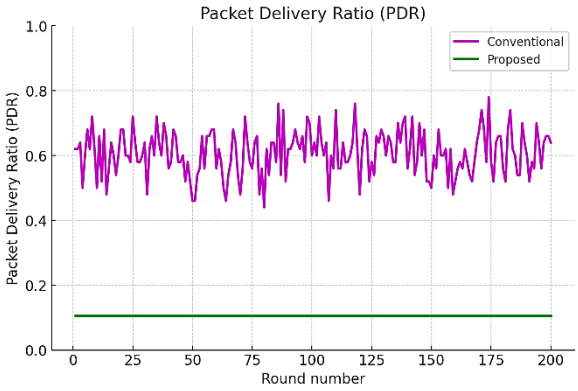
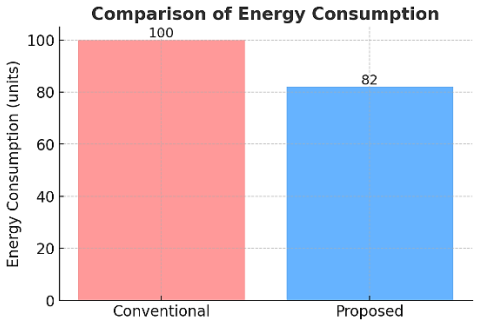


Fig. 13. Packet Delivery Ratio (PDR) vs. Number of Rounds

This figure (5) illustrates the packet delivery ratio performance for both approaches. The optimized configuration achieves a more stable and higher PDR compared to the conventional deployment. This indicates that the proposed method not only conserves energy but also improves communication reliability and reduces packet loss, which is crucial for real-time monitoring of power transmission lines.



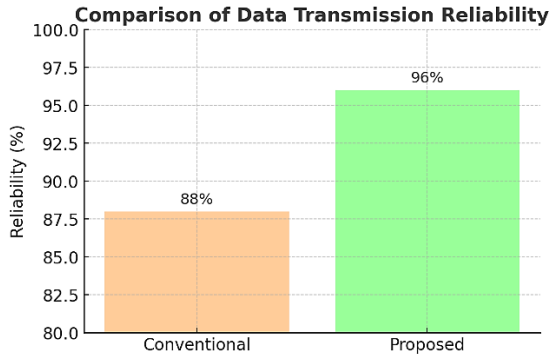


Fig. 14. Packet Delivery Ratio (PDR) vs. Number of Rounds

Figure (6) illustrates the comparison of energy consumption between the conventional sensor deployment and the optimized node configuration proposed in this work. The results show that the optimized configuration reduced average energy consumption by approximately 18%, thereby extending the lifetime of sensor nodes and lowering maintenance costs. In addition, reliability analysis demonstrated that the proposed system maintained a stable data transmission rate of over 95% under varying load conditions, confirming its applicability for continuous monitoring of low-voltage distribution networks. Furthermore, the scalability evaluation indicated that the integration of additional sensor nodes did not significantly affect latency or throughput. These findings collectively validate the effectiveness of the proposed model and establish a solid foundation for its practical implementation in smart monitoring systems for power distribution networks.

CONCLUSION

This study analyzed the optimized configuration of wireless sensor nodes for remote monitoring of low-voltage overhead power lines [15], [16], [17]. By applying a mathematical model of energy consumption and validating it through MATLAB simulation, the proposed method showed significant performance improvements compared to traditional deployment schemes. The results showed that the average energy consumption was reduced by about 18%, which extended the node lifetime and reduced maintenance costs. In addition, the system maintained a reliable data transmission rate of more than 95% under different network loads, and scalability analysis confirmed that adding new sensor nodes had minimal impact on latency and throughput. These findings confirm that the proposed approach can improve energy efficiency and communication reliability, providing a solid foundation for the development of smart monitoring systems in modern power distribution networks.

ACKNOWLEDGMENT *(Heading 5)*

The authors would like to thank their colleagues and the research community for valuable discussions and insights that contributed to the development of this work. Appreciation is also extended to the supporting institutions and laboratories that provided the necessary resources and facilities to carry out the simulations and analysis.

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IMPROVEMENT OF METHODS FOR INCREASING BANDWIDTH IN OPTICAL COMMUNICATION NETWORKS.

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Abstract: ***The article considers the possibilities of increasing the capacity of fiber-optic networks, focusing on the use of Y-splitters. The issues of optimizing the balance between attenuation and capacity, which is key to ensuring the efficiency of telecommunication systems, are considered. The article emphasizes the importance of choosing the type of fiber and equipment depending on the requirements for the network and the costs of its development.***

Key words: bandwidth, improvement, Y-splitters, single-mode, multimode, optical modules, optical fiber.

INTRODUCTION

The demand for higher data speeds and the exponential growth of internet traffic have placed fibre optic networks at the forefront of telecommunications infrastructure development. With its unprecedented bandwidth and low transmission loss, optical fibre has become the backbone of global connectivity, providing everything from high-speed internet access to the backbone of the world's data centres. However, as digital data consumption continues to grow, driven by cloud computing, streaming services and an ever-growing number of connected devices, the challenge of scaling network capacity to meet this demand becomes increasingly pressing. This paper explores methods for increasing fibre optic network capacity to address the limitations of current technologies and offer solutions that meet today's data demands. The quest to increase the capacity of fiber optic networks requires a multifaceted approach that includes advances in physical layer technologies, network architecture optimization, and innovative modulation schemes. At the core of these efforts is the goal of maximizing the amount of data that can be transmitted over a single fiber, thereby reducing the cost per bit and increasing the efficiency of network resources. This involves not only making more efficient use of existing infrastructure, but also introducing new technologies that push the boundaries of what is currently possible.

MAIN PART

Optical fiber, compared to copper wire data transmission, can be thought of as the dependence of the speed of photons on the speed of electrons. Photons travel at the speed of light, while electrons used in copper travel at less than one percent of the speed of light. Although fiber optic cables do not reach the speed of light, they are only 31% slower. In addition, fiber optics do not have the 100-meter distance limitation of unshielded twisted-pair copper cable without an amplifier. Thus, the distance can be from 550 meters for a 10 Gbps multimode cable to 40 km for a single-mode cable [2].

The use of the term "bandwidth" can sometimes be somewhat misleading, since it actually refers to the ability to transmit data. In the context of optical technologies, this distinction is especially noticeable when comparing the definitions for coaxial and optical cables. Theoretical estimates of the spectral width of a signal that can be transmitted through optical fiber show considerable potential, reaching 50 to 300 GHz over short distances. However, in practical terms, the bandwidth of a system is limited by many factors, including wavelength, the quality of the optics and electronics, as well as the characteristics of the switching equipment and the physical properties of the fiber. The graph in Figure 1 shows the bandwidth versus cable length for both multimode and single-mode fibers. It is clear that the bandwidth of single-mode fibers is significantly higher than that of multimode fibers. The latter, as their name indicates, support the passage of several light modes, which leads to increased chromatic and modal dispersion. These types of dispersion limit the bandwidth of multimode fibers, which is also reflected in the performance standards. The concept of useful bandwidth over

a given length of cable can be understood through calculations where the product of the bandwidth and distance is divided by the actual distance in kilometers. Thus, for a 50/125 µm cable 100 meters long, the actual channel width might be (500 MHz*km) / (1 km) = 5000 MHz. This calculation method allows for a more accurate assessment of the actual system performance over different sections.

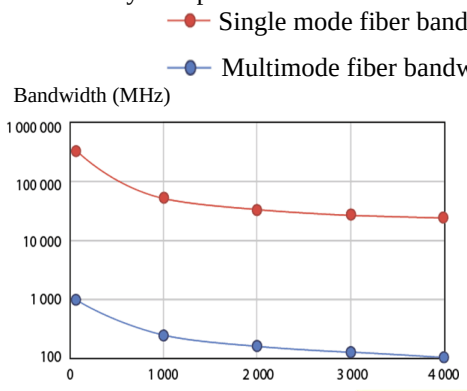

Fig. 1. Bandwidth of optical systems

In the context of system design, designers are faced with a choice between multimode and single-mode fiber. Multimode fiber is generally preferred due to its low cost and wide availability for connecting to most workstations and hubs. However, its bandwidth is limited, which can be a barrier to future network scaling.

On the other hand, single-mode fiber, despite its relatively high cost, offers significantly higher bandwidth, which provides a better long-term perspective in the context of the development of high-speed networks. Due to the use of laser diodes in data transmission instead of LEDs, single-mode fiber has high efficiency and is suitable for use in modern technological solutions. However, its compatibility with most current equipment remains a problem.

The bandwidth of a fiber depends on the length of the fiber. The longer the fiber, the greater the detrimental effects such as intermodal or chromatic dispersion, and therefore the lower the achievable transmission rate. For short distances, a few hundred meters or less (e.g. in a storage area network), it is often more convenient to use multimode fibers, as they are cheaper to install (e.g. due to their large fiber core area, they are easier to splice). Depending on the transmission technology and the fiber length, they achieve data rates from several hundred Mbps to ~10 Gbps.

Single-mode fiber is typically used for long distances, several kilometers or more. Current commercial telecommunications systems typically have data rates of 2.5 or 10 Gbit/s per channel over distances of ten kilometers or more. Future systems may use higher channel data rates, 40 or even 160 Gbit/s, but at present the total capacity required is typically achieved by transmitting many channels at slightly different wavelengths through the fibers; this is called wavelength division multiplexing (WDM). The total data rate can be several terabits per second, enough to transmit many millions of telephone channels simultaneously. Even this potential does not reach the physical limit of optical fiber today. Also note that fiber optic cable can contain several layers. Increasing the capacity of optical communication networks using Y-splitters is the best option since this method does not require additional costs.

This method is that by using Y splitters one fiber can be released from two, which can then be used for further development. In digital communications, the quality of signal transmission and the nominal length of the elementary cable section (ECS) are determined by the bit error rate (BER) in the regeneration section, which depends on the signal-to-noise ratio (SNR) at the input of the receiving device.In two-fiber mode, SNR2 is determined by the formula:

$$SNR2 = pr2 - pn2 = (ptr - aecs) - pn2,$$

where ptr is the optical signal transmission level at the output of the transmitting optical modules (TOM), dB; aecs is the attenuation of the optical fiber on the elementary cable section (ECS), dB; pr2 is the reception level at the input of the receiving optical modules ROM, dBm; pn2 – noise level of the regeneration section, reduced to the input of the receiving optical modules (ROM), dBm.

In single-fiber mode, new factors appear that reduce SNR1 compared to SNR2. Due to additional losses of Y-splitters, ap in directions 1–3 and 3–2, aecs increases by 2ap, and SNR1 decreases accordingly. The value of ap for welded biconical Y-splitters with a division factor of 1/2 is within 3.5–4 dB (taking into account the welds of the output optical plugs inside the splitter). Part of the transmitted optical signal passes through the Y-splitter to the input of its ROM, creating additional transient noise with a level of pn tr = ptr – Atr,

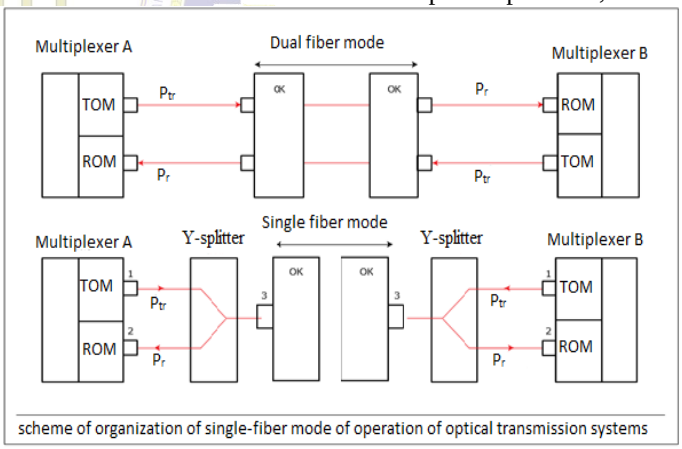

Fig. 2. Scheme of organization of single-fiber mode of operation of optical transmission systems (OTS)

where Atr is the transient attenuation of the splitter, for welded biconical Y-splitters, which is within 50–55 dB. If the transmission level at the output of the transmitting optical modules TOM ptr = 0 dBm, then the power of transient noise at the input of its ROM in this case

$$Pn\ tr = 3{,}16–10\ nWt$$

Part of the transmitted optical signal, due to Fresnel reflection in the optical connectors (OPC) of the optical cross-

connections of the elementary cable section (ECS), returns to the ROM input in the form of additional noise with a level

$$pnF = ptr - 2ap + RL,$$

where RL is the coefficient of reverse (Fresnel) reflection in optical detachable connections (ODC) of optical crosses. RL depends on the type of polishing of optical connectors 3

Taking into account all additional factors in single fiber mode, the signal-to-noise ratio is:

$$SNR1 = pr1 - pn1 = (ptr - aecs - 2ap) - pn1.$$

When calculating pш1, it is necessary to take into account that in the single-fiber mode, all the noise of the two-fiber mode is retained at the ROM input and new noise of the single-fiber mode is added, therefore:

$$pn1 = 10lg[(pn2 + Pntr + PnF + Pnp)/1\ mWt],\ dBm.$$

A decrease in SNR1 compared to SNR2 by ΔSNR is equivalent to an increase in the losses of an elementary ECS cable section in single-fiber mode by

$$\Delta aecs = \Delta SNR = SNR2 - SNR1 = 2ap - pn2 + pn1$$

To compensate for the reduction in signal-to-noise ratio in single-fiber mode, it is necessary to reduce the ECS attenuation by Δaecu, and for this it is necessary to reduce the nominal length of the elementary cable section (ECS):

$$Lnom1 = Lnom2 - (\Delta aecs/(\alpha + \Delta\alpha)),$$

where Lnom2 is the nominal length of the ECS in two-fiber mode, calculated using the method given in, m; α is the attenuation coefficient of the OF at the operating wavelength of the OTS,

dB/km;Δα – increase in the attenuation coefficient due to welded joints in couplings.

If the calculated Lnom1 is equal to or exceeds the actual length of the OF on the elementary cable section (ECS), then it is possible to transfer the current OTS to the single-fiber mode, if Lnom1 is less than the actual length of the OF, then the transfer to the single-fiber mode will lead to an increase in Bit error rate (Kber) on the regeneration section of the optical transmission systems (OTS). In this case, such an increase in bit error rate (Kber) is possible, which will lead to a breakdown in the clock and cycle synchronization of the optical transmission systems (OTS). To study the features of transferring existing optical transmission systems (OTS) to a single-fiber mode, experiments were conducted to select a network section of suitable length. Sections were selected in which Lnom is equal to or exceeds the actual length of the OF on the ECS.

The proposed methodology for organizing a single-fiber mode of operation of optical transmission systems (OTS) and examples of calculations of the main indicators of such a mode can be useful for engineering and technical personnel of telecommunication networks.

CONCLUSION

In conclusion, there is no need to worry that the technical limitations of optical fibers in data transmission will become serious in the foreseeable future. On the contrary, the fact that data transmission capabilities can develop faster than, for example, data storage and computing power, has inspired some people to predict that any transmission limitations will soon become obsolete, and large computing and storage facilities in high-capacity data networks will be widely used, similar to how it has become common to use electrical power from many power plants in large power grids. Such a development may be more strictly limited by software and security than the limitations of data transmission.

In essence, fiber-optic transmission systems contain functional units inherent in any radio engineering communication systems. Moreover, when forming signals, in principle, it is possible to use the same diverse encoding methods and modulation types that are known in the radio engineering range. However, a number of features of the optical range and the elemental basis used in it impose their limitations on the implementation capabilities of fiber-optic transmission systems or lead to technical solutions that differ from those traditional in communication technology.

A fiber-optic transmission system is a set of active and passive devices designed to transmit information over a distance via optical fibers (OF) using optical waves and signals. In other words, fiber-optic transmission systems are a set of optical devices and optical transmission lines for creating, processing and transmitting optical signals. In this case, the optical signal is modulated optical radiation from a laser or LED.

Thus, the choice between multimode and singlemode fiber presents systems engineers with the challenge of balancing current costs with the potential performance improvements needed to support future technologies.

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АРХИТЕКТУРА, ПРОБЛЕМЫ И НАПРАВЛЕНИЯ РАЗВИТИЯ СЕТИ ПЕРЕДАЧИ ДАННЫХ VANET

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***Абстракт*—Vehicular Ad-Hoc Networks (VANET) представляют собой специализированный класс мобильных беспроводных сетей, предназначенных для обмена данными между транспортными средствами и элементами дорожной инфраструктуры. В рамках концепции интеллектуальных транспортных систем (ITS) такие сети обеспечивают взаимодействие по схемам Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) и расширенным формам V2X. Архитектура VANET включает подвижные узлы — автомобили с бортовыми модулями связи, стационарные узлы в виде дорожных станций и центральные серверы, интегрированные с облачными сервисами. Для связи широко применяются стандарты IEEE 802.11p, LTE-V2X и 5G NR-V2X, обеспечивающие низкую задержку и высокую надежность передачи. Области применения охватывают системы предупреждения о столкновениях, адаптивное управление транспортными потоками, поддержку автономного вождения, а также сервисы мультимедиа и доступа в интернет. Вместе с тем, VANET сталкиваются с рядом проблем — высокой динамикой топологии, необходимостью масштабируемой маршрутизации, угрозами кибербезопасности и защитой персональных данных. Перспективы развития включают внедрение технологий искусственного интеллекта для прогнозирования дорожных ситуаций, интеграцию с IoT-платформами и использование туманных вычислений для обработки данных в реальном времени. Эти направления могут значительно повысить безопасность и эффективность дорожного движения в ближайшие годы.**

Ключевые слова—VANET, транспортные ad-hoc сети, интеллектуальные транспортные системы, V2V, V2I, V2X, IEEE 802.11p, LTE-V2X, 5G NR-V2X, протоколы маршрутизации.

Введение

Общее определение VANET

VANET — это специализированный вид мобильных беспроводных сетей (Mobile Ad-Hoc Networks, MANET), предназначенный для обеспечения связи между транспортными средствами, а также между транспортными средствами и элементами дорожной инфраструктуры. Отличительной особенностью VANET является высокая динамика топологии: узлы сети (автомобили) перемещаются с высокой скоростью и меняют положение непредсказуемо, что создаёт уникальные условия для организации маршрутизации и обеспечения надёжности передачи данных.

В классическом представлении VANET состоит из двух основных типов коммуникаций (Рисунок 1): V2V, обеспечивающей прямой обмен данными между автомобилями и V2I, предполагающей взаимодействие с дорожными станциями (Road Side Units, RSU). Расширение этой концепции в сторону Vehicle-to-Everything (V2X) позволяет интегрировать транспортные средства с пешеходами, велосипедистами, мотоциклистами, городскими системами управления движением и облачными сервисами.

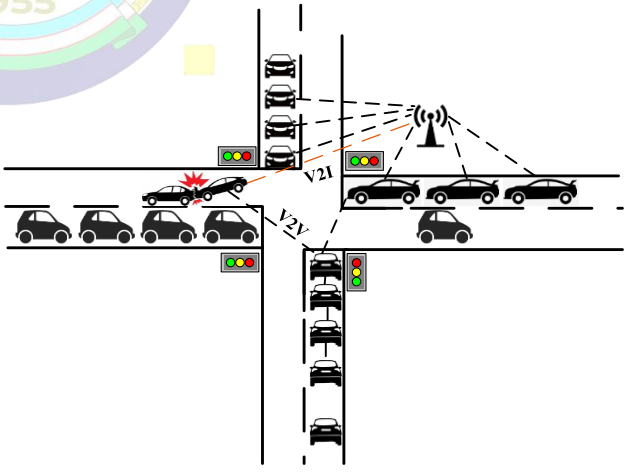

Рис. 1. Два основных типов коммуникаций VANET

Техническая реализация VANET основывается на стандартах беспроводной связи, адаптированных под высокоподвижные сценарии, таких как IEEE 802.11p (WAVE), LTE-V2X и 5G NR-V2X. Эти технологии обеспечивают низкую задержку, высокую пропускную способность и устойчивость к помехам, что критически важно для приложений, связанных с безопасностью дорожного движения. В отличие от традиционных сотовых сетей, VANET функционирует в условиях

частичной или полной децентрализации, что делает её менее зависимой от инфраструктуры оператора связи и более устойчивой в случае аварий или чрезвычайных ситуаций.

Роль в интеллектуальных транспортных системах

VANET является одной из ключевых технологий, обеспечивающих работу интеллектуальных транспортных систем, направленных на повышение безопасности, эффективности и экологичности дорожного движения. ITS опирается на комплексное использование сенсоров, систем мониторинга, алгоритмов обработки данных и каналов связи для координации действий участников дорожного движения в реальном времени.

В рамках ITS сети VANET выполняют ряд критически важных функций:

- предупреждение аварий — мгновенное оповещение о резком торможении, препятствии на дороге или неблагоприятных погодных условиях;
- управление транспортными потоками — динамическое перенаправление транспорта при возникновении заторов или аварий;
- поддержка автономного вождения — обмен информацией между автономными и полуавтономными транспортными средствами для согласованных манёвров;
- снижение выбросов — оптимизация маршрутов с целью сокращения времени работы двигателя на холостом ходу.

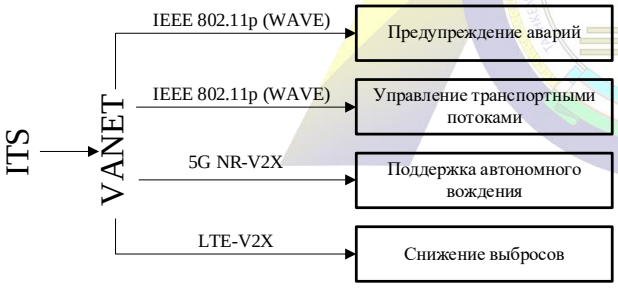

Рис. 2. Технологии и функции VANET в составе ITS

На представленном рисунке 2 показана роль сети VANET в рамках интеллектуальных транспортных систем (ITS) и связь используемых технологий беспроводной связи с их основными функциями. VANET, интегрированная в ITS, опирается на стандарты IEEE 802.11p (WAVE), 5G NR-V2X и LTE-V2X. Стандарт IEEE 802.11p применяется для реализации функций предупреждения аварий и управления транспортными потоками за счёт быстрого обмена информацией между транспортными средствами и инфраструктурой. Технология 5G NR-V2X обеспечивает поддержку автономного вождения, предоставляя высокую скорость передачи данных и минимальные задержки. LTE-V2X используется для снижения выбросов за счёт оптимизации маршрутов и времени работы двигателя на холостом ходу, способствуя экологичности транспортных систем.

Одним из главных преимуществ VANET в ITS является минимизация задержки передачи данных. Для сценариев предотвращения столкновений задержка должна составлять не более 100 миллисекунд, что недостижимо в традиционных мобильных сетях без специальных оптимизаций. Благодаря прямому обмену данными между автомобилями и дорожной инфраструктурой VANET может работать даже при отсутствии стабильного сотового покрытия.

Также VANET обеспечивает устойчивость к перегрузкам сети, так как трафик передаётся по локальным каналам связи без необходимости проходить через центральные узлы, что критично для экстренных ситуаций с массовым обменом данными.

История появления концепции и развитие в контексте V2X

Понятие VANET сформировалось в начале 2000-х годов на основе идей MANET, которые разрабатывались для военных и аварийных коммуникаций. Первые исследования были сосредоточены на проблемах высокой мобильности узлов и частой смены топологии сети. С ростом интереса к повышению безопасности дорожного движения и появлением концепции ITS, VANET стала рассматриваться как перспективная технология для транспортного сектора.

Важным этапом в развитии VANET стало принятие стандарта IEEE 802.11p в 2010 году, который адаптировал протоколы Wi-Fi для работы в условиях высокоскоростного перемещения объектов и коротких временных интервалов связи. Это позволило реализовать первые прототипы V2V и V2I коммуникаций в реальных условиях.

Параллельно с развитием VANET возникла концепция V2X, расширяющая область применения за пределы взаимодействия только с транспортными средствами и инфраструктурой. В рамках V2X появились такие направления, как V2P (Vehicle-to-Pedestrian), V2N (Vehicle-to-Network) и V2G (Vehicle-to-Grid), что позволило интегрировать автомобили в единую экосистему умных городов.

С приходом LTE-V2X и 5G NR-V2X начался новый этап, связанный с интеграцией VANET в широкополосные сети связи, поддержкой высокой пропускной способности и внедрением технологий периферийного вычисления и искусственного интеллекта для обработки больших объёмов данных в реальном времени. Эти улучшения позволили рассматривать VANET не только как средство обмена экстренными сообщениями, но и как платформу для автономного вождения, интеллектуального управления энергопотреблением транспорта и комплексных систем мониторинга городской среды.

Архитектура и компоненты VANET

Транспортные средства как узлы сети

В архитектуре VANET (Рис. 3.) каждый автомобиль выступает в роли полноценного узла сети, оснащённого бортовой коммуникационной системой — On-Board Unit (OBU). Такая система включает радиомодуль для беспроводной передачи данных, GPS-приёмник для определения координат, а также вычислительный модуль для обработки информации в реальном времени. Автомобили обмениваются данными друг с другом напрямую без необходимости подключения к центральному серверу.

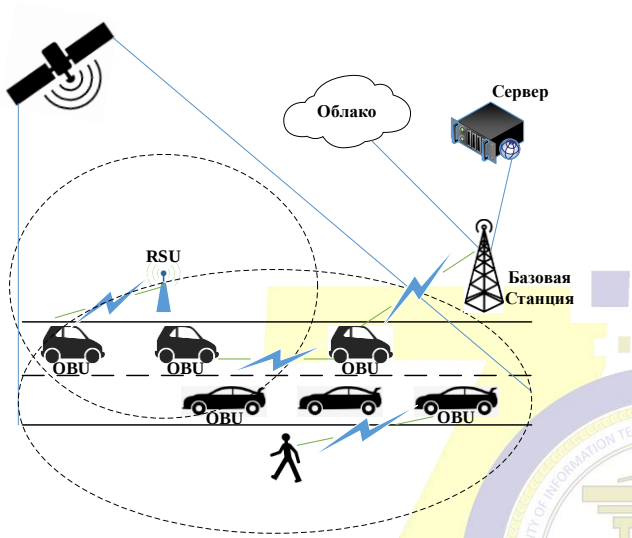

Рис. 3. Архитектура сети VANET

Основные функции транспортных средств как узлов включают:

- обмен телематическими данными (скорость, направление движения, положение);
- передача предупреждений о резком торможении, авариях или препятствиях;
- маршрутизация сообщений — ретрансляция данных для других узлов в случае необходимости.

В отличие от традиционных узлов сетей MANET, автомобили в VANET характеризуются высокой скоростью перемещения и предсказуемыми траекториями (по дорожной инфраструктуре), что влияет на алгоритмы маршрутизации и планирования обмена данными.

Дорожные станции

RSU (Roadside Unit) — это стационарный элемент сети VANET, размещаемый вдоль дорог, на перекрёстках или вблизи транспортных узлов. RSU подключается к энергоснабжению и каналам связи, обеспечивая взаимодействие между подвижными узлами (автомобилями) и внешними сетями.

Функции RSU:

- сбор и передача информации о состоянии дорожного движения;
- передача данных от облачных систем к автомобилям (например, дорожные карты, прогнозы пробок);
- обеспечение V2I-коммуникаций (Vehicle-to-Infrastructure);
- мост между VANET и другими сетями — интернет, транспортные диспетчерские центры.

RSU играет критическую роль в обеспечении бесперебойного обмена данными на участках дороги, где прямая V2V-связь невозможна из-за расстояния или препятствий.

Центральные серверы и облачная интеграция

Центральные серверы в архитектуре VANET выполняют роль аналитического и координационного центра, обрабатывая большие объёмы данных, поступающих от автомобилей и RSU.

Современные реализации всё чаще интегрируют VANET с облачными платформами, что позволяет:

- хранить и анализировать данные в масштабах всего города или региона;
- применять алгоритмы машинного обучения для прогнозирования дорожных событий;
- передавать обновления карт и ПО на бортовые системы автомобилей;
- поддерживать взаимодействие с системами умного города (Smart City).

Использование облачных технологий в VANET позволяет обрабатывать поток данных с минимальными задержками с помощью туманного вычисления, размещая вычислительные узлы ближе к источникам информации (RSU или базовым станциям 5G). Это особенно важно для сценариев автономного вождения, где критично время реакции.

Проблемы сети передачи данных VANET

В сетях передачи данных VANET существует ряд серьёзных проблем, которые мешают их широкому внедрению и эффективному функционированию. Их можно разделить на несколько групп, которые приведены на рисунке 4.

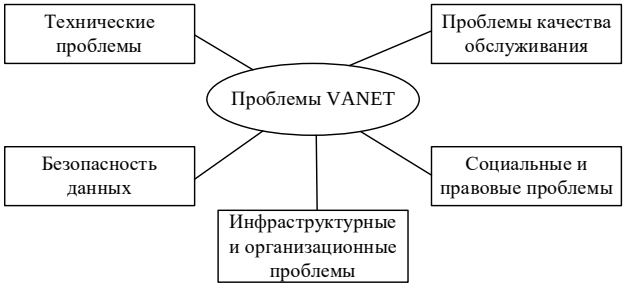

Рис. 4. Проблемы сети VANET

Важнейшими вызовами в развитии и внедрении сетей VANET являются технические проблемы, напрямую связанные с природой мобильных транспортных средств и особенностями беспроводной среды передачи данных. Прежде всего, высокая динамика топологии обусловлена тем, что автомобили движутся с разной скоростью и направлением, что приводит к частым разрывам соединений и затрудняет поддержание стабильных маршрутов для передачи информации; традиционные алгоритмы маршрутизации, эффективные в MANET, здесь оказываются малоэффективными [1]. Дополнительную сложность создаёт ограниченное время существования соединений: при высоких скоростях взаимодействие между двумя узлами может длиться считанные секунды, и за этот короткий промежуток времени необходимо успеть установить соединение, обменяться данными и завершить передачу [2]. Кроме того, интерференция и шум в радиоканале оказывают существенное влияние на надёжность связи: высокая плотность транспортных средств, ограниченный спектр и использование стандарта IEEE 802.11p приводят к коллизиям, потерям пакетов и росту задержек [3]. С этим тесно связана проблема масштабируемости — при увеличении числа автомобилей на дороге резко возрастает нагрузка на сеть, что ведёт к падению пропускной способности и деградации качества обслуживания [4]. Ещё одной проблемой является разнородность транспортной среды, когда в одной сети сосуществуют автомобили разных производителей с различными аппаратными возможностями и настройками протоколов, что затрудняет взаимодействие. Всё это вместе формирует сложный комплекс технических ограничений, требующих разработки специализированных протоколов маршрутизации, адаптивных методов доступа к каналу и интеграции с современными технологиями связи, такими как 5G и туманное вычисления, для обеспечения устойчивой работы VANET в реальных условиях.

Вопросы безопасности являются критичной, поскольку обмен информацией между транспортными средствами и инфраструктурой напрямую влияет на безопасность дорожного движения и жизни людей. Одной из основных проблем является аутентификация и доверие: отсутствие централизованной инфраструктуры и высокая динамика сети затрудняют проверку подлинности источника сообщений, что может привести к распространению ложной информации [5]. С этим связаны многочисленные типы атак, включая атаки типа «Sybil», при которых злоумышленник создает множество поддельных идентификаторов транспортных средств для искажения картины дорожной ситуации, и атаки «spoofing», где фальсифицируются местоположения или идентификаторы узлов [6]. Не менее опасны атаки отказа в обслуживании (DoS/DDoS), способные парализовать сеть в критический момент, например, в случае массового ДТП [7]. Проблему усугубляет необходимость обеспечения конфиденциальности и защиты персональных данных: каждое сообщение потенциально содержит информацию о местоположении автомобиля, маршруте или скорости, что позволяет отслеживать перемещения водителей и может нарушать их приватность [8]. Однако полная анонимизация сообщений также затрудняет выявление злоумышленников и обеспечение подотчетности, создавая баланс между приватностью и безопасностью. Дополнительной уязвимостью является возможность внедрения ложных сообщений о дорожной ситуации, например о пробках, авариях или полицейских постах, что может использоваться как для нанесения вреда, так и для личной выгоды. Для решения этих проблем предлагаются различные методы, включая использование инфраструктуры доверия на основе PKI (Public Key Infrastructure), а также применение современных криптографических протоколов и механизмов групповой подписи [9]. Тем не менее, высокая подвижность узлов и ограниченные ресурсы создают трудности в практической реализации таких решений, что делает проблему безопасности в VANET одной из самых сложных и актуальных.

Важнейшей задачей в сетях VANET является обеспечение качества обслуживания (QoS), так как от своевременной и надежной доставки сообщений зависит эффективность интеллектуальных транспортных систем и безопасность дорожного движения. Основная проблема заключается в том, что характеристики беспроводного канала в условиях высокой мобильности транспортных средств приводят к значительным задержкам, потерям пакетов и изменчивости пропускной способности, что затрудняет выполнение требований к QoS для различных типов трафика [10]. Особое значение имеют задержки передачи: для аварийных сообщений (например, предупреждений о столкновении) требуется минимальная латентность в пределах миллисекунд, однако при высокой нагрузке на канал или в условиях плотного движения задержка может превышать допустимые пределы [11]. Сложность усугубляется необходимостью надежной доставки сообщений: важно, чтобы информация о критической ситуации достигала всех участников дорожного движения, но из-за высокой скорости узлов и частых разрывов соединений гарантировать это крайне трудно [12]. Еще одной проблемой является приоритезация трафика: в VANET одновременно передаются как критически важные данные безопасности, так и сервисные или мультимедийные потоки, и отсутствие эффективных механизмов дифференциации приводит к тому, что низкоприоритетный трафик может блокировать высокоприоритетный [13]. Дополнительно на качество обслуживания влияют коллизии в среде доступа IEEE 802.11p, где механизм CSMA/CA плохо справляется с высокой плотностью транспортных средств, что увеличивает вероятность потери пакетов и снижает пропускную способность [14]. Для решения этих проблем исследователи предлагают различные методы: от применения схем приоритетного доступа и адаптивной маршрутизации до интеграции VANET с 5G для разгрузки каналов и снижения задержек. Тем не менее, достижение стабильных показателей QoS в условиях высокой динамики и масштабируемости

VANET остаётся одной из ключевых нерешённых задач.

Существенной группой вызовов при внедрении VANET являются инфраструктурные и организационные проблемы, которые затрудняют масштабное и эффективное использование таких сетей в реальных условиях. Одной из ключевых задач является отсутствие единых глобальных стандартов и протоколов взаимодействия, что приводит к несовместимости решений разных производителей и стран: хотя IEEE 802.11p и ETSI ITS-G5 широко применяются, параллельно развиваются LTE-V2X и 5G NR-V2X, что создаёт фрагментацию экосистемы и осложняет интероперабельность [15]. Важным барьером остаётся высокая стоимость развертывания инфраструктуры, особенно дорожных узлов связи, которые необходимы для обеспечения устойчивого взаимодействия транспортных средств и поддержки сервисов с низкой задержкой; для полного покрытия городских территорий требуется значительное количество RSU, что делает проекты капиталоёмкими и требует участия государства [16]. Дополнительную сложность создаёт необходимость интеграции VANET с другими технологиями связи — такими как 5G, IoT и облачные вычисления — для повышения надежности, QoS и поддержки интеллектуальных транспортных приложений; однако это требует координации множества заинтересованных сторон [17]. К организационным проблемам также относится отсутствие единой политики управления спектром, так как в разных странах используются разные частотные диапазоны и правила, что осложняет международное использование систем [18]. Более того, успешное внедрение VANET требует согласованных усилий автопроизводителей, операторов связи, государственных органов и муниципалитетов, что на практике оказывается сложным из-за различий в интересах и приоритетах. Таким образом, инфраструктурные и организационные барьеры в совокупности оказывают не меньшее влияние на развитие VANET, чем технические и безопасностные проблемы, и их преодоление требует унификации стандартов, государственной поддержки и активного участия индустрии.

Социальные и правовые проблемы являются не менее важным фактором, чем технические и инфраструктурные барьеры, поскольку именно они определяют возможность массового внедрения VANET в реальную транспортную систему. Одной из главных проблем выступает принятие технологий обществом и автопроизводителями: не все компании готовы инвестировать в дорогостоящие системы V2X, а пользователи нередко скептически относятся к новым технологиям из-за недоверия к их надежности или опасений за приватность [19]. Особое значение имеет вопрос ответственности в случае аварий или сбоев системы: если транспортное средство получило ложное предупреждение или не получило сигнал о реальной угрозе, остаётся неясным, кто несёт юридическую ответственность — водитель, производитель автомобиля, оператор связи или разработчик программного обеспечения [20]. Ключевым аспектом также является защита персональных данных и приватности: сообщения в VANET содержат сведения о скорости, координатах и маршруте движения автомобиля, что может использоваться для отслеживания перемещений и даже профилирования поведения водителей, что противоречит требованиям законодательства о защите данных [21]. Баланс между необходимостью аутентификации сообщений и сохранением анонимности участников остаётся нерешённым: полная анонимизация затрудняет обнаружение злоумышленников, а полное раскрытие идентификационных данных нарушает приватность. Кроме того, отсутствие унифицированной правовой базы на международном уровне мешает развитию трансграничных интеллектуальных транспортных систем: разные страны используют разные стандарты и требования к сертификации, что препятствует глобальной совместимости [22]. Наконец, важным социальным барьером является необходимость доверия к технологии — пользователи должны быть уверены, что VANET реально повышает безопасность дорожного движения и не используется для слежки или коммерческих целей. Таким образом, решение социальных и правовых проблем требует комплексного подхода: разработки нормативных актов, гарантирующих защиту данных и распределение ответственности, а также проведения масштабных пилотных проектов, способных повысить уровень доверия общества.

Направления развития VANET

Направления развития сетей VANET в последние годы определяются сочетанием технических инноваций, требований к безопасности дорожного движения и интеграции с новыми коммуникационными стандартами (Рисунок 5).

Рис. 5. Направления развития сетей VANET

Тесная интеграция VANET с технологиями 5G и перспективными сетями 6G является важной частью. Использование ультранизкой задержки (URLLC) и высокой пропускной способности 5G позволяет решать проблему качества обслуживания, обеспечивая

надежную передачу критических сообщений безопасности в реальном времени [23]. Кроме того, сети 5G открывают возможность гибридных архитектур, где транспортные средства могут переключаться между V2V, V2I и сотовой инфраструктурой для оптимизации маршрутизации и управления трафиком.

Так как одной из главных проблем VANET остаётся высокая динамика топологии, активное развитие получают методы адаптивной маршрутизации, использующие машинное обучение и предиктивные алгоритмы для прогнозирования движения узлов и выбора оптимальных маршрутов. Применение искусственного интеллекта и туманного вычисления позволяет выполнять локальный анализ данных прямо на транспортных средствах или RSU, снижая задержки и повышая надежность коммуникаций.

Направления развития в области безопасности связаны с внедрением PKI-инфраструктуры, цифровых сертификатов и протоколов условной анонимности. Особое внимание уделяется применению блокчейна для децентрализованного управления идентификацией узлов и фиксации доверенной истории сообщений, что повышает защиту от атак «Sybil» и «spoofing».

Для массового внедрения VANET необходимо развитие дорожной инфраструктуры и унификация стандартов. Ведётся работа над согласованием IEEE 802.11p, ETSI ITS-G5, LTE-V2X и 5G NR-V2X для обеспечения интероперабельности. Международные организации активно занимаются формированием стандартов, а правительства многих стран включают VANET в национальные программы по развитию ITS.

Заключение

В ходе исследования были рассмотрены архитектура и основные принципы функционирования сетей VANET, а также их место в составе интеллектуальных транспортных систем. Показано, что данные сети являются ключевым инструментом для повышения безопасности дорожного движения, оптимизации транспортных потоков и поддержки концепции автономного вождения. Определены перспективные направления развития VANET, включающие интеграцию с сетями 5G/6G, применение методов искусственного интеллекта и предиктивной маршрутизации, а также тесную интеграцию с IoT и облачными платформами. Не менее важным направлением является унификация международных стандартов и развитие дорожной инфраструктуры, обеспечивающей полноценное функционирование сетей.

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USE OF BIG DATA IN THE FIELDS OF UZBEKISTAN AND FOREIGN COUNTRIES

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***Abstract*— The article analyzes the use of big data in healthcare. Various approaches have been described to the definition of the concept (Big Data), the scope of this technology; the most demanded technologies by industries are shown. Considered the prerequisites for the use of big data in healthcare, as well as the advantages and disadvantages of using big data in healthcare. The historical experience of using Big Data in Uzbekistan and the USA is noted, specific examples of application in Uzbekistan, Europe, the USA, and China are analyzed. The article provides a forecast for the big data market in Uzbekistan healthcare and shows a practical example of using Python as part of the analysis large flow of medical data. Conclusions are drawn about the characteristic trends in the use of large data in different countries. The conclusion is made about the importance of using big data in healthcare and other modern subjects.**

Keywords*— *big data; healthcare; analytics; patent; forecast; projects

INTRODUCTION

To date, big data technologies have penetrated various industries, the most relevant of which is healthcare. Analysts predict rapid growth big data market, and the feasibility of their applications in the healthcare system are widely discussed by the international community. The aim of the study is to consider big data market in healthcare. In the disclosure of the goal, the following tasks can be distinguished:

1. Analysis of the theoretical foundations of Big Data.

2. Consideration of preconditions, advantages and disadvantages of Big Data in healthcare.

3. Analysis of Uzbekistan and foreign experience application of big data technologies in healthcare.

4. Demonstration of a case study of the application of big data in healthcare and making a market volume forecast.

As the main research methods comparison methods, descriptions, analytical alignment in a straight line - for building forecasts.

THE MAIN PART

Prerequisites for the development of Big Data in healthcare

Toward Big Data in Healthcare can be attributed

• data obtained from diagnostics;

• data from monitoring sensors;

• information obtained during an emergency help;

• results of application of unconventional medicine;

• normative documents in the field of healthcare;

• drug data, etc. An example of big data in healthcare all information about genetic features of the body, which is hundreds GB per person. PricewaterhouseCoopers in the report "Global top health industry issues: Defining the healthcare of the future" 5 identified 8 factors that contributing to the simplification of the health care system and its active progress:

1. Use of artificial intelligence.

2. Drawing up clear instructions for the use of artificial intelligence.

3. Comfortable conditions for the patient.

4. Transformation of clinical trials.

5. Use of technology to distribute remote services.

6. Formation of valuable medical technologies.

7. Cyber security.

8. Social factors - income level and education, etc.

Also, according to the report, the following global trends in the development of healthcare can be identified: a decrease in trust in institutions and technologies; hyam (patients demand more information about treatment choices), population aging. Significant part of the population is aging and presents more and more requirements for local health infrastructure and social institutions. According to

according to the UN, in mid-2019 the number of people aged 65 and over was 703 million people, i.e. about 10% of the total world population.

Advantages and disadvantages use of Big Data in healthcare

Big Data technologies contribute to simplification some processes in healthcare. For example, with the help of Big Data analysis, the quality of clinical trials will improve. In addition, as the main advantages of using such technologies

can be identified..

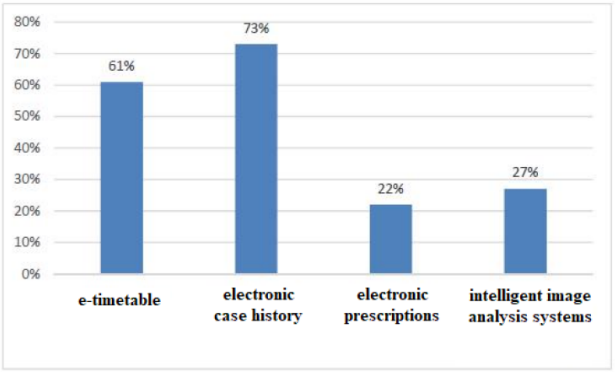

Fig. 1. Digital technologies used in medical practice

The ability to independently control your health. Simplify the decision-making process about the patient's diagnosis due to computer analysis of the anamnesis. Transition from traditional medical methods to improving methods while maintaining the accumulated experience. It is worth noting that the attitude of doctors themselves to change. As part of the Uzbekistan Internet project "Doctor at Work" is held annually study of the behavior of doctors. In particular, in 2019, a survey of doctors was conducted on topic of Big Data prospects in healthcare. 1112 doctors took part in the survey, of which 70% are employees of budgetary institutions. According to the survey, 93% of doctors see Advantages of Big Data over traditional ones tools. On fig. 2 are percentages voted for commonly used digital technologies. It can be seen from the figure that more often the electronic medical record is used in total and electronic schedule. As the main advantages of systems intelligent image analysis can highlight: saving time (86% of votes), more accurate diagnosis (38%), more efficient treatment (10%), reduction in the percentage of serious diseases (4%). At the same time, only 53% of physicians agree to the implementation of an IT system in order to analyze rii of the disease of patients. This is due to the shortcomings of technologies for collecting, storing and processing big data. IT systems can make mistakes and break down, and any mistake in healthcare is expensive, and working with new technologies can be time consuming. It should be noted that Big Data technologies require privacy, so it is necessary to preserve privacy. Access to some information can even be detrimental. An example can serve as the sale of information about the disease to increase insurance premiums due to the risk of heart attack. Big Software Implementation Data will be expensive in healthcare, since any error in the program or logic her work can cost a person life.

RESULT

Historical development of Big Data

USA

World leader in implementation and application big data technologies in healthcare is the USA. [7] The relevance of big data application in the country is based on economic efficiency. A number of analysts believe that large data in healthcare will create an additional $300 billion in financial flow primarily by reducing the cost of healthcare. Some American scientists believe that even a small influx of investment in big data can significantly improve the standard of living of people. Back in the 90s. in the United States, individual medical societies began to create registers and managing them. In 1997, the American College of Cardiology created the National Registry cardiovascular data (NCDR) in order to to formalize data collection and reporting for diagnostic catheterization. Since NCDR has grown to 10 different registries containing over 15 million unique entries patients covering the entire spectrum of cardiovascular care. California scientists have proven that elementary analysis of data from social networks able to detect behavior that provokes emergence of HIV, create a system of measures to fight epidemics. The same Californian university introduced big data technologies in local therapy hospitals. The system is programmed to constantly monitor changes in the patient's condition, calculates the risk of sepsis. Boston hospitals are also embracing big data technologies. When performing major operations, the risk of death is predicted outcome. Sometimes, based on the proposed analytics system, a decision is made to transfer surgery the next day to stabilize patient indicators. Among the first projects in the USA are Oncospace, or smart database. This database stores all images of cancerous tumors of the neck, head, pancreas, information about the anamnesis the patients themselves. The results of applying this of the project have shown that the efficiency and safety of radiotherapy programs are improved. As a separate area of application of big data, it is worth highlighting the study of human DNA. There is a company in the USA Affymetrix, which develops chips.

Europe

In the scope of Big Data in France in 2017, the SNDS data system was developed, that brings together health information person from various sources. This system has become widespread only in France, but throughout Europe. Its uniqueness lies in the possibility of combining death information, disability information, insurance databases companies. Access to SNDS and have government services and institutions in the field of health. Data security in the system provided by the French Internet Regulator (CNIL), which is based on on legislation on the protection of personal data 9. The Internet of Things is predicted to great prospect of value creation in healthcare (rapid detection of diseases, treatment of chronic diseases, etc.) - order €16–35 billion in 2020–2025 [9]. Norway is also already using systems big data in healthcare. The university hospital in the capital is working with the Power BI system, which allows faster collect data and improve the accuracy of research. All this contributes to the redistribution funds for higher priority medical problems.

China

China differs from other countries in that began to build special centers for analysis big data. In particular, the construction of a state big data center is underway. in the field of healthcare. Investment size in the creation of such a center amounted to $ 1 billion. USA. China is currently building a large DNA sequencing center. The center will be used to collect information about the gene pool of ethnic

Chinese. The project is being implemented by the state-owned company Yangzi Group, Southeast university and Nanjing Medical University. The center also plans to study genetic mutations characteristic of various diseases 10. Thus, the introduction of big data in healthcare still depends on significant data collection and timely analysis to determine the most suitable basics for optimizing health, individual prevention, diagnosis and treatment of diseases. Most Application Projects big data in health care to study the human genome and solve the problem of timely detection of oncology.

Uzbekistan

Summarizing all of the above, it is worth noting that at the moment the implementation of projects big data in Uzbekistan healthcare is mainly occupied by universities and research centers. In the US, subjects are not only universities, but also companies that provide investment support. In Europe, in addition to universities, in similar projects are also interested in government services. China, most likely, is in first place in terms of the level of development of such projects - state corporations jointly with universities are actively developing large healthcare data. One of the significant results of the work is a system designed to diagnose melanoma (malignant tumor skin). The developed system makes it possible to distinguish melanoma from benign and premalignant formations according to the examination. In recent years, two groups involved in the development of Big Data in healthcare. The first group is part of the information and analytical agency The Tashkent Health Department is Data Analysis Center. The implemented projects of the Center include the project “Personnel analytics". It provides information about working doctors and various indicators their activities [5]. In addition, at a lecture by a representative of the Center data analysis by E. Prokofieva February 18 2020, it was announced that as planned projects can be considered epidemic forecasting in schools, balancing therapeutic sites, cancer recognition lungs, etc. All projects are implemented within the framework of smart city concept. According to the center Regional Science Vienna Technological University, Smart city — a city with conditions for the growth of human capital. For A smart city is characterized by human-centeredness, accessibility and openness, protection of personal data, etc. Analysis of medical data within the city is considered as step in the implementation of the Smart City concept. Uzbekistan big data market in healthcare is developing mainly through research centers and institutions, but companies implementing their decisions in real practice, quite a bit. It is important to expand the scope big data applications, because it will allow optimize costs time and material resources to develop new treatment approaches, improve quality of medical training workers. Usage big data is the key to the development of preventive measures in healthcare. In accordance with the Healthnet roadmap in 2017, a number of Big Data benchmarks were achieved. In particular, there was the Health software platform was developed Heuristics using big data technologies. The platform is used to collect biometric data of athletes for the purpose organization of training programs. The Uzbekistan market is characterized by a large a variety of IT companies specializing in the application of big data technologies. These companies have great potential for entering the healthcare market. In accordance with the Healthnet roadmap in 2020–2025 development of Big Data is planned in health care, the first professional centers are expected to appear using software products for continuous body monitoring. In 2026–2035 It is planned to create a whole network of such centers. It should be noted that in Uzbekistan only the first steps in the use of technologies are starting. big data in healthcare. In 2018, the administration of the Tashkent region, together with the Uzbekistan company Rubius, began big medical data analysis project. In 2012, all medical institutions in Tashkent regions connected to a unified medical information system. A striking example of the use of Big Data in Uzbekistan healthcare should be considered assistance in attaching to a dental clinic. Starting from January 1, 2017, dental clinics switched to per capita financing. Problems with attaching people, attending the polyclinic at the place of residence and regularly, was not.

CONSLUSION

However, there was a problem attachments of people visiting the clinic not at the place of residence. This problem was solved Big Data technologies, with the help of which the location of the real location of the mobile phone. conclusions The above examples show that it is important to expand the scope of big data, as this will optimize the cost of time and material resources for the development of new approaches to treatment, to improve the quality of training of medical workers. The use of large data is the key to developing preventive measures in healthcare.

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ANALYSIS OF METHODS FOR FORMING CADASTRAL INFORMATION OF TELECOMMUNICATION FACILITIES

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Abstract - The article considers methods for forming cadastral information on telecommunication infrastructure objects that play a key role in ensuring the sustainable operation and development of modern communication networks. The article analyzes the features of telecommunication objects, including linear structures (fiber-optic communication lines, underground and overhead cables), antenna mast structures, communication nodes and data processing centers. A comparative analysis of traditional accounting methods (geodetic survey, topographic plans, design documentation) and modern technologies (geographical information systems, earth remote sensing, laser scanning, 3D modeling) is carried out. Their advantages and disadvantages are identified according to the criteria of accuracy, speed, automation and scalability.

Key words *- cadastral registration, telecommunications infrastructure, GIS, remote sensing, laser scanning, linear communication facilities, antenna mast structures, data processing centers*

I. Introduction

Modern development of the telecommunications industry is impossible without reliable and accurate information about infrastructure facilities, which is necessary for their operation, accounting, taxation and network development planning. One of the most important management tools in this area is cadastral registration of telecommunications infrastructure facilities, which allows systematization of data on the location, technical characteristics and legal status of the relevant structures and linear facilities.

A special feature of cadastral registration of telecommunications objects is that they include not only traditional capital structures (communications node buildings, data processing centers, antenna masts), but also linear extended structures - cable and fiber-optic communication lines, overhead lines, underground utilities. These objects are difficult to describe using classical cadastral methods focused on real estate with fixed coordinates and boundaries. In this regard, there is a need to develop and apply specialized methods for the formation of cadastral information that take into account the specifics of the telecommunications industry.

In recent years, there has been a trend towards digital cadastral systems, which actively use geographic information technologies (GIS), earth remote sensing (ERS), laser scanning and 3D modeling. These tools improve accuracy, speed up the process of entering data and integrate them into national real estate and infrastructure databases. In this case, the standardization of data formats and interaction between telecom operators and state cadastral registration authorities play an important role.

The relevance of the study of methods for the formation of cadastral information is due to the need to improve the accuracy and reliability of data on telecommunications facilities, create a unified information base for effective management and investment, integrate national cadastral systems with international standards, ensure transparency of the legal status of objects and optimize taxation processes.

II. Features of telecommunications infrastructure facilities

Telecommunication infrastructure is a set of engineering structures and technical means that ensure the transmission, reception, processing and storage of information. Unlike classical real estate objects (residential and industrial buildings), communication objects have specific characteristics that create additional difficulties in their cadastral registration. These features are related to their purpose, spatial location, length and functional parameters.

For the purposes of cadastral registration, objects can be conditionally divided into several categories:

1) Linear communication facilities: fiber-optic communication lines (FOCL), copper cable lines, overhead communication lines, underground cable communications. The peculiarity of linear communication facilities is their extended nature, passage through different land plots, the need to record the routing and intersections with other engineering networks.

2) Antenna-mast and tower structures: cellular communication masts and towers, relay towers, satellite communication antennas (stationary and mobile). The peculiarity is the presence of fixed coordinates, but the difficulty in taking into account the height, supporting structure and attached elements.

3) Stationary nodes and communication centers: switching centers, Internet access nodes, data processing centers (DPC). The peculiarity is that they represent real estate with a complex internal engineering structure, including cable entries, server rooms, cooling and power supply systems.

4) Radio relay, satellite, base stations: ground stations of satellite communications, radio relay lines and stations, base stations of mobile communications. The peculiarity is that they depend on the coverage area, antenna

characteristics, require consideration of the radio frequency spectrum and sanitary safety zones.

5) Access and distribution infrastructure: cable distribution cabinets (CDC), communication wells and couplings, optical distribution boxes. The peculiarity is a large number of small objects requiring mass accounting, but often not having a separate cadastral number.

The difficulties of cadastral registration of telecommunication facilities are as follows:

- the length and intersection of land plots (communication lines can pass through tens and hundreds of plots with different legal status);
- invisibility of linear objects (underground cable lines cannot be identified visually, which requires the use of geodetic and geoinformation methods);
- high-rise structures (when taking into account antenna-mast objects, it is necessary to record not only the base, but also the parameters of the height and supporting structure);
- development dynamics (the communications infrastructure is being actively modernized, which requires constant updating of cadastral data).
- regulatory ambiguity (in many jurisdictions there are no uniform rules for cadastral registration of linear telecommunication structures).

III. Methods of formation of cadastral information

Formation of cadastral information on telecommunications infrastructure objects includes collection, processing, systematization and entering of data into state and corporate databases. In modern conditions, both traditional methods of geodetic accounting and innovative technologies based on geographic information systems (GIS), earth remote sensing (ERS), laser scanning and 3D modeling are used.

Table 1 provides a comparison of the most frequently used methods for generating cadastral information.

Table 1

Comparative characteristics of methods

No.	Method	Accuracy	Price	Speed of execution	Automation	Scalability	Restrictions
1	**Geodetic survey**	Very high (centimeters)	Tall	Low	Low	Limited (requires on-site visit)	High labor costs, local nature
2	**Topographic plans and maps**	Average	Average	Average	Low	Average	The need for regular updates
3	**Documentation of telecom operators**	Medium-high	Low	Tall	Average (with automation)	Tall	Data is often out of date, there is no single standard
4	**Geographic information systems (GIS)**	Tall	Average	Tall	Tall	Very high	Standardization of formats and staff training are required
5	**Earth Remote Sensing (ERS)**	Medium-high	Average	Tall	High (auto recognition)	Tall	Not suitable for underground applications
6	**Laser scanning and 3D modeling (LiDAR)**	Very high	Tall	Average	Medium-high	Average	High cost of equipment, large volumes of data
7	**Integration of OSS / BSS and cadastral systems**	Tall	Average	Very high	Very high	Very high	Unification of formats and interaction between departments is necessary

Comparative analysis shows that traditional methods (geodesy, topographic plans) provide high accuracy, but are not suitable for large-scale tasks due to high cost and labor intensity. The most promising are GIS technologies, remote sensing and integration of operator data, as they provide a balance of accuracy, speed and scalability. Laser scanning and 3D modeling are used for high-precision tasks, but their mass implementation is limited due to high cost.

IV. Conclusion

Telecommunication infrastructure objects are highly complex for cadastral registration due to their length, diversity and specificity of operation. This requires the development of special methods for recording their characteristics, integration with geographic information systems and standardization of approaches at the national and international level.

Formation of cadastral information in the telecommunications sector requires the use of methods that ensure accuracy, efficiency and cost-effectiveness. Different approaches have both advantages and limitations, which necessitates their comparative assessment. Methods for forming cadastral information on telecommunications infrastructure facilities are gradually evolving from traditional geodetic and cartographic approaches to digital technologies using GIS, earth remote sensing and 3D modeling. Integration of operator data and state cadastral systems is a key area of development, ensuring accuracy, relevance and automation of accounting.

Building upon this foundation, a detailed modeling of the State Cadastre of Communication Objects (GKOC) illustrates how a unified, GIS-based digital system can effectively manage complex infrastructure elements—such as base stations, fiber-optic lines, mobile towers, and postal networks—within the broader Unified State Cadastre System (ESGK). The model emphasizes not only spatial accuracy and automation but also structured workflows for data submission, validation, and classification.

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CALCULATION OF MEASURING AMPLIFIER WITH AUTOMATABLE AND DIGITAL COMPARATOR

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***Abstract* - The development of technologies currently predisposes to the use of the method of adsorption separation in the analysis of multicomponent mixtures in many industries and the national economy and is gradually replacing traditional chemical and physicochemical methods. Obtaining highly pure substances with a percentage of trace impurities less than 10-6% is possible only when using an adsorption unit with a large number of columns used. The efficiency of adsorption methods is significantly increased due to the automation of data processing at the outlet of the adsorption plant. The automation process includes pairing the adsorption unit with a personal computer and for this it is necessary to use such devices for processing signals at the output of the adsorption unit, such as amplifiers, analog-to-digital converters. This article is devoted to the design and development of an instrumentation amplifier with automatic scaling and a digital comparator that provides switching gains. The article discusses the calculation and development of a digital comparator for an instrumentation amplifier with auto scaling. A detailed selection of the type of analog-to-digital converter is presented, the choice of which took into account the frequency, cost and error of the existing types used for processing signals at the outlet of the adsorption plant.**

Keywords— signal processing devices measuring amplifier, digital comparator, operational amplifier, autoscaling.

I. Introduction

In various industries, often in the determination or purification of multicomponent substances from impurities, adsorption units with a gas or liquid carrier are used, with the help of which the quality of the products is monitored and regulated. In accordance with the task, an adsorption analysis method is selected, the essence of which is the separation of multicomponent mixtures, which has recently become increasingly important in the medical and biological fields of research. Increasing the sensitivity and reliability of adsorption equipment opens up completely new prospects for using adsorption analysis methods to solve biomedical problems, changing the possibilities of studying the composition of samples of biological origin, not only in relation to biological speed the origin, accuracy and simplicity of the study, but also the purity of separation of multicomponent mixtures. In addition, the use of adsorption methods in combination with methods such as spectrometry, nuclear magnetic resonance, infrared spectroscopy, etc. allows for unique biochemical studies. In this case, the signals coming from the adsorption unit in the form of a peak described by the Gauss function characterize the percentage of the test substance with high accuracy and to automate this process, the necessary condition is the use of devices for processing this signal [1]. The efficiency of adsorption methods is significantly increased due to the automation of data processing at the output of the adsorption installation, which develops mainly in three directions: the use of universal general purpose personal computers for processing, the use of specialized computing devices [2].

The results of the stage of the primary processing of information at the output of the adsorption unit are the initial data for the stage of final processing carried out by a personal computer [3]. The use of computer technology for the primary processing of information inevitably leads to the need to convert the input analog information to digital form and to avoid signal loss, the amplification of the signal under study should be used.

In general, the automation process involves pairing the adsorption unit with a personal computer, and to achieve this, it is necessary to use such devices for processing signals at the output of the adsorption unit as amplifiers, analog-to- digital converters, and a device for determining the beginning and end of the peak [4].

II. Methodology

In nuclear radiation spectrometers, amplification stages are subject to stringent requirements for stability, linearity, speed and noise.

Traditionally, such amplifiers were developed on transistors, obtaining typical values of instability of gain of 5.10^{-50} C, integral non-linearity of 5.10^{-4}, rise time of 50 μs and noise brought to the input, supply voltage of 5 Mv with the bandwidth of amplifiers generally accepted in spectrometry [5,6]. Spectrometric amplifiers with similar parameters are currently produced by a number of foreign companies. The first operational amplifiers developed in integrated design could not provide such characteristics. Their main disadvantage was a large rise time, amplification of the output parameters exceeding 1 μs [7]. With the advent of fast operational amplifiers having a slew rate > 10 V / μs [8], it became possible to create

spectrometric amplifiers based on them that are comparable in quality to transistor ones. Our goal was to study the parameters of amplifier stages on fast operational amplifiers. Non-inverting amplification cascades consisting of K140UD11, 154UD3, 154UD4, K544UD2, K574UD1 operational amplifiers with a gain of 10 V in the dynamic range of 10 V were studied. Standard frequency correction and balancing were used in operational amplifiers [9].

When working on a cable, an emitter follower on a KT315V transistor with an initial current of 4 mA included in the feedback circuit was used as the output power amplifier of such a cascade. In the parallel feedback circuit, resistors C2-29V with ratings of 500 Ohms and 5 kOhm were used. To compare the results, the same measurements of a transistor amplifier stage, similar to that described in [10], were performed.

Changing the rise time, defined as the front of the output pulse of the cascade voltage by the levels (0.1x0.9) *Umax*using standard generators and oscilloscopes, is not difficult.

The input voltage of an analog-to-digital converter should range from 1 to 10 V, with an input signal value of less than 1 V, the relative error increases, therefore this article is devoted to the development of an amplifier that will provide changes in the input signal within the specified voltage fluctuation.

Usually in practice, the ratio of the maximum to the minimum content of substances in a multicomponent mixture is equal to:

Mmax/Mmin= 1000.

Take into account the attitude

Uin max/Uin min= 10.

Based on the above circumstances, the ratio of the maximum gain (Ky max) to the minimum gain will be:

Ky max /Ky min = 100

Therefore, when developing an amplifier with a programmable gain, we choose

Ky max /Ky min = 128.

Since the gain in the amplifier under development will be measured in binary code, in the differential measuring amplifier, which, upon receipt of a digital command, can establish during 15 μs any of the eight values of the gain, which varies binary from 0.5 to 64. The amplifier It operates in the frequency range up to 200 kHz with an input (output) signal of ± 10 V with a nonlinearity of the amplitude characteristic of 0,02%.

In communication technology, when conducting work on radar, seismic research and performing a nuclear experiment, data acquisition devices with a wide range of input signal are needed. Usually, this requirement is satisfied by the inclusion of an amplifier with a nonlinear amplitude characteristic in the device [11]. However, maintaining high speed with increasing gain is provided by a significant complication of the amplifier circuit, for example, the construction of a specialized input stage, if it is a measuring amplifier with a differential input. In fig. 1 is a diagram of a differential measurement amplifier with digital gain programming. The scheme excludes the dependence of the gain on the resistance of the keys, which avoids the individual adjustment of each gain value [12].

The amplifier consists of series-connected converters: a voltage-to-current converter and a current-to-voltage converter, performed on operational amplifiers and resistive dividers. The circuit lacks discrete transistors. The input voltage-to-current converter is built on an operational amplifier, the M3 output of which is connected to the inverting input via a resistive voltage divider R1, R3, which forms a negative feedback circuit. The current output of the converter is connected to the non-inverting input of the operational amplifier through a resistor R6 or R7. The selection and connection of the resistor is carried out using the analog switch M5. This choice sets one of two possible values of the coefficient of transfer of the voltage-to-current converter.

With equal values of the resistances of the resistors of the divider R1÷R4, the transmission coefficient is determined by the expression:

$$K_{c.c} = \frac{I_{outc.c}}{U_{innoninv} - U_{ininv}} = \frac{1}{R_i} \qquad (1)$$

where *Ioutc.c.*– output current of the converter; *Uin non inv.*, *Uininv* - voltage at its non-inverting and inverting inputs; *Ri* - is the resistance of the resistors R6 or R7.

To eliminate the influence of the resistance of the keys of the M5 switch on the gain, two keys are used to connect each resistor. Through one key - potential - a connection is provided for the purpose of positive feedback, through another - current - the load is connected to the output of the converter [13,14].

The potential input is connected directly to the output of the resistor R6 or R7 to the current switch. Thus, the current switch is part of the load, the resistance of which at a sufficiently high output resistance of the voltage-to-current converter has practically no effect on the value of the output current. To improve the characteristics of the converter, a voltage follower is introduced into the positive feedback circuit to the operational amplifier M4, which separates potential keys and a resistive divider. Moreover, on the one hand, due to the small size input current and high input resistance of the operational amplifier eliminates the flow of current through the potential switch key M5.

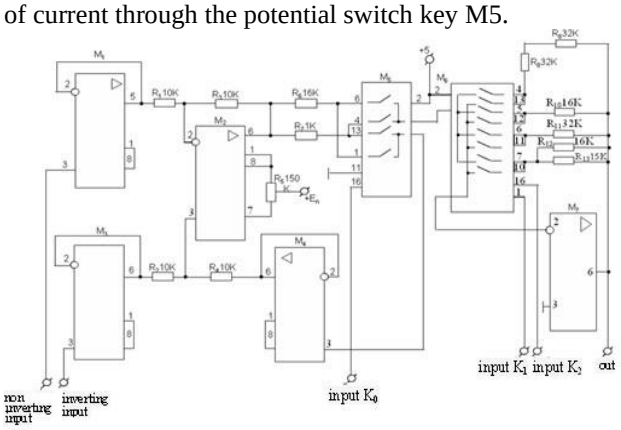

Fig. 1. Schematic diagram of an amplifier with autoscaling: M1 - M4 K140UD7; M5 - K1043KG1; M6 - K1043KG2; M7 - K140UD7

Given the absence of residual voltage for the keys on field-effect transistors, this inclusion almost completely eliminates the influence of the key on the accuracy of the converter. On the other hand, the inclusion of a voltage

follower prevents the current of the resistive divider R2, R4 from passing to the converter output, which not only improves its accuracy characteristics, but also provides a high value of the attenuation coefficient of the input common-mode voltages [15]. To increase the input impedance of the device, two more voltage followers are introduced into the operational amplifiers M1, M2, separating the non-inverting and inverting divider of positive which the inverting input and output turn on a resistor that sets the gain. The non-inverting input of the operational amplifier is connected to a common bus, which provides zero voltage at the inverting input, to which the output current of the voltage-to- current converter is supplied. In this case, the transfer coefficient of the current-to-voltage converter:

$$K_{c.v.c} = \frac{I_{out}}{U_{intc.v.c}} = R_j \qquad (2)$$

where *Uout* - is the voltage at the output of the amplifier, *Ri* - is the resistance of the resistor connected between the output and the inverting input of the operational amplifier M7. As such a and negative feedback. The current-to-voltage converter is built on an operational amplifier M7, between resistor, resistors R8÷R13 are used.

The scheme of the current-to-voltage converter provides four values of the transmission coefficient, set by the analog switch M6, connecting the resistors R8÷R13 with the output of the operating amplifier M7 through potential switches and with the output of the current-to-voltage converter through current ones. In this case, the output voltage of the operational amplifier M7 is determined by the voltage drop only on the resistors R_8÷ R13 and the influence of the key resistance is excluded [16].

Table 1 Logical state of coefficient

Gain		*Logical state*		
		Int Ko	*Int K1*	*Int K2*
K1	0,5	1	1	1
K2	1	1	1	0
K3	2	1	0	1
K4	4	1	0	0
K5	8	0	1	1
K6	16	0	1	0
K7	32	0	0	1
K8	64	0	0	0

In the circuit of the current converter, the voltage includes four values of the transmission coefficient set by the analog switch M6, connecting the resistors R8 and R13 with the output working amplifier M7 through potential switches and with the output converter of current to voltage through current ones. In this case, the output voltage of the operational amplifier M7 is determined by the voltage drop only on the resistors R8÷R13 and the influence of the key resistance is excluded [17,18,19].

The circuit uses resistors of only two multiple values of 16 and 32 kOhm. Four resistance values are obtained through the use of series (R8, R9) and parallel connection (R12, R13) resistors.

The gain of the described amplifier is equal to:

$$K_g = K_{c.v.c}K_{c.v.c} = Rj/Ri \qquad (3)$$

Also, the product of the corresponding values of the gain factors determines the total number of gain values. For the circuit shown in fig. 1, there will be eight such values. Table 1 shows the dependence of the gain on logical states at the control inputs of the amplifier.

When switching a programmable differential amplifier from one gain to another, an important role is played by a device that provides switching of the gain. The basis of this device is a comparator, that is, a device for comparing the output signal with a pre-set reference signal. In practice, an analog comparator K554CA3 is often used for these purposes. But the disadvantages of the analog comparator are: Dependence on the power source, that is, when power surges occur, the reference direction changes. When the ambient temperature changes, the analog elements have properties that create a large drift of the quiescent current.

Therefore, the author used a digital comparison of the output code of the analog-to-digital converter with the reference codes [20,21].

The reference codes are selected so that their values are 2% less than the maximum value of the analog-to-digital converter and 2% less than ¼ of the maximum output code of the analog-to-digital converter. Define the values of these codes. Based on the foregoing, we take the maximum value of the output code to be 11111111111111, while the first bit is considered the highest, and the last is the least significant. It follows that code № 1, the value of which is 2% less than the nominal, is 111110101101. The value 2% is set for the case when the gain of the amplifier is floating. This can happen when the temperature changes or a slight change in the values of the resistors that specify the gain of the amplifier. If you do not set this 2% barrier, then when switching, a complete loss of information is possible if the value of the input signal of the analog-to-digital converter increases above the possible code of the analog-to-digital converter. Or the amplifier may go into output mode. To obtain a more accurate result of processing the input signal, this 2% barrier is introduced into the data processing program of the analog-to-digital converter on the computer. As a result, we obtain the data for processing the adsorption signal with an error corresponding to the technical task of work.

Figure 2 shows a schematic diagram of a digital device for controlling the gain of an amplifier of an analog-to- digital converter. The basis of this device are 12-bit code comparison schemes based on the K555CP1 chip. This microchip is a circuit for comparing 2-digit and 4-digit numbers. But given that the analog-to-digital converter in question has 12 bits, we connect 3 microchips of the K555CP1 type in cascade. The cascade connection diagram is shown in fig. 2.

The circuit uses two 12-bit comparison circuits. One circuit compares the output code of an analog-to-digital converter with reference code № 1. In this case, the output signal of the comparison circuit A> B is used.

To protect the digital control circuit of the amplifier gain from accidental bursts of the input signal or surges on the power source, a circuit based on the K155IR13 microcircuit is assembled in the form of a shift register. The control circuit of the operation of the programmable differential

amplifier provides a change in the gain of the amplifier of the 4th tactical pulse *tu tact*of an analog-to-digital converter [22].

Let us consider in more detail the operation of this device. The device consists of two shift registers of type K155IR13, each of which performs the function of protecting against accidental bursts of signal for options A>B and A<B.

At the time of the signal A>B or A<B, respectively, the shift register is brought into reference mode.

In the initial state, the shear mode at the output of *Q3* is set to zero. When a signal arrives, A>B or A<B, respectively, the register begins to shift the input signal equal to one, applied to the input DR.

When a 4th tactical pulse is exposed, output *Q3* displays a level one, which, through a delay line made on the elements $R = 360$ Ohm and $C = 22$ pF, resets the shift register through the reference time interval *tu*. During *tu*a unit level at the output of *Q3*transfers the reversing counter to another gain. After that, a signal equal to zero is automatically established at the input R of the shift register due to the disappearance of the level A>B.

To dock the comparison circuit with the programmable differential amplifier circuit, the K155IE7 chip is used, shown in fig. 2.

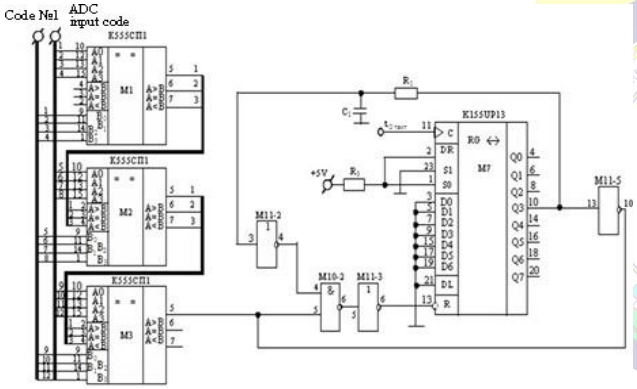

Fig. 2. Scheme of cascade connection of an analog-to-digital converter with a chip of type K555CP1

Thus, when developing a digital comparator for a measuring amplifier with auto-scaling, a circuit diagram was developed for controlling the operation of a programmable differential amplifier, in which two 12-bit comparison circuits were used. When exposed to the 4-th tactical pulse, the shift register is reset. In this case, a single pulse level at the output translates the reversible counter to another gain. As a result, a signal equal to zero is set at the input of the shift register [22].

III. RESULTS AND DISCUSSION

The developed measuring amplifier with auto-scaling and a digital comparator are designed to amplify the signal coming from the adsorption unit and provide switching of the gain. Using the above processing devices, the following diagram of the input voltage change of the analog-to-digital converter is shown in fig.3.

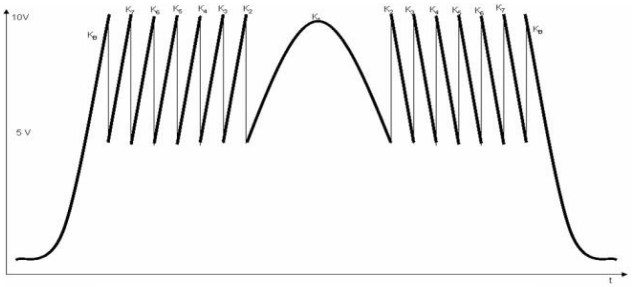

Fig. 3. Chart of output signal change with auto scaling

Due to the positive feedback, the output resistance of the voltage-to-current converter remains high in the specified range of transmission coefficients and is determined by the expression:

$$R_{outc.v.c.} \approx 0{,}5 K_{OA} R_i \qquad (4)$$

Where *KOA* - is the gain of the open operational amplifier M3. If *KOA>>KU*, which is usually observed, then the condition

$$R_{outc.v.c.} >> R_j . \qquad (5)$$

Thanks to this, the M7 operational amplifier, on which the output current-to-voltage converter is built, works with almost 100% negative feedback in a wide range of gain values. At the same time, the M7 bandwidth is kept at the highest possible level and does not depend much on the gain, which explains the good frequency properties of the amplifier in comparison with other schemes. In practice, a decrease in the gain of the operational amplifier with increasing frequency leads to a violation of conditions (5), and the frequency properties of the amplifier deteriorate.

An analysis of the amplifier circuit shows that its transfer characteristic is close to the characteristic of the oscillating link with the attenuation parameter close to unity in the range of the gain coefficient 1x100. In this case, the reduction in the pass band with the gain increase is proportional to the square root of this increase, and the emission in amplitude the frequency response in the region of the upper boundary of the pass band is minimal, which provides a short time for the establishment of the transition characteristic in a wide range of values gain.

Amplifier parameters Common-mode input voltage range ±10V; differential input voltage range ± 10V; input voltage at a frequency f = 110 kHz – $7 \cdot 10^5$ Ohms; cutoff frequency at full power> 200kHz at $k = 0.5 \div 64$; attenuation coefficient of common-mode input voltages at f= 50 Hz - 80 dB at $K = 0.5$. Output voltage range; nonlinearity of the amplitude characteristic of the transmission coefficient < 0.02% at $k = 0.5 \div 64$; the time of establishing the output voltage ±10 V with an error of δ= 0.1% - 10 μs at $K = 0.5 \div 1$ and 20 μs at $K = 64$; the time of establishment of the output voltage with δ = 0.1% when switching transmission coefficients –15 μs, the voltage of power supplies is ±15 V.

IV. CONCLUSION

This paper presents the calculation and development of a measuring amplifier with auto-scaling and a digital comparator providing switching of the gain. In the developed amplifier, the gain measurement is carried out in binary code, therefore, to ensure compliance, a differential measuring amplifier is developed, which, upon receipt of a digital command, establishes during 15 μs any of eight values of the gain, which varies in binary range from 0.5 to 64. The amplifier operates in the frequency range up to 200

kHz with an input (output) signal of ±10 V with non-linearity of the amplitude characteristic of 0.02%. The calculation and development of a digital comparator for a measuring amplifier with auto scaling was performed. The results of the development of a digital comparator for a measuring amplifier with auto scaling are considered. A schematic diagram of the operation control of a programmable differential amplifier is presented. The diagram shows the use of two 12-bit comparison circuits. As a result, the gain is changed to the 4th tactical pulse tu tact and the clock of the analog-to-digital converter. Special attention is paid to the construction of a digital comparator for an amplifier with auto scaling. When cleaning and analyzing various substances, given that this process is reproduced in real time, the use of the above devices enables timely and high-quality signal processing at the output of the adsorption unit, since determining the percentage ratio of components in a substance is a very important task in various industries. Since, in some substances, there are impurities that even in very small proportions lead to severe consequences and therefore the purification of substances from impurities is considered a very important task and, when automating this process, the proposed signal processing devices are the proposed measuring amplifier devices with auto scaling and a digital comparator.

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CALCULATION OF SATELLITE LINK CHARACTERISTICS BASED ON ANTENNA BEAMWIDTH AND GEOGRAPHICAL COORDINATES

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***Abstract* — This paper presents a methodology for calculating satellite link characteristics based on the antenna beamwidth and the geographical location of the ground station. The algorithm includes the sequential determination of antenna gain, its conversion into a linear value, computation of the cosine coefficient between the station and the satellite, calculation of the slant range, and the half-power beamwidth. The obtained results provide an accurate representation of the relationship between antenna design parameters and the geometric conditions of communication, making the developed algorithm an effective tool for educational purposes and for analyzing fundamental processes in satellite communication systems.**

Keywords — satellite link budget, antenna gain, beamwidth, half-power beamwidth, slant range, satellite geometry, satellite systems

INTRODUCTION

The development of satellite technologies is closely related to the requirements of modern telecommunication infrastructure, which ensures stable information transfer at both global and regional levels. The antenna is a key element of such systems, and its parameters directly determine the link budget and the quality of communication [1, 6]. In recent years, particular attention has been given to methodologies that establish a connection between the geometric characteristics of antennas, in particular beamwidth, and the energy and spatial properties of the channel [2]. In this context, the creation of algorithms that provide accurate computation of the main parameters of a satellite link, given the coordinates of the ground station and the structural characteristics of antennas [3], has become an urgent task.

Existing approaches to the calculation of satellite link parameters often rely on specialized software packages or require the application of complex models of radio-technical analysis [7]. Such methods provide high accuracy but are characterized by complexity and significant computational costs. At the same time, there remains a need for formalized and compact algorithms that make it possible to explicitly trace the influence of initial geometric and geographical parameters on link characteristics. The implementation of such algorithms contributes to the unification of calculations and enables accurate comparison of different satellite channel configurations.

Modern satellite systems are characterized by increasing architectural complexity and growing requirements for the accuracy of preliminary calculations. In link design, it is necessary to consider not only energy parameters but also geometric factors associated with the location of ground stations and the position of the satellite. Under these conditions, algorithms that ensure the sequential execution of key analytical steps - from the calculation of antenna gain and its conversion into a linear value to the determination of slant range and half-power beamwidth - acquire particular importance. This sequence of steps makes it possible to systematically characterize the performance of the link and to identify limitations associated with structural or geographical conditions [1, 4].

The scientific novelty of the study lies in the formalization of an algorithm that integrates the basic equations of satellite communication into a single logical structure. The developed approach provides a complete analytical cycle: starting from initial parameters, it enables the determination of antenna gain, the distance between the ground station and the satellite, as well as the angular characteristics of the radiation pattern. The practical value of the methodology is that it can be applied for the preliminary assessment of satellite system parameters, for the comparison of different design solutions, and for the identification of factors that critically affect link performance.

PROBLEM IDENTIFICATION

In practice, current methods for calculating satellite communication links still do not provide a unified approach for simultaneously accounting for antenna beamwidth and the geographical position of the ground station. In specialized scientific and technical sources [11, 12], key link parameters are typically considered in isolation—for example, separate procedures are proposed for calculating antenna gain based on beamwidth and for determining slant range from the coordinates of the ground station. This fragmentation complicates the assessment of the combined

influence of antenna beamwidth and ground station location on the overall link performance and often forces engineers to rely on iterative calculations or specialized software tools for scenario analysis. As a result, the fundamental relationships between the geometric configuration of the channel and the antenna characteristics become difficult to trace, which negatively affects both the efficiency of link design and the conceptual understanding of the processes. In the field of design, such fragmentation also complicates the application of calculation principles, as specialists are forced to combine separate formulas without a unified and illustrative model. This once again highlights the necessity of an analytical solution that explicitly demonstrates the interaction between antenna parameters and link geometry in calculations.

This limitation becomes especially critical when evaluating link reliability and efficiency. Research has shown that antenna system parameters have a significant impact on the reliability of a satellite link [13], while the choice of frequency band directly affects signal attenuation [14]. However, these aspects are usually examined separately, without an integrated method for their joint assessment in combination with spatial geometry. It therefore remains challenging to determine whether the degradation of link performance results from a suboptimal antenna beamwidth (which reduces antenna gain and increases the half-power beamwidth) or from the geometric location of the ground station (which increases slant range and defines the coverage footprint). The absence of a unified calculation framework turns such cause-and-effect identification into a labor-intensive trial-and-error process, where critical design trade-offs may be overlooked. For instance, increasing beamwidth may extend coverage area but simultaneously reduces antenna gain, requiring careful balancing to preserve signal quality at longer slant ranges.

Moreover, the growing diversity of satellite communication scenarios further exposes the limitations of existing approaches. Ground stations communicating with satellites in low Earth orbit, medium Earth orbit, and geostationary orbit face vastly different slant ranges and coverage footprints. For example, a ground station communicating with a geostationary satellite must account for a much longer slant range and lower elevation angle compared to one communicating with a low-Earth orbit satellite. This necessitates different antenna beamwidth requirements to maintain coverage [15]. At the same time, emerging applications such as satellite IoT networks and remote agricultural monitoring systems [16, 17] demand rapid and accessible link evaluation tools capable of accommodating varied spatial configurations without relying on complex and time-consuming computational procedures. In these conditions, dependence on comprehensive simulations or specialized software alone is impractical, reinforcing the need for a compact analytical algorithm.

Therefore, the development of the algorithm proposed in this article is both timely and necessary. The presented solution represents a formalized compact analytical algorithm that explicitly connects antenna beamwidth and geographical coordinates to the fundamental characteristics of a satellite communication link. By consolidating the determination of antenna gain, the geometric alignment coefficient (cosine factor), the slant range, and the half-power beamwidth into a coherent sequence, this algorithm directly eliminates the methodological gap identified above. The advantage of this integrated approach lies in its transparency and reproducibility, where the influence of each initial parameter is explicitly traced. This ensures that the impact of narrowing antenna beamwidth or shifting the latitude of the ground station on final link parameters can be assessed within a single unified calculation rather than through multiple fragmented analyses. Consequently, the design and evaluation process is greatly simplified, and various satellite link configurations can be consistently compared on a unified basis. Essentially, the proposed algorithm serves as a universal tool for quantitative satellite link analysis, and its efficiency and benefits are demonstrated in the subsequent sections presenting results and discussion.

METHODOLOGY

The methodology for calculating satellite link characteristics is based on the application of fundamental equations of radio communication, which establish the relationship between the geometric parameters of the antenna, its structural features, and the spatial location of the ground station with the energy and angular characteristics of the link. The algorithm consists of several sequential stages, each of which has its own physical justification.

The first step is to determine the antenna gain of the onboard transponder. This parameter reflects the ability of the antenna to concentrate the transmitted or received energy in a given direction [3]. The smaller the antenna beamwidth, the higher the gain, which is explained by a narrower radiation pattern and, consequently, a greater power density in the operating direction. In satellite systems, this parameter plays a decisive role in constructing the link budget [5], since it directly affects the level of the received signal at the ground station. The antenna gain is expressed through the beamwidths Φ_0 and Φ_1 as follows:

$$G_b = 44.4 - 10 \cdot \lg(\Phi_0) - 10 \cdot \lg(\Phi_1), dB$$

Where: Φ0 – antenna beamwidth in the vertical plane, degrees; Φ1 – antenna beamwidth in the horizontal plane, degrees; Gb – antenna gain in decibels (dB).

For subsequent calculations, the antenna gain must be converted from logarithmic form to its linear representation. The logarithmic form (in decibels) is convenient for comparison and analysis, but in other computations the absolute value is required, representing the ratio of power in a given direction to that of an isotropic radiator. Therefore, the following transformation is applied:

$$G_b^{lin} = 10^{\frac{G_b}{10}}$$

Where: Gblin – antenna gain in linear scale, times;

The next important stage is the calculation of the angular coefficient ψ, which characterizes the spatial relationship between the ground station and the satellite. This parameter accounts for the geographical conditions of the communication link, reflecting the dependence on the ground station latitude and the longitude difference. The angle ψ serves as an intermediate value necessary for further calculation of the slant range:

$$\cos\psi = \cos\xi \cdot \cos\Delta\lambda \qquad (3)$$

where: ψ – angular coefficient between the ground station and the satellite; ξ – latitude of the ground station, degrees; Δλ – longitude difference between the ground station and the satellite, degrees.

After determining the angular coefficient, the slant range between the ground station and the satellite is calculated. This parameter describes the actual geometric distance traveled by the radio signal and is critical for estimating delays, losses, and energy parameters of the channel. Unlike a simple radial distance, the slant range incorporates the angular offset of the station relative to the satellite and is determined by the following formula:

$$d = 42644 \cdot \sqrt{1 - 0.295 \cdot \cos\psi} \qquad (4)$$

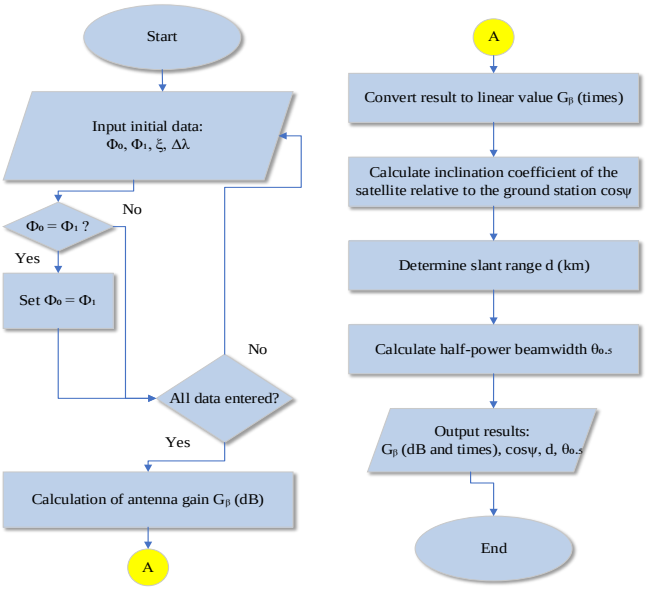
where: d – slant range between the ground station and the satellite, km.

The final stage of the methodology involves the determination of the half-power beamwidth. This value defines the angular region within which the antenna radiation power decreases by half relative to its maximum value. The parameter is essential for analyzing pointing accuracy and link stability, as it directly depends on the antenna gain and its physical characteristics [8]. The half-power beamwidth is calculated as:

$$\theta_{0.5} = \sqrt{\frac{4.9 \cdot 10^3 \cdot g}{G_b^{lin}}} \qquad (5)$$

where: g=0.5 is the antenna surface utilization factor [9, 10].

Thus, the proposed algorithm includes a sequence of logically connected steps, starting from the initial data and resulting in a complete set of calculated characteristics that describe both the energy component of the link (antenna gain, slant range) and its angular parameters (half-power beamwidth).



Algorithm for calculating satellite link characteristics

The algorithm is structured to reflect the natural sequence of physical and technical processes occurring in a satellite communication link. The process begins with the input of initial data that define the antenna and its spatial configuration. A verification of data completeness and adjustment of the beamwidth parameters is then performed. The next step is the calculation of antenna gain, which serves as the primary antenna characteristic. Once determined, the algorithm proceeds to its conversion into a linear value required for subsequent computations.

The following stage consists in calculating the angular coefficient ψ, which links the geographical parameters of the ground station with the satellite position. This step is followed by the determination of the slant range, representing the actual propagation distance of the signal. The algorithm concludes with the calculation of the half-power beamwidth, which characterizes the spatial selectivity of the antenna.

In this way, the proposed sequence provides a comprehensive description of link parameters, combining antenna characteristics with channel geometry. The logical structure of the algorithm makes it universal and applicable for analyzing a wide range of satellite system configurations.

Results and Discussion

The sequence of steps within the proposed algorithm reflects the fundamental interdependence between the geometric and energy parameters of the satellite communication link. The use of simple analytical expressions allows the influence of the initial data on the resulting characteristics to be explicitly demonstrated [1, 2]. Variations in the antenna beamwidth lead to significant changes in the gain and, consequently, in the half-power beamwidth. Similarly, the geographical parameters directly affect the slant range, which ultimately determines signal losses and propagation delays in the link.

It should be emphasized that the developed methodology preserves both transparency and consistency of the computational process. Each stage of the algorithm

logically follows from the previous one, forming a closed analytical cycle that ensures the reliability of the obtained results. This sequential structure contributes to a clearer identification of critical factors influencing the performance of the communication link.

Thus, the proposed algorithm can be regarded as a universal tool for the quantitative analysis of satellite links. Its results are comparable with those obtained from more complex models, while its step-by-step structure guarantees simplicity, clarity, and reproducibility of the calculations, which are crucial advantages in the study of satellite communication systems of varying complexity.

CONCLUSION

In this paper, a structured algorithm for calculating the fundamental characteristics of a satellite communication link was developed. The methodology integrates the determination of antenna gain, its conversion into a linear scale, the computation of the angular coefficient, the calculation of the slant range, and the derivation of the half-power beamwidth. The sequence of these operations forms a complete analytical framework that reliably represents the interdependence between antenna parameters and the geometrical conditions of communication.

The results of the study confirm that the proposed algorithm ensures a consistent and transparent calculation process while maintaining comparability with more sophisticated analytical models. This makes it a valuable tool for quantitative assessment of satellite links under various design scenarios.

An important practical implication of this work is the possibility of implementing the proposed algorithm in the form of dedicated software. Such an application would provide an effective means of automating the calculation process, reducing the probability of computational errors, and enabling real-time analysis of satellite communication parameters. The integration of the algorithm into software solutions would therefore expand its applicability in both research and engineering practice.

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RADIOELEKTRON APPARATLARNI LOYIHALASHDA ELEKTROMAGNIT MOSLLASHUVNI TA’MINLASHDA KOMPLEKS YONDASHUV

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Annotatsiya- Ushbu maqola radioelektron apparatura (REA) ichidagi elektromagnit moslashuvchanlik masalalarini tahlil qilishga bag‘ishlangan. Yangi komponentlar bazasini yaratish, yangi materiallar va texnologiyalarning paydo bo‘lishi elektromagnit moslashuvchanlik (EMC) masalalarini hal qilishda kompleks yondashuvni talab qiladi. Maqolada zamonaviy simsiz aloqa tizimlarini loyihalashda qo‘llaniladigan usullar va yondashuvlar ko‘rib chiqilgan. Shuningdek, parazit signallarni kamaytirish, ekranlash texnologiyalari, kondensator va induktivlik g‘altaklaridagi xalaqitlarni bartaraf etish usullari, shuningdek, bosma platalardagi o‘tkazgichlar joylashuvi va filtrlar orqali EMCni ta’minlash bo‘yicha amaliy tavsiyalar keltirilgan. Maqola ilmiy va amaliy jihatdan muhandislar uchun foydali manba hisoblanadi.

Kalit so‘zlar- elektromagnit moslashuvchanlik, shovqinbardoshlik, keng polosali kirish, elektromagnit energiya manbai, ekranlash, parazit sig‘im, teshikli ekranlar, to‘r ekranlar, xalaqitni bostiruvchi filtrlari.

LXXXVII. KIRISH

Yangi komponentlar bazasini va ularning ishlashining fizik tamoyillarini ishlab chiqish, yangi materiallar va ishlab chiqarish texnologiyalarining paydo bo‘lishi, loyihalashning yangi yondashuvlari va usullarini faol joriy etish — bularning barchasi bir tomondan ishlab chiquvchiga o‘z ish samaradorligini sezilarli darajada oshirish va tamoman yangi funksional darajadagi ishlanmalarni yaratish imkonini beradi, ammo boshqa tomondan malaka va qo‘llaniladigan texnik yechimlarga qo‘yiladigan talablarni ham keskin oshiradi.

Elektromagnit moslik va shovqinga bardoshlilik talablarini ta’minlash masalasida bu muammo ayniqsa dolzarbdir, chunki ular ishlab chiqilayotgan radioelektron vositalarning tezkorligi va murakkabligi bilan bevosita bog‘liq.

An’anaviy ravishda elektromagnit moslikning quyidagi darajalari ajratib ko‘rsatiladi: tizimlararo, tizim ichidagi va apparat ichidagi [6].

LXXXVIII. APPARAT ICHIDAGI ELEKTROMAGNIT MOSLIKNI TA’MINLASH

Apparat ichidagi elektromagnit moslik (EMM) va shovqinga bardoshlilikni ta’minlash — bu soha hozirgi vaqtgacha deyarli e’tibor qaratilmagan yo‘nalishlardan biridir. Natijada, shakllangan ishlab chiqarish jarayonlarida elektromagnit moslik (EMM) va shovqinga bardoshlilik (ShB) talablarini ta’minlash masalalari elektron vositalar (EV)ni ishlab chiqishda ikkinchi darajali rol o‘ynab keldi.

Bunga bir qismi elektromagnit jarayonlarni ko‘p darajali ierarxik tuzilmalarda tavsiflaydigan matematik apparatning murakkabligi sabab bo‘lsa, yana bir qismi ularni formal shaklda ifodalash va yechish usullarining murakkabligi bilan izohlanadi. Bundan tashqari, ishlab chiquvchilar uchun mexanik mustahkamlikni ta’minlash, issiqlik rejimlarini normallashtirish, tashqi beqarorlashtiruvchi omillardan himoyalanish, ishonchlilikni oshirish kabi boshqa muhim masalalar ustuvor ahamiyat kasb etgan.

Biroq hozirgi vaqtda shunday chegara nuqtasiga yetildiki, radioelektron vositalar (REV)ni yanada samarali ishlab chiqish faqat elektromagnit moslik va shovqinga bardoshlilik talablarini hisobga olish va ularni ta’minlash masalalarini hal qilish bilangina mumkin bo‘lib qoldi. Bu ayniqsa zamonaviy aloqa vositalarida — millimetr va santimetr to‘lqinlar, ya’ni mobil aloqa, simsiz keng polosali kirish tizimlari va boshqa GHz diapazonlarida ishlaydigan qurilmalarda — alohida ahamiyat kasb etadi.

Elektromagnit moslashuv muammosini keltirib chiqaradigan asosiy tarkibiy qismlar quyidagilar: elektromagnit energiya manbai, elektromagnit energiyaning ta’siri natijasida normal ishlay olmaydigan qabul qiluvchi qurilma va ular orasidagi parazitli ta’sirlar o‘tayotgan yo‘l. Har bir holatda ushbu uchta element

mavjud bo‘ladi, garchi ularni ayrim vaziyatlarda aniq ajratib ko‘rsatish qiyin bo‘lsa ham.

JADVAL1. SHOVQIN HOSIL QILUVCHI OMILLAR

Shovqin hosil qiluvchi omillar	***Rezistor turi yoki uni qo‘llash usuli***	***Keltirib chiqarilgan ta’sir***
Chiqishlar orasidagi sig‘im	Attenuatorda –	O‘zgaruvchan tok bo‘yicha yerga ulanmagan nuqtaga YuCh (yuqori chastotali) signalning o‘tishi
Umumiy sig‘im (yer va chiqishlar orasidagi sig‘imni ham qo‘shgan holda)	uchaytirgichning teskari aloqa zanjiridagi yuklama anod qarshiligi	**Signal tarkibiy qismlarining chastotaga bog‘liq faza siljishlari**
Induktivlik	Attenuatordagi shuntlovchi rezistor	To‘liq qarshilikning chastotaga qarab o‘zgarishi. Ayniqsa 100 MGts dan past chastotalarda past qarshilikli rezistorlarda yaqqol seziladi
Yuqori chastotali maydonlarning ta’siri	Kompozit Metall plyonkali rezistorlar **Simli rezistorlar**	**Qarshilikning o‘zgarishi va qizib ketishi.** O‘z-o‘zidan induksiya EYUKi hosil bo‘lishi, u o‘ramlar soni va maydon kuchiga proportsional bo‘lib, boshqa zanjirlarga ta’sir qiladi.

Asosan elektromagnit moslik talablarini ta’minlash kamida ushbu uch elementdan ikkitasi aniqlanib, keyinchalik ularning birining ta’sirini yo‘qotish yoki zaiflashtirish orqali amalga oshiriladi.

LXXXIX. ELEKTROMAGNIT ENERGIYANING MANBADAN QABUL QILUVCHIGA PARAZIT TA’SIR MEXANIZMLARI

Elektromagnit energiyaning manbadan qabul qiluvchiga parazitli ta’sir mexanizmlarini to‘rtta asosiy guruhga ajratish mumkin:

- umumiy qarshilik orqali yoki konduktiv bog‘lanish (elektr toki);
- induktiv bog‘lanish (magnit maydon);
- sig‘im orqali bog‘lanish (elektr maydon);
- nurlanish orqali bog‘lanish (elektromagnit maydon).

Amaliyotda parazitli ta’sirlar ko‘pincha ushbu mexanizmlarning murakkab kombinatsiyasi ko‘rinishida bo‘lib, hatto manba va qabul qiluvchi aniq ma’lum bo‘lganda ham ularni aniqlashni qiyinlashtiradi. Parazitli ta’sir bir nechta yo‘llar orqali sodir bo‘lishi mumkin va bunday holatlarda bitta yo‘lni zaiflashtirish uchun ko‘rilgan choralar boshqa yo‘lning ta’sirini kuchaytirishi ham mumkin.

Elektr va magnit maydonlarning o‘zaro bog‘liqligini hisobga olgan holda zanjirlarning batafsil va to‘liq tahlili Maksvel tenglamalari yordamida bajarilishi mumkin. Ammo bunday tahlillar natijasida yuzaga keladigan murakkab matematik ifodalar ko‘pincha hodisalar fizik ma’nosini yo‘qotishiga va ishonchsiz natijalarga olib keladi.

Parazitli (ya’ni, juda kichik) bog‘lanishlarni to‘liq ko‘rib chiqish maqsadga muvofiq emas, chunki u juda kichik aniqlikdagi tuzatishlar beradi. Shu sababli, yaqin elektr maydoni orqali parazitli bog‘lanish magnit maydon hisobga olinmagan holda kichik parazit sig‘im orqali elektr maydoni hisobga olinmagan holda kichik parazit o‘zaro induktivlik orqali induktiv bog‘lanish sifatida ko‘rib chiqiladi.

Xuddi shuningdek, yaqin magnit maydoni orqali parazitli bog‘lanish ham Pechatli plata (PP) topologiyasini loyihalash bosqichi sxemaviy (mantiqiy yoki elektr sxemalar) ma’lumotlardan geometrik ma’lumotlarga (PP chizmasida yoki integral sxema kristallining maydonida elementlarni joylashtirish va ularni bog‘lovchi o‘tkazgichlar sxemasini yaratishga) o‘tishni anglatadi. Shu bilan birga, bu ishlab chiqilayotgan mahsulotning model tavsifidan uning haqiqiy fizik ko‘rinishiga o‘tishdir. Faqat ana shu bosqichda o‘tkazgichlarning haqiqiy xususiyatlari — uzunligi, kengligi, yuzasi va natijada sig‘imi, qarshiligi hamda induktivligi aniqlanadi, bu esa mahsulotning asosiy chiqish parametrlarini belgilaydi.

Elektromagnit moslikni ta’minlash uchun pechatli plata topologiyasiga qo‘yiladigan asosiy talab elementlarni joylashtirish va keyinchalik ularni ulash chiziqlarini chizishdan iboratdir.

O‘tkazgichlarni chizish, komponentlarni joylashtirish, elektr aloqalarini ajratish — bularning barchasi to‘g‘ri ishlaydigan pechatli plataning optimal sxemasini yaratish uchun optimallashtirilishi lozim. Iqtisodiy jihatdan samarali va funksional ishlaydigan variantni yaratish uchun quyidagilarga e’tibor qaratish zarur:

- pechatli plataning formatini to‘g‘ri tanlash (bir qatlamli, ikki qatlamli, ko‘p qatlamli);
- har bir signal o‘tkazgichi yonida signalni qaytarish uchun o‘tkazgich bo‘lishini ta’minlash;
- har bir integral sxema uchun to‘g‘ri elektr ajratishni ta’minlash;

- o‘tkazgich va halqa uzunliklarining me’yorda bo‘lishi;
- kommutatsiya maydonidagi o‘tkazgichlarning kesishishlar soni;
- o‘tkazgichlarning burilishlar soni;
- qatlamlararo o‘tishlar soni;
- elementlar va o‘tkazgichlar o‘rtasidagi parazitli bog‘lanish parametrlarini kamaytirish;
- ulagichlarning optimal joylashuvi;
- kabel va ulagichlarning to‘g‘ri tanlanishi;
- filtrlovchi elementlarning to‘g‘ri joylashuvi;
- yuzada haroratning bir tekis bo‘lishi va boshqa omillar.

Elementlarni joylashtirishning asosiy vazifasi ularning konstruktiv moduldagi joylashuvini belgilashdan iborat. Joylashtirish shunday amalga oshirilishi kerakki, u ulanish chiziqlarini chizishning keyingi bosqichida texnologik va konstruktiv talablarni hisobga olgan holda eng yaxshi sharoitlarni ta’minlasin. Elektromagnit moslik talablarini ta’minlash masalalari elektron vositalarni loyihalash va elementlarni joylashtirishda ayniqsa dolzarb, chunki ular ishlab chiqilayotgan qurilmalarning murakkabligi bilan bevosita bog‘liqdir. Bitta qurilmaning elementlari o‘rtasidagi elektromagnit nomoslik ko‘plab parazitli jarayonlar natijasida yuzaga keladi. murakkab tizimga kiruvchi turli qurilmalar orasida elektromagnit nomoslikka sabab bo‘ladi. Kuchli elektromagnit maydonlar ta’sirida rezistorlar qizishi va natijada ularning qarshiligi o‘zgarishi mumkin. Shuni ham hisobga olish kerakki, kompozit rezistorlar bunday maydonlarda faqat qiziydigan bo‘lsa, simli va spiral rezistorlar induktiv g‘altaklar kabi o‘zini tutishi mumkin. Mikroelektronikada qo‘llaniladigan plyonkali rezistorlar keramika asosiga yotqizilgan yupqa kremniy qatlami yoki yarimo‘tkazgich asosiga cho‘ktirib yotqizilgan metall qatlamidan iborat bo‘ladi. Kichik o‘lchamlari tufayli bunday rezistorlar nominal qarshilik qiymatlarining tor diapazoni va sig‘im hamda aktiv oqishlarning mavjudligi bilan tavsiflanadi. Bundan tashqari, agar yarimo‘tkazgich asosidan foydalanilsa, bunday rezistorlarning kichik o‘lchamlari unda noxush o‘tishlarining hosil bo‘lishiga olib kelishi mumkin. Kondensatorning o‘z induktivligi, sig‘imi va chiqishlarining aktiv qarshiligi qo‘llanilayotgan kuchlanishdagi sakrash paytida kondensatorning zaryadlanish (zaryadsizlanish) tezligini chegaralaydi. Ushbu omillarni yuqori chastotali yoki vaqtni belgilovchi zanjirlarni loyihalashda hisobga olish zarur.

2-jadvalda kondensatorlarda yuzaga keladigan shovqinlarning turli turlari va ularni bartaraf etish usullari keltirilgan.

JADVAL2. KONDENSATORLARDA YUZAGA KELADIGAN SHOVQINLARNING TURLARI VA ULARNI BARTARAF ETISH USULLARI

Shovqin hosil qiluvchi omil	***Sabablar***	***Bartaraf etish usuli***
Kondensator orqali tok sakrashlari	Issiqlik va kuchlanishning birgalikdagi ta’siri	**Qo‘llanilayotgan kuchlanishni kamaytirish uchun ketma-ket ulangan bir nechta kondensatorlardan foydalanish. O‘zini tiklovchi kondensatorlarni (masalan, tantal yoki folga anodli) qo‘llash**
YuCh kondensatorlarida (kumush-keramika va kumush qoplamali slyuda turlarida) tasodifiy shovqin	Kumushning dielektrik bilan yomon yopishishi, bu tasodifiy va kutilmagan sig‘im o‘zgarishlariga olib keladi	Kondensatorni sifatlirog‘iga almashtirish
Elektrolitik kondensatorning miltillashi	Ruxsat etilgan kuchlanishning oshib ketishi yoki kondensatorning qizib ketishi	Kuchlanish va haroratning ruxsat etilgan qiymatlaridan oshib ketmasligi
Juda past chastotalarda kondensatorning zaryadlanishi va zaryadsizlanishi vaqtida yuzaga keladigan shovqinli impulslar	Dielektrikdagi razryad (ayniqsa dielektrik sifatida qo‘llaniladigan polistirol va kvarts uchun xos)	Juda past chastotalarda ushbu dielektriklar qo‘llanilgan kondensatorlardan voz kechish. Elektrolitik kondensatorlardan foydalanishni afzal ko‘rish
Polietilen kondensatorlaridagi shovqin impulsları	Ekspluatatsiya vaqtida davom etadigan polietilenning polimerizatsiyasi	Boshqa dielektrikli kondensatorlardan foydalanish
Polietilen, kvarts yoki slyuda kondensatorlarida (ayniqsa kichik sig‘imlarda) tasodifiy shovqin	Svet, radioaktiv zarralar va rentgen nurlanishi ta’sirida dielektrikning ionlanishi	Ekranlash yoki boshqa himoya vositalari

Ba’zi chastotalarda kuchaygan yoki kamaygan so‘nish	Rezonans hodisalari	Kondensatorlarning to‘g‘ri konstruksiyasini va montajini tanlash, ekranlash
Kondensator induktiv xarakterga ega bo‘lgan zanjir sifatida o‘zini tutadi	Chiqishlarning uzunligi juda kichik bo‘lganda ham ularning induktivligi juda katta bo‘ladi	Kondensatorlarni parallel ulash va ularni qaytish o‘tkazgichi bilan imkon qadar yaqin joylashgan koaksial yoki polosa o‘tkazgichlari orqali eng qisqa yo‘llar bilan ulash

G‘altakning o‘ramlararo sig‘imi ma’lum bir chastotada parallel rezonans hosil bo‘lishiga olib keladi. G‘altaklarning asosiy xususiyatlariga magnit oqimining sochilishi, tashqi magnit maydonlarga sezgirligi, ular tomonidan hosil qilinadigan shovqin darajasi va parametrlarning barqarorligi, shuningdek, o‘zakning to‘yinish darajasi (o‘zakli g‘altaklar uchun) kiradi. 3-jadvalda induktivlik g‘altaklaridagi shovqinlarning ayrim sabablari va ularni bartaraf etish usullari keltirilgan.

JADVAL3. INDUKTIVLIK G’ALTAKLARIDAGI SHOVQINLARNING SABABLARI VA ULARNI BARTARAF ETISH USULLARI

Hodisa	***Sabab***	***Bartaraf etish usuli***
Signalning noxush o‘tishi yoki, aksincha, yo‘qligi	Parazit rezonans	To‘g‘ri konstruksiyalash va ekranlash
Quvvatning ortiqcha yo‘qotilishi	Sirt effekti, o‘tkazgichning qarshiligi, girdobiy toklar, gisterezisdagi yo‘qotishlar	Ko‘p simli o‘tkazgich, magnitsiz o‘zak va toroidal o‘ramdan foydalanish
Samarali induktivlikning o‘zgarishi	Taqsimlangan sig‘im induktivlikning ko‘rinma o‘zgarishini keltirib chiqaradi	Taqsimlangan sig‘imni kamaytirish*
O‘zaro induktivlik tufayli yuzaga keladigan halaqitlar	**Ikki g‘altak, g‘altak va o‘tkazgich yoki turli zanjirlarning ikki elementi orasidagi geometrik yaqinlik**	Elementlar orasidagi masofani oshirish, ekranlash, g‘altaklar va zanjir elementlari o‘qlarining o‘zaro perpendikulyarligini ta’minlash
O‘tkinchi jarayonlar	Tokni ulash yoki uzish	Elektromagnit relelar uchun qo‘llaniladigan usullar bilan bir xil
* O‘ramni seksiyalash yoki qadamli o‘rashni joriy etish hisobiga (chastota diapazoniga qarab)		

1) Induksion jarayonlar sodir bo‘ladigan qurilmalar

Bu qurilmalarning ishlashi ular bilan bog‘langan zanjirlardagi tok va kuchlanish sakrashlari hamda ular tomonidan yaratiladigan magnit maydonlarning potensial halaqit qabul qiluvchilarga ta’siri kabi halaqit keltirib chiqaruvchi mexanizmlar bilan bog‘liq. Transformatorlar va drossellar radiochastotali induktiv g‘altaklarga nisbatan ancha katta quvvatlarda ishlaganligi sababli, ular nisbatan kuchli halaqitlar manbai hisoblanadi.

Ichki halaqit manbalariga barcha kuchaytirish elementlari kiradi, ular tasodifiy o‘zgaruvchi (fluktuatsion) kuchlanishlar va toklarni hosil qiladi. Agar kuchaytirgich kaskadlarida faol element sifatida tunnel diodi qo‘llanilsa, unga ulangan zanjirlarning ekvivalent sig‘imlari yoki induktivliklari parazit tebranishlarni (odatda chastotasi taxminan 1 MGts) keltirib chiqarishi mumkin. Barcha stabilitronlar diskret shovqin va chastotaga teskari proporsional bo‘lgan shovqin manbalari hisoblanadi. Ammo qotishma stabilitronlaridagi shovqin darajasi diffuzion stabilitronlarga qaraganda yuqoriroq bo‘ladi.

Past signal darajasida ishlaydigan tranzistorlar halaqitlarga nisbatan yuqori sezgirlikka ega bo‘lishi mumkin. Yarim o‘tkazgich materiallariga xos bo‘lgan shovqin kuchaytiriladigan va aniqlanadigan signallarning minimal qiymatlariga cheklov qo‘yishi mumkin.

O‘ziga xos shovqinlardan biri yuqori chastotali tranzistorlarda (100 MGts va undan yuqori) yuzaga keladi, agar ular nominal ish chastotasidan ancha past chastotalarda ishlasa. Bunday shovqin ish chastotasi diapazonida parazit tebranishlar paydo bo‘lishi bilan izohlanadi.

Pechat platalardagi o‘tkazgichlarning joylashuvi elektromagnit moslashuvchanlikka katta ta’sir ko‘rsatadi, bu ham elektromagnit nurlanish, ham elektromagnit maydonlarga sezgirlik nuqtai nazaridan muhimdir. Bundan tashqari, pechat platalarni boshqa qurilmalar bilan bog‘laydigan tashqi kabellar ham elektromagnit moslashuvchanlikka sezilarli ta’sir ko‘rsatadi. Bunday qurilmalarga boshqa signal manbalari, doimiy yoki o‘zgaruvchan tok manbalari va hokazo kiradi.

Bir-biridan ma’lum masofada joylashgan ikki elektr zanjiri orasida elektromagnit bog‘lanish quyidagi yo‘llar orqali paydo bo‘lishi mumkin:

- elektr maydoni orqali;
- magnit maydoni orqali;
- elektromagnit nurlanish maydoni orqali;
- ularni bog‘lovchi simlar va to‘lqin yo‘riqchilari orqali.

Elementlar, bloklar va zanjirlarni tez o‘zgaruvchan elektromagnit maydonlar ta’siridan himoya qilishning eng radikal usuli bu **ekranlash**dir.

Elektromagnit ekranlash radioelektron qurilmalar konstruksiyalarida keng va turlicha qo‘llaniladi. Ekranlash, aslida, ekranlashning o‘zi va tarmoqlar hamda kommunikatsiyalarni filtratsiya qilishni o‘z ichiga olgan chora-tadbirlar majmuasi sifatida qaraladi.

Amal qilish prinsipi bo‘yicha quyidagi turlar farqlanadi:

- **Elektrostatik ekranlash** — elektr maydonini ekran sirtida metall massasida yopish va elektr zaryadlarini qurilma korpusiga uzatishga asoslanadi.
- **Magnitostatik ekranlash** — magnit maydonini ekranning qalinligi ichida yuqori magnito‘tkazuvchanlik hisobiga yopishga asoslanadi. Bunda ekran materiali yuqori magnit o‘tkazuvchanlikka ega bo‘lishi kerak.
- **Elektromagnit ekranlash** — girdobiy toklar yordamida magnit induksiyasidan foydalanishga asoslanadi.

Ekranlarni o‘rganish va hisoblash Makswell tenglamalariga asoslanadi. Ko‘plab adabiyotlarda keltirilgan murakkab matematik ifodalarga kirmagan holda, ekranlash samaradorligi bog‘liq bo‘lgan asosiy parametrlarni aniqlovchi formula keltirilishi mumkin.

Bundan tashqari, sxema orasidagi bog‘lanishlarning tuzilishi ham elektromagnit moslashuvchanlikka katta ta’sir ko‘rsatadi. Shuningdek, quyidagi manbalarni inobatga olish kerak:

– signallarning tarqalishi vaqtida kechikishlar, signallar shaklining buzilishi;

– signallararo kross-halaqitlar;

– moslashtirilmagan yuklamalar va bir jinsli bo‘lmagan o‘tkazgichlar sababli signalning qaytishi;

– quvvat va yerga ulash zanjirlari orqali yuzaga keladigan halaqitlar.

$$\delta = \frac{1}{\sqrt{\pi f \mu_{a\sigma}}}$$

bu yerda, δ – sirt qatlamining qalinligi

μ - magnit o‘tkazuvchanlik;

σ – **xususiy elektr o‘tkazuvchanlik**.

Ushbu ifodadan ko‘rinadiki, ekranlash samaradorligi ekran materiali va qatlam qalinligiga bog‘liq.

Metall ekranlar uzoq vaqtdan beri ma’lum va keng qo‘llanib kelinadi. Ular yuqori samaradorlikka ega bo‘lib, bu samaradorlik tushayotgan elektromagnit nurlanish (EMI) chastotasi oshishi bilan ortadi. Texnologik jihatdan ular yopiq va teshikli listlar, setkalar, trubkalar ko‘rinishida tayyorlanadi yoki yupqa qoplama shaklida qo‘llaniladi.

Biroq, metall ekranlar yuqori elektr o‘tkazuvchanligi sababli muhim kamchilikka ega: yuqori aks ettirish koeffitsiyenti, bu erkin fazodagi to‘lqin qarshiligi va ekran qarshiligi o‘rtasidagi katta farq tufayli yuzaga keladi.

Shuningdek, bunday ekranlarning samaradorligi elektr kontaktlarining sifati va ishonchliligiga juda bog‘liq. Kontaktlar buzilganda elektromagnit to‘lqin qayta nurlanishi kuzatiladigan sohalar paydo bo‘ladi.

Teshib qo‘yilgan yoki setka shaklidagi ekranlarning samaradorligi esa chastota oshishi bilan kamayadi, bu esa ularning qo‘llanish sohasini cheklaydi (4-jadval).

JADVAL4. EKRAN MATERIALI SAMARADORLIGINING CHASTOTAGA BOG‘LIQLIGI

Ekran turi	***Ekran materiali***	***Chastota, kHz***				
		10	***100***	***1000***	***Chastotaga bog‘liqligi***	***100000***
Metall listlar qalinligi **0,5 mm**	Po‘lat	64	87	120	120	120
	Mis	67	70	80	120	120
	Alyuminiy	65	66	88	120	120
Metall to‘rlar	Mis, 0,1 mm diametrli simdan tayyorlangan, 1×1 mm katakli	65	55	50	42	32
	Po‘lat, 0,1 mm diametrli simdan tayyorlangan, 1×1 mm katakli	48	47	42	36	29,5

Zanjirlar orasidagi sig‘imiy va/yoki induktiv bog‘lanishlarni kamaytirish magnit yumshoq materiallardan tayyorlangan ekranlash orqali amalga oshiriladi. Eng ko‘p qo‘llaniladigan magnit yumshoq

materiallardan biri permalloylar hisoblanadi. U temir-nikel qotishmasi bo‘lib, past kuchlanishli maydonlarda juda katta boshlang‘ich magnit o‘tkazuvchanlikka ega. Bu xususiyat uning amalda anizotropiya va magnitostriktsiyaning yo‘qligi bilan bog‘liq.

Ekranlar tayyorlash texnologiyasi turlicha bo‘lib, ishlatiladigan materiallar va ularning qo‘llanish sohalariga bog‘liq. Hozirgi vaqtda RQA (radioelektron apparatura) ishlab chiqarishda ichki va tashqi sirtlarni vakuum usulida metallizatsiya qilish texnologiyasi qo‘llaniladi. Bunda elektromagnit nurlanishlarning turli chastotalarida ekranlash samaradorligini oshiruvchi kompozitsion materiallardan foydalaniladi.

Parazit jarayonlarga qarshi kurashning boshqa usullari turli sxemotexnik yechimlarni qo‘llash orqali amalga oshiriladi. Elektr ta’minoti zanjirlarida, interfeys signallari zanjirlarida, bosma plata yo‘llarida va yerga ulash simlarida konduktiv xalaqitlarni bostirish (yoki kamaytirish)ning asosiy va samarali vositalaridan biri — bu xalaqitni bostiruvchi filtrlardir.

Xulosa

Xulosa qilib aytganda, bugungi kunda elektromagnit moslashuvchanlik va shovqinbardoshlik masalalariga bag‘ishlangan nazariy hamda amaliy natijalarni tahlil qiluvchi juda ko‘plab ilmiy ishlar mavjud. Ushbu tadqiqotlar elektromagnit moslashuvchanlik va shovqinbardoshlik muammosini radioelektronikaning alohida yo‘nalishi sifatida ko‘rsatadi. Mazkur materiallarda keltirilgan ilmiy jihatlarni tahlil qilgan holda aytish mumkinki, zamonaviy radioelektron vositalar, ularning element bazasi, texnikasi va texnologiyalari rivojlanishi bilan bir qatorda elektromagnit moslashuvchanlik va shovqinbardoshlik masalalari ham uzluksiz rivojlanib, yanada murakkablashib bormoqda. Bu esa o‘z navbatida, elektromagnit moslashuvchanlik va shovqinbardoshlikni ta’minlashga oid ko‘plab masalalarni hal qilish uchun chuqur ilmiy tadqiqotlar va kompleks yondashuvni talab qiladi.

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A REVIEW OF DEEP LEARNING METHODS FOR ENHANCED VIDEO COMPRESSION

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***Abstract*— Video Compression is a significant aspect of multimedia technology, in which the goal to minimize the size of video data, while also preserving its perceptual quality, for effective transmission and storage. Traditional approaches such as transform coding, predictive coding, and entropy coding are some of the much earlier discovered approaches in this area. And accordingly, traditional standards such as H.264/AVC, H.265/HEVC, and H.266/VVC offer high compression ratios but suffer from computational complexity, limited scalability, and hardware constraints. In particular, VVC's advanced partitioning mechanisms introduce significant encoding overhead, rendering it impractical for real-time and mobile applications. Additionally, browser and platform support for HEVC remains fragmented, impeding global adoption. To address these challenges, deep learning (DL) has emerged as a promising paradigm, introducing end-to-end codecs, generative models (GANs, Transformers), and recurrent architectures (RAE, DRAE) for adaptive and perceptually optimized compression. This paper presents an overview of deep learning-based video compression methods. Using the PSNR, SSIM, VMAF metrics the paper demonstrates that existing methods often fail to balance bitrate reduction with perceptual quality.**

[82] ***Keywords— video compression, deep learning, VMAF, transformer, perceptual optimization***

INTRODUCTION

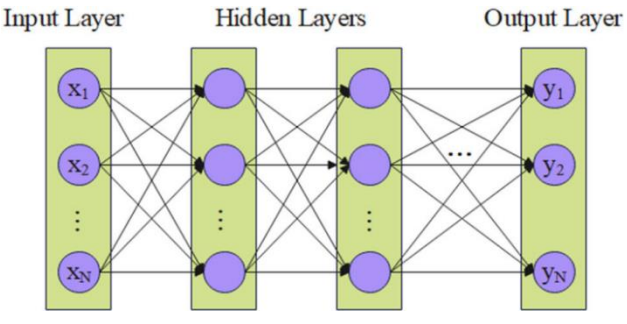
The rapid advancement of broadcasting and streaming technologies necessitates efficient video compression methods capable of handling increasing data volumes while maintaining high image fidelity (4K/8K). The growing popularity of devices supporting Ultra High Definition (UHD) resolution—such as televisions, smartphones, and virtual reality systems—has imposed heightened demands on encoding algorithms, which must deliver high processing speeds with minimal latency. The continuous rise in traffic across video-on-demand platforms (e.g., Netflix, YouTube), along with the global deployment of 5G networks, has made video codec optimization a particularly urgent challenge. The problem of increasing data volumes requires the elimination of redundant information in TV signals while maintaining visual quality. Standards such as H.264, H.265, and H.266, along with emerging hybrid coding techniques, play a key role in this process [1, 2].

Modern video compression standards such as H.264/AVC (Advanced Video Coding), H.265/HEVC (High Efficiency Video Coding) and VVC (Versatile Video Coding) provide a high compression ratio, but require significant computing resources and are not adapted to the content. Video communication, streaming and media storage systems require video compression with the highest possible quality/bitrate ratio. A major obstacle to achieving this in the latest international standard, H.266/VVC is its encoding complexity. For instance, the block partitioning mechanism known as Quad Tree with nested Multi-Type Tree introduces exponentially increasing computational overhead during intra- and inter-frame prediction processes. Encoders built under this standard consume significantly more time to generate bitstreams than decoders require to reconstruct them. This asymmetry, along with other technical challenges, renders the standard experimental one.

The global adoption of the previous international standard, H.265/HEVC, is contingent upon licensing policies, hardware compatibility, and platform support. These factors have limited its accessibility in developing countries. Moreover, not all modern web browsers support this standard:

- Microsoft Edge offers partial support for H.265, provided the user has Windows 10+ with the HEVC Video Extension installed;
- Google Chrome and Mozilla Firefox offer limited support for it;
- Opera does not support H.265 at all [3].

As video resolution (4K, 8K) and streaming volume continue to grow, there is an increasing need for more intelligent and adaptive approaches. Deep learning (DL) methods have introduced a new paradigm—learned video compression—which includes end-to-end codecs (ETELVC), generative models (GANs, Transformers), recurrent autoencoders (RAE/Deep Recurrent Autoencoder (DRAE)), and hybrid neural modules designed to replace traditional encoding blocks [4]. These approaches rely on deep neural networks (DNNs), whose general architecture is illustrated in Figure 1.



The basic architecture of DNN [5]

Convolutional Neural Networks (CNNs), Generative Adversarial Networks (GANs), Recurrent Neural Networks (RNNs), and Deep Recurrent Autoencoders (DRAEs) are among the principal variants of deep learning architectures applied in video compression.

Despite offering novel approaches, AI-based methods face a number of limitations that hinder their widespread adoption in practical systems.

REVIEW OF EXISTING DL METHODS

End-to-End Learning-based Video Compression

Recent advancements in deep learning have led to the development of intelligent video compression frameworks that aim was to reduce data redundancy while preserving perceptual quality. Below, we examine several representative models that exemplify the evolution of learning-based video compression.

Deep Video Compression (DVC) is recognized as one of the pioneering end-to-end neural architectures for video coding. It employs a convolutional neural network (CNN) to extract spatial features and utilizes optical flow estimation for inter-frame motion compensation. While DVC demonstrates promising compression efficiency, it exhibits notable limitations in dynamic scenes characterized by abrupt motion. Specifically, the reliance on optical flow can result in motion estimation errors, leading to visible artifacts such as ghosting or blurring. To address these shortcomings, post-processing techniques—typically involving refinement networks or residual enhancement modules are applied to the reconstructed frames [6].

Scale-Space Flow builds upon the foundational structure of DVC by introducing multi-scale motion estimation. This approach leverages hierarchical representations of video frames to capture motion at varying spatial resolutions. By integrating coarse-to-fine flow refinement, Scale-Space Flow enhances the robustness of motion compensation, particularly in scenes with complex or non-linear motion trajectories [7]. The model demonstrates improved temporal consistency and reduced artifact prevalence compared to its predecessor.

Recurrent Learned Video Compression (RLVC) encompasses a class of models that incorporate Recurrent Autoencoders (RAEs) and Recurrent Probabilistic Models (RPMs) to achieve low-latency and temporally-aware compression. These architectures exploit the sequential nature of video data by modeling temporal dependencies across frames using recurrent neural units such as Long Short-Term Memory (LSTM) or Gated Recurrent Units (GRU). The autoencoder framework encodes each frame into a latent representation, which is then decoded to reconstruct the original content. The recurrent structure enables the model to maintain contextual coherence over time, making it particularly effective for streaming applications and real-time encoding scenarios [8].

Despite their architectural sophistication, these models share several limitations. A common drawback is the reliance on a single motion hypothesis, which assumes a deterministic and uniform motion field across frames. This assumption fails in complex scenes involving occlusions, non-rigid motion, or rapid transitions, leading to degraded reconstruction quality. Moreover, learning-based video compression systems are inherently computationally intensive, requiring substantial GPU (Graphics Processing Unit) resources for both training and inference [9]. The training process itself demands large-scale annotated datasets to ensure generalization across diverse content types, which poses a barrier to scalability and deployment.

While learning-based video compression models such as DVC, Scale-Space Flow, and RLVC represent significant strides toward adaptive and perceptually optimized coding, their practical implementation is constrained by computational overhead, data requirements, and limitations in motion modeling. These challenges underscore the need for hybrid architectures and more efficient learning paradigms to bridge the gap between theoretical performance and real-world applicability.

Generative Adversarial Neural Network (GAN)

GAN is one of the DL approaches that involves two network generators and a discriminator. GAN develops realistic frames that helps to minimize the bit rate required while maintaining high visual quality. In conventional GAN, the network learns a mapping from noise to a target distribution which is similar to real samples [10]. Nevertheless, they have a number of serious limitations, especially in applied video coding systems:

- Training instability due to the adversarial nature of generator–discriminator optimization. This often leads to convergence issues, especially in high-resolution or complex scenes. A common problem is mode collapse, where the generator produces a limited set of repetitive patterns;
- Unpredictability of the quality of images generated by GAN. It can generate visually realistic frames, but does not guarantee an exact reconstruction of the original content. This is problematic for video codecs, which require determinism and reproducibility;
- Difficulty of integration into video coding standards (e.g., HEVC, VVC), which require a strict bitstream structure compatible with decoders. GAN-based methods often do not meet these requirements, which makes it difficult to implement them in broadcast and telecommunication systems.

C. Variational Autoencoder (VAE)

VAE is a powerful tool for video compression, particularly when maintaining high quality at reduced bitrates is essential. Unlike traditional codecs, VAE uses a probabilistic model to represent video data in a compact latent space, allowing for more flexible control over compression and decompression. It learns to map input data (video) to a latent space using an encoder, and then decompress it using a decoder. The video version of VAE extends this approach to the time axis, taking into account motion and dynamics between frames [11]. If we consider analytically the loss function L in VAE video compression, we must take into account that the encoder transforms video

frames into latent variables z, from which the decoder reconstructs the video:

$$L = E_{q(z|x)}\left[\log p(x|z)\right] - D_{KL}(q(z|x) \| p(z)), \quad (1)$$

where $E_{q(z|x)}\left[\log p(x|z)\right]$ is the reconstruction term, the expected value of the logarithm of the likelihood of reconstructing the input data x from the latent representation z; $D_{KL}(q(z|x) \| p(z)$ - is the Kullback–Leibler divergence, measuring the distance between the approximate posterior q(z|x) and the prior distribution p(z), typically N(0,I). KL divergence measures how much the distribution we are learning deviates from the normal distribution [12]. This loss function L plays a central role in training the model, enabling simultaneous compression and accurate reconstruction.

D. Transformer-DLVC

Transformer-DLVC is a generalized architecture that integrates transformer models with deep learning-based video compression (DLVC). Transformer models are employed to efficiently encode video sequences, replacing or augmenting traditional codec components such as motion prediction, compensation, and entropy coding.

Transformer-DLVC captures temporal dependencies between frames, extracts global contextual features, and substitutes complex motion estimation blocks found in conventional codecs. Its core components are:

1. Patch Embedding: frames are split into patches, which are transformed into feature vectors;
2. Temporal Transformer: simulates movement and changes between frames;
3. Latent Bottleneck (VAE or AE): compression of features into a compact representation;
4. Entropy Model (PixelCNN, Hyperprior): probability estimation for efficient coding;
5. Decoder reconstructs the video sequence.

VISUAL QUALITY METRICS

Limited perceptual optimization is a common drawback in many modern video compression methods, including both traditional codecs (e.g., HEVC) and deep learning-based models. This limitation arises from the reliance on mathematical metrics such as Mean Squared Error (MSE) and Peak Signal-to-Noise Ratio (PSNR), which do not reflect human visual perception.

MSE and PSNR measure pixel-wise differences but fail to capture perceptual nuances [13]. For instance, minor distortions in skin texture may be visually noticeable yet yield low MSE values. While SSIM accounts for structural similarity, it still overlooks aspects such as color perception, motion, depth, and semantic context.

As an alternative to the above metrics, VMAF (Video Multi-Method Assessment Fusion) is a metric developed by Netflix that combines several perception models. It consists of:

1. Detail Loss Metric;
2. Temporal Consistency;
3. Visual Information Fidelity;
4. SSIM и другие.

These indicators are fed into a machine learning model (typically Support Vector Machine or Random Forest) trained on Mean Opinion Scores (MOS), resulting in a quality metric that closely aligns with viewer perception.

PSNR and SSIM often show poor correlation with perceived quality, making VMAF the preferred metric. For example, many GAN-based approaches demonstrate gains in PSNR but suffer degradation in VMAF due to texture artifacts [14].

EXPERIMENTAL EVALUATION

For analysis, the most widely used video compression models were selected: Autoencoder-based, VAE-based [15], CNN-in-loop, and Transformer-based codecs. All models were evaluated on standard video datasets (DL3DV-ALL-4K), converted to the YCbCr format.

All measurements were conducted using SI units. Bitrate was measured in megabits per second (Mbps), quality in decibels (dB), and VMAF scores ranged from 0 to 100.

ANALYSIS RESULTS OF STANDARDIZED COMPRESSION METHOD AND AI-BASED MODELS

Compression Method	***Quality assessment metrics for reconstructed images***			*Bitrate*
	PSNR	*SSIM*	*VMAF*	
HEVC	34.2	0.91	89.5	1.20
VAE-based	35.1	0.92	90.8	0.95
Transformer-DLVC	36.5	0.94	94.7	0.72

During HEVC testing, PSNR and VMAF values were observed in the range of 34–35 dB and 88–90 points, respectively. These results are consistent with comparative evaluations of H.265 codecs against AV1 and other compression standards [16].

VAE-based models have demonstrated improved perceptual quality at moderate bit rate reductions [17]. Transformer-based architectures yield superior performance in both VMAF and PSNR, particularly when combined with perceptual loss functions and entropy-aware coding mechanisms.

The experimental evaluation revealed several limitations inherent to current deep learning-based video compression models:

- Weak modeling of AE and VAE timing dependencies does not take into account motion between frames, resulting in loss of coherence.
- Constrained Perceptual Optimization Using MSE instead of perceptual loss functions reduces visual quality.
- The high computational complexity of the Transformer model requires significant resources, especially at high resolution.

Based on literature review and experimental findings, several challenges must be addressed to enable broader adoption of deep learning (DL) methods in video compression.

Despite reported improvements in objective metrics such as PSNR, many early AI-based models—such as Deep Video Compression (DVC)—are prone to generating artifacts (e.g., checkerboard patterns or distortions during abrupt motion), which degrade subjective video quality. In contrast, traditional codecs incorporate built-in filters (e.g., Deblocking Filter) to mitigate such issues.

DL-based models, particularly those employing Recurrent Neural Networks (RNNs) or complex contextual analysis, demand significant computational power for both encoding and decoding. This limits their applicability on resource-constrained devices such as smartphones and IoT systems.

Flexible scalability in terms of resolution and bitrate remains a challenging task for AI-driven codecs, although some DL models have proposed partial solutions.

Optimization of DL algorithms using MSE often leads to blurred outputs, as neural networks tend to average out fine details to minimize error. This results in the loss of subtle textures, which is noticeable in subjective quality assessments.

Training data scarcity is a common issue in video processing. DL models often generalize poorly when applied to unseen content types. Furthermore, the low interpretability of neural codecs complicates standardization efforts.

Hardware implementation of existing DL-based video compression methods also poses significant barriers to real-world deployment due to excessive power consumption. Despite their strong performance in PSNR, SSIM, and VMAF metrics, GPU- and FPGA (Field Programmable Gate Array)-based implementations typically consume hundreds of watts per stream, severely limiting their use in real-time systems and mobile platforms. In contrast, traditional codecs such as HEVC and VVC benefit from ASIC (Application-Specific Integrated Circuit) solutions with power consumption in the range of a few watts, making them far more energy-efficient.

CONCLUSION

The conducted analysis indicates that, despite the notable progress of deep learning in video compression, key challenges—namely, high encoding complexity and lack of standardization—remain unresolved. These issues necessitate further development of hybrid compression algorithms that combine the strengths of traditional and AI-based approaches.

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ТЕЛЕКОММУНИКАЦИОННАЯ СЕТЬ С ПРИОРИТЕТНЫМ ОБСЛУЖИВАНИЕМ ПОТОКОВ ИНФОРМАЦИИ

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***I. Аннотация*—Механизм приоритетной обработки трафика в телекоммуникационных сетях основан на делении всего возможного сетевого трафика на небольшое количество классов и назначении каждому классу некоторого числового признака - приоритета. Деление на классы (классификация) может осуществляться разными способами. Способ классификации, как правило, не связан непосредственно с работой алгоритмов обслуживания, реализующих механизмы приоритезации, -главное, чтобы все пакеты, которые поступают в очередь, имели признак приоритетности. Пакеты могут разбиваться на классы по приоритетам в соответствии с типом сетевого протокола, по которым обрабатываются потоки пакетов, образующих трафик (например, IPX или IP, такой способ классификации подходит только для устройств, работающих на канальном уровне согласно семиуровневой модели OSI ISO), или на основании адресов назначения и отправителя, или идентификаторов пользовательских приложений, или любых других комбинаций признаков, содержащихся в полях форматов задействованных сетевых протоколов. Это все создают необходимость передачи в рамках одного канального ресурса разнородных, противоречивых по нормам на достоверность, задержку пакетов, объем информации и вынуждают к необходимости разработки эффективных моделей систем массового обслуживания (СМО) и сетей СМО, алгоритмов, учитывающих специфику совместной передачи смешанного разнородного потока информации (трафика). В связи с этим, в данной статье разработан алгоритм расчета характеристик телекоммуникационной сети с приоритетным обслуживанием потоков информации. Приведены математические модели расчета характеристик разнородных потоков информации с относительными и абсолютными приоритетами. Разработанный алгоритм расчета характеристик приоритетных потоков информации позволяет учитывать интенсивность поступление и обслуживания поступающих потоков, загрузку и надежность цифровых каналов связи и повышать эффективность телекоммуникационных сетей.**

Ключевые слова—телекоммуникационные сети, алгоритм, приоритетное обслуживание, разнородные потоки, математические модели, абсолютные и относительные приоритеты, время задержки пакетов, интенсивность, загрузка цифровых каналов.

ВВЕДЕНИЕ

В настоящее время телекоммуникационные сети строятся на базе множества коммутационных устройств, каждое из которых может работать независимо от других устройств, самостоятельно определяя правила, по которым оно будет обрабатывать поступающие на него пакеты (Рис-1). Также современные коммутационные устройства вырабатывают свои правила коммутации пакетов по заложенным в них алгоритмам [1,3]. Правила обмена служебной информацией между устройствами и способы её применения для выработки согласованных правил обработки пакетов определяются множеством разнообразных служебных протоколов, каждый из которых решает некоторое подмножество задач администрирования сети. Использование множества служебных протоколов отнюдь не делает сетевое администрирование простым.

Системы обслуживания с относительным приоритетом играют важную роль в повышении эффективности и качества обслуживания. Благодаря новым технологиям и возможностям, эти системы способны оптимизировать процессы и улучшить уровень обслуживания. Одним из ключевых факторов, влияющих на эффективность систем обслуживания, является автоматизация процессов. Благодаря использованию программного обеспечения и цифровых решений, можно сократить время на выполнение задач и устранить возможные ошибки. Это позволяет повысить производительность и снизить затраты[2,4,5].Улучшение качества обслуживания также является важной задачей систем обслуживания с относительным приоритетом. Благодаря возможности установления приоритетов и персонализации обслуживания, системы способны предоставлять более индивидуальный и удовлетворительный уровень обслуживания. Это повышает удовлетворенность клиентов и укрепляет их лояльность к компании.

Кроме того, инновации в системах обслуживания, такие как использование интеллектуальных технологий и цифровых решений, способствуют улучшению качества обслуживания. Благодаря этому, системы могут предоставлять более точные и быстрые решения, а также обеспечивать безопасность обслуживания с приоритетом. Теория массового обслуживания как раздел теории вероятностей возникла сравнительно недавно, но за очень небольшой

срок превратилась из очень специальной области исследований, связанной лишь с задачами телефонной связи, в обширную область исследований, в которой нуждаются самые разнообразные направления человеческой деятельности. Практические аспекты обслуживания с приоритетом необычайно широки и разнообразны. Сюда относятся и многочисленные задачи теории связи, и вопросы медицинского обслуживания населения, и проблемы обработки информации, и важнейшие аспекты проектирования вычислительных систем, и задачи автоматизации производственных процессов, и многое многое другое. Во всех этих случаях мы имеем дело с массовой обработкой некоторых объектов при учете влияния случайных факторов. С бурным развитием вычислительной техники, усложнением ее структуры, созданием локальных сетей и многопроцессорных систем появилась необходимость выделить ряд направлений в исследовании задач теории массового обслуживания. Наиболее важным из них является математическая теория приоритетных моделей [6,10,11]. В частности, эта теория занимается вопросами оптимизации процессов. Например, в больших приложениях распределенной архитектуры, построенных на основе технологии клиент-сервер, обслуживающему серверу приходится в течение некоторого времени выполнять заявки, поступающие от клиентов, что приводит к необходимости назначения приоритетов. Смысл этой операции заключается в том, чтобы предоставить определенным клиентам преимущественное право на обслуживание, на основе различия их друг с другом. При этом сами процессы могут различаться между собой по разным характеристикам, таким как: размер, важность, пени за простой процессора, наличие определенных прав у клиента и т.д. Таким образом, обеспечивается льготное обслуживание одних процессов с высоким приоритетом за счет других с низким. В связи с этим, появляется необходимость описать систему массового обслуживания более формально [12,14].

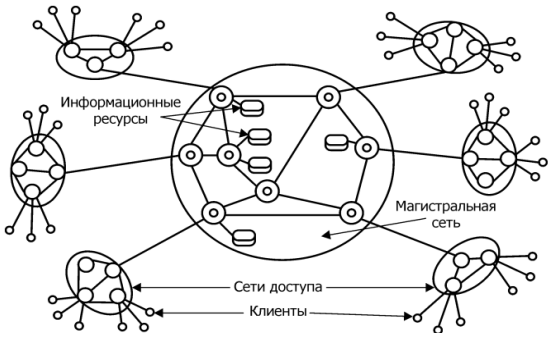

Рис. 1- Структура многоуровневой телекоммуникационной сети.

Главным критерием эффективности обслуживания потоков информации в телекоммуникационных сетях является обеспечение выполнения требований по временным ограничениям в процессе их проектирования и планирования. Планирования работы по проектированию телекоммуникационных сетей облегчается тем, что в телекоммуникационной сети имеются информация о её вероятностно-временных характеристиках, пропускной способности каналов связи, объеме нагрузок в её узлах и т. д. Эти данные могут быть использованы при разработке алгоритма расчета основных характеристик телекоммуникационных сетей с учетом приоритетности поступающих потоков информации. Анализ исследования в этой области показывает, что в настоящее время недостаточно изучены вопросы разработки алгоритмов оптимизации структуры телекоммуникационных сетей с многоуровневой структурой, базирующихся на системном подходе. Не до конца изучены также математический аппарат описания процессов передачи разнородного потока информации, учитывающий надежность, а также приоритетность этих потоков информации. Существующие алгоритмы исследования телекоммуникационных сетей, формализующих процессы оптимизации их структуры по критерию общесетевых приведенных затрат, а также телекоммуникационные сети связи специального назначения и алгоритм расчета вероятностно-временных характеристик разнородных потоков также недостаточно изучены.

Разработка алгоритма расчета характеристик телекоммуникационных сетей с приоритетным обслуживанием потоков информации состоит из следующих разделов [16,18,19,20]:

расчет суммарного потока в телекоммуникационной сети с относительным и абсолютным приоритетами;

расчет вероятности своевременной доставки речи в трактах пакетной транспортной сети, состоящих из разнородных звеньев передачи с относительным и абсолютным приоритетами;

расчет времени ожидание начала обслуживания пакета с относительным и абсолютным приоритетами;

расчет среднего времени пребывания пакета в звене телекоммуникационной сети с относительным и абсолютным приоритетами.

При разработке алгоритма расчета характеристик телекоммуникационных сетей с приоритетным обслуживанием будет соблюдаться следующая иерархия ее компонентов: звено передачи потоков информации, тракт транспортной системы передачи потоков информации и многоуровневая телекоммуникационная сеть в целом.

Методы исследования

Количество мест для ожидания заявок каждого типа - неограниченно. Приоритетная дисциплина в рассматриваемой модели -- смешанная, рассматриваются две модели: в первой модели приоритет может быть или относительным, или абсолютным с обслуживанием заново прерванного требования, а во второй приоритет является абсолютным с потерей или обслуживание заново прерванного требования. Также для системы с тремя входящими пуассоновскими потоками, произвольным временем обслуживания каждого потока, в которой между первым и вторым потоком, а также между первым и третьим потоком установлена дисциплина

относительного приоритета, а между первым и третьим дисциплина абсолютного приоритета с обслуживанием заново (модель №1) было найдено распределение количества требований наименее приоритетного потока (третьего) в условиях критической загрузки.

В качестве основных показателей, характеризующих степень удовлетворения заданного уровня требований по вероятностно-временным характеристикам, примем среднее время доставки сообщений – T и вероятность своевременной доставки сообщений – Q. В соответствии с [19,20] для телекоммуникационной сети с многоуровневой структурой вероятность доставки сообщений определяется из соотношения [7,8,9]:

$$Q = \left| \frac{EXP(-\frac{\nu_э}{m\mu_э})(1-\frac{\lambda}{m\mu_э})}{1-\frac{\lambda}{\nu_э}(1-EXP(-\frac{\nu_э}{m\mu_э}))} \right|^n \quad (1)$$

где: Q – вероятность своевременной доставки сообщений; $\nu_э$ – эквивалентная интенсивность старения сообщений; λ - интенсивность поступления потоков информации; m – число каналов связи; n – число узлов в сети; $\mu_э$ – эквивалентная интенсивность обслуживания сообщений, которая определяется как [12, 13,14]:

$$\mu_э = \frac{C_э К_г}{V} \quad (2)$$

здесь $C_э$ – эквивалентная пропускная способность цифровых каналов связи; V – средний объем сообщений; $K_г$ - коэффициент готовности каналов связи.

Тогда с учетом (2) выражение (1) будет иметь вид [10,12,15]:

$$Q = \left| \frac{EXP(-\frac{\nu_э V}{mC_э К_г})(1-\frac{\lambda V}{m\mu_э})}{1-\frac{\lambda}{\nu_э}(1-EXP(-\frac{\nu_э V}{mC_э К_г}))} \right|^n \quad (3)$$

Среднее время доставки сообщений в звене передачи пакетов определяется как:

$$T = \frac{V}{C_э K_г - \lambda V}(1 + \frac{C_э К_г К_п}{V_d}) \quad (4)$$

где: $К_п$ -коэффициент простоя канала. Учитывая выражение (1), формула (4) имеет вид:

$$T = \frac{(2mC_э К_г - \lambda V)}{2mC_э К_г (mC_э К_г - \lambda V)}(1 + \frac{mC_э К_г К_п}{Vd})n \quad (5)$$

С учетом вышеприведенных общесетевая задержка потоков информации в телекоммуникационной сети с многоуровневой структурой определяется [5,6]:

$$T = \frac{1}{\Lambda}\sum_{r=2}^{R}\left[2(\lambda_{r-1,r} m_{r-1,r} T_{r-1,r}) + 2(\lambda_{r,r} m_{r,r} Tr, r)_{r,r} + (\lambda_r n_r T_r)\right] \quad (6)$$

где: Λ - суммарная интенсивность входящего потока в сеть;

R - число ступеней иерархии;

λ - интенсивность поступления потоков информации;

n_r- число узлов коммутации на r-ой ступени;

m_r- число каналов связи r-ой ступени;

$m_{r-1,r}$ - число каналов связи в межуровневой подсети с индексом (r-1,r)

$$m_{r,r} = \frac{n_r k_r}{2}, \quad m_{r-1,r} = n_{r-1} \quad (7)$$

Аналитическое соотношения (6), позволяет связать основные вероятностно-временные характеристики потоков (время задержки, вероятность доставки пакета, интенсивность поступления потоков) с параметрами телекоммуникационной сети (число каналов, число узлов коммутации, число ступеней иерархии) и структурными особенностями топологии, а также позволяет рассчитать среднее время доставки пакета в многоуровневой сети.

Интенсивность поступления потоков сообщений в межуровневых подсетей определяется [17,18]:

$$\lambda_{r,r-1} = \frac{\Lambda}{n_r}[1 - \eta_r + \beta_r(\eta_{r+1} - \eta_r)] \quad r = 1, R-1 \quad (8)$$

где Λ - суммарная интенсивность входящего потока в сеть; β_r - маршрутный коэффициент; η_r - количество узлов коммутации в r - ступени иерархии. Интенсивность потоков сообщений для каналов зоновых подсетей определяется:

$$\lambda_{r,r} = \frac{\Lambda\pi_r}{n_r K_r}(1 - \beta_r)(\eta_{r+1} - \eta_r) \quad r = 2, R-1 \quad (9)$$

Интенсивность потоков сообщений для узлов коммутации определяется:

$$\lambda_r = \frac{\Lambda}{n_r}[2(1 - \eta_r) + \beta_{r-1}(\eta_r - \eta_{r-1}) + (\pi_R - 1)(1 - \beta_r)(\eta_{r+1} - \eta_r)], \quad (10)$$

Вероятность своевременной доставки Q для многоуровневой телекоммуникационной сети будем вычислять как величину, средневзвешенную по различным маршрутам, относительно доли протекающего по ним потока

$$Q = \sum_{r=2}^{R} \frac{\phi_r + \alpha_r \psi_r (Q_r Q_{r,r})^\pi}{Q_r} \prod_{i=1}^{r-1} \alpha_i \theta_i (Q_{i+1} Q_{i,i+1})^2 \quad (11)$$

где: R- число ступеней иерархии; π – число маршрутов в сети; φ_r узловой коэффициент замыкания нагрузки на r -й ступени определяется [3,4]:

$$\phi_r = \frac{\beta_{r-1}(\eta_r - \eta_{r-1})}{1 - \eta_r + \beta_{r-1}(\eta_r - \eta_{r-1})}, r = 2, R \quad (12)$$

сетевой коэффициент замыкания нагрузки r -й ступени определяется выражением:

$$\psi_r = \frac{(1-\beta_r)(\eta_{r+1} - \eta_r)}{1 - \eta_r}, r = 2, R-1 \quad (13)$$

узловой коэффициент межступенчатого транзита r -й ступени определяется выражением,

$$\alpha_r = 1 - \varphi_r \quad (14)$$

сетевой коэффициент межступенчатого транзита r -й ступени определяется выражением:

$$\theta_r = 1 - \psi_r \qquad (15)$$

С учетом полученных аналитических формул расчета характеристик телекоммуникационных сетей, представим полный алгоритм расчета вероятностно-временных характеристик телекоммуникационной сети с многоуровневой структурой с приоритетным обслуживанием потоков информации (рис.2) [19,20].

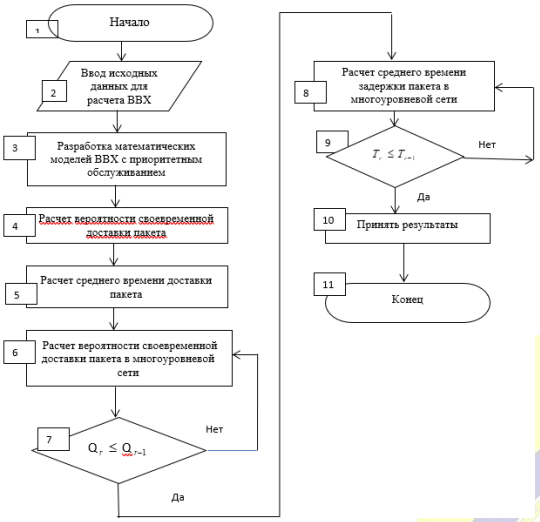

Рис. 2 Алгоритм расчета характеристик телекоммуникационной сети с приоритетным обслуживанием потоков информации

Разработанный алгоритм позволяет произвести расчет среднего времени задержки и вероятности своевременной доставки приоритетных потоков информации в телекоммуникационной сети с многоуровневой структурой. Данный алгоритм является унифицированным и допускает возможность обобщения полученных положений на системы обслуживания с более сложными дисциплинами обслуживания.

ЧИСЛЕННЫЕ РЕЗУЛЬТАТЫ

Среднее время доставки пакета для многоуровневой телекоммуникационной сети (Т) вычисляется по формуле (6) и получаем следующий график зависимости средней задержки от загрузки канала связи.

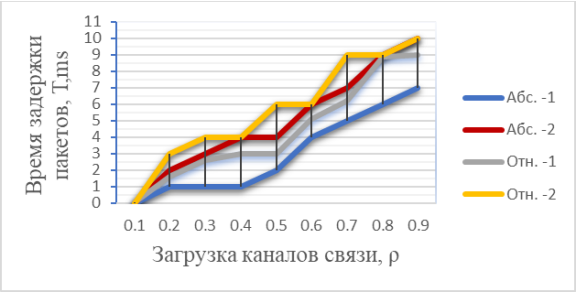

Рис. 3. График зависимости средней задержки пакетов от загрузки каналов связи при различных приоритетных дисциплинах обслуживания

С помошью формулу (6) были произведены численные расчеты и получен график зависимости средней задержки пакетов от загрузки каналов связи с несколькими приоритетами, который представлен на рисунке 3. Стратегия обслуживания приоритетных потоков информации в телекоммуникационных сетях с многоуровневой структурой, построенная на основе дисциплины обслуживания пакетов с абсолютным приоритетом, позволила обеспечить малое время задержки в обслуживании более срочных категорий информации.

Расчеты показали, что, введение дисциплины обслуживания с абсолютным приоритетом с двумя приоритетами предполагает заметное улучшение обслуживания 1-го приоритета за счет увеличения времени задержки пакетов 2-го приоритета. С увеличением загрузки каналов постепенно увеличиваются среднее время задержки пакета в обоих приоритетах. При значениях загрузки (от 0,1 до 0,9) среднее время задержки пакета не меняется (абсолютный приоритет 1), в остальных случаях наблюдается увеличения средней задержки пакетов (относительный приоритет 1 и абсолютный приоритет 2). Это означает, что абсолютный приоритет обеспечивает меньшее время передачи по сравнению с относительным приоритетом независимо от величины загрузки каналов связи.

ЗАКЛЮЧЕНИЕ

Таким образом, в данной работе разработан алгоритм расчета вероятностно-временных характеристик телекоммуникационных сетей с приоритетным обслуживанием потоков информации. Разработанный алгоритм позволяет рассчитать вероятностно-временные характеристики разнородных потоков информации, учитывать показатели надежности каналов связи. Предложенное аналитическое соотношения (6) позволяет связать основные вероятностно-временные характеристики потоков (время задержки, вероятность доставки пакета, интенсивность поступления потоков) с параметрами сети (число каналов, число узлов коммутации, число ступеней иерархии) и структурными особенностями топологии. Соотношение (6) позволяет рассчитать среднее время доставки пакета в многоуровневой телекоммуникационной сети с приоритетным обслуживанием потоков информации. Научная значимость результатов данной статьи заключается в разработке математических моделей, позволяющих определить эффективность приоритетных систем обслуживания, связать вероятностно-временные характеристики потоков информации со структурными параметрами сети, алгоритма расчета вероятностно-временных характеристик разнородных потоков информации, учитывающих приоритетность и надежность поступающих потоков.

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ПРЕДВАРИТЕЛЬНАЯ ОБРАБОТКА УЗБЕКСКОЙ РЕЧИ ДЛЯ ФУНКЦИЙ ИЗВЛЕЧЕНИЕ

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В этой статье мы описываем процесс создания основы для распознавания эмоций узбекской речи (SER). Насколько нам известно, это первая работа в области SER, которая использует спонтанные речевые эмоции на узбекском диалекте. SER представляет собой активную исследовательскую проблему в области обработки родного языка (NLP). Она направлена на обнаружение различных эмоций, таких как удовлетворение, разочарование и гнев, из аудио речей с использованием различных классификаторов. Предварительная обработка речевого сигнала является первым и самым важным шагом в процессе SER. Более того, предварительная обработка речи очень важна в приложениях, где тишина или окружающий шум совершенно нежелательны. Обнаружение активности голоса является распространенной процедурой, которая играет ключевую роль в предварительной обработке речевых сигналов и шумоподавлении. Предварительное выделение речи помогает системе быть более эффективной в вычислительном отношении. В этой работе предложен метод предварительной обработки для извлечения признаков из естественной узбекской речи. Предварительная обработка речи состоит из очистки речевого сигнала от окружающих и нежелательных шумов, обнаружения речевой активности и нормализации длины голосового тракта.

Введение

Предварительная обработка — это самый первый шаг после сбора данных, которые будут использоваться для обучения систем распознавание речевых эмоций (SER – Speech Emotion Recognition). Некоторые из этих методов предварительной обработки используются для извлечения признаков, в то время как другие используются для нормализации этих признаков, чтобы вариации говорящего и записи не влияли на процесс распознавания.

Поскольку эмоции помогают нам лучше понимать друг друга, естественным результатом является распространение этого понимания на компьютеры.

Распознавание речи уже является частью нашей повседневной жизни благодаря умным мобильным устройствам, которые способны принимать и отвечать на голосовые команды с помощью синтезированной речи. Распознавание речевых эмоций может использоваться, чтобы эти устройства также могли обнаруживать наши эмоции.

Практически для каждого приложения голосовые сигналы необходимо предварительно обработать перед использованием их в качестве входного сигнала. Предварительная обработка любых данных повышает производительность приложений. В области машинного обучения (МО) предварительная обработка является спасением различных случайных и полезных данных, когда нам приходится работать с данными, которые не готовы к обучению. Для работы с голосом или речью за последнее десятилетие было проведено несколько типов исследований предварительной обработки [2]. Речь, произнесенная пользователем, содержит три вида, а именно голосовую речь, невокализованную речь и тишину. Поэтому как невокализованная речь, так и немой фрагмент речи не нужны и бесполезны для обработки и извлечения, и это самая сложная часть для отделения полезных голосовых данных для извлечения от принимающих сигналов.

Для извлечения реальных голосовых признаков первый шаг состоит в удалении невокализованной и немой части речи и создании полезных данных. Для извлечения признаков необходима предварительная обработка, такая как шумоподавление, пред искажение, кадрирование. Таким образом, в этой статье выполняется несколько процессов предварительной обработки для извлечения признаков из данных непрерывной речи. Этапы предварительной обработки включают шумоподавление, обнаружение голосовой активности, пред искажение, кадрирование, функция (наиболее популярное функция Хэмминга) и нормализацию, которая предоставляет окончательные данные для извлечения полезной речи.

Нынешний общепринятый узбекский язык базируется на разговорном и письменном наречии Ферганской долины, которому свойственно отсутствие гармоничного сочетания гласных звуков. Однако в целом лингвисты насчитывают очень много наречий (диалектов) узбекского языка, образующих весьма разветвленную структуру. Нынешние разговорные наречия, существующие в

самом Узбекистане, разделяют на две большие группы: «акающие» — которые также подразделяются на две подгрупп, отличающихся друг от друга применением начальных букв «дж» или «й», «окающие» — такая манера говорить свойственна больше жителям столицы и Ташкентской области, Бухары, Самарканда, а также некоторых других прилегающих территорий. Лингвисты же классифицируют все диалекты узбекского языка по 4- м группам: Кыпчакский говор, наиболее родственный и созвучный казахскому, был сформирован в давние времена среди кочующих узбекских народов. Сегодня он распространен на землях всего Узбекистана, впрочем, как и в остальных государствах этого региона. К кыпчакскому диалекту относится и аутентичный сурхандарьинский говор. Также к кыпчакско-ногайской ветви тюркских языков наравне с казахским, ногайским и карагачским относится и каракалпакский язык. Он очень схож лексически с казахским языком, однако имеет ряд значительных различий в орфографии. К узбекским наречиям, включенным в огузскую группу, относятся специфичные диалекты северо-западного района и южных областей страны. Сюда же входит, например, хорезмский, довольно специфичный говор, очень напоминающий туркменский язык. Согласно классификации, разработанной известным исследователем Узбекской культуры Самойловичем А.Н., эта группа включает хивинско-узбекский и, конечно, хивинско-сартовский говор. Южно-узбекские диалекты широко распространены сегодня в центральных вилоятах (областях) современного Узбекистана, и на востоке страны. Также к этой группе стоит отнести и городские наречия севера Афганистана. Эта категория диалектов считается наиболее похожей на персидский язык, что отразилось и на фонетике, и на лексической основе. Узбекские диалекты севера, получившие наибольшее распространение на юге Казахстана. Несмотря на такое изобилие разнообразных наречий и диалектов, родственных и свойственных узбекскому современному языку, его классической нормой официально признан в большей степени северный (ферганский) язык и в некоторой степени — южные диалекты, при этом на первом говорят более 17 миллионов этнических узбеков, а на втором – примерно полтора миллиона представителей узбекской и ряда других наций, в настоящее время проживающих на территориях Турции, Афганистана и Пакистана. После 1937 года классический статус узбекского языка официально закрепился за фергано-ташкентскими диалектами.

Среди работ по Узбекской диалектологии, по понятным причинам, до сих пор преобладали монографические описания диалектных районов и отдельных говоров. Такие описательные монографии были необходимы не только в начальный период работы, когда каждое новое описание, в сущности, было открытием неизведанного; и теперь, при любых задачах более широкого научного синтеза, они остаются важнейшей материальной базой диалектологического исследования. Чем больше будет собрано и описано фактов, тем более прочными явятся и построенные на них обобщения. Что касается этих обобщений, то до сих пор они ограничивались по преимуществу определением и локализацией изучаемого говора в общих рамках диалектного членения соответствующего национального языка, т.е. вопросами классификации диалектов данного языка, опирающейся в свою очередь на общую классификацию тюркских языков и наречий. Следует сразу же отметить, что в этой области еще многое остается сейчас дискуссионным и требует методологического пересмотра и более прочного теоретического обоснования. Диалекты тюркских языков», авторы его, по-видимому, рассматривают каждый национальный язык (в его современном состоянии) как «систему» диалектов, распадающихся на наречия, говоры и подговоры, между которыми надлежит установить границы, запечатлев их в конце соответствующего монографического очерка на «карте диалектов» данного языка. Между тем такая точка зрения, сознательно или бессознательно, исходит из старого представления о «родословном древе» языков и диалектов, выдвинутого А. Шлейхером более ста лет назад. Давно отвергнутая в теории, эта концепция продолжает тем не менее существовать на практике как основа многих генетических классификаций языков и диалектов не только тюркских, но и индоевропейских. Абстрактный схематизм придает этой концепции видимую простоту, соблазнительную и сейчас для многих языковедов, однако, не учитывающую всей реальной исторической сложности языкового развития. Подобно тому как «язык-основа» данной генетически родственной семьи языков распадается с этой точки зрения на группы и подгруппы, а эти последние — на отдельные исторически известные языки, так по тому же принципу «родословного древа» каждый язык в свою очередь распадается на наречия и диалекты, говоры и подговоры, представляющие последовательные «ответвления» общенародного языка, его «ветки» и «веточки».

Многоязычный

Как и в любой стране с достаточно большой территорией, в Узбекистане существует сразу несколько диалектов, на которых говорят его жители. Все их можно поделить на две условные группы: так называемые «окающие» (манера речи в Ташкенте, Самарканде, Бухаре) и прочие, «акающие» группы диалектов.

Все их можно классифицировать более подробно — для понимания, насколько пестра картина единого языка Узбекистана.

- Южно-узбекские — так, ферганский диалект наиболее близок к литературной

норме. За ним даже закреплен официальный эталон произношения (произошло это в 1937 г.).

- Юго- и северо-запад Узбекистана. Здесь говорят на хорезмском диалекте — одном из древнейших доисламских языков, используемых на территории современного Узбекистана.
- Диалекты, очень близкие к казахскому. Их наличие неудивительно, ведь эти два народа очень близки исторически и территориально.

Посмотрим на примере фонетические особенности хорезмского диалекта:

- наличие контрастирующих гласных и частичное сохранение сингармонизма;
- различение кратких и долгих гласных (и — и:; а — а:; о — о:; у — у:): ат — лошадь, а: т — имя; ал — бери, а: л — красный;
- озвончение анлаутных к, т: гу: з (ср. куз) «осень»; да: л (ср. тол) «ива»; депа (ср. тепа) «холм»;
- отпадение конечных к, қ: катты (ср. қаттиқ) «твёрдый»; аджы (ср. аччиқ) «горький»;

Слова первой группы превалируют в лексике хорезмского диалекта, что сближает его с узбекским литературным языком. В нижеследующей таблице приводится сравнение таких слов:

Таблица 1.

Просторечие	Литературное написание	Перевод
гун	кун	день
бозор	бозор	рынок
адам	одам	человек

Литературный обзор

Было проведено много исследований для предварительной обработки и извлечения признаков. Поэтому ниже мы представляем некоторые связанные работы, которые рассматривают методы предварительной обработки речевого сигнала.

В этой области было проведено множество исследований. Некоторые из них описаны кратко. Были проведены различные исследования для изучения методов шумоподавления речи. Был выдвинут подход, основанный на глубоком обучении, для улучшения шумоподавления реальной речи без использования предварительно очищенных речевых сигналов [3]. Их исследование показало, что предложенный подход к шумоподавлению с помощью глубокого обучения более эффективен, чем обычный подход контролируемого шумоподавления. Чтобы снизить вычислительные затраты на задачи шумоподавления с помощью глубокого обучения, неречевые сегменты следует удалять перед шумоподавлением речевого сигнала. С этой целью разработали стратегию шумоподавления речи для обнаружения речевых сегментов до начала задачи шумоподавления. Их основные результаты доказали, что точность предлагаемой стратегии шумоподавления аналогична или лучше, чем у метода шумоподавления на основе Вейвлет преобразования, известного как одна из последних процедур шумоподавления на основе глубоких нейронных сетей.

Благодаря огромным достижениям в области сетей, основанных на глубоком обучении, производительность методов шумоподавления речи была улучшена.

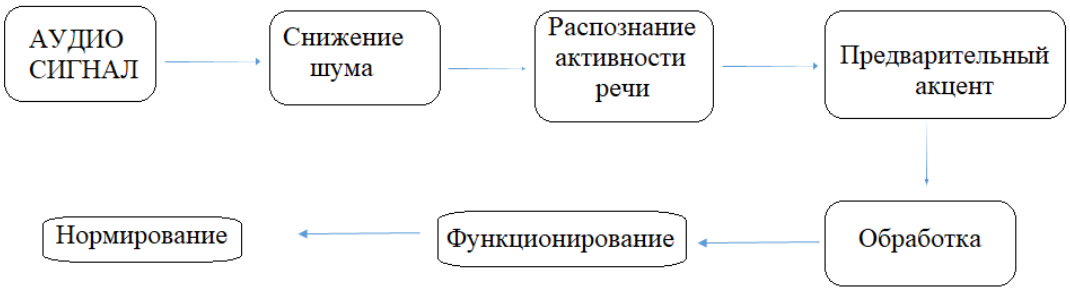
В дополнение к шумоподавлению речи, обнаружение активности голоса (VAD – Voice Activity Detection) представляет собой фундаментальную фазу в обработке речи. Производительность обработки речи, распознавания речи и улучшения речи в значительной степени зависит от производительности вывода VAD. Был рекомендован надежный алгоритм фонового шума VAD, чтобы не только различать озвученные и неозвученные части речи, но и определять отсутствие или наличие речи. Более того, VAD является ключевой деятельностью, которая была применена для обеспечения бытовых приборов с голосовым управлением [4]. В этом отношении представили простую в интеграции домашнюю систему автоматизации на основе VAD для улучшения процессов автоматизации голосовых команд. Выбор подходящих методов функций, следовательно, играет важную роль в обработке сигнала. Было проведено несколько исследований для выбора лучшей функции для использования при функциональной обработке речевого сигнала. Было проведено сравнительное исследование различных функций.

Кроме того, новый метод был предложен для того, чтобы улучшить стабильность характеристик сигнала и уменьшить ключевые изменения, которые происходят в сигнале на этапе функциональной обработки [5]. Для реализации системы распознавания речевых эмоций предварительная обработка сигнала должна выполняться в соответствии с вышеупомянутыми шагами. На первом этапе, после сбора данных,

используются методы предварительной обработки для улучшения процесса извлечения признаков.

В этой части исследования предварительная обработка сигнала включает некоторые процессы, а именно шумоподавление, обнаружение голоса, пред искажение, кодирование и нормализацию. Таким образом, получение чистого сигнала для использования на следующем этапе (извлечение признаков) является решающим шагом. На рисунке 1 показан рабочий процесс предварительной обработки для извлечения признаков.

Рисунок 1.



Шумоподавление

Распространение шума в атмосфере обычно обнаруживается одновременно с речевым сигналом. Этот механизм оказывает непосредственное влияние на скорость распознавания [6]. Таким образом, необходимо интегрировать методы шумоподавления, чтобы устранить или

минимизировать захваченный шум. Мы предложили метод огибающей для шумоподавления. Из звуковой спектральной огибающей мы сократили и удалили части данных, которые находятся ниже порога настройки. Таким образом, мы выбрали порог, равный 0,009 децибел.

Обнаружение голосовой активности (VAD). Высказывание состоит из трех основных элементов, а именно: тишина, невыраженная речь и выраженная речь.

Задача состоит в обнаружении речевого высказывания среди этой смеси различных речевых высказываний и последовательностей тишины. Чтобы обнаружить возникновение речевого высказывания из других типов речевых высказываний или неречевых молчаний, мы использовали метод, называется обнаружением конечной точки или обнаружением активности голоса (VAD). Этот метод рекомендуется некоторыми исследователями в процессе предварительной обработки речевого сигнала. Следует отметить, что существует несколько методов, используемых для обнаружения активности голоса, таких как скорость пересечения нуля, кратковременная энергия и метод автокорреляции. Последний, например, известен своей способностью измерять сходство между сигналом самим собой, задержанным во времени. Более того, использование этого метода направлено на извлечение избыточных шаблонов и придание периодического характера сигналам. Метод автокорреляции, по-видимому, наиболее вероятно обнаружит эти голосовые сигналы.

Предварительное выделение

В случае высоких частот часто наблюдается уменьшение частотных компонентов, связанных с речевым аудиосигналом.

Однако для некоторых систем, таких как система кодирования речи, невозможно избежать высоких частот. Итак, чтобы исправить эту проблему, желательно заменить высокочастотные компоненты фильтрами пред искажения [7]. Эта операция направлена не только на ослабление высоких частот, сопровождаемых механизмом выборки, но и на компенсацию излучения губ, характеризующего аудиосигнал речи. Пред искажение является стандартным шагом на этапе предварительной обработки. Оно используется, когда оцифрованная речевая форма волны имеет этап высокого динамического диапазона, усиленный наличием добавленного шума. В этом случае рекомендуется пред искажение.

Кадрирование – учитывая нестационарный аспект речевого сигнала, свойства этого сигнала отличаются своей динамичностью и подвижностью во времени. Поэтому обработка этих свойств в движущемся контексте невозможна. Однако в случае коротких временных интервалов сигнал становится стационарным и пригодным для обработки [8]. Метод фрейминга, вероятно, решит эту проблему, связанную с нестационарным характером временных рядов.

Используя эту технику, мы можем заполнить пробелы, упомянутые выше, разбивая непрерывные речевые сигналы на серии блоков,

называемые длинами кадров от 20 до 40 миллисекунд для облегчения обработки.

Благодаря своим достоинствам в облегчении обработки речевых сигналов, кадрирование признано эффективным инструментом для обработки речевых сигналов. Действительно, кадры, полученные после фрагментации речевого сигнала, равны и характеризуются краткостью, которая позволяет им быть стационарными, что упрощает обработку их свойств [11]. Чтобы справиться с этими ограничениями, мы выбрали окна фиксированной длины в 25 миллисекунд.

Использованная литература

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4G/5G TRANSPORT NETWORK BASED ON ATMOSPHERIC OPTICAL COMMUNICATION SYSTEM

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Abstract — **The article summarizes the characteristics of telecommunication systems, the main factors of the development of the speed of data transmission in telecommunication networks, including modern mobile communication networks, the characteristics of the atmospheric optical communication system, a comprehensive solution to the task of designing atmospheric optical communication systems to determine the capabilities of optical channels. The organization project of the network Fronthaul transport based on atmospheric optical communication systems is presented.**

Keywords — atmospheric optical communication system, backup, telecommunications, networks, mobile communication, project, radio frequencies, spectrum.

INTRODUCTION

Today, increasing the speed of data transmission in telecommunications networks, including modern mobile networks, is one of the main factors in their development.

The fronthaul or transport network is the connection layer between the Base Band Unit and the Remote Radio Head to provide high-bandwidth channels to meet the needs of multiple radio transmission units. Fronthaul can be implemented using various technologies such as fiber optic, cellular, or millimeter-wave. Fiber is ideally suited for the C-RAN architecture because it provides the highest bandwidth requirements.

MAIN PART

According to the working document approved by the ITU (International Telecommunication Union) for 5G, the implementation of the Fronthaul network will be possible using various channels, including high-speed wireless channels. [1].

However, the maximum connection speed in E-band wireless networks does not exceed 6 Gbps. [2]. Therefore, one of the options for the Fronthaul transport network in the first phase of the implementation of 5G networks is the use of atmospheric optical communication systems. Today, the transmission speed in atmospheric optical communication systems can reach 10 Gbit/s with sufficient reliability at distances of up to 5-6 km. In addition, they have the advantage over other wireless systems in that they operate in the range above 400 GHz and do not require frequency licenses for their use. [3].

When designing data transmission networks, including AOCS systems, one of the indicators characterizing the quality characteristics of the network is reliability. The amount of reliability is determined by criteria. For data transmission networks, one of the main indicators of reliability for a resilient system is the availability coefficient, which characterizes the probability that the data transmission network will be able to operate at an arbitrary point in time.

When designing atmospheric optical communication systems, it is necessary to approximate and present in mathematical form the empirically obtained IDF-MVD (integral distribution function of meteorological visibility distance) data. As an example, we will approximate the IDF-MVD data for the city of Andijan using the MATLAB program. Analytical IDF-MVD functions for all months for the Andijan region were obtained (Table 1), and based on these data, it is possible to estimate the losses in atmospheric communication channels in the Andijan region [4].

The dependence of the SMKM length of the intervals obtained by dividing the distance of the AOCS route for the city of Andijan and the availability coefficient of the atmospheric channel in them on the operating wavelength of the AOCS is presented in Table 2.

The graphs KT-AK =f(SMKM) (KT-AK - atmospheric channel readiness coefficient) constructed according to the data in Table 2 are shown in Figures 1- [4].

Table 1

Approximation expressions for the range 0.45-10 km (Andijan region)

Months	Analytical expression
January	$F(S_m) = 0.000274 \cdot S_m^4 - 0.003779 \cdot S_m^3 - 0.007879 \cdot S_m^2 + + 0.2807 \cdot S_m + 0.008247$
February	$F(S_m) = 0.0006088 \cdot S_m^4 - 0.01311 \cdot S_m^3 + 0.07965 \cdot S_m^2 - - 0.008019 \cdot S_m - 0.02148$
March	$F(S_m) = -0.0002834 \cdot S_m^4 + 0.002981 \cdot S_m^3 + 0.01051 \cdot S_m^2 - - 0.02032 \cdot S_m + 0.006416$
April	$F(S_m) = -0.000219 \cdot S_m^4 + 0.004961 \cdot S_m^3 - 0.0205 \cdot S_m^2 + + 0.02701 \cdot S_m - 0.01005$
May	$F(S_m) = 0.0004975 \cdot S_m^4 - 0.005933 \cdot S_m^3 + 0.02249 \cdot S_m^2 - - 0.03051 \cdot S_m + 0.01173$
June	$F(S_m) = 0.0005891 \cdot S_m^4 - 0.007411 \cdot S_m^3 + 0.0293 \cdot S_m^2 - - 0.04039 \cdot S_m + 0.01577$
July	$F(S_m) = 0.0005689 \cdot S_m^4 - 0.007294 \cdot S_m^3 + 0.03004 \cdot S_m^2 - - 0.04189 \cdot S_m + 0.01605$
August	$F(S_m) = 0.0005323 \cdot S_m^4 - 0.006473 \cdot S_m^3 + 0.02451 \cdot S_m^2 - - 0.3154 \cdot S_m + 0.01133$
September	$F(S_m) = -0.0003638 \cdot S_m^4 + 0.007674 \cdot S_m^3 - 0.03527 \cdot S_m^2 - - 0.05155 \cdot S_m - 0.02039$
October	$F(S_m) = -0.0002795 \cdot S_m^4 + 0.004954 \cdot S_m^3 - 0.01308 \cdot S_m^2 + + 0.01564 \cdot S_m - 0.006239$
November	$F(S_m) = -0.000403 \cdot S_m^4 + 0.006699 \cdot S_m^3 - 0.02065 \cdot S_m^2 + + 0.04408 \cdot S_m - 0.02419$
December	$F(S_m) = -8.098 \cdot 10^{-6} \cdot S_m^4 + 0.0001848 \cdot S_m^3 + 0.01067 \cdot S_m^2 + +0.04866 \cdot S_m + 0.06931$
Average per year	$F(S_m) = 0.000163 \cdot S_m^4 - 0.002256 \cdot S_m^3 + 0.01478 \cdot S_m^2 + + 0.01184 \cdot S_m + 0.01252$

Table 2

Availability coefficient of the atmospheric channel at different working wavelengths of the AOCS for the city of Andijan

S_{MKM}, km	$K_{T\text{-}AK}$		
	λ_1=0,785 mkm	λ_2=0,91 mkm	λ_3=1,55 mkm
1	2	3	4
0,45	0,9794	0,9794	0,9794
0,7	0,9744	0,9751	0,9779

1,1	0,9661	0,9687	0,9763
1,3	0,9603	0,9636	0,9728
1,5	0,9538	0,9578	0,9689
2,2	0,9291	0,9361	0,9564
3	0,8999	0,9120	0,9436
3,5	0,8796	0,8970	0,9365
4,1	0,8599	0,8830	0,9299
7	0,7246	0,7749	0,8889
10	0,3788	0,4889	0,7533

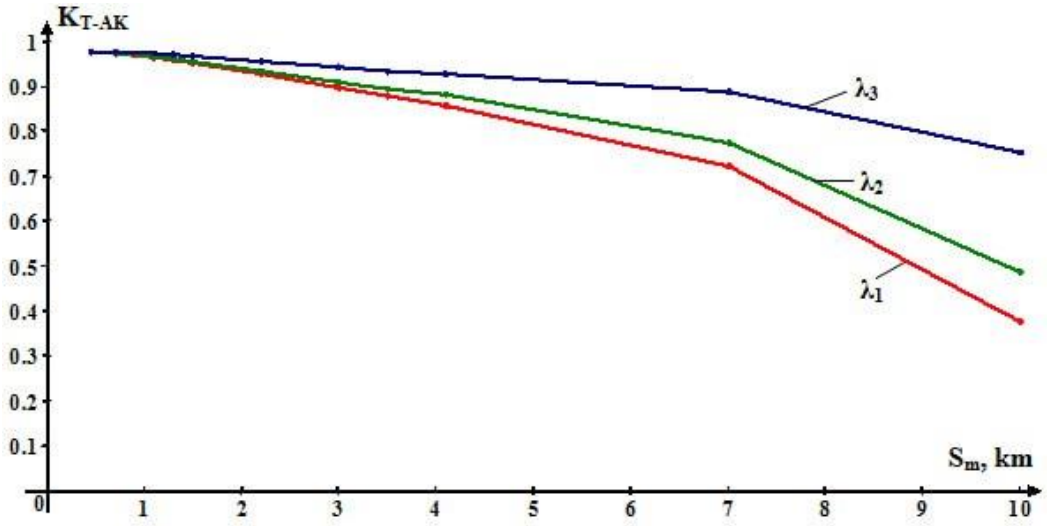

Figure 1. Dependence of the atmospheric channel availability coefficient at different working wavelengths of the AOCS for the city of Andijan

At a distance of up to one kilometer from the AOCS, the atmospheric channel availability coefficient is almost as high at wavelengths λ1=0.785 μm, λ2=0.91 μm, and λ3=1.55 μm. As the distance increases, the availability coefficient decreases for λ1=0.785 μm and λ2=0.91 μm, and is at its highest at λ3=1.55 μm.

Conclusion

It is very difficult to realistically meet the required availability coefficient (KT-AK) of the AOAT system for selected sections of the atmospheric channel route, therefore, the option of organizing a channel with a backup was considered. A radio channel in the millimeter wave range can be used as a backup channel.

Modern atmospheric optical communication systems provide for monitoring the KT-AK value in the atmospheric channel. When backing up an optical channel, the availability coefficient is calculated by recording the operating time on the backup channel, if there is no such function, the operating time on the backup channel is determined by the threshold value of the BER (Bit error ratio) parameter, and if it exceeds the permissible norm, the connection is disconnected.

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TELEKOMMUNIKATSIYA TARMOQLARIDA TRAFIKNI SINFLASHTIRISH VA FILTRLASH: TAHLILIY YONDASHUVLAR

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***Annotatsiya* — So‘nggi yillarda internet xizmatlarining jadal rivojlanishi va multimedia ilovalari hajmining keskin ortishi tarmoq trafigini samarali sinflashtirish hamda filtrlash zaruratini yanada kuchaytirmoqda. An’anaviy port raqamlariga asoslangan yondashuvlar va paket mazmunini chuqur tahlil qiluvchi (DPI) usullar bugungi kunda o‘z dolzarbligini yo‘qotmoqda, chunki tarmoqlardan o‘tayotgan trafikning aksariyati shifrlangan shaklda uzatiladi. Shu bois statistik atributlarga asoslangan va mashinali o‘qitish metodlariga tayanuvchi yondashuvlar eng samarali yechim sifatida qaralmoqda. Ushbu maqolada tarmoq trafigini sinflashtirishning dolzarbligi, mavjud muammolari va asosiy metodlari tahlil qilinadi. Shuningdek, mashinali o‘qitish yondashuvlarining trafikni aniqlash, QoS va xavfsizlikni ta’minlashdagi afzalliklari yoritilib, sinflashtirish jarayonida uchraydigan asosiy cheklovlar ham ko‘rib chiqiladi.**

Kalit so‘zlar — Tarmoq trafigi, filtrlash, shifrlangan trafik, statistik atributlar, mashinali o‘qitish, QoS.

KIRISH

Internet foydalanuvchilari sonining ortib borishi tarmoq administratorlari va internet xizmat provayderlari uchun tobora ko‘proq murakkabliklarni yuzaga keltirmoqda. Xususan, katta hajmdagi trafikni samarali boshqarish, xizmat sifatini (QoS) ta’minlash hamda tarmoq xavfsizligini mustahkamlash dolzarb masalaga aylanmoqda. Tarmoq trafigini sinflashtirish va filtrlash ushbu muammolarni hal qilishning eng samarali vositalaridan biri bo‘lib, u tarmoq resurslaridan oqilona foydalanish, xizmatlarni ustuvorlashtirish va xavfsizlikni oshirish imkonini beradi.

Tadqiqotlar natijalariga ko‘ra, internet trafigining atigi 10–20 foizi kechikishlarga o‘ta sezuvchan bo‘lsa-da, bunday oqimlarni noto‘g‘ri boshqarish butun tarmoq unumdorligiga salbiy ta’sir ko‘rsatadi. Shu sababli trafikni to‘g‘ri sinflashtirish va filtrlash nafaqat tarmoq o‘tkazuvchanligini yaxshilashda, balki barqaror ishlashini ta’minlashda ham muhim ahamiyatga ega. Bundan tashqari, tarmoq trafigini filtrlash davlat xavfsizligiga tahdid soluvchi zararli oqimlarni aniqlash va bartaraf etishda ham samarali vosita bo‘lib xizmat qiladi.

Adabiyotlar Tahlili

So‘nggi yillarda tarmoq trafigini sinflashtirish bo‘yicha ko’plab tadqiqotlari olib borilgan va ular mavjud yondashuvlarni muhokama qilish, samaradorligini baholash va kelajakdagi tadqiqot yo‘nalishlarini belgilashda muhim rol o‘ynaydi.

A. Madhukar va C. Williamson [1] ikki yil davomida Calgary universiteti internet tarmog‘ida P2P ilovalari trafigini port raqamlariga asoslangan holda tahlil qilgan. Natijalarda portga asoslangan yondashuvdan foydalanilganda aniqlik 30% dan 70% gacha bo‘lgan. Bu esa P2P ilovalar uchun bunday yondashuvning samarasizligini ko‘rsatdi.

Moore va Papagiannaki [2] ham portga asoslangan yondashuvning jiddiy kamchiliklarini ko‘rsatib o‘tgan. Genome ilmiy tadqiqot kampusidagi tarmoq trafiklarini o‘nta parametr asosida sinflashtirishganida umumiy trafikning 30–70% noto‘g‘ri aniqlangan. Bundan tashqari, IP pog‘onasida shifrlash TCP va UDP headerlarini chalkashtirib yuborgan, natijada port raqamlarini to‘g‘ri aniqlash imkoni bo‘lmagan.

Sen, Spatschek va Wang [3] P2P trafiklarini portga asoslangan holda sinflashtirib, VPN va VPN bo‘lmagan oqimlarni farqlashda faqat 30% aniqlikka erishgan. Bu natijalar ham portga asoslangan usulning ishonchsizligini ko‘rsatadi.

Umuman olganda, portga asoslangan usulning afzalligi uning oddiyligi, yuqori tezlikda ishlashi va past hisoblash resurslarini talab etishidir [4]. Ammo, zamonaviy tarmoqlarda dinamik portlardan keng foydalanilishi hamda trafikning katta qismi shifrlangani sababli, bunday usul bugungi kunda ishonchli deb hisoblanmaydi.

Portga asoslangan yondashuvning kamchiliklarini bartaraf etish uchun foydali yuk (payload) asosida sinflashtirish keng qo‘llanila boshlandi. Ushbu yondashuvda paketlarning dastlabki baytlari, protokol imzolari yoki signaturalaridan foydalaniladi.

A.W. Moore va K. Papagiannaki [2] tadqiqotida esa oqim yuklamasining dastlabki K bayti, protokol imzolari va semantik tahlil metodlari qo‘llanilgan. Natijalar shuni

ko‘rsatdiki, payload asosidagi usullar portga asoslanganlarga qaraganda ancha yuqori aniqlik beradi, biroq paketlarning shifrlanishi va katta hajmli trafikda hisoblash murakkabligining ortishi asosiy cheklov sifatida qolmoqda.

Valenti [5] tomonidan taqdim etilgan tdqiqotda mashinali o‘qitish algoritmlariga asoslangan trafik tasniflanishi tahlil qilgan. Ushbu tadqiqotda statistik atributlarga asoslangan ML klassifikatorlarning afzalliklari va imkoniyati keng yoritilgan. Shuningdek, mualliflar ikkita turli feature set yordamida tasniflash modelini ishlab chiqib, atribut tanlashning tasniflashga aniqligiga bevosita ta’sir ko‘rsatishini isbotlashgan.

Pacheco [6] tadqiqotlari ham mashinali o’qitishga asoslangan tasniflash o’rganilgan va tasniflashning umumiy jarayoni tizimli tarzda izohlangan. Ular jarayonni bir necha asosiy bosqichlarga ajratgan: ma’lumot yig‘ish, atributlarni ajratib olish, oldindan ishlov berish, model qurish va natijalarni baholash. Har bir bosqichda ilgari olib borilgan tadqiqotlarga murojaat qilingan va mavjud muammolar yoritilgan. Shuningdek, mualliflar statistik asoslangan klassifikatsiya yondashuvlarida kuzatiladigan trendlar va dolzarb masalalarga alohida to‘xtalganlar.

Salman [7] o‘z ishlarida mashinali o‘qitishning barcha asosiy yondashuvlari – supervised, unsupervised va semi-supervised algoritmlarni keng qamrab olgan holda taqqoslashni amalga oshirishgan. Ularning sharhida faqat algoritmlar emas, balki data collection va data presentation jarayonlari ham muhim omil sifatida ko‘rsatib berilgan. Chunki mashinali o‘qitish asosida ishlovchi tasniflash modellarining sifatli va balanslangan dataset mavjud bo‘lgandagina samarali ishlaydi. Ushbu maqola yakunida mualliflar kelgusidagi tadqiqotlar uchun bir qator tavsiyalarni ham bergan.

Adabiyotlarni tahlil qilish shuni ko‘rsatadiki, portga asoslangan va DPI usullari bugungi kunda past aniqlik va yuqori hisoblash murakkabligi tufayli samarasiz hisoblanmoqda. Foydali yuk asosidagi yondashuv aniqlikni oshirsa-da, shifrlangan trafik sharoitida qo‘llanishi qiyin. Mashinali o‘qitish va chuqur o‘rganish yondashuvlari esa yuqori aniqlikni ta’minlaydi, ammo katta dataset va hisoblash resurslariga talab qo‘yadi.

TRAFIKNI SINFLASHTIRISHDAGI DOLZARB MUAMMOLAR

Zamonaviy tarmoqlarda sinflashtirish va filtrlash samaradorligini pasaytiruvchi asosiy muammolar quyidagilardan iborat:

Shifrlangan trafikning ustuvorligi: Bugungi kunda internet trafigining deyarli barcha qismi shifrlangan holda uzatiladi. Bu esa, port asosidagi va paketlarning tarkibiga asoslangan sinflashtirish usullarini samaradorligiga salbiy tasir qiladi. Chunki bu yondashuvlar odatda ochiq holatdagi ma’lumotga tayanadi. Shifrlangan trafikdan foydalanuvchi protokol, xizmat turi yoki dastur haqidagi aniq ma’lumotni ajratib olish murakkablashadi, bu esa noto‘g‘ri sinflashtirish va filtrlash xavfini oshiradi. Shifrlash usullarining keng qo‘llanilishi va shifrlash protokollarining doimiy yangilanishi sababli, shifrlangan tarmoq trafigini sinflashtirish hozirgi kunda jiddiy qiyinchiliklarni keltirib chiqarmoqda [8-9].

Protokollarning doimiy o‘zgarishi va dinamik portlardan foydalanish: Ko‘plab ilovalar bugungi kunda standart bo‘lmagan portlardan foydalanadilar (masalan, BitTorrent va eDonkey kabi xizmatlar o‘z trafiklarini aniqlashni qiyinlashtirish uchun portlarni dinamik tarzda belgilaydi) va portlar doimiy ravishda o‘zgartirib turadi. Bu esa, portga asoslangan yondashuvlarni samaradorligini keskin tushiradi.

Real vaqtda sinflashtirish muammosi: Trafikni real vaqt rejimida tahlil qilish uchun statistik atributlarni tezda hisoblash, fragmentatsiyalangan sessiyalarni birlashtirish va modelga kiritish talab etiladi. Bu esa tarmoq qurilmalarida hisoblash resurslarining ortiqcha yuklanishiga olib kelishi mumkin.

Yangi yoki noma’lum ilovalarni aniqlashdagi qiyinchilik: An’anaviy mashinani o‘qitish usullari faqat oldindan ma’lum sinflar uchun ishlaydi. Internetda esa har kuni yangi xizmatlar va trafik turlari paydo bo‘layotgani sababli, tasniflovchi modelni doimiy yangilab borish zarur bo‘ladi.

Universal dataset mavjud emas: Bugungi kunda universal tarmoq trafiklar to‘plami (dataset) mavjud emas. Zamonaviy, sifatli, realistik va aniq yorliqlangan (labelled) ochiq ma’lumotlar to‘plamlarining yetishmasligi tarmoq trafigini sinflashtirish bo‘yicha tadqiqotlarda eng katta to‘siqlardan biri hisoblanadi. Mavjud datasetlar esa, odatda, muayyan tarmoq muhiti yoki xizmat turiga bog‘liq bo‘lib, har doim ham boshqa tizimlar yoki tadqiqot sharoitlariga mos kelavermaydi.

Hisoblash resurslariga bo‘lgan talab: Trafikni chuqur tahlil qilishga asoslangan usullar (DPI) katta hajmdagi paketlar oqimini doimiy ravishda tahlil qilishni talab qiladi. Bu esa hisoblash quvvatiga yuqori talab qo‘yadi. Ayniqsa, real vaqt rejimida sinflashtirish tizimlarda ushbu talab tarmoq qurilmalarida ortiqcha yuklanish, tahlilning kechikishi va umumiy ishlash samaradorligining pasayishiga olib keladi.

Ma’lumotlarning belgilanishi (labeling) qiyinligi: Real vaqtdagi tarmoq trafigini qo‘lda belgilash juda ko‘p mehnat talab qiladi va xatolar ehtimoli yuqori. Bu esa mashinani o‘rganish modellarining o‘qitilishi sifatiga bevosita ta’sir qiladi.

METODOLOGIYA

Umumiy Ishlash Jarayoni

Mashinali o‘qitishga asoslangan trafikni sinflashtirish metodologiyasi bir nechta bosqichlardan iborat bo‘lib, ular ma’lumotlarni yig‘ishdan boshlab, modelni baholashgacha bo‘lgan jarayonni qamrab oladi. Ushbu jarayon quyidagi asosiy bosqichlarni o‘z ichiga oladi:

Ma’lumotlarni yig‘ish: Trafik tarmoqdan PCAP formatida maxsus dasturiy vositalar yordamida yozib olinadi yoki ochiq ma’lumotlar bazalaridan (datasets) olinadi.

Oqimlarga ajratish: Oqimlar manba IP, manzil IP, manba porti, manzil porti kabi atributlar asosida aniqlanadi.

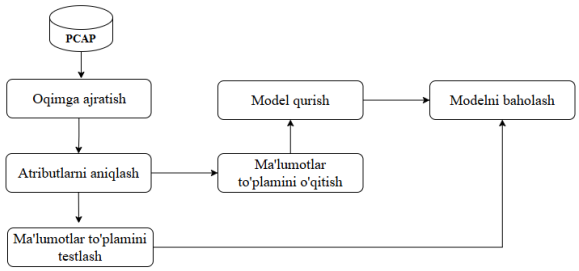
Atributlarni ajratish va tanlash: Har bir oqimdan statistik xususiyatlar ajratib olinadi. Shundan so‘ng atributlar tanlash usullari (CFS, IG, GR, va boshqalar) yordamida eng samarali atributlar aniqlanadi.

Ma’lumotlar to‘plamini tayyorlash: Oqimlardan ajratilgan atributlar asosida o‘qitish (training) va test (testing) uchun alohida ma’lumotlar to‘plami shakllantiriladi yoki N-fold kross-validatsiya usuli qo‘llaniladi.

Modelni qurish: Tanlangan mashinaviy o‘qitish algoritmlari asosida model yaratiladi.

Modelni baholash: Qurilgan modelning samaradorligi aniqlik (Accuracy), aniqlik darajasi (Precision), bo‘yicha baholash.

Bu umumiy jarayon Rasm 1 orqali tasvirlangan bo‘lib, u tarmoq trafigini statistik xususiyatlar asosida avtomatik tarzda tasniflashni bosqichma-bosqich ko‘rsatib beradi.



Rasm.1. Tarmoq trafigini sinflashtirish jarayoninig umumiy blok-sxemasi

Bu jarayon natijasida yaratilgan model real vaqt rejimida yoki oflayn tarzda trafik turlarini aniqlashda qo‘llanilishi mumkin. Baholash natijalariga qarab model takomillashtiriladi yoki moslashtirilgan variantlar ishlab chiqiladi.

Tarmoq trafigini mashinali o‘qitish yordamida tasniflashda quyidagi bosqichlar ketma-ketligi amalga oshirildi: ma’lumotlarni yig‘ish, atributlarni aniqlash, modelni o‘qitish, hamda tasniflash va baholash bosqichlari.

Ma’lumotlarni yig‘ish

Ma’lumotlarni yig‘ish tarmoq trafigini tasniflash tizimining dastlabki va eng muhim bosqichi hisoblanadi. Ushbu jarayonning asosiy vazifasi tarmoq infratuzilmasida kechayotgan real ma’lumot almashinuvini aks ettiruvchi xom trafikni aniq, to‘liq va tizimli shaklda yig‘ish, saqlash hamda keyingi ishlov berish uchun tayyorlashdan iborat.

Trafik namunalarini yig‘ishda ikki asosiy manba qo‘llaniladi. Birinchisi, real traffikni yig‘ish, bunda kompyuter, IoT yoki mobil qurilmalarda YouTube, Skype, HTTP va fayl yuklash kabi ilovalar ishga tushiriladi va hosil qilinayotgan oqimlar maxsus vositalar yordamida yozib olinadi. Bu usulning afzalligi shundaki, yig‘ilgan trafik real sharoitlarni to‘liq aks ettiradi. Ikkinchisi esa, ochiq datasetlar bo‘lib, boshqa tadqiqotchilar tomonidan yig‘ilgan va ommaga taqdim etilgan ochiq ma’lumotlar bazalari qo‘llaniladi. Masalan, ISCX VPN-nonVPN (VPN va oddiy trafik), USTC-TFC (ilova darajasidagi oqimlar), CIC-IDS (normal va zararli trafiklarni qamrab oluvchi) datasetlari keng ishlatiladi.

Atributlarni ajratib olish

Atributlarni ajratib olish sinflashtirishning umumiy samaradorligiga bevosita ta’sir qiluvchi muhim bosqichdir. Ushbu jarayonda har bir oqimdan statistik ko‘rsatkichlar hisoblab chiqiladi. Bu ko‘rsatkichlar trafik oqimlarining xarakterini tavsiflab, turli trafik turlarini farqlash imkonini beradi.

Keraksiz yoki takrorlanuvchi belgilarni olib tashlash uchun atributlarni kamaytirish qo‘llaniladi, bu esa model aniqligini oshiradi va hisoblash yuklamasini kamaytiradi. Bugungi kunda keng ishlatiladigan atribut tanlash metodlari quyidagilar:

Wrapper – tasniflagich natijalari asosida eng samarali atributlar to‘plamini tanlaydi.

Filter – atributlar orasidagi statistik munosabatlarga tayanadi.

CFS (Correlation-based Feature Selection) – atributning yorliq bilan bog‘liqligini va atributlararo korrelyatsiyani baholaydi.

CON (Consistency-based Subset Selection) – sinfga bog‘liqlikdagi barqarorlik asosida ishonchli atributlarni aniqlaydi.

Gain Ratio (GR) va Information Gain (IG) – atributlarning entropiyani kamaytirish qobiliyatini va sinf farqliligini aniqlashdagi ahamiyatini baholaydi.

Ma’lumotlar to‘plamini tayyorlash

Atributlar ajratilib tanlangach, sinflashtirish uchun yakuniy ma’lumotlar to‘plami shakllantiriladi. Ushbu to‘plam modelni qurish va baholash uchun asos bo‘lib xizmat qiladi. Amalda ikki yondashuv qo‘llaniladi:

Training/Test split – ma’lumotlar ikki mustaqil to‘plamga bo‘linadi. Katta hajmli training set modelni o‘rgatishda, test set esa ilgari ko‘rilmagan namunalar asosida samaradorlikni baholashda ishlatiladi.

K-fold cross-validation – ma’lumotlar N ta teng qismga bo‘linadi va har safar N−1 qism training, qolgan qism test uchun olinadi. Bu jarayon N marta takrorlanadi. Tadqiqotlar shuni ko‘rsatadiki, 10-fold cross-validation amaliyotda yetarli aniqlikni ta’minlaydi [10-11].

Modelni qurish

Avvalgi bosqichda shakllantirilgan o‘qitish to‘plami asosida, tarmoq trafigini ilova turlari yoki protokollariga ko‘ra avtomatik tasniflay oladigan model yaratiladi. Hozirgi kunda mashinaviy o‘qitish algoritmlari sinflashtirish va klasterlash muammolarini samarali hal etishda keng qo‘llanilmoqda. Biroq barcha holatlar uchun yagona, universal algoritm mavjud emas; har bir algoritmning o‘z afzalliklari va cheklovlari bo‘lib, tanlov vazifa xususiyatlari va ma’lumotlar turiga qarab amalga oshiriladi. Mashinaviy o‘qitish yondashuvlari:

Nazoratli o‘qitish: Modelni o‘rgatishda yorliqlangan ma’lumotlardan foydalaniladi. Maqsad — kirish atributlari asosida to‘g‘ri sinfga ajratish.

Nazoratsiz o‘qitish: Ma’lumotlarda yorliqlar mavjud emas, model o‘xshash trafik turlarini mustaqil guruhlaydi. Misollar: k-Means, DBSCAN, Hierarchical Clustering.

Yarim-nazoratli o‘qitish: Kichik hajmdagi yorliqlangan va katta hajmdagi yorliqlanmagan ma’lumotlardan birgalikda foydalaniladi. Bu usul real tarmoqlarda keng qo‘llaniladi, chunki ko‘pincha belgilanmagan trafik namunalarining ulushi katta bo‘ladi. 1-jadvalda turli mashinaviy o‘qitish usullarining afzalliklari, jarayonlari va samaradorligi taqqoslab beriladi.

MASHINAVIY O‘QITISH YONDASHUVLARINING TAQQOSLANISHI

Yondashuv turi	**Kirish ma’lumoti**	**Foydalanish maqsadi**	**Murak-kabliligi**	**Aniqlik**
Nazoratli o‘qitish	Barcha ma’lumotlar yorliqlangan	Natijalarni hisoblash	Oddiy	yuqori
Nazoratsiz o‘qitish	Barcha ma’lumotlar yorliqsiz	Yashirin qonuniyatlarni aniqlash	Murakkab	past
Yarim nazoratli o‘qitish	Qisman yorliqlangan	O‘rganishni takomillashtirish	Vazifaga uzviy bog‘liq	past

Modelni baholash

Model yaratilganidan so‘ng, uni real sharoitlarda qo‘llashdan avval, uning samaradorligini sinchkovlik bilan baholash zarur. Baholash jarayoni modelning trafikni to‘g‘ri sinflarga ajratish qobiliyatini aniqlashga xizmat qiladi. Ayniqsa nazoratli (supervised) mashinaviy o‘qitish yondashuvida bu bosqich muhim ahamiyatga ega, chunki model foydalanuvchi tomonidan berilgan yorliqlangan trafik asosida o‘rgatilgan bo‘ladi.

Modelni baholash quyidagi asosiy mezonlar asosida amalga oshiriladi:

Accuracy: Model tomonidan to‘g‘ri sinflangan namunalar sonining umumiy namunalar soniga nisbati.

Precision: Muayyan sinfga tegishli deb topilgan namunalarning nechta qismi haqiqatan shu sinfga tegishli ekanligini ko‘rsatadi.

Recall- Haqiqiy sinfga tegishli bo‘lgan barcha namunalardan nechtasini model to‘g‘ri aniqlaganini bildiradi.

F1-score: Precision va Recall ko‘rsatkichlarining o‘rtacha qiymatini bildiradi va ularning muvozanatli bahosini beradi.

Confusion Matrix: Har bir sinf uchun to‘g‘ri va noto‘g‘ri tasniflangan holatlarni ko‘rsatadigan matritsa bo‘lib, tasniflashdagi xatoliklar ko‘lamini aniqlashda yordam beradi.

Baholash natijalari sinflashtirish modelining real muhitga joriy etilishi yoki qo‘shimcha optimallashtirishga muhtojligini aniqlashda muhim asos bo‘lib xizmat qiladi.

XULOSA

Ushbu maqolada zamonaviy tarmoqlarda tarmoq trafigini samarali sinflashtirish va filtrlashning dolzarbligi, mavjud muammolari hamda turli metodologiyalar ko‘rib chiqildi. An’anaviy portga asoslangan va DPI usullari shifrlangan trafikning keng tarqalishi, protokollarning doimiy o‘zgarishi va dinamik portlardan foydalanish sababli o‘z samaradorligini yo‘qotmoqda. Shu bilan birga, real vaqt rejimida sinflashtirishning resurs talabchanligi, universal datasetlarning yetishmasligi va qo‘lda ma’lumot belgilashning murakkabligi ham dolzarb muammolar sifatida qayd etildi.

Tahlil natijalari shuni ko‘rsatadiki, statistik atributlarga asoslangan va mashinali o‘qitish algoritmlaridan foydalanuvchi yondashuvlar shifrlangan trafikni aniqlashda samarali yechim bo‘lishi mumkin. Xususan, paket sarlavhalari va oqim darajasidagi ko‘rsatkichlar turli trafik turlarini yuqori aniqlik bilan farqlash imkonini beradi.

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ПРИНЦИПЫ ПРОЕКТИРОВАНИЯ ОПТИЧЕСКОЙ СЕТИ ДОСТУПА НА ОСНОВЕ WEB-КАРТОГРАФИИ

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***Аннотация*—В статье рассмотрены ключевые показатели, влияющими на способ современного проектирования сетей доступа для конкретного населенного пункта, являются его социально-экономические и географические параметры – географические, строительные, инфраструктурные и параметры потребители-население. Основным параметром для создания веб-картографического инструмента является классификация по профилю объекта и потребителей оптической связи в зависимости от их назначения и типа подключения, требований к скорости передачи данных для цифровых сервисов, подробно рассмотренные в статье. Web-карта – это интерактивное отображение географической информации, которая имеет базовую карту, содержащую пространственную привязку веб-карты, а также схему размещения листов, которой должны следовать все кэшированные слои. Основным элементом Web-карты является картографическое изображение, набор информации об объектах и явлениях, их местоположении, свойствах, взаимосвязях, динамике.**

Ключевые слова—оптическая сеть доступа, планирование телекоммуникационных объектов, профиль абонента, user profile, web-карта

Введение

Телекоммуникационные операторы по всему миру стараются максимально увеличить свое территориальное присутствие в зонах своих государств, поэтому их главной целью является снижение удельных затрат на проектирование и реконструкцию сетей доступа [1]. Чтобы решить эту проблему, операторы изучают перспективные решения для сетевой архитектуры, которые можно было бы легко масштабировать в зависимости от плотности потребителей и объемов трафика, одновременно повышая качество обслуживания клиентов [2-5].

Строительство инженерных и линейно-кабельных объектов требует опыта и широкой инженерной интуиции персонала, основанной на готовых решениях от производителей телекоммуникационного коммутационного оборудования. В связи с ускоренным развитием сетей широкополосного доступа наблюдается тенденция к установке избыточного оборудования для систем передачи информации, как для активного, так и для пассивного оборудования; такая избыточность приводит к неэффективному использованию телефонной канализации, появлению неэффективно используемого оборудования различных операторов и провайдеров в многоэтажных жилых и административных зданиях.

Для оптимального планирования сети на заданной территории необходимо точно спрогнозировать, в каких местах и в какой момент времени появятся новые источники и получатели информации. В процессе прогнозирования необходимо учитывать огромное количество статистических данных и предпроектных материалов, таких как значимость административного объекта, телефонная плотность, плотность населения и его рост в ближайшем будущем, генерируемый трафик в сети, спрос на услуги широкополосного доступа и т.д. Изучение проектирования и эксплуатации сетей доступа показывает, что в результате наибольших просчетов в определении объема работ по оптимальному выбору мест установки активного и пассивного оборудования возникают ошибки в прогнозах и ожидаемых местах интенсивности нагрузки относительно генерируемого сетевого трафика.

Основные Показатели, Используемые При Планировании Телекоммуникационной Инфраструктуры

Ключевые показатели, влияющие на способ современного проектирования сетей доступа

Известно, что возрастающие требования к характеристикам скорости передачи транспортных сетей требуют новых правил проектирования линейных кабельных сооружений и выбора оборудования для промежуточных и оконечных узлов связи [6]. Ключевыми показателями, влияющими на способ современного проектирования сетей доступа для конкретного населенного пункта, являются его социально-экономические и географические параметры, такие как [7-9]:

"географические" параметры – это тип района, проектируемое пространство;

"строительные" параметры – это плотность застройки, процентное соотношение зданий частного сектора, малоэтажных и многоэтажных многоквартирных домов, среднее количество этажей в малоэтажном и многоэтажном здании и т.д.

"инфраструктурные" параметры – это наличие кабельной канализации, опор для подвешивания кабелей и возможность использования беспроводного/мобильного доступа, наличие кабельных каналов в жилых зданиях, наличие инфраструктуры для электроснабжения промежуточных узлов, качество электроснабжения;

параметры "население" – это количество жителей, которые проживают в данном районе на постоянной основе, количество дополнительных людей, одновременно проживающих в этом районе в туристический период, процентная доля населения младшей, средней и старшей возрастных групп, которые заинтересованы в услугах.

Мы предлагаем структурно объединить все параметры на уровне общих параметров, полностью характеризующих объект. При этом параметры могут определяться как централизованно (обращаться одновременно к конкретному списку объектов), так и рассчитываться для каждого конкретного объекта отдельно. Объект можно классифицировать по профилю, который является динамическим фактором и может дополняться дополнительными параметрами для проведения изыскательских работ на местности. С целью устранения влияния негативных факторов, влияющих на методы проектирования современных сетей доступа, а также для создания системы автоматического расчета, предлагается использовать централизованное хранение информации в едином центре обработки данных с использованием элементов облачных технологий для создания веб-картографического инструмента. Поэтому ключевым фактором является классификация по профилю объекта и потребителей оптической связи в зависимости от их назначения и типа подключения, требований к скорости передачи данных для цифровых сервисов.

Классификация телекоммуникационных объектов и потребителей оптической связи

В мировой литературе по проектированию телекоммуникационных объектов имеется несколько видов классификаций. На сегодняшний день одним из оптимальных является решение, учитывающее требования строительных норм и правил в соответствии с задачей планирования, разделение потребителей широкополосного доступа по категориям, предусматривающее их зависимость от требований профиля (user profile) к высокоскоростному ресурсу, потоку трафика и мощности установленного оборудования, [10]. Здесь мы приводим ссылку на документ нашего государства – Республики Узбекистан [10], но специалистам ясно, что в каждом государстве есть аналогичные нормативные документы [7-9].

Объекты подразделяются на следующие группы:

1. Телекоммуникационные объекты (расположение активного оборудования – базовая станция, точка доступа Wi-Fi, точка доступа Wi-MAX, RLL, OLT, коммутатор, MSAN, пассивное оборудование - сплиттер, ODF, оптическая связь и т.д.).
2. Многоэтажные жилые здания (район расположения – город, район, микрорайон или квартал, улица, номер дома, количество потребителей и требования к услугам широкополосного доступа).
3. Нежилые здания (регион расположения – город, район, микрорайон или квартал, улица, номер дома, количество потребителей, назначение здания с указанием вида деятельности и потребности в услугах широкополосного доступа и т.д.).
4. Частные жилые здания (регион расположения – город, район, улица, район расселения частных домохозяйств, нуждающихся в услугах широкополосного доступа и т.д.).

Все изыскательские работы по подготовке к проектированию оптической сети выполняются с учетом норм [10] и национальных стандартов [11], а для объектно-ориентированного проектирования предусмотрены следующие изыскания на месте:

уточнение характеристик здания – это номер дома, количество этажей, количество входы и боковые стороны входа в подъезды, количество квартир и других арендуемых помещений;

уточнение распределения квартир по подъездам и этажам (разработка эскизов поэтажных и межэтажных планов);

определение наличия и количества существующих стояков (межэтажных каналов) в подъезде;

определение местоположения оптического распределительного шкафа ODC и оптической распределительной коробки ODB.

Для домов частного сектора обследования на месте предусматривают следующее:

уточнение географической конфигурации населенных пунктов в зависимости от их удаленности от узлов коммутации телекоммуникаций;

определение количества домов (абонентов) в коттеджном поселке по типовым проектам или индивидуальным проектам, кадастровому плану земельных участков;

уточнение данных о расположении улиц с разработкой эскизов планов улиц и фотографий с указанием количества улиц, их конфигурации (круговой/линейной), количества переулков;

разъяснение существующей инфраструктуры о наличии и принадлежности установленных опор воздушных линий электропередачи и проложенной кабельной канализации.

Также необходимо выполнить некоторые специальные действия, связанные с выбором

местоположения основных элементов сконфигурированной сети. Они включают в себя выбор схемы коммутации оптического распределения (одноуровневого или каскадного), общего коэффициента разветвления, выбор местоположения распределительного шкафа ODC, выбор типов ODC и мест их установки. В то же время выбор местоположения OLT в здании АТС основан на решениях об оптимальном расстоянии от оптического перехода, оптимальном подключении к интерфейсам сети передачи данных и к системе электроснабжения и заземления, удобстве обслуживания персоналом.

При распределении проектируемых территорий мы руководствуемся следующими требованиями проектных групп [12-13]:

- определяем границы проектируемых территорий с указанием естественных барьеров;
- наличие рек, садов, бульваров, оврагов, железных дорог, больших промежутков между городскими зданиями и т.д.;
- в случае отсутствия естественных промежутков границы территорий кабинетов должны проходить по внутриквартальной территории;
- широкие улицы с улучшенным дорожным покрытием, автомагистрали и т.д. также могут быть границами кабинетных зон;
- количество уличных переходов в распределительной сети должно быть минимальным.

Web-карты Для Проектирования Городских И Сельских Телекоммуникационных Сетей

Перед началом строительства телекоммуникационной инфраструктуры необходимо провести три основных этапа планирования телекоммуникационных и коммуникационных исследований:

- стратегическое планирование сети, при котором принимаются решения о целесообразности развертывания сети и определении размера зоны развертывания, а также о способе строительства, типе кабеля и технологии использования кабельной канализации;
- высокоуровневое сетевое планирование – это этап, на котором принимаются структурные решения для конкретной области географического планирования; структурные решения включают в себя определение местоположения основных элементов сети;
- детальное сетевое планирование – заключительный этап планирования с проектной документацией, которая может быть передана строительным компаниям.

Этап высокоуровневого сетевого планирования является наиболее сложным, включает в себя огромный объем исходных данных и требует привязки к картографическим данным местности, таким как дороги, тротуары, подземные переходы и назначение зданий (административных, социальных, промышленных, жилых). Различные здания в зависимости от назначения создают индивидуальный трафик на сетевую инфраструктуру, а индивидуальность заключается в различных требованиях каждого объекта к норме потребления [14-15].

Реальные свойства конкретных объектов зависят от их положения относительно множества действующих факторов. Поэтому в конкретных исследованиях общее понятие географического положения дифференцируется на физико-географическое, экономико-географическое, политико-географическое и т.д. [16]. Для телекоммуникационного сектора это объекты связи типа мини-АТС, телефонные коллекторы, шкафы и т.д., и все они могут быть отображены на электронной цифровой "веб-карте".

Веб-карта – это интерактивное отображение географической информации. Все web-карты должны содержать базовую карту. Базовая карта определяет пространственную привязку web-карты, а также схему размещения листов, которой должны следовать все кэшированные слои. Элементами web-карты являются ее составные части, включая само картографическое изображение, легенду и оформление рамки. Основным элементом является картографическое изображение, то есть содержимое карты, набор информации об объектах и явлениях, их местоположении, свойствах, взаимосвязях, динамике. На web-картах используются символы и цвета для обозначения объектов, а ключ к карте объясняет, что они означают. Ключи к карте часто представляют собой прямоугольники в углу карты, и информация, которую они предоставляют пользователям, важна для понимания карты.

На рис.1 показаны интерфейсы web-карты территории Франции с указанием муниципалитетов и поставщиков услуг (скриншот с веб-сайта Arcep.fr, регулирующей организации по электронным коммуникациям, почте и распространению прессы во Франции) [17].

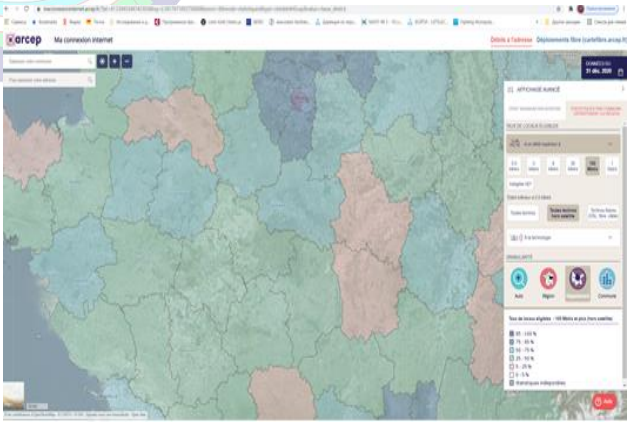

Рис.1. Web-карта территории Франции с указанием муниципалитетов и поставщиков услуг

На рис.2 показаны интерфейсы визуализации (скриншоты с веб-сайта Arcep.fr [17]) в контексте муниципалитетов, цветами обозначены области, где проходят оптические линии, где операторы связи планируют новое строительство, а также обозначена скорость, согласно требованиям BEREC (Body of European regulators for electronic communications

BEREC – Орган европейских регуляторов электронных коммуникаций) [18].

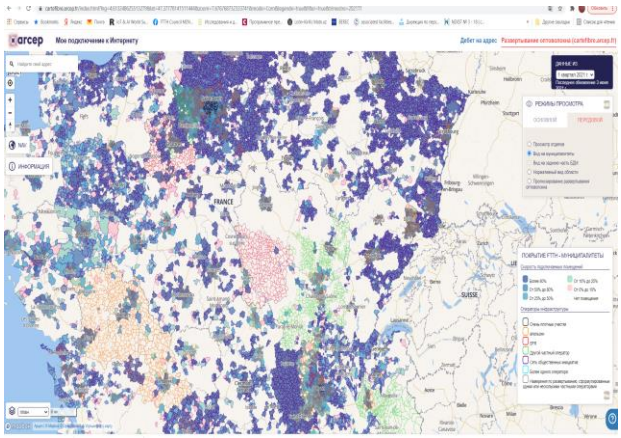

Рис.2. Визуализация зоны покрытия сети Интернет на территории Франции с указанием поставщика услуг

Веб-картография – это область компьютерных технологий, связанная с передачей пространственных данных конечному пользователю с использованием компьютерных сетей. Основными инструментами для создания веб-карт являются HTML, каскадные таблицы стилей (CSS), JavaScript.

Заключение

В результате проведенных исследований было выявлено, что для достижения оптимального планирования при проектировании оптической сети доступа требуется очень большая степень абстракции, относительно топологических условий местности, которые требуют глубокого инженерно-технического анализа решений с реальным соотношением существующей телекоммуникационной сети.

Предложенные основные четыре объекта классификации (объекты телекоммуникационной коммутации, многоэтажные жилые здания, нежилые здания и частный сектор) могут быть использованы для предварительных расчетов при планировании оптической широкополосной сети.

Оптимальное распределение территорий (деление на районы) достигается путем комплексного анализа населенных пунктов с указанием на веб-карте их точного местоположения и границ подключения к местам расположения активного и пассивного оборудования. При расчете определенных участков сети в соответствии с классификацией требуется обработать большой объем исходных данных, что требует географического картирования элементов сети в режиме реального времени с формированием зон узловых участков с их суммарной необходимой нагрузкой для территориального планирования сети в целом.

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TUGUNLARNI KLASTERLASH ASOSIDA SIMSIZ SENSOR TARMOQNING YASHOVCHNLIGINI OSHIRISH

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Annotatsiya: **Ushbu maqolada simsiz sensor tarmoqlarda (SST) tugunlarni klasterlash orqali tarmoqning yashovchanligini oshirish muammosi ko'rib chiqiladi. SST kichik, arzon va kam energiya iste'mol qiluvchi tugunlardan tashkil topib, atrof-muhit monitoringi, harbiy kuzatuv, sanoat va sog'liqni saqlash sohalarida keng qo'llanilmoqda. Tadqiqotda LEACH algoritmi kabi mavjud markazlashtirilgan yechimlardan farqli ravishda SOM (Self-Organizing Map) neyron tarmog'iga asoslangan klasterlash algoritmi taklif etiladi. Ushbu yondashuv tugunlarning qoldiq energiyasi, markaziyligi, konsentratsiyasi va klaster bosh tuguni bo'lish chastotasini hisobga olib, optimal klaster boshlarini tanlaydi. Modellashtirish natijalari MATLAB muhitida 100 ta tugun uchun bajarilgan bo'lib, FND (birinchi tugunning ishdan chiqishi), HNA (yarim tugunlarning ishdan chiqishi) va TP (uzatilgan paketlar soni) ko'rsatkichlari orqali samaradorlik baholandi. Natijalar shuni ko'rsatdiki, taklif etilgan algoritm LEACH bilan solishtirganda tizimning ishlash muddatini 65,2% ga oshiradi, energiya muvozanatini yaxshilaydi hamda tugunlar o'rtasidagi yuklamani optimallashtiradi. Xulosa qilib aytganda, SOM asosidagi klasterlash SST samaradorligini oshirib, ularning uzoq muddat barqaror ishlashini ta'minlaydi.**

*2) **Kalit so'zlar: Simsiz sensor tarmoqlar, klasterlash algoritmlari, SOM (Self-Organizing Map) neyron tarmog'i, energiyani tejash, LEACH protokoli, optimal klaster boshlarini tanlash, tarmoq yashovchanligi, energiya samaradorligi, tarmoq topologiyasi, MATLAB simulyatsiyasi.***

XC. I.KIRISH

Simsiz sensorli tarmoqlar so'nggi yillarda katta e'tiborni tortdi. Simsiz sensor tarmoqlari keng tarqalgan hisoblashning birinchi haqiqiy misollaridan biri bo'lib, kichik, aqlli, hisoblash kuchli va arzon sensorli qurilmalar oxir-oqibat atrof-muhitga kirib borishidir. Tarqalgan sezish, kam quvvatli protsessorlar va simsiz aloqalarning kombinatsiyasi ushbu texnologiyadan yashash muhitini monitoring qilish va atrof-muhit monitoringi, harbiy maydonini kuzatish kabi harbiy yechimlar, charchoq monitoringi va tijoriy dasturlar kabi keng ko'lamli ilovalarda foydalanish imkonini beradi. inventarizatsiyani boshqarish.

Markazlashtirilgan va taqsimlangan yondashuvlar o'rtasida yaxshi kelishuvni topish uchun endi SOM neyron tarmog'iga asoslangan klasterlash algoritmini joriy qilish taklif etilgan. Ushbu yechimda sensor tugunlari mahalliylashtirilgan shovqinlar orqali tarmoq topologiyasi ma'lumotlarini to'playdi, so'ngra kam energiya xarajatlari bilan tarmoqni ishga tushirish bosqichida tayanch stantsiyaga uzatiladi. LEACH-C kabi boshqa markazlashtirilgan algoritmlardan farqli o'laroq, ishga tushirish bosqichida tayanch stansiya tarmoq topologiyasi haqida yangilangan ma'lumotlarni GPS-yoqilgan sensorlar va energiyani ko'p talab qiladigan protseduralardan foydalanmasdan oladi.

II. ADABIYOTLAR TAHLILI

Simsiz sensor tarmoqlarda ma'lumot uzatish samaradorligini oshirish bo'yicha ko'plab ilmiy tadqiqotlar mavjud. 5G/IMT-2020 texnologiyalari asosida kengaytirilgan reallik ilovalarini qo'llash bo'yicha olib borilgan ishlarda yuqori tezlik va past kechikish asosiy talablar sifatida ko'rsatib o'tilgan [2]. Aqlli shahar infratuzilmasini yaratishda sensorlardan ma'lumot yig'ish va ularni AR ilovalariga uzatishda tarmoqli topologiyalarni qo'llash samaradorligi ta'kidlangan [4]. ZigBee spetsifikatsiyasi asosida qurilgan mesh topologiyasi arzonligi, ishonchliligi va o'z-o'zini tashkil etish xususiyatlari bilan ajralib turishi ko'plab ishlarda tasdiqlangan, ammo multimedia trafigida cheklovlarga ega ekanligi qayd etilgan [7]. SSTni qurishda ZigBee texnologiyasining amaliy imkoniyatlari IoT konsepsiyasi doirasida muhim bosqich sifatida baholangan [10]. ZigBee texnologiyasining uchuvchi sensor tarmoqlarida qo'llanishi bo'yicha o'tkazilgan tajribalar uning funksionalligini turli qurilmalarda to'liq amalga oshirish mumkinligini ko'rsatgan [13]. ZigBee arxitekturasida koordinator, marshrutizator va oxirgi tugunlarning vazifalari hamda xavfsizlik siyosatlari bo'yicha qator tadqiqotlar olib borilgan, bunda marshrutlashning dinamikligi alohida urg'u bilan o'rganilgan [14]. ITU-T Y.1540 tavsiyasida xizmat sifatiga ta'sir qiluvchi omillar – o'tkazuvchanlik, kechikish, jitter va ishonchlilik multimedia xizmatlari uchun hal qiluvchi mezon sifatida belgilangan [17]. LLN tarmoqlarida tasvir va ovoz sifatini ta'sir etuvchi parametrlar o'rganilib, ZigBee texnologiyasidan foydalanish multimedia uchun ma'lum darajada samarador natija berishi isbotlangan [1,18]. ITU-T R.913 metodologiyasida multimedia sifatini subyektiv baholash usullari ishlab chiqilib, ular sensor tarmoqlarida ovoz va tasvir sifatini tekshirishda keng qo'llanilgan [5,17].

III. METODOLOGIYA

Avval klaster bosh tugunlarining optimal soni aniqlash lozim bo'ladi. Klaster bosh tugunlarining optimal soni, K_{opt} , LEACH dagi kabi hisoblash va aloqa energiyasi modellari yordamida analitik tarzda aniqlanishi mumkin. Barcha olingan ma'lumotlarni bir paketga yig'ib uzatadi. Klaster bosh tuguni barcha qabul qilingan ma'lumotlarni l o'lchamdagi paketga siqib chiqarganda ko'rib chiqiladi. M x M mintaqasida bir xil taqsimlangan N ta tugun olingan. Agar k klaster mavjud bo'lsa, har bir klaster o'rtacha N/k tugunlarga ega (bitta klaster boshi va (N/k) - 1 ta klaster bo'lmagan bosh). ρ ∈[0,1] - siqish koeffitsienti, l - tugundan klaster bosh tuguniga uzatiladigan ma'lumotlar paketlarining uzunligi, P - klasterdagi klaster bo'lmagan tugunlar soni va LM - uzunlik klasterdan tayanch stantsiyaga uzatiladigan siqilgan ma'lumotlar hisoblandi.

$$L_M = (P - (P - 1)p)l \quad (1)$$

Bazaviy stantsiya odatda tugunlardan uzoqda joylashganligi sababli, klaster bosh tugunining energiya tarqalishi ko‘p yo‘nalishli modelga (quvvat yo‘qolishi d^4) ergashadi deb taxmin qilinadi. Shunday qilib, bitta freymda klaster bosh tugunida tarqalgan energiya quyidagi ifoda bilan aniqlanadi:

$$E_{BT} - \left(\frac{N}{k} - 1\right) lE_{elec} + L_m\left(E_{elec} + \varepsilon_{mp} d_{TOBS}^4\right) \quad (2)$$

Bu yerda E_{elec} - elektronikaning energiyasi, 50 nJ/bit), ε_{mp} - qabul qiluvchining sezgirligi va shovqin ko‘rsatkichi. d_{TOBS} - klaster bosh tugunidan tayanch stantsiyagacha bo‘lgan masofa.

Klasterning bosh tuguni bo‘lmagan har bir tuguni o‘z ma’lumotlarini klaster bosh tuguniga har bir kadrda bir marta uzatadi. Klaster bosh tugunigacha bo‘lgan masofa kichik bo‘lgani uchun, klaster tuguni bo‘lmagan bosh tugunida energiya tarqalishi Friess bo‘sh joy modeli (quvvat yo‘qolishi d^2) bo‘yicha qabul qilinadi. Har bir klaster bo‘lmagan bosh tugunida tarqaladigan energiya quyudagicha hisoblanadi:

$$E_{BT\,emas} = lE_{elec} + l\varepsilon_{fs} {d_{TOCH}}^2 \quad (3)$$

Bu yerda ε_{fs} qabul qiluvchining sezgirligi va shovqin ko‘rsatkichiga bog‘liq. d_{TOCH} – oddiy tugundan klaster bosh tuguniga qadar bo‘lgan masofa.

$$E\left[{d_{TOCH}}^2\right] = \frac{M^2}{2\pi k} \quad (4)$$

Shunday qili, oddiy tugundan energiya tarqalishi quyidagi ifoda bilan aniqlanadi:

$$E_{KB-emas} = lE_{elec} + l\varepsilon_{fs}\frac{M^2}{2\pi k} \quad (5)$$

Bundan tashqari, har bir kvadrat uchun klasterda umumiy energiya sarflanadi:

$$E_{cluster} = E_{BT} + \left(\frac{N}{k} - 1\right) E_{KB-emas} \approx E_{BT} + \frac{N}{k} E_{BT-emas} \quad (6)$$

Kanalda tarqalgan umumiy energiya quyidagi ifoda bilan aniqlanadi:

$$E_{umumiy} = kE_{klaster} = k\left[E_{BT} + \frac{N}{k} E_{BT-emas}\right] \quad (7)$$

(2) va (3) ni (7) ga almashtirib, quyidagilarni olamiz:

$$E_{umumiy} = nl\left[2E_{elec} + \varepsilon_{fs}\frac{M^2}{2\pi k}\right] - klE_{elec} + kL_M\left[E_{elec} + \varepsilon_{mp} {d_{TOBS}}^4\right] \quad (8)$$

k ga nisbatan E_{jami} hosilasini nolga o‘rnatish orqali topiladi , bu esa:

$$k_{opt} = \sqrt{\frac{nl\varepsilon_{fs}M^2}{2\pi\left[plE_{elec} - 2lE_{elec} - l\varepsilon_{mp}{d_{TOBS}}^4 + pl\varepsilon_{mp}d_{TOBS}^4 + \left[E_{elec} + pl\varepsilon_{mp}d_{TOBS}^4\right]pl\right]}} \quad (9)$$

Klaster bosh tugunlari orasidagi minimal masofa sensor tugunlari tomonidan energiya tarqalishini kamaytirish uchun klaster bosh tugunlari orasidagi minimal masofani hisobga olgan holda butun maydon bo‘ylab joylashtiriladi. Bu ikkita klaster bosh tuguni bir-biriga yaqin bo‘lmasligini ta’minlaydi va shu bilan tarmoqning ishlash muddatini oshiradi. M x M mintaqasida bir tekis taqsimlangan, klaster bosh tugunlari orasidagi minimal masofa R_{sep} quyidagi formula bilan aniqlanadi:

$$R_{sep} = \sqrt{\frac{M^2}{\pi k_{opt}}} \quad (10)$$

$P_{Broadcast}$ va P_{Search} ta’rifi (6), (7), (8) tenglamalarga asosan quyidagi radioaloqa parametrlariga murojaat qilgan holda: f = 914 MGts, λ= 0,328 m,$G_T = G_R$ =1,L = 1, $h_T = h_R$=1,5 m kesishish masofasi quyidagicha aniqlanadi:

$$d_{crossover} = \frac{4\pi\sqrt{Lh_T}\,h_r}{\lambda} = 86.2$$

Shunday qilib,

$$P_R = G_T G_R h_T h_R \frac{P_T}{d^4} = 5.1 * \frac{P_T}{d^4} \quad (11)$$

Qabul qilgichning minimal termal shovqin darajasi 99 dBm, qabul qiluvchining shovqin ko‘rsatkichi 17 dB deb faraz qilinsa va signalni xatosiz qabul qilish uchun signal-shovqin nisbati kamida 30 dB bo‘lishi kerak deb faraz qilinsa, muvaffaqiyatli qabul qilish uchun minimal qabul qilingan signal darajasi tomonidan beriladi.: PR ≥ -99+17+30=-52 dBm→6,3 mkVt. PRni (11) ga almashtirib, quyudagi olinadi:

$$P_T = \begin{cases} 9.24 * 10^{-3} d^2 & agar\ d < d_{crossover} \\ 1.24 * 10^{-6} d^4 & aks\ holda \end{cases} \quad (12)$$

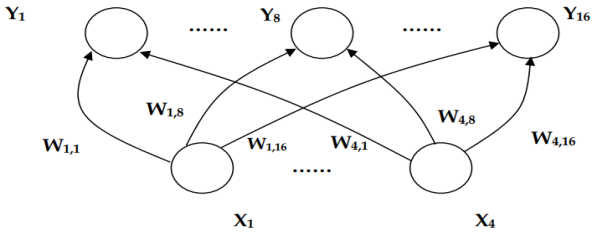
Klasterni sozlash bosqichi

Klasterni sozlash bosqichida tayanch stansiya K_{opt} klaster bosh tugunlarini tanlashi kerak . Ushbu qaror to‘rtta parametrga asoslanadi, xususan:

- Tugunning qoldiq energiyasi: tanlangan tugun yuqori qoldiq energiyaga ega bo‘lishi kerak, chunki klaster bosh tugunlari yuqori quvvat sarflaydigan operatsiyalarda ishtirok etadi. Ushbu tugunlar ma’lumotlarni to‘plashi va tayanch stantsiyaga kattaroq paketlarni uzatishi kerak.
- Markazlik: Tugunning markaziyligi - bu klaster uchun qanchalik markaziy ekanligiga qarab tugunning ahamiyatini tasniflaydigan qiymat. Tanlangan tugun past markazlashganlik qiymatiga ega bo‘lishi kerak, bu tugun tugunning markaziy ekanligini ko‘rsatadi, atrofidagi tugunlar, shu bilan tugunlar va klaster bosh tuguni o‘rtasida energiya tarqalishini kamaytiradi.
- Konsentratsiya: yaqin atrofdagi tugunlar sonini aniqlaydi. Tanlangan tugun yuqori tugun konsentratsiyasiga ega bo‘lishi kerak, bu esa klaster bosh tugunlarini eng kerakli joylarda tanlashni ta’minlaydi.
- Klaster bosh tugunining chastotasi: Xuddi shu tugunning qayta saylanishiga yo‘l qo‘ymaslik uchun tayanch stantsiya har bir tugunning klaster bosh tugunisifatida saylangan sonini kuzatishi kerak.

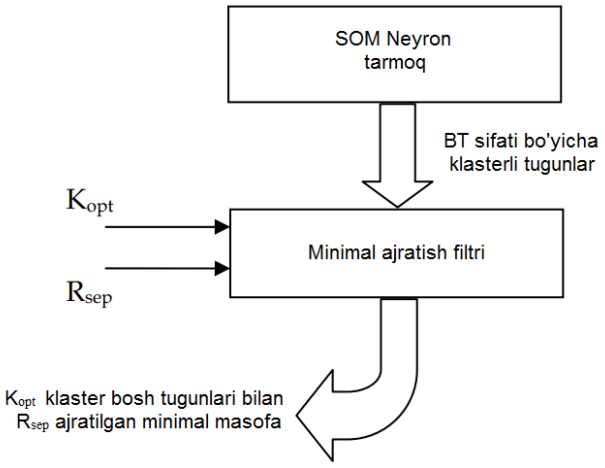
Klaster bosh tugunini tanlash muammosini hal qilish uchun 4 ta kirish va 16 ta chiqish neyroniga ega SOM topologiyasi yetarli. Tarmoq 1-rasmda ko‘rsatilganidek, klaster bosh tugunining sifatiga qarab ma’lumotlarni 16 toifaga bo‘lish uchun ishlatiladi. Wi,j og‘irliklari dastlab shunday o‘rnatiladi: Y1 neyroni yuqori sifatli tugunlarga, Y16 neyron esa past sifatli tugunlarga mos keladi. Keyinchalik bu og‘irliklar 10 000 me'yorlashtirilgan test vektorlari asosida standart SOM o‘qitish metodologiyasi yordamida sozlanadi.

Neyron tarmog‘ining chiqishi - bu klaster bosh tugunlarining sifatiga qarab tartiblangan klasterli tugunlar ro‘yxatidan olinadi. Keyin ushbu ro‘yxat tanlangan klaster boshlari orasidagi minimal bo‘linish masofasini kafolatlaydigan minimal bo‘linish filtriga qo‘llaniladi.



1-rasm. O‘z-o‘zini tashkil etuvchi xaritaning tuzilishi

Klaster bosh tugunini tanlash mexanizmining umumiy ishlashi 2-rasmda ko‘rsatilgan.



2-rasm. Klaster bosh tugunini tanlash mexanizmi

Klasterni o‘rnatish ishga tushirish bosqichida tayanch stansiya tugunlardan yuborilgan barcha ma’lumotlarni to‘playdi va 1-jadvalda ko‘rsatilganidek, jadval tuzadi. Har bir tugunning boshlang‘ich energiyasi oldindan aniqlangan va klaster bosh tuguni chastotasi bir-necha marta aniqlaydi. Tugun klaster bosh tuguni sifatida tanlanadi va dastlab nolga o‘rnatiladi.

Barcha tugunlar uchun markazlashtirilganlik, kontsentratsiya, energiya va BT chastotasi 1-jadvaldan normallashtirilgan va ularning klaster bosh tugun sifatiga ko‘ra klaster tugunlari uchun neyron tarmoqqa qo‘llaniladi. Klasterlash jarayonidan so‘ng neyron tarmoqning chiqishiga filtrlash algoritmi qo‘llaniladi.

Barcha tugunlar uchun markazlashtirilganlik, kontsentratsiya, energiya va BT chastotasi 1-jadvaldan normallashtirilgan va ularning klaster bosh tugun sifatiga ko‘ra klaster tugunlari uchun neyron tarmoqqa qo‘llaniladi. Klasterlash jarayonidan so‘ng neyron tarmoqning chiqishiga filtrlash algoritmi qo‘llaniladi.

d_{g_min} xarajat funksiyasining parametrlarini hisoblab chiqadi va d_{g_max} tanlangan kanallar uchun quyidagicha.

$$d_{g_min} = \min(d_{TOBS})$$

$$d_{g_max} = \max(d_{TOBS})$$

Bazaviy stansiyasi tanlangan klaster bosh tugunlariga joriy tur haqida ma’lumot beradi va shuningdek, xarajatlar funktsiyasi parametrlarini o‘z ichiga oladi.

P Broadcast sobit quvvatiga ega tarmoqdagi barcha tugunlarga, jumladan, ularning tugun identifikatori va xarajat funksiyasi parametrlarini uzatadi.

Tarmoqdagi tugunlar “Advert BT” xabarlarini oladi va har bir klaster bosh tuguni uchun narxni hisoblab chiqadi. Turli xil xarajat funktsiyalaridan foydalanish mumkin, ulardan ikkitasi bu yerda ko‘rsatilgan:

Qabul qilingan signal darajasiga asoslangan standart xarajat funktsiyasi. Ko‘pgina algoritmlarda tugunlar quvvat sarfini kamaytirish uchun qabul qilingan signal kuchiga qarab klaster bosh tugunlarini tanlaydi. Biroq, bu yondashuv klaster bosh tugunlarining ma’lumotlarni uzatish bosqichida energiyani tezda yo‘qotishiga olib kelishi mumkin, chunki tayanch stansiyadan uzoqroqda joylashgan klaster bosh tugunlari tayanch stantsiyaga yaqin joylashgan tugunlarga qaraganda ko‘proq energiya sarflaydi.

Olingan masofa va energiya ko‘rsatkichiga asoslangan kengaytirilgan xarajat funktsiyasi taqdim etilgan ushbu xarajat funktsiyasi masofaviy o‘lchovni ham, tugun energiyasiga nisbatan klaster bosh tugunining energiyasini ham hisobga oladi.

Tayanch stantsiyadan uzoqda joylashgan klaster bosh tuguni tugunining narxi tugun energiyasiga nisbatan klaster bosh tugunining energiyasiga muvofiq qoplanadi.

1-jadval

Bazaviy stansiyasi tomonidan to‘plangan ma’lumotlar

Tugun identifikatori	Markazlik	Konsentratsiya	Energiya	BT chastotasi	Masofa BS ga	Qo‘shni tugunlar
1	**0,34**	**1**	**0,5**	**0**	**80.5**	**54**
2	**0,532**	**3**	**0,5**	**0**	**75.2**	**5, 10, 14**
3	**0,784**	**2**	**0,5**	**0**	**97.6**	**65, 88**
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Har bir tugun minimal xarajat bilan klaster bosh tugunini tanlaydi va tanlangan klaster bosh tuguniga, jumladan, tugun identifikatori, narx va eksklyuziv belgi holatini qo‘shish so‘rovi xabarini yuboradi. Ikkinchisi tugun tomonidan klaster bosh tugunlariga faqat bitta kanal xabarini olganligi to‘g‘risida xabar berish uchun ishlatiladi, bu tugun tarmoqning chekkasida ekanligini ko‘rsatadi. Eksklyuziv belgi tugunlar orasidagi ustuvorliklarni aniqlash uchun ishlatiladi.

Klaster bosh tugunlari qo‘shilish so‘rovi xabarlarini oladilar va tugunlarga ularning qabul qilinganligi haqida xabar beradilar.

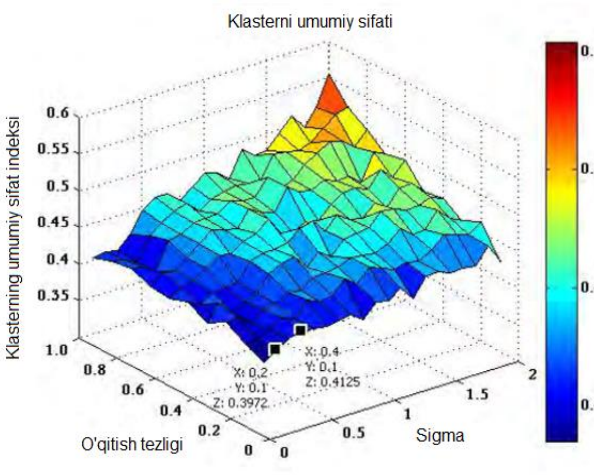
Ma’lumotlarni uzatish bosqichi va klaster bosh tugunini aniqlash

Ma’lumotlarni uzatish bosqichida tugunlar o‘lchovlarni amalga oshiradilar va klaster bosh tuguniga uzatishdan oldin har bir paketga holat va qoldiq energiya ma’lumotlarini qo‘shadilar. Klaster bosh tugunlari ushbu ma’lumotlarni oladi, ularning holati va qoldiq energiyasi haqida ma’lumot qo‘shadi, uni siqib chiqaradi va qabul qilingan paketni tayanch stantsiyaga yuboradi. Bu tayanch stansiyaga tarmoqdagi barcha tugunlarning energiya darajasini va holatini yangilash imkonini beradi. Har safar tayanch stansiya klaster boshi o‘lganligini aniqlasa, u qayta klaster xabarini uzatadi.

Klasterni o‘rnatish bosqichi vaqt va energiya sarfiga ega bo‘lganligi sababli, klasterni o‘rnatish qo‘shimcha xarajatlarining umumiy samaradorlikka ta’sirini kamaytirish uchun ma’lumotlarni uzatish bosqichi ushbu bosqichdan uzoqroq bo‘lishi kerak. Boshqa tomondan, har bir tugundagi energiya cheklanganligi sababli, juda uzoq ma’lumotlarni uzatish fazasi klaster boshi tugunining energiyasini yo‘qotadi va hali ham energiyaga ega bo‘lgan bosh tugun bo‘lmagan tugunlar va tayanch stantsiya o‘rtasidagi aloqani cheklaydi.

IV. Natijalar

Algoritmni to‘liq sinab ko‘rishdan oldin SOM neyron tarmog‘ining ikkita parametrini, ya’ni o‘rganish tezligi va sigmani optimallashtirish kerak. Ushbu optimal parametrlarni aniqlash uchun simulyatsiya dastlab statsionar tarmoqda amalga oshiriladi. Neyron tarmog‘ining klasterlash ko‘rsatkichi (U) da belgilanganidek umumiy klaster sifat indeksini hisoblash yo‘li bilan baholanadi. 3-rasmga murojaat qilgan holda, SOM neyron tarmog‘ining optimal parametrlari: o‘rganish tezligi = 0,1 va sigma = 0,2 olingan.



3-rasm. Klaster sifatining umumiy indeksi

SOM neyron tarmog‘ining ushbu optimal parametrlaridan foydalanib, to‘liq algoritm simsiz sensorli tarmoq simulyatorida sinovdan o‘tkazilishi mumkin, bu misolda simulyator MATLABda amalga oshirilgan. Simulyatsiya 100 m dan 100 m gacha bo‘lgan maydonda bir xil taqsimlangan 100 ta tugunlarda amalga oshirildi, tayanch stantsiya koordinatalarda (150 m, 50 m) joylashgan. Ushbu simulyatsiyada ishlatiladigan energiya parametrlari 2-jadvalda keltirilgan.

2-jadval

Hisoblangan energiya parametrlari

Dastlabki batareya quvvati	0,5 J
Energiya modeli parametri, e_{fs}	$1 * 10^{-11}$
Energiya modeli parametri, e_{mp}	$1{,}3 * 10^{-15}$
Electronics Energy , E_{ec}	50 nJ/bit
Ma’lumotlar paketining uzunligi	4000 bit
Paket uzunligini boshqarish	200 bit

Algoritmning ishlashini uchta ko‘rsatkich bilan baholash mumkin. Bular (1) birinchi tugunning ishdan chiqishi uchun zarur bo‘lgan vaqtni belgilaydigan birinchi tugunning ishdan chiqishi (FND), (2) tarmoqning yarmi qachon ishdan chiqishini aniqlaydigan yarim faol tugunlar (HNA) va (3) uzatilgan paketlar (TP). FND da sensor tugunlari tomonidan uzatiladigan paketlarning umumiy sonini beradi. Algoritmning haqiqiyligi va ishlashini baholash uchun 100 ta tugunning 50 dan ortiq tasodifiy yaratilgan tarmoqlari simulyatsiya qilinadi. Ishlash ko‘rsatkichlarining o‘rtacha va standart og‘ishi bo‘yicha LEACHga nisbatan yaxshilanish 3-jadvalda ko‘rsatilgan.

3-jadval.

Ishlash ko‘rsatkichlari

Ko‘rsat-kichlar	Standart xarajatlar funktsiyasi		Kengaytirilgan xarajat funktsiyasi	
	O‘rtacha	Standart	O‘rtacha	standart
FND	**51,1%**	**4,8%**	**65,2%**	**4,6%**
HNA	**34.%**	**0,9%**	**32,8%**	**0,8%**
TP	**27,6%**	**4%**	**36,1%**	**3,3%**

4-jadval.

Turli xil algoritmlarning ishlashini yaxshilash

Algoritm	LEACH ustidan yaxshilanish
EEPSC (Zahmati va boshqalar al , 2007)	**45%**
LEACH-C (Heinzelman , 2002)	**62,5%**
LEACH-Deterministik (Handy va boshqalar, 2003)	**30%**
SOMga asoslangan Algoritm	**65,2%**

Ushbu natijalar algoritm tugunlar orasidagi energiya muvozanatini oshirish va energiya tarqalish tezligini kamaytirish orqali yuqori sifatli klasterlarni yaratishga qodir ekanligini ko‘rsatadi. Bu, o‘z navbatida, FND va HNA ning sezilarli yaxshilanishiga olib keladi, natijada tayanch stantsiya tomonidan qabul qilingan paketlar soni ko‘payadi. Bundan tashqari, vaznli masofa-energiya ko‘rsatkichiga (w1 va w2 0,9 ga o‘rnatilgan) asoslangan xarajat funktsiyasidan foydalanish energiya tarqalishini va tugunlar o‘rtasida energiya taqsimotini yanada optimallashtiradi, bu esa tarmoqning ishlash muddatini oshirish bilan yanada yaxshilanadi. 3-jadvalda ko‘rsatilgandek LEACH bilan solishtirganda FNDda 65,2% gacha va FND ning HNA ga o‘tish vaqtining qisqarishi keltirilgan.

V. XULOSA

Mazkur tadqiqotda simsiz sensor tarmoqlar (SST) samaradorligini oshirish va ularning uzoq muddat ishlashini ta’minlash masalasi ko‘rib chiqildi. SST bugungi kunda atrof-muhit monitoringi, harbiy kuzatuv, sog‘liqni saqlash va sanoat sohalarida keng qo‘llanilib kelmoqda. Biroq mavjud yechimlarning asosiy muammosi tugunlarning tezda energiyasi tugashi, ma’lumot uzatishda kechikishlar va paketlarning yo‘qotilishi bilan bog‘liq. Shu sababli maqolada SOM (Self-Organizing Map) neyron tarmog‘iga asoslangan klasterlash algoritmi taklif qilindi. Ushbu yondashuv tugunlarning qoldiq energiyasi, markaziyligi va klaster boshini tanlash chastotasini hisobga olgan holda optimal klasterlashni ta’minlaydi.

MATLAB muhitida olib borilgan simulyatsiya natijalari taklif etilgan algoritm LEACH protokoli bilan solishtirganda samaradorligini yaqqol namoyon etdi. Natijalar tarmoqning ishlash muddatini 65,2% ga oshirish, energiya muvozanatini yaxshilash va uzatiladigan paketlar sonini ko‘paytirish imkonini berdi. ZigBee texnologiyasi asosidagi tajribalar esa multimedia trafigi (ovoz va tasvir) uzatishda paket yo‘qotilishi va kechikish muammolarini yoritdi. WiFi asosidagi modellashtirish yuqori o‘tkazuvchanlikni ta’minlasa-da, energiya sarfi yuqoriligi sababli SST uchun har doim ham maqbul emasligi aniqlandi.

Umuman olganda, taklif etilgan metodologiya SST ishlash samaradorligini oshirishda muhim qadam bo‘lib, u kelajakda aqlli shaharlar, sanoat tarmoqlari va kengaytirilgan reallik ilovalarida qo‘llanishi mumkin. Ushbu yondashuv SSTning barqarorligini ta’minlash, energiyani tejash va xizmat sifatini yaxshilashda keng istiqbollarga ega.

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SIMSIZ SENSOR TARMOQLARIDA TO‘LDIRILGAN REALLIK ILOVALARINING ISHLASH SAMARADORLIGINI BAHOLASH

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Annotatsiya: **Ushbu maqolada simsiz sensor tarmog‘iga (SST) asoslangan to‘ldirilgan reallik ilovalari uchun multimedia kontentini uzatish bo‘yicha eksperimental tadqiqot natijalari keltirilgan. IEEE 802.15.4 va ZigBee protokoli, shuningdek IEEE 802.11 simsiz sensor tarmog‘ida ma’lumotlarni uzatish texnologiyalari sifatida qaraladi.Ushbu texnologiyalarni tanlash oraliq tugunlar orqali o‘tish orqali to‘ldirilgan reallik ilovalari uchun ma’lumotlarni o‘z-o‘zini tashkil qilish va yetkazib berish qobiliyatiga ega bo‘lgan internet ashiyolari qurilmalarining bir-biri bilan o‘zaro ta’sirini ta’minlaydi. Ishning birinchi qismida tarmoq fragmenti orqali ovoz va tasvirni uzatish xususiyatlari eksperimental tarzda ochib berilgan. Ovozni uzatishda turli tillar hisobga olinadi va qabul qiluvchi tomonning idrok sifati aniqlanadi. Ishning ikkinchi qismida oraliq tugunlar orqali ma’lumotlarni uzatish xususiyatlari eksperimental tarzda ochib berilgan, tabiiy va simulyatsiya modellashtirishdan foydalanilgan. O‘tkazilgan tadqiqotlar va keyingi tahlillar asosida tarmoq ishlash parametrlarining tarmoqdagi tugunlar soniga va o‘tishlar soniga bog‘liqligi keltirilgan.**

Kalit so’zlar: ZigBee protokol, trafik, tugun, shlyuz, IoT, LLN.

XCI. I.KIRISH

Hozirgi vaqtda zamonaviy aloqa tarmoqlarini modernizatsiya qilishning harakatlantiruvchi omillaridan biri beshinchi avlod aloqa tarmoqlari 5 G / IMT -2020 doirasida o‘zaro ta’sir stsenariylariga o‘tishdir [1, 2]. Beshinchi avlod tarmoqlari stsenariylarni nazarda tutadi, ular asosida internet ashiyolari qurilmalari va ilovalari o‘rtasida uzluksiz aloqa ta’minlanishi kerak [3]. Bunday stsenariylardan biri bu o‘z-o‘zini tashkil etuvchi tarmoq strukturasida internet ashiyolari qurilmalarining bir-biri bilan o‘zaro ta’siri.O‘z-o‘zini tashkil etuvchi tarmoqlar odatda tarmoqli topologiyaga ega bo‘lib, belgilangan joyga marshrutni qurish orqali ma’lumotlarni tugundan tugunga yetkazish imkonini beradi. Aqlli shaharlarni qurish uchun mos yozuvlar arxitekturasiga ko‘ra, sensorlardan ma’lumotlarni olish imkoniyati bilan turli shahar infratuzilmasi obyektlarining doimiy monitoringini ta’minlash kerakligini hisobga olsak, bunday obyektlardan ma’lumotlarni to‘plash uchun tarmoqni tashkil qilish, shuningdek, ko‘proq ma’lumot mazmuni uchun ularni to‘ldirilgan reallik ilovalariga yetkazib berish uchun tarmoqli topologiyadan foydalanish mumkin bo‘ladi [4]. Internet of Things so‘nggi qurilmalari ma’lum obyektlarga o‘rnatilgan sensorlardan ma’lumotlarni to‘playdi va ularni keyingi qayta ishlash uchun serverga yuboradi. Tarmoqning har bir bo‘lagi, serverda ishlov berish, kengaytirilgan haqiqat ilovasiga yuborish tegishli tarmoq kechikishini keltirib chiqarganligi sababli, ushbu jarayonni amaliy xizmat tugunlari yordamida optimallashtirish taklif etiladi u foydalanuvchi va ma’lumotlar yig‘ish tarmog‘iga yaqin joyda joylashgan.

II. ADABIYOTLAR TAHLILI

5G/IMT-2020 texnologiyalari asosida kengaytirilgan reallik ilovalarini qo‘llash bo‘yicha tadqiqotlarda yuqori tezlik va past kechikish asosiy talablar sifatida qayd etilgan. Ushbu tadqiqotlar IoT qurilmalari uchun qulay aloqa muhitini ta’minlashga qaratilgan [2]. [4] Aqlli shahar infratuzilmasini qurish bo‘yicha olib borilgan ishlarda sensorlardan ma’lumot olish va ularni AR ilovalariga yetkazib berishda tarmoqli topologiyalardan foydalanish samaradorligi ko‘rsatilgan. [7] ZigBee spetsifikatsiyasi bo‘yicha o‘z-o‘zini tashkil etuvchi mesh topologiyasi arzonligi va avtonomligi bilan ko‘plab tadqiqotlarda tasdiqlangan. Shuningdek, multimedia trafigi uchun cheklovlari mavjudligi ham qayd etilgan. [10] Simsiz sensorli tarmoqlarni tashkil etishda ZigBee texnologiyasining amaliy imkoniyatlari ko‘plab ilmiy ishlarda ko‘rib chiqilgan bo‘lib, u IoT konsepsiyasi doirasida rivojlanishning muhim bosqichi sifatida baholangan. [13] Uchuvchi sensor tarmoqlarda ZigBee texnologiyasidan foydalanish bo‘yicha tajribalar o‘tkazilib, turli turdagi qurilmalar orqali uning funksionalligini to‘liq amalga oshirish mumkinligi aniqlangan. [14] ZigBee tarmog‘i arxitekturasida koordinator, marshrutizator va oxirgi qurilmalarning roli va funksiyalari bo‘yicha tadqiqotlar olib borilgan. Ushbu ishlarda marshrutlashning dinamikligi va xavfsizlik siyosatlari asosiy e’tibor qaratilgan masalalar sifatida ko‘rsatilgan. [17] ITU-T Y.1540 tavsiyasida tarmoq sifatiga ta’sir qiluvchi omillar

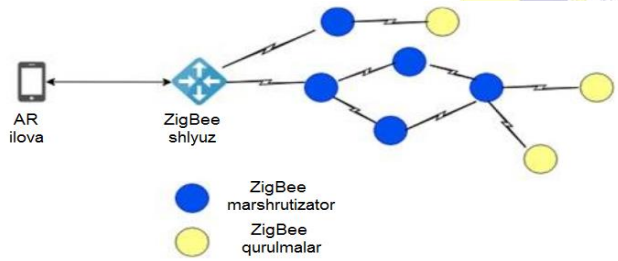
(o‘tkazish qobiliyati, ishonchlilik, kechikish, jitter va yo‘qotishlar) multimedia xizmatlari uchun asosiy mezon sifatida belgilangan. [18] LLN tarmoqlarida tasvir va ovoz uzatish sifatiga tarmoq parametrlarining ta’sirini o‘rganishga bag‘ishlangan tadqiqotlarda ZigBee texnologiyasining multimedia uchun ma’lum darajadagi samaradorligi qayd etilgan. ITU-T R.913 metodologiyasi asosida tasvir va ovoz sifatini subyektiv baholash usullari multimedia xizmatlarini sinovdan o‘tkazishda keng qo‘llanilgan. ITU-T P.910 tavsiyasida ta’riflangan ACR usuli multimedia kontentining idrok etilish sifatini foydalanuvchilar baholashlariga asoslangan holda tahlil qilish imkonini berishi ilmiy ishlarda keng qo‘llanmoqda.

III. METODOLOGIYA

ZigBee protokoli orqali tasvir va nutqni uzatish sifati parametrlarini baholash shaffof kanal rejimi

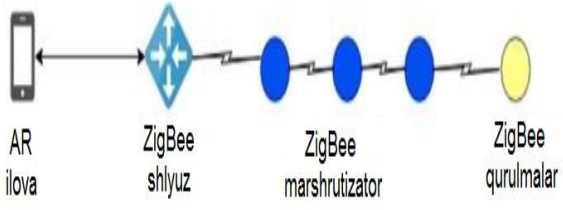
Hozirgi kunda LLN (Low-Power and Lossy Net-works)juda mashhur, bu foydalanuvchilar uchun keng funktsional imkoniyatlarni ochib beradi, ya’ni o‘z-o‘zini tashkil qilish, arzon narx va oson joylashtirish.

Birinchi stsenariy tarmoq zichligining kengaytirilgan reallik ilovalari uchun ma’lumotlarni yetkazib berishning aylanma kechikishiga ta’sirini ko‘rib chiqishdir. Ushbu stsenariyda tarmoqdagi tugunlar soni tajribaning har bir bosqichida ortadi, so‘rovni shakllantirish va yuborish va javob olish vaqtlari tegishli jurnal faylida qayd etiladi. Tarmoqdagi tugunlarning taqsimlanishi 1-rasmda ko‘rsatilgan.



1-rasm. Tarmoqdagi tugunlarni taqsimlash (tarmoq zichligini oshirish)

Ikkinchi stsenariy shlyuz va oxirgi tugun o‘rtasidagi marshrutizatorlar sonining ko‘payishini ko‘rib chiqilgan, ya’ni har bir paket uchun ulanishlar soni ortadi.Tarmoqdagi marshrutizatorlarning taqsimlanishi 2-rasmda ko‘rsatilgan.



2-rasm. Tarmoqdagi tugunlarni taqsimlash (marshrutizatorlar sonining ko‘payishi)

So‘rovni yuborish va tegishli javobni olish vaqtini yozib olish uchun to‘ldirilgan reallik ilovasi, masalan - “**Request 1**” raqami bilan so‘rovni yaratadi va yuboradi va yuborish vaqti keyingi qayta ishlash uchun faylda saqlanadi. Bundan tashqari, agar sensor tugun “**Request 1**” ni qabul qilsa, u mos keladigan " Javob 1" bilan javob beradi . Kengaytirilgan reallik ilovasi “**Response 1**” javobini olganda , u javob olingan vaqtni faylga yozib oladi.

Yo‘qotishlar ehtimolining trafik intensivligiga bog‘liqligi

Modelning tuzilishi avvalgi tajribada qo‘llanilganiga o‘xshaydi. Tarmoq 13 ta tugundan iborat bo‘lib, ular bitta “chiziqli” marshrutni ifodalaydi. UDP datagrams manba tugun va 11 ta tranzit tugunlari orqali maqsad tugun o‘rtasida uzatiladi. Tajriba davomida uzatilgan va qabul qilingan datagrammalar yozib olinadi. Tajriba natijalari 1-jadvalda keltirilgan, yo‘qolgan datagramlar nisbatining harakat intensivligiga empirik bog‘liqligi ko‘rsatilgan .

Bu yerda C_a^2va C_s^2 mos ravishda kirish taqsimotining kvadratik o‘zgarish koeffitsientlari oqim va xizmat ko‘rsatish vaqti;

nb **- bufer hajmi;**

p- tizim yuklaqnishi;

p_o ***– yo‘qotishlar ehtimoli, marshrutning tranzit uchastkalari soniga qarab (*****11 ta tranzit tugunlari bilan o‘tkazilgan tajriba natijalariga ko‘ra p_o = 0,1).**

and frictional uncertainties during manipulator operation[8]. Ma’lumotlar quyudagi qiymat bilan approksimasiyalanadi:

$$p = p_o + \frac{1-p}{1-p^{\frac{2}{c_a^2+c_s^2}n_b+1}} p^{\frac{2}{c_a^2+c_s^2}n_b} \quad (1)$$

1-jadval

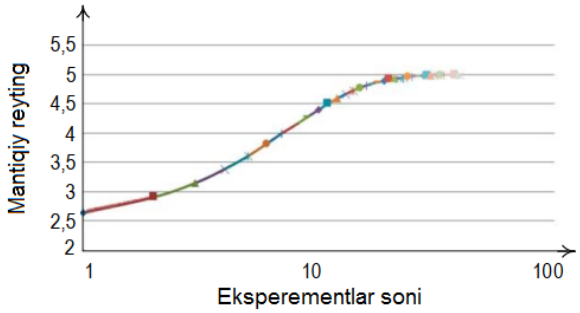
Yo‘qolgan datagramlar nisbatining harakat intensivligiga empirik bog‘liqligi

Trafik intensivligi, Mbit/s	Deytagramlar orasidagi o‘rtacha interval, ms	Tajriba-ning davomiy-ligi, s	Deytagram	
			Yubo-ril-gan, dona.	Qab-ul qilin gan, dona.
1.	8000	15 919	2037	1866
2.	4000	15 335	3863	3506
3.	2667	15 324	5823	5287
4.	2000	15 817	7970	7255
5.	1600	15,151	9374	8437
6.	1333	15,201	11404	10306
7.	1143	15,135	13294	12002
8.	1000	15,119	15124	13432
9.	0,889	10,251	11826	8859
10.	0,800	10,232	12923	8866

11.	0,727	10,118	13795	8712
12.	0,667	10 170	15375	8778
13.	0,615	10,137	16577	8781
14.	0,571	10 553	18473	9233
15.	0,533	10,121	19031	8718

Baholash subyektiv usullar yordamida amalga oshirildi tarmoq ish faoliyatini tavsiflovchi obyektiv ko‘rsatkichlar va axborotni subyektiv idrok etish o‘rtasidagi munosabatni o‘rganish paydo bo‘lishiga qarab foydalanuvchilar uzatish paytida ma’lumotlar siafatiga ta’sir etuvchi omillar hisobga olnigan. Olingan natijalarni vizual ravishda ko‘rsatish uchun logistika egri chizig‘ining [22] yaqinlashuvidan foydalanildi.

$$\sigma = \frac{5}{1+e^{\frac{-t-t_0}{B}}} \quad (2)$$



3-rasm. Mantiqiy approksimasiya

Tahlilning keyingi bosqichi olingan natijalar o‘rtasidagi bog‘liqlikni aniqlash edi. Yo‘qotishlar va uzatish tezligi bilan uzatish sifatini subyektiv baholash o‘rtasidagi bog‘liqlik darajasini aniqlash uchun biz korrelyatsiya koeffitsientini hisoblaymiz. Subyektiv baholash va yo‘qotishlar o‘rtasidagi korrelyatsiya koeffitsienti 0,904 va sub'ektiv baholash va uzatish tezligi 0,318 ekanligiga asoslanib, baholashlar ZigBee tarmog‘i orqali uzatish tezligidan ko‘ra yo‘qolgan paketlar soniga ko‘proq bog‘liq degan xulosaga kelish mumkin .

Tadqiqot natijalariga ko‘ra quyidagi xulosalar chiqarish mumkin.

1) ovozni uzatish sifati an’anaviy aloqa tarmoqlari sifatiga nisbatan sezilarli darajada past. ZigBee tarmog‘i orqali ovoz sifatiga katta ta’sir paketlarni yo‘qotish darajasiga ta’sir qiladi .
2) Ayni paytda ZigBee tarmog‘i orqali oqimli video uzatish kanal o‘tkazuvchanlik qobiliyati kamligi sababli kechikish va jitter talablari past bo‘lgan past aniqlikdagi tasvirlarni uzatish mumkin.
3) Ovoz foydali ma’lumotlarning yo‘qolishi bilan ishlaydigan kodeklar yordamida siqilganida, - paketni tarmoq orqali etkazib berish ehtimoli oshadi, lekin tarmoq orqali uzatish paytida paket yo‘qolsa, foydali ma’lumotlarning katta segmenti yo‘qoladi. Yaxshilangan siqish algoritmiga ega kodekni tanlash natijalarni yaxshilaydi.
4) Smartfonda Android operatsion tizimi uchun ishlab chiqilgan to‘ldirilgan reallik ilovasi ishga tushirildi. Simsiz Wi-Fi kirish nuqtasi orqali dastur xizmat ko‘rsatish tuguniga ulangan va vaqti-vaqti bilan obyektlardan ma’lumot olish uchun so‘rov yubordi. Ko‘rsatilayotgan xizmat sifatini qo‘shimcha tekshirish uchun arizada so‘rov yuborilgan va javob olingan vaqtlar qayd etilgan .
5) Ilovalar xizmati tugunida noshir-obunachi tamoyili asosida ishlaydigan server ishga tushirilgan. ZigBee Gateway uchun Python tilida yozilgan dastur ishlatilgan. Dastur USB - UART adapteri orqali AT buyruqlari asosida USB shlyuzini boshqardi. Dastur quyidagicha ishlaydi: shlyuz sensor ma’lumotlarini qabul qiladi va uni bulut xizmatiga va dastur xizmati tuguniga yo‘naltiradi. Shu bilan birga, shlyuz dasturga xizmat ko‘rsatish tugunidan (mijozdan) so‘rovlarni qabul qiladi va ularni oxirgi tugunlarga yo‘naltiradi. Keyin shlyuz so‘nggi nuqtalardan javoblarni oladi va ularni to‘g‘ridan-to‘g‘ri mijozga xizmat qilish uchun dasturga xizmat ko‘rsatish tuguniga yo‘naltiradi.
6) Oxirgi qurilma uchun Python dasturlash tilida ishlab chiqilgan dastur ishga tushirildi. U ZigBee modulini boshqaradi.USB-UART adapteri orqali AT buyruqlari yordamida.Dastur sensor ma’lumotlari vaqti-vaqti bilan yaratilishi va shlyuzga yuborilishini hisobga olgan holda ishlaydi, ammo oxirgi qurilma ularni shlyuzdan (ya’ni mijozdan) qabul qilganda so‘rovlarga javob beradi.

Eksperimental tadqiqot stsenariylari

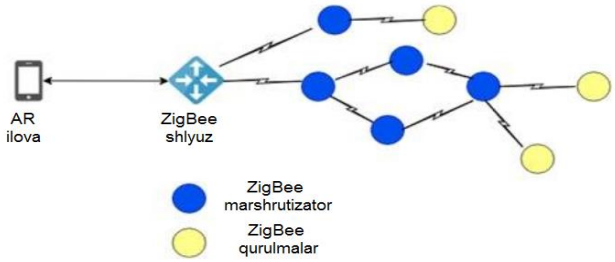
Xizmat sifatini baholash uchun to‘ldirilgan reallik ilovasidan so‘rovni yaratish va jo‘natishdan keyin javobni kutish vaqti ko‘rib chiqiladi.

Birinchidan to‘ldirilgan reallik ilovasi xizmat ko‘rsatish tuguniga so‘rov yuboradi, so‘ngra xizmat ko‘rsatish tuguni bu so‘rovni ma’lumotlarni yig‘ish tarmog‘i shlyuziga, shlyuz esa so‘rovni oxirgi sensor tuguniga yo‘naltiradi. So‘rovni qabul qilgandan so‘ng, sensorli tugun shlyuzga javob yuboradi, u uni xizmat ko‘rsatish tuguniga yo‘naltiradi, bu esa o‘z navbatida bu javobni to‘ldirilgan reallik ilovasi mijoziga yuboradi.

Laboratoriya o‘rnatish tuzilishiga ko‘ra, simsiz sensorlar tarmog‘ining fragmenti mijozga ma’lumotlarni taqdim etish vaqtiga katta ta’sir ko‘rsatishini kuzatish mumkin. Yuqorida aytib o‘tilganidek, ZigBee tarmog‘ining to‘r topologiyasi kechikishlarni keltirib chiqaradi va ma’lumotlarni uzatish jarayoniga ta’sir qiladi, shuning uchun ushbu stsenariyni ko‘rib chiqishda tugun zichligi va o‘tgan marshrutizatorlar soni kabi tarmoq xususiyatlarini hisobga olish kerak.Shu munosabat bilan, ikkita eksperimental stsenariyga mos keladigan tajribalar uchun ZigBee tarmog‘i o‘rnatildi .

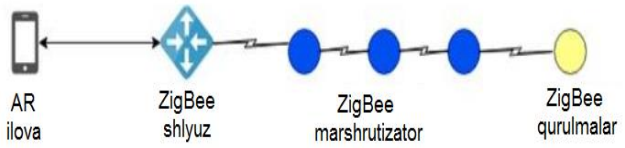
Birinchi stsenariy tarmoq zichligining kengaytirilgan reallik ilovalari uchun ma’lumotlarni yetkazib berishning aylanma kechikishiga ta’sirini ko‘rib chiqishdir. Ushbu stsenariyda tarmoqdagi tugunlar soni tajribaning har bir

bosqichida ortadi, so‘rovni shakllantirish va yuborish va javob olish vaqtlari tegishli jurnal faylida qayd etiladi. Tarmoqdagi tugunlarning taqsimlanishi 4-rasmda ko‘rsatilgan.



4-rasm. Tarmoqdagi tugunlarni taqsimlash (tarmoq zichligini oshirish)

Ikkinchi stsenariy shlyuz va oxirgi tugun o‘rtasidagi marshrutizatorlar sonining ko‘payishini ko‘rib chiqilgan, ya’ni har bir paket uchun ulanishlar soni ortadi.Tarmoqdagi marshrutizatorlarning taqsimlanishi 5-rasmda ko‘rsatilgan.

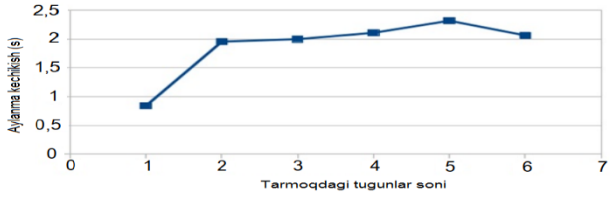


5-rasm. Tarmoqdagi tugunlarni taqsimlash (marshrutizatorlar sonining ko‘payishi)

So‘rovni yuborish va tegishli javobni olish vaqtini yozib olish uchun to‘ldirilgan reallik ilovasi, masalan - “**Request 1**” raqami bilan so‘rovni yaratadi va yuboradi va yuborish vaqti keyingi qayta ishlash uchun faylda saqlanadi. Bundan tashqari, agar sensor tugun “**Request 1**” ni qabul qilsa, u mos keladigan " Javob 1" bilan javob beradi . Kengaytirilgan reallik ilovasi “**Response 1**” javobini olganda , u javob olingan vaqtni faylga yozib oladi. Har bir tajribadan so‘ng, har bir so‘rov va javobning xabarlarini jo‘natish va qabul qilish vaqtini qayd qiluvchi ikkita fayl yaratiladi. Shu tarzda, to‘ldirilgan reallik mijozi va sensorli tugun o‘rtasidagi aylanish kechikishini hisoblash mumkin.

IV. EKSPERIMENTAL NATIJALARNI TAHLIL QILISH

Tarmoqdagi ushlashlar sonining ko‘payishi bilan o‘zgarib turadigan aylanish kechikishi olindi. Birinchi stsenariy bo‘yicha tajriba natijalari 6-rasmda keltirilgan.

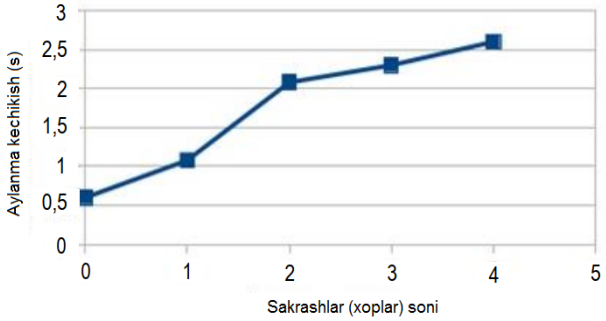


6-rasm. Javob vaqti (RTT) da tarmoq zichligining ta’siri

Tarmoqdagi tugunlar soni qancha ko‘p bo‘lsa, - kechikish shunchalik katta bo‘ladi. Tarmoqning yuqori zichligi uzatish muhitiga bir vaqtning o‘zida kirish natijasida ko‘proq kanallar ishg‘ol qilinishi yoki to‘qnashuvlar sodir bo‘lishini anglatadi. Shunday qilib, xabarlar shlyuz va oxirgi tugun o‘rtasida o‘tishda kechikishi mumkin.

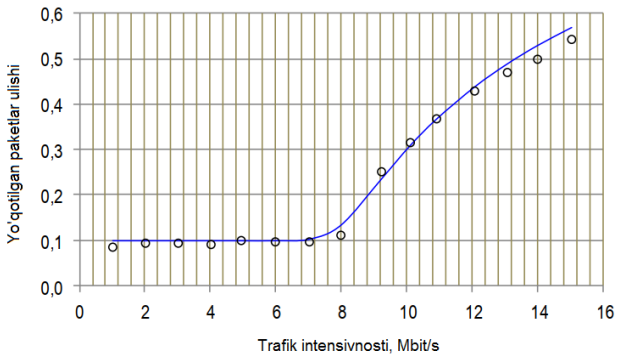
Ikkinchi stsenariyda o‘tgan marshrutizatorlar soni ko‘rib chiqildi. Bunday holda, har bir so‘rov va javob marshrutizatorlarning butun zanjiridan o‘tdi. Shunga ko‘ra, marshrutizatorlar soni ortib borishi bilan aylanma safarning kechikishi ortishi kerak. Ikkinchi stsenariy bo‘yicha aylanma safarning kechikishining ulanishlar soniga bog‘liqligi 7-rasmda ko‘rsatilgan. Ma’lumotlarga ko‘ra, shlyuz va oxirgi tugun o‘rtasidagi marshrutizatorlar soniga qarab aylanma kechikish ortib borishini ko‘rish mumkin.

Kechikish o‘lchovlariga asoslanib, shuni ko‘rish mumkinki, agar dastur so‘nggi tugunga so‘rov yuborsa va undan javob kutsa, unda bunday aylanma kechikish sezilarli bo‘lib, idrok sifatiga salbiy ta’sir qiladi. Ushbu yondashuvni optimallashtirish uchun to‘plangan ma’lumotlarni keshlash tavsiya etiladi.

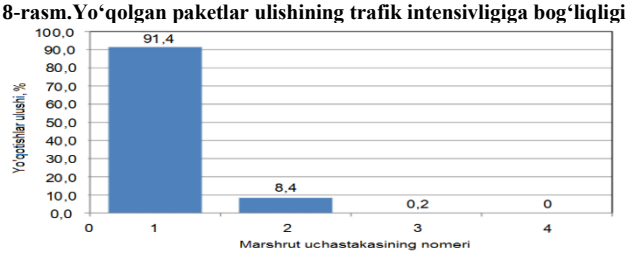


7-rasm. **Javob vaqti (RTT) ga marshrutizatorlar sonining ta’siri**

Ma’lumotlar tugunda saqlanishi yoki bulutga so‘rov bo‘yicha olinishi mumkin. Bunday holda, to‘ldirilgan reallik ilovasi xizmat ko‘rsatish tuguniga ulanganda, unga mos keladigan obyektlar haqidagi ma’lumotlar darhol yuboriladi, bu esa idrok etishning yaxshiroq sifatini ta’minlaydi.



8-rasm.Yo‘qolgan paketlar ulishining trafik intensivligiga bog‘liqligi



9-rasm.Yo‘qolgan paketlarning marshrut uchastkalari bo‘yicha taqsimlanishi

Yuqoridagi natijalardan ko‘rinib turibdiki, WiFi texnologiyasidan foydalangan holda qurilgan o‘z-o‘zini tashkil etuvchi tarmoqning ishlash sifati sezilarli darajada uning parametrlariga, xususan, marshrut uzunligi va intensivligiga bog‘liq. Biroq o‘tkazuvchanlik qobiliyatining raqamli qiymatlari marshrut uzunligi va tarfik intensivligini juda keng chegaralarda o‘zgartirishda yuzaga keladigan imkoniyatlar va kechikish qiymatlari, foydalanish orqali qurilgan tarmoq uchun olingan qiymatlardan sezilarli darajada farq qiladi.Simulyatsiya tajribalarida ZigBee texnologiyalarining o‘tkazuvchanlik qobiliyati *RTT bo‘ylab yubosrishida* kechikishi 30 ms dan oshmadi, eng yomon holatda va o‘tkazuvchanlik unchalik emas 2 Mbit/s dan pastga tushdi. Bundan xulosa qilish mumkinki, WiFi standartlaridan foydalanish simsiz sensor tarmoqlarini qurish uchun, ba’zi hollarda ko‘plab to‘ldirilgan reallik ilovalari uchun maqbuldir.Operatsion parametrlarning marshrut uzunligiga bog‘liqligi eng mos keladigan tarmoq konfiguratsiyasini tanlash imkonini beradi, unda marshrut uzunligi ham, ish parametrlari ham hal qilinayotgan qo‘llaniladigan muammolar talablariga javob beradi.

V. XULOSA

O‘z-o‘zini tashkil qiluvchi tarmoqqa asoslangan to‘ldirilgan reallik ilovalarida ma’lumotlarni yetkazib berishning yangi yondashuvlari ko‘rib chiqildi.Taklif etilayotgan yondashuv beshinchi avlod aloqa tarmoqlarida 5G/IMT-2020 da qo‘llaniladigan stsenariylardan biri bo‘lib, Smart Citydagi mavjud yechimlarda amalga oshirish uchun ko‘rib chiqilishi mumkin. IEEE tarmoqlari doirasi 802.15.4 multimedia ma’lumotlarini uzatish uchun xosdir. Ushbu tarmoqlar multimedia ma’lumotlarini uzatish sifatiga past talablar mavjud bo‘lganda qo‘llaniladi. Bunday tarmoqlardan foydalanishning asosiy afzalligi - bu tarmoqlarning arzonligi, yuqori avtonomligi, soddaligi va ishonchliligi, bu kelajakda to‘ldirilgan reallik ilovalari uchun multimedia ma’lumotlarini uzatish uchun ushbu tarmoqlarni ko‘rib chiqish imkonini beradi.

Mesh tarmoqlariga asoslangan to‘ldirilgan reallik xizmatlarini taqdim etish usullari taklif etilmoqda va - to‘ldirilgan reallik xizmatlari uchun xizmat ko‘rsatish sifati ko‘rsatkichlari baholanadi.

Kelajakda model tarmog‘ining ishlab chiqilgan fragmenti asosida LPWAN texnologiyalari asosida axborot uzatish bilan qo‘shimcha stsenariylarni ishlab chiqish taklif etiladi.

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8-sho‘ba. Geoinformatika, masofadan zondlash va geointellektual tizimlar

DARAXT QOPLAMINI ANIQLASH UCHUN GEOFAZOVIY VA MASOFADAN ZONDLASH MA'LUMOTLARINI INTEGRATSIYA QILISH

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***Annotatsiya* — Ushbu maqolada shahar hududlarida daraxt qoplamini aniqlash jarayonini takomillashtirish maqsadida geofazoviy (GIS) va masofadan zondlash (RS) ma'lumotlarini integratsiya qilish metodologiyasi ilgari suriladi. Toshkent shahri Yunusobod tumani tadqiqot obyekt sifatida tanlanib, 2024-yilning yoz mavsumida olingan Sentinel-2 multispektral tasvirlari (10 m o'lchamda) tahlil qilindi. Tadqiqotda True Color Image (TCI), Enhanced Vegetation Index (EVI) kabi indekslar hisoblanib, ular maxsus tayyorlangan daraxt qoplamining vektor poligonlari bilan integratsiya qilindi. Natijalar shuni ko'rsatadiki, indekslar orqali olingan raster ma'lumotlar va vektor qatlamlar bir-birini to'ldiruvchi vosita sifatida daraxt qoplamining zichligi va salomatligini aniqroq baholash imkonini beradi. Ushbu yondashuv urban ekologiyasini monitoring qilishda, yashil hududlarni boshqarishda va uglerod balansini hisoblashda amaliy ahamiyat kasb etadi.**

Kalit so'zlar — daraxt qoplami, geofazoviy ma'lumotlar, masofadan zondlash, spektral indekslar, vegetatsiya indekslari

XCII. KIRISH

Shahar o'rmonlari shahar muhitida barqarorlikni ta'minlaydigan muhim ekologik funksiyalarni bajaradi, jumladan karbon yutilishi, havoni ifloslantiruvchi moddalarning kamaytirilishi, mikroiqlimni tartibga solish va aholining dam olish imkoniyatlariga hissa qo'shadi [1]. Shu sababli, shahar ekotizimlarining ko'rinishini yuqori fazoviy aniqlikda belgilash shaharsozlik, landshaft rejalashtirish va ekologiya sohalari uchun dolzarb masala hisoblanadi. An'anaviy maydon tadqiqotlari katta vaqt, mehnat va resurs talab qilishi sababli, ayniqsa tez rivojlanayotgan urban hududlarda keng qamrovli monitoringni amalga oshirish murakkablik tug'diradi. Shu nuqtai nazardan, masofadan zondlash texnologiyalari — xususan multispektral sun'iy yo'ldosh tasvirlari — o'simlik indekslarini hisoblash orqali o'simliklarning umumiy tarqalishini aniqlashda qulay va samarali vosita hisoblanadi [2,3].

Biroq, yuqori aniqlikdagi multispektral tasvirlarga qaramay, kichik yoki siyrak daraxt qoplamlarini, ayniqsa binolar yoki boshqa sun'iy strukturalar orasidagi ob'ektlarni, aniq ajratish qiyin bo'lishi mumkin. Bunday cheklovlar, ayniqsa, individual daraxtlarni aniqlash va ularning biomassa yoki uglerod zahirasini aniqlashda muhim ahamiyat kasb etadi [4,5]. Shu bois, bu boradagi keyingi qadam masofadan zondlash metodlarini yanada takomillashtirish va shahar o'rmonlarini yuqori aniqlikda o'lchash yondoshuvlarini ilgari surishdir.

Yuqori aniqlikdagi vektor shaklidagi alohida daraxt qoplamini poligonlarini masofadan zondlash indekslari – True Color Image (TCI) va Enhanced Vegetation Index (EVI) – bilan integratsiya qilish orqali har ikki ma'lumot turining komplementar kuchini birlashtirish mumkin. Vektor ma'lumotlari aniq daraxt qoplam chegaralari va daraxt atributlarini taqdim etsa, raster indekslari barglarning holati va biomassa zichligi haqidagi spektral ma'lumotlarni qamrab oladi [7]. Ushbu yondashuv aniqlikni oshiradi va har bir daraxt salomatligini baholash imkonini beradi, bu esa shahar muhitida maqsadli boshqaruv choralarini qo'llash uchun juda zarurdir. Ushbu maqolada biz bu metodologiyani 2024 yil iyun oyida olingan Sentinel-2 Level-2A tasviri va maxsus tayyorlangan vektor daraxt qoplamlari ma'lumotlar to'plami yordamida Toshkent shahrining Yunusobod tumani misolida qo'lladik [1].

Ushbu tadqiqot uchun Toshkent shahrining Yunusobod tumani tanlanishiga bir nechta sabablar bor. Birinchidan, hududda urbanizatsiya jarayonlari juda tez kechmoqda, natijada yashil hududlarni saqlab qolish dolzarb masalaga aylandi. Ikkinchidan, ushbu tuman shahar aholisining asosiy yashash zonalaridan biri bo'lib, daraxt qoplamining zichligi ekologik muhit va havo sifati uchun muhim ahamiyatga ega. Shu sababli, tadqiqot hududi sifatida aynan Yunusobod tanlandi va Sentinel-2 sun'iy yo'ldosh tasvirlari asosida daraxt qoplamining fazoviy bahosi o'tkazildi.

XCIII. ILGARI O'RGANILGAN ISHLAR

So'nggi o'n yillikda shahar daraxt qoplamini aniqlash masofadan zondlash (RS) va geofazoviy axborot tizimlari (GIS) integratsiyasi orqali faol o'rganilmoqda [6,7]. Bu borada turli metodologiyalar ishlab chiqilgan bo'lib, ularning har biri ma'lum ustunlik va cheklovlarga ega.

Vegetatsiya indekslariga asoslangan yondashuvlar.

NDVI (Normalized Difference Vegetation Index) uzoq yillar davomida eng keng qo'llanilgan indekslardan biri bo'lib, daraxt qoplamini aniqlashda samarali natijalar bergan [2]. Lekin shahar hududlarda asfalt, beton va tuproq fonining kuchli ta'siri sababli NDVI qiymatlarida noto'g'ri tasniflanish kuzatilgan. Shu bois, EVI (Enhanced Vegetation Index) ko'plab tadqiqotlarda urban muhit uchun yaxshiroq deb topilgan [3]. Masalan, AQSh va Yevropa

shaharlarida o‘tkazilgan tadqiqotlarda EVI daraxt biomassasini aniqlashda NDVI’ga qaraganda yuqori korrelyatsiyani ko‘rsatgan.

Yuqori fazoviy aniqlikdagi sun’iy yo‘ldosh ma’lumotlari.

Ko‘plab ishlarda Landsat-8 OLI, WorldView-3, PlanetScope kabi tasvirlar qo‘llanilgan[5]. Ularning fazoviy aniqligi 0.3–5 m gacha bo‘lgani sababli individual daraxtlarni aniqlash imkonini beradi. Ammo, bunday ma’lumotlar ko‘pincha tijorat asosida taqdim etiladi va katta hududlar uchun iqtisodiy jihatdan qimmatga tushadi. Shu sababli, bepul foydalanish mumkin bo‘lgan Sentinel-2 tasvirlari 10 m aniqligi, yuqori vaqt chastotasi (5 kunda qaytariluvchi) va global qamrovi sababli keng qo‘llanmoqda [8]. Masalan, Xitoyning Pekin shahrida Sentinel-2 asosida shahar yashil hududlari monitoringi amalga oshirilgan bo‘lib, daraxt qoplamining mavsumiy dinamikasi tahlil qilingan .

GIS va RS integratsiyasi.

So‘nggi tadqiqotlarda GIS vektor ma’lumotlarini raster indekslari bilan birlashtirish orqali aniqlikni oshirishga erishilgan. Masalan, Germaniyada o‘tkazilgan tadqiqotda shahar bog‘lari va daraxt qoplamining vektor chegaralari NDVI xaritalari bilan ustma ust joylashtirilganda, biomassa va barg zichligini baholashda xatolik 12 % ga kamaygani aniqlangan. Shu kabi, Hindistonda olib borilgan ishlarda vektor qatlamlari yordamida EVI indekslari statistik tahlil qilingan va har bir daraxt qoplamining o‘rtacha spektral qiymatlari hisoblab chiqilgan .

Cheklovlar.

Shunga qaramay, mavjud ishlarda bir nechta muammolar davom etmoqda [3,5]:

- Siyrak va kichik daraxt qoplamlari ko‘pincha noto‘g‘ri tasniflanadi.
- Shahar hududida fon aralashuvi (asfalt, beton, soyalar) indekslarni buzadi.
- Mavsumiy o‘zgarishlar hisobga olinmaganda natijalar noto‘g‘ri bo‘lishi mumkin.

Shu bois, ushbu maqolada Sentinel-2 ma’lumotlari asosida EVI va TCI indekslarini vektor daraxt qoplamlari bilan integratsiya qilish orqali yuqori aniqlikka erishish yondashuvi taklif qilinadi [8,9]. Bu metodologiya mavjud ishlardagi kamchiliklarni qisman bartaraf etib, shahar hududlarida ekologik monitoring uchun samarali yechim bo‘lib xizmat qilishi mumkin.

XCIV. Materiallar va usullar

A. *Tadqiqot hududi va ma’lumotlar*

Yunusobod tumani, Toshkent shahrining shimoliy sektorida joylashgan bo‘lib (41.342° K, 69.256° V), taxminan 35 km² maydonni egallaydi. Ushbu hudud shahar landshaftining muhim tarkibiy qismi bo‘lib, unda turar-joy massivlari, tijorat zonalari, transport yo‘llari va keng ko‘lamli jamoat bog‘lari mavjud. Aynan jamoat bog‘lari va ko‘kalamzor hududlarning tarqalishi tumanning ekologik muvozanatini ta’minlashda asosiy o‘rin tutadi. Urbanizatsiya jarayonlarining yuqori sur’ati natijasida yashil qoplamning saqlanishi va uning sifatini monitoring qilish ekologik boshqaruv uchun dolzarb masalaga aylangan.

Hududning iqlimi kontinental bo‘lib, yozda juda issiq (o‘rtacha 35–40 °C), qishda esa sovuq (−2–5 °C) haroratlar kuzatiladi. Bunday iqlim sharoiti tufayli fenologik o‘zgarishlar — barglarning bahorda ko‘klashishi, yozda maksimal biomassaga erishishi va kuzda sarg‘ayib to‘kilishi — aniq namoyon bo‘ladi. Shu sababli, yoz fasli daraxt biomassasini baholash uchun eng qulay davr hisoblanadi.

Vegetatsiya qatlami asosan mahalliy chinor, eman, tut daraxtlaridan tashkil topgan bo‘lib, ular shahar ko‘kalamzor hududlarining asosiy qismini egallaydi. Bundan tashqari, past qatlamda butalar va o‘tlar tarqalgan bo‘lib, ular daraxt qoplamining umumiy ko‘rinishini to‘ldiradi. Ushbu o‘simlik turlari spektral indekslar qiymatlariga turlicha ta’sir ko‘rsatadi: masalan, zich bargli daraxtlar EVI va NDVI qiymatlarida yuqori ko‘rsatkich beradi, siyrak butalar esa nisbatan past qiymatlar qayd etadi.

Masofadan zondlash ma’lumotlari sifatida Sentinel-2 L2A mahsulotlari ishlatildi. Ma’lumotlar Copernicus Open Access Hub platformasidan 2024-yil iyun oyida yuklab olindi. Sentinel-2 dasturi Yevropa Kosmik Agentligi (ESA) tomonidan taqdim etilgan bo‘lib, uning asosiy afzalligi yuqori fazoviy aniqlik (10–20 m), keng spektral diapazon (13 kanal) va bepul foydalanish imkoniyatidir. Tadqiqot uchun aynan S2A va S2B sun’iy yo‘ldoshlarining tasvirlari tanlandi. Tanlov mezonlari quyidagilardan iborat edi[10].:

- Bulut qamrovi < 5 % bo‘lishi, chunki bulutlar spektral indekslarni buzishi mumkin.
- Iyun oyidagi yozgi mavsum — daraxt biomassasining maksimal davri.
- Level-2A mahsulotlari — ular allaqachon atmosferaviy tuzatishdan o‘tkazilgan bo‘lib, yuzaga yaqin reflektivlik (Surface Reflectance) qiymatlarini beradi.

Tahlil uchun Sentinel-2 tasvirlarining asosiy multispektral kanallari tanlab olindi:

- B2 (490 nm, ko‘k) — barglardagi xlorofill yutilish zonasini aniqlash.
- B3 (560 nm, yashil) — o‘simliklarning yashil reflektivligi.
- B4 (665 nm, qizil) — xlorofill yutilishi va o‘simlik stressini kuzatish.
- B8 (842 nm, NIR) — barg biomassasi va o‘simlik zichligini baholashda muhim kanal.

Har bir kanal 10 m fazoviy aniqlikda raster shaklida yuklab olindi va keyinchalik vegetatsiya indekslarini hisoblash uchun asosiy manba sifatida

ishlatildi. Ushbu kanallar kombinatsiyasi daraxt qoplamini aniqroq ajratish imkonini beradi.

1-rasmda 2024-yil 29-iyun holatiga ko‘ra Yunusobod tumanining True Color Image (TCI) tasviri keltirilgan. Ushbu tasvir B4 (qizil), B3 (yashil) va B2 (ko‘k) kanallarining kombinatsiyasi asosida qurilgan bo‘lib, inson ko‘zi ko‘radigan tabiiy ranglarda daraxt qoplamini vizual kuzatishga imkon beradi. TCI tasviri keyingi bosqichlarda hisoblangan vegetatsiya indekslari (masalan, EVI) bilan taqqoslash uchun asosiy vizual manba sifatida ishlatildi.

1-rasm. Toshkent shahar Yunusobod tumani TCI tasviri (2024-yil 29 iyun holatiga)

B. Ma’lumotlarni oldindan qayta ishlash

Sentinel-2 L2A mahsulotlari dastlab Top-of-Atmosphere (TOA) reflektivlik qiymatlarida taqdim etiladi. Bu qiymatlar atmosferadagi molekulalar, aerosol, chang va bulutlarning yutilishi yoki tarqalishi sababli asl yer sathini to‘liq ifodalab bera olmaydi. Shu sababli, tahlilni boshlashdan oldin barcha tasvirlar atmosferaviy tuzatish jarayonidan o‘tkazildi va Surface Reflectance (SR) ko‘rinishiga keltirildi.

Atmosferaviy tuzatish uchun ESA Sen2Cor (v2.11) moduli qo‘llanildi. Ushbu modul quyidagi jarayonlarni amalga oshirdi:

- Aerosol tuzatishi — havodagi chang va tutun zarrachalarining spektral aks ettirishga ta’sirini kamaytirdi.
- Suv bug‘lari va gaz qatlamlari tuzatishi — infraqizil va qizil spektral diapazonlarda yutilishni hisobga oldi.
- Bulut tasnifi va maskalash — QA60 va SCL (Scene Classification Layer) yordamida bulutlar va ularning soyasi aniqlanib, tegishli piksellar maskalandi.
- Yuzaga yaqin reflektivlik (SR) qiymatlari hosil qilindi va ularning fizik birliklari % formatida ifodalandi.

Natijada B2 (ko‘k), B3 (yashil), B4 (qizil) va B8 (NIR) kanallari bo‘yicha tozalangan va atmosfera ta’siridan xoli bo‘lgan rasterlar olindi.

Keyingi bosqichda bulutlarni maskalash amalga oshirildi. Har bir Sentinel-2 tasvirining sifat bandlari (QA60) va Scene Classification Layer (SCL) tahlil qilinib, 5 % dan kam bulut qamroviga ega bo‘lgan sahifalar tanlab olindi. Bulutli va soyali piksellar noaniq spektral natijalar berishi mumkinligi sababli ular maskalab tashlandi[11].. Natijada toza vegetatsiya qoplami tasvirlari keyingi hisob-kitoblarga asos sifatida ishlatildi.

Barcha raster ma’lumotlar WGS 84 / UTM Zone 42N (EPSG:32642) tizimiga qayta proyeksiyalandi. Bu qadam Toshkent shahri hududini mos kartografik tizimda aniqlik bilan aks ettirish imkonini berdi va GIS muhitida boshqa fazoviy qatlamlar bilan integratsiyani osonlashtirdi.

Vektor shaklidagi daraxt qoplamining shapefile ma’lumotlari ham oldindan tozalanib, geometrik sifat nazoratidan o‘tkazildi:

- O‘zaro kesishish (topology check) — bir-biriga mos kelmagan yoki noto‘g‘ri kesishgan poligonlar aniqlanib, tuzatildi.
- Geometriya tekshiruvi — bo‘sh, noto‘g‘ri yoki chala poligonlar bartaraf qilindi.
- Douglas–Peucker algoritmi yordamida soddalashtirish — daraxt qoplamining poligonlari 1 m tolerans bilan soddalashtirildi, bu esa katta hajmdagi vektor ma’lumotlarini yengillashtirdi va hisoblash tezligini oshirdi. Shu bilan birga, poligonlarning tabiiy shakli saqlab qolindi.

Shuningdek, vektor va raster ma’lumotlar bir xil koordinata tizimida (EPSG:32642) moslashtirildi. Bu bosqich integratsiya jarayonida o‘lcham va joylashuv bo‘yicha xatoliklarning oldini oldi.

Umuman olganda, ushbu oldindan qayta ishlash bosqichi natijasida:

1. Atmosfera ta’siridan tozalangan spektral ma’lumotlar olindi.
2. Bulutli hududlar maskalandi.
3. Raster va vektor ma’lumotlari bir xil koordinata tizimida moslashtirildi.
4. Geometriyasi soddalashtirilgan va xatolardan tozalangan daraxt qoplamining shapefile qatlamlari yaratildi.

Bu tayyorlangan ma’lumotlar keyingi bosqichlarda vegetatsiya indekslari hisoblash, rastr-vektor integratsiyasi va statistik tahlil uchun asosiy kirish ma’lumotlari sifatida xizmat qildi.

C. Integratsiya va tahlil

Oldindan qayta ishlangan multispektral tasvirlardan o‘tkaziladigan birinchi bosqich – daraxt qoplamining holatini baholash uchun spektral indekslarni hisoblash. Ushbu tadqiqotda quyidagi indekslar qo‘llanildi:

TCI (True Color Image) – Sentinel-2 tasvirlarining haqiqiy rangli ko‘rinishi bo‘lib, inson ko‘zi ko‘radigan tabiiy ranglarda hududni tasvirlash imkonini beradi. Ushbu tasvir B4 (qizil), B3 (yashil) va B2 (ko‘k) kanallarining kombinatsiyasi asosida hosil qilindi. TCI daraxt qoplamining umumiy tarqalishini vizual baholash hamda boshqa vegetatsiya indekslari, jumladan EVI bilan natijalarni solishtirish uchun asos sifatida ishlatildi.

EVI (Enhanced Vegetation Index) – bu vegetatsiya qoplamining zichligi, barg biomassasi va o‘simlik salomatligini aniq baholash uchun ishlab chiqilgan indeksdir. EVI, NDVI dan farqli o‘laroq, tuproqning aks ettiruvchi xususiyatlari va atmosferadagi yutilish effektlarini hisobga oladi, shuningdek, yorug‘likning o‘zgarishiga nisbatan sezgirlik darajasi past. Shu sababli, EVI shahar hududlarida yoki o‘simlik zichligi yuqori bo‘lgan joylarda yanada ishonchli natijalar beradi.

$$EVI = 2.5 * \frac{NIR - Red}{NIR + 6 * Red - 7.5 * Blue + 1} \quad (1)$$

Ushbu tadqiqotda EVI (Enhanced Vegetation Index) daraxt biomassasi va barg zichligini aniqlashda asosiy indeks sifatida tanlandi. Biroq, faqat indeks xaritalariga tayanish yetarli emas, chunki ayrim hollarda indeks qiymatlari hududning haqiqiy vegetatsiya qoplamasiga to‘liq mos kelmasligi mumkin. Shu sababli, TCI tasvirlari yordamida indeks natijalari vizual ravishda tekshirildi. EVI va TCI tasvirlarini taqqoslash daraxt qoplamining haqiqiy tarqalishini tasdiqlash va noto‘g‘ri tasniflangan hududlarni aniqlash imkonini berdi [12].

2-rasmda EVI tasviridagi ranglar klassifikatori quyidagicha:

- qiymati -1.0 dan 0 gacha – #d7191c kodli rangda
- qiymati 0 dan 0.1 gacha – #f07c4a kodli rangda
- qiymati 0.1 dan 0.2 gacha – #fec981 kodli rangda
- qiymati 0.2 dan 0.4 gacha – #ffffc0 kodli rangda
- qiymati 0.4 dan 0.6 gacha – #c4e687 kodli rangda
- qiymati 0.6 dan 1.0 gacha – #77c35c kodli rangda

Har bir olingan tasvir bo‘yicha indekslar hisoblanib, o‘zaro taqqoslandi. Keyingi bosqichda indeks xaritalari asosida daraxt qoplamining tarqalishi va zichligini aniqlash uchun piksellar bo‘yicha tahliliy filtrlar va o‘lchovli chegaralar (masalan, EVI > 0.6 = qalin daraxt qoplami) qo‘llandi. Bu yerda har bir indeks orqali olingan xaritalar overlay operatsiyasi yordamida land-use vektor qatlamlari bilan kesishtirilib, faqat o‘rmon va bog‘ hududlari doirasida tahlil davom ettirildi [13, 14].

Shuningdek, mavsumiy o‘zgarishlarni o‘rganish maqsadida indekslar bo‘yicha vaqt seriyalari tahlili o‘tkazildi. Har bir indeksning vaqt bo‘yicha dinamikasi grafigi tuzilib, vegetatsiya fazalaridagi o‘sish, stabilizatsiya va stress davrlari aniqlandi. Ushbu yondashuv daraxt qoplamining biologik faolligi va ekotizimning holatini chuqurroq tushunishga yordam beradi [15].

2-rasm. Hudud uchun EVI va TCI tasvirlar solishtiruvi.

2-rasmda ko‘rsatilganidek, EVI xaritalarida yuqori qiymatlar daraxt biomassasining katta zichligini bildiradi. Ushbu hududlar TCI tasvirida ham to‘liq yashil qoplam sifatida ajralib turadi, bu EVI indeksining ishonchliligini tasdiqlaydi. Shu bilan birga, EVI qiymati past bo‘lgan hududlar TCI tasvirida ochiq tuproq yoki kam o‘simlikli joylar sifatida ko‘rinib, indeks natijalari bilan yuqori darajada moslikka ega bo‘ldi. Biroq, ayrim zich, ammo kichik daraxt qoplamlari bo‘lgan hududlarda EVI qiymatlari past chiqqan, TCI tasvirlari esa daraxtlarni aniq ko‘rsatgan. Bu kelajakda indeks chegaralarini moslashtirish zarurligini ko‘rsatadi [16].

XCV. MUHOKAMA

Olingan natijalar shuni ko‘rsatadiki, EVI indeksi daraxt biomassasi va barg zichligini aniqlashda yuqori ishonchlilikka ega bo‘lsa-da, ayrim kichik yoki siyrak daraxt qoplamlarini aniqlashda cheklovlarga duch keladi. Shu sababli, TCI tasvirlari bilan integratsiya qilish natijalarni tekshirish va tasdiqlashda muhim vosita bo‘lib xizmat qildi. Bu yondashuv nafaqat umumiy yashil hududlarni baholash, balki daraxtlarning salomatlik darajasini ham aniqlash imkonini berdi. Biroq, indeks qiymatlarining ba’zi hollarda vegetatsiya qoplamining haqiqiy ko‘rinishiga to‘liq mos kelmaganligi kelgusida moslashtirilgan chegaralar va qo‘shimcha ma’lumot manbalarini jalb etish zaruratini ko‘rsatadi.

Shuningdek, tadqiqot shuni ko‘rsatdiki, geofazoviy vektor ma’lumotlarini masofadan zondlash indekslari bilan birlashtirish shahar landshaftlarini aniqroq tahlil qilish imkonini beradi. Bu metodologiya urbanizatsiya jarayoni tez kechayotgan hududlarda yashil hududlarning monitoringini samarali tashkil etish va ekologik xavflarni erta aniqlash uchun qo‘llanilishi mumkin. Kelgusida ushbu yondashuvni boshqa fasllarda ham sinovdan o‘tkazish va yuqori fazoviy aniqlikka ega bo‘lgan qo‘shimcha sun’iy yo‘ldosh ma’lumotlari bilan boyitish shahar ekologik boshqaruvi uchun yanada to‘liqroq va barqaror natijalar taqdim etadi.

XCVI. XULOSA

Ushbu tadqiqot shahar daraxt qoplamini aniqlashda EVI va TCI tasvirlarini, shuningdek, alohida qoplam vektor

ma’lumotlari bilan multispektrli sun’iy yo‘ldosh indekslarini integratsiya qilish orqali yuqori aniqlikka erishish mumkinligini ko‘rsatdi. EVI orqali olingan daraxt biomassasi zichligi TCI tasvirlari yordamida vizual tasdiqlandi, bu esa natijalarning ishonchliligini oshirdi. Ushbu yondashuv aniq qoplam chegaralari va spektral o‘simlik indekslarini birlashtirish orqali raster-yagona usullarga nisbatan ustun natijalar berdi. Yunusobod tumani misolida olingan natijalar shahar o‘rmonlarini monitoring qilish, daraxt salomatligini baholash hamda yashil hududlarni samarali boshqarishda amaliy yordam beradi. Shuningdek, EVI va TCI tasvirlarini birgalikda qo‘llash kelajakdagi tadqiqotlarda daraxt qoplamining biologik faolligini aniqlash va shahar ekologik boshqaruv strategiyalarini takomillashtirish uchun samarali yechim sifatida tavsiya etiladi.

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KICHIK KOSMIK KEMA BAZASIDAGI SUN'IY YO'LDOSH RADIOMONITORING TIZIMI ORQALI RADIONURLANISH MANBALARINING JOYLASHGAN JOYINI ANIQLASH

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Annotatsiya. Bugungi kunda mavjud yer usti radiomonitoring vositalari yordamida radiomonitoring vazifalarini sifatli bajarish murakkabligicha qolmoqda. Katta hududga ega davlatlar radiochastota spektrini kuzatish tizimining samaradorligini oshirish uchun radiomonitoring stansiyalari sifatida past orbitali kichik kosmik apparatlardan foydalanish maqsadga muvofiq hisoblanmoqda. Mazkur maqolada burchak o'lchash uslubi orqali radionurlanish manbalarining koylashgan joyini aniqlash yoritiladi

Kalit so'zlar: radionurlanish manbasi, radiomonitoring, koordinatalarni aniqlash, past orbitali sun'iy yo'ldosh, kichik kosmik kema, radiochastota spektri.

I. KIRISH

Hozirgi vaqtda radiomonitoring tizimlarining samaradorligini oshirish vazifasi o'z dolzarbligini yo'qotmasdan kelmoqda. Radiomonitoring tizimlarining asosiy maqsadi radiochastota spektridan foydalanishni davriy yoki doimiy monitoring qilish bo'lib qolmoqda. Yer tizimlarida bir qator kamchiliklari mavjud, masalan, radiomonitoring zonasining cheklanganligi, radionazorat punktlarining soni yetrali emasligi, qiyin iqlim sharoitida va murakkab relyefli hududlarda radio monitoringi tadbirlarini olib borishni qiyinligi. Shuni ham ta'kidlash kerakki, radiomonitoring jarayonlari yetarlicha avtomatlashtirilmagan, jumladan, avtomatlashgan radiomonitoring jarayonlarining yetarli darajada emasligidir.

Murakkab relyefli hududlarda (tog' va tog' tizmali, suv va boshqalar) yer usti radiomonitoring vositalari yordamida radiomonitoringни amalga oshirish ushbu jarayonlarni murakkablashtiradi. Shu munosabat bilan, katta hududlarga ega bo'lgan mamlakatlar uchun sun'iy yo'ldosh tizimlariga asoslangan radio monitoring tizimlari eng istiqbolli hisoblanadi. Bunday tizimlar bir qator afzalliklarga ega: yuqori samaradorlik, tezkorlik, global ko'rinish va hududni to'liq qamrab olish.

Radio nurlanish manbalarining joylashishini aniqlash uchun ma'lum metodlar bo'lib, qabul qilingan signal darajasiga (received signal strength (RSS)), signal tashuvchi faza (POA - carrier phase of arrival), kelish vaqti tafovuti (FDOA - time difference of arrival), kelish burchagi (AOA – angle of arrival или направлении прихода DOA – direction of arrival), kelish chastota tafovuti (FDOA – frequency difference of arrival), dopler chastota tafovuti (doppler difference – DD) va aralash uslublar bo'lib, ikki yoki uchta yuqoridagi uslublardan tarkib topadi. Bugungi kunda sun'iy yo'ldosh tizimlarida eng ko'p qo'llaniladigan usullar TDOA va FDOA hisoblanadi. Biroq, bunday usullar bir nechta sun'iy yo'ldoshlarni talab qilib, bu iqtisodiy nuqtai nazardan samarasizdir. Shuning uchun bitta past orbitali sun'iy yo'ldosh bazasida radiomonitoring funksiyalarini amalga oshirish dolzarb muammo hisoblanadi.

Kichik kosmik kemadan foydalangan holda radio monitoring tizimini yaratishda turli xil yerdagi radionurlanish manbalaridan kosmik apparatning bortdagi qabul qilgichining kirishida signal darajalari to'g'risida ma'lumotlar bo'lishi kerak. Maqolada radioaloqa byudjeti tahlil qilinadi, bu radiochastota spektridan foydalanishni radio monitoringi uchun past orbitali kichik kosmik apparatdan foydalanish imkoniyatini ko'rsatadi.

Radionurlanish manbalarining joylashган joyini aniqlash vazifasini hal qilishda koordinatalarni aniqlash usulini tanlash kerak. Mazkur maqolada past orbitali sun'iy yo'ldosh turkumidan foydalangan holda radionurlanish manbalarining koordinatalarini aniqlash usullarini ko'rib chiqadi va taklif qilinadi. Biroq, radio monitoring tizimini yaratishning birinchi bosqichida bitta kichik kosmik apparatdan foydalanishni ko'rib chiqish tavsiya etiladi, bu esa radiomonitoring tizimini soddalashtiradi va arzonlashtiradi.

II. TADQIQOT USULLARI

Bitta kichik kosmik apparat bazasidan radionurlanish manbalarining koordinatalarini (kenglik va uzunlik) aniqlash uchun kosmik apparat aylana qutbli orbitada (orbital og'ishi i = 90°) joylashgan bo'lishi kerak. Uning metodi 1-rasmda ko'rsatilgan.

1-rasmda quyidagi belgilar qo'llanilgan: O - Yerning og'irlik markazi; D – radionurlanish manbasining joylashuvi; B – kichik kosmik apparat joylashuvi.

Radionurlanish manbasi joylashuvining

kengligini aniqlashda ellipsda qurilgan AOB uchburchak parametrlarini tahlil qilish asosida aniqlandi (ZOY tekisligining sferoid kesmasi). A nuqtasi radionurlanish manbasi joylashgan жойдан parallel bilan kesishish nuqtasida (ya'ni, bir xil kenglikda) kosmik kemaning yo'lidagi sirtda joylashgan; tomoni Re=OA (Yerning radiusi), φ kengligiga ko'ra; OB=RO tomoni (kichik kosmik apparat orbitasining radiusi); φ – radionurlanish manbasining kengligi (OA yo'nalishi va ekvator tekisligi orasidagi burchak); α – kichik kosmik apparat kengligi (OB yo'nalishi va ekvator tekisligi orasidagi burchak).

AOB uchburchakdagi burchaklar : (φ – α) – γ kengliklar farqi, y AB tomoniga qarama-qarshi; β – burchak, bu nuqtada kichik kosmik apparatdan OB yo'nalishiga nisbatan A ko'rinadi, u OA tomonlariga qarama-qarshidir; k – uchburchakdagi 3-burchak, OB tomoniga qarama-qarshi. Uchburchakning 3 ta ma'lum parametrlari bilan uning boshqa parametrlarini topish oson. Bunday holda, OB tomoni va β burchagi ma'lum (skanerlash paytida aniqlanadi), boshqa parametrlar φ ga bog'liq. Shuning uchun iteratsiya usulini qo'llash kerak bo'ladi. Yer yuzasi sharsimon bo'lmaganligi va sirtini matematik ifodalash qiyin bo'lgan geoid shakliga ega bo'lganligi sababli, bir qator amaliy masalalarni yechishda, geoid yuzasi o'rniga sferoid yuzasi (ellipsoid ko'rinishli) olinadi – geoidning shakliga o'xshash.

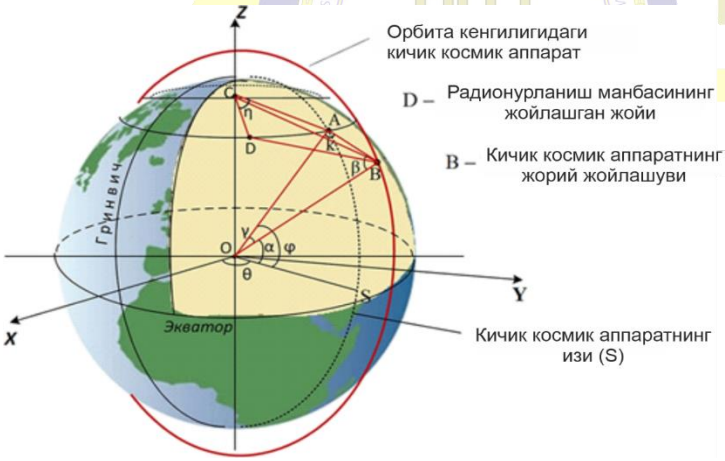
O'zbekiston Respublikasi hududining radiomonitoring sohasi shimoliy kenglikning =37° dan φ=45° gacha diapazonda joylashgan (radiomonitoring sohasining o'rtacha qiymati φ=41°). Aynan o'rta kenglikda biz kichik kosmik apparatning orbital balandligini tanlaymiz h (bizning holatimizda h=650 km). Aylana orbitasining radiusini aniqlash uchun RO Ellipsoidning radiusini (Yerning og'irlik markazidan sirtgacha bo'lgan chiziqli masofa) hisoblash talab qilinadi. Xolbuki bu kenglikka bog'liq. Re (φ =41°) uchun 6378137 m bo'ladi.

III. ILMIY NATIJALAR

Ushbu tizimni amalga oshirish uchun kichik kosmik apparatda 2 ta panjarali faol fazali antenna bo'lishi lozim. Radionurlanish manbasini aniqlash uchun pamjarali faol fazali antenna yer yuzasining ma'lum bir qismini skanerlash burchagiga ega bo'lishi kerak.

1.1. Radionurlanish manbasining joylashuv kengligini aniqlash uchun algoritm

1-rasmdan ko'rinib turibdiki, agar OB tomoni va β burchak ma'lum bo'lsa (skanerlash paytida aniqlanadi), qolgan parametrlar aniqlanishi kerak bo'lgan φ ga bog'liq bo'ladi.



1-rasm. Bitta kichik kosmik apparat bazasida radionurlanish manbasining koordinatalarini aniqlash

Uchburchakning faqat ikkita parametri ma'lum bo'lganligi sababli, iteratsiya usulini qo'llash kerak bo'ladi. Shuningdek, kichik kosmik apparat orbitasidan radionurlanish manbasi joylashuvining qaysi kenglik diapazoni "ko'rinib turadi" degan savolga javob olish kerak. Buning uchun tenglamalar tizimini yechish kerak:

- ellipsning kanonik tenglamasi:

$$\frac{Y^2}{a^2}+\frac{Z^2}{b^2}=1$$

Bu erda Y va Z - ellipsning koordinatalari, a - katta yarim o'q,

b - kichik yarim o'q.

- kichik kosmik apparat joylashgan nuqtadan ellipsga teginish tenglamasi:

$$\frac{Y_k Y_b}{a^2}+\frac{Z_k Z_b}{b^2}=1.$$

Ekvatorda kichik kosmik apparatning koordinatalarini tanlash qulay (Yb=7016299 m; Zb = 0 m). Birinchidan, Zb= 0 m da biz Zk= a2/b2 keyin Zk o'tamiz:

$$Z_k=\sqrt{\left(1-\frac{a^2}{Y_b^2}\right)*b^2}$$

Kesishish nuqtasi koordinatalari Zk=2648836 m; Yk=5798016,7 m.

Kesishish nuqtasining kengligi

$$\varphi_k=\operatorname{arctg}\left(\frac{Z_k}{Y_k}\right)=24{,}55°$$

Shunday qilib, kichik kosmik apparat bilan ekvatorda radionurlanish manbalari 0° dan 24,55°

gacha kenglik diapazonida, ya'ni O'zbekiston Respublikasi hududidan tashqarida ko'rinadi. Kichik kosmik apparatni α=40° kenglikka o'tganda raionurlanish manbasi joylashgan joylarning ko'rinadigan kengliklarining taxminan bir xil diapazoni saqlanib qoladi (40° dan 61,55° gacha).

β ni noaniq baholash hisobiga φ ni aniqlashning xatoligini kamaytirish φ(β) ning qaysi uchastkasiga bog'liqligi muhimdir.

Buning natijasini, masalani teskari yechish orqali olish mumkin (ma'lum φ dan foydalanib, biz β ni aniqlaymiz). Quyidagi hisoblash formulasi yordamida natijalarni olishimiz mumkin (hisoblash natijalari 1-jadvalda keltirilgan:

1-jadval – α=40° β ning φ radionurlanish manbasi joylashuvi kengligiga bog'liqlik ko'rsatkichi

$\beta(\varphi) = \arcsin\left[R(\varphi) * \frac{\sin(\gamma)}{AB(\gamma)}\right]$ φ, °	γ, °	$R_э(\varphi)$, m	AB(γ), m	β (γ), °
40	0	6369274	647024,9	0
41	1	6368905	657822,6	9,72798
42	2	6368535	688504,6	18,8332
43	3	6368163	736578,7	26,9026
44	4	6367790	798894,6	33,7804

1-jadvalda ma'lum bo'ladiki, β(φ) bog'liqlikning boshlang'ich qismiga e'tibor berish kerakligi ko'rsatilgan. GPS/GLONASS yordamida manbaning joylashishni yuqori aniqlashga erishish mumkin.

Radionurlanish manbasining kengligini aniqlashda mumkin bo'lgan xatolarni ko'rib chiqamiz. Antenna nurining yo'nalishini Yerning og'irlik markaziga (O nuqtasi) noto'g'ri o'rnatish tufayli Δφo xatoligini (boshqa apparat xatolari ham shu yerga kiritilishi mumkin) quyidagi formula bilan aniqlanishi mumkin:

$$\Delta\varphi_o = \left(\frac{\Delta\varphi}{\Delta\beta}\right) * \Delta\beta_o$$

2-jadvalda boshlang'ich α = 40° bo'lganda ΔφoΔβo o'rtacha bog'liqlik qiymati keltirilgan; Δφ/Δβ = 0,1028° (1-jadvaldagi ma'lumotlar).

2-jadval – Δφo/Δβo bog'liqligi

$\Delta\varphi_{o,}$°	0,1028	0,09252	0,08224	0,07196	0,06168	0,0514	0,04112	0,03084	0,02056	0,01028
$\Delta\beta_{o,}$ °	1	0,9	0,8	0,7	0,6	0,5	0.4	0.3	0.2	0,1

Xatolikni quyidagi formula yordamida chiziqli o'lchamlarga aylantirish mumkin:

$$\Delta l_0 = \sqrt{\left[R_э^2(40,5) + R_э^2(40,5+\Delta\varphi_0) - \right.} \\ \left. -2 \cdot R_э(40,5+\varphi_0) \cdot \cos\Delta\varphi_0\right]$$

Xulosa qilib aytganda, oxirgi misoldan foydalanib, biz relefning dengiz sathidan balandligi (hm=1000 m bo'lsin)da radionurlanish manbasining joylashuvining kengligini aniqlashdagi xatoga ta'sirini baholaymiz.

Bunda Rэ (41,6°) + 1000 = 6369683 m, yangi qiymat AB=653318,427 m, yangi qiymat β = 7,8238°, o'zgarish Δβ = 0,013° va xatolik Δφ=0,1024*0,013 = 0,001°. Chiziqli o'lchamlarda bu taxminan 111 metrni tashkil etadi.

1.2. Radionurlanish manbasi joylashuvining uzunligini aniqlash uchun taklif qilingan algoritm

Radionurlanish manbasining kengligini φ aniqlagandan so'ng (1.1-kichik bo'limda keltirilgan usuldan foydalanib), uzunlikni aniqlashga o'tamiz. 1-rasmda ko'rsatilgan ABD , ACD , BCD uchburchaklar parametrlarini tahlil qilish asosida radionurlanishmanbasining uzunligini aniqlashning o'ziga xosligini ko'rib chiqamiz. Signal paydo bo'lganda radionurlanish manbasining yo'nalishi μ burchak (μ - kichik kosmik apparatdan (B nuqta) dan radionurlanish manbasiga (D nuqta) va A nuqtaga yo'nalishlar orasidagi burchak) yordamida aniqlanadi, shuningdek uzunlikni tuzatish η belgisi kichik kosmik apparat (Θ) uzunligiga nisbatan g'arbiy yo'nalishda - (+ (musbat)) va sharqiy yo'nalishda– (- (manfiy)) bo'ladi. 1-rasmda radionurlanish manbasining faqat g'arbiy joylashuvi (D nuqtasi) ko'rsatilgan, xuddi shunday, D nuqta sharqiy yo'nalishda bir xil μ burchak ostida bo'lishi mumkin.

A nuqtasi - yuqorida muhokama qilingan parallelning Yer yuzasida kichik kosmik apparat orbitasining izi bilan kesishish nuqtasidir. C nuqtasi OZ o'qida radionurlanish manbasi joylashgan parallel bo'ylab tekislik bilan kesishgan nuqtada (ya'ni bir xil kenglikda) joylashgan . Bu qism A va D nuqtalari yotadigan aylana bo'lib, C nuqta esa bu doiraning markazidir. Doira radiusi R=AC =DC=Rэ(φ)*cosφ.

BC tomoni – kichik kosmik apparat va C nuqta orasidagi masofa, BD tomoni – kichik kosmik apparat va radionurlanish manbasi orasidagi masofa, BA tomoni – kichik kosmik apparat va A nuqta orasidagi masofa, AD tomoni (doira akkordi), η tuzatmani aniqlash uchun bilish lozim bo'lgan qiymat. Barcha masofalarni aniqlash uchun A , B , C va D nuqtalarining koordinatalari talab qilinadi.

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$$AD = \sqrt{(X_d - X_a)^2 + (Y_d - Y_a)^2}$$

AD va R bo'yicha uzunlik (η) uchun tuzatishni aniqlaymiz:

$$\eta = 2 \cdot \arcsin\left(\frac{AD}{2R}\right)$$

Radionurlanish manbasining (v) uzunligini aniqlaymiz:

Radionurlanish manbasining uzunligi v = Θ-η (agar radionurlanish manbasi kichik kosmik apparatning g‘arbiy qismida bo‘lsa);

Radionurlanish manbasining uzunligi v =Θ+η (agar agar radionurlanish manbasi kichik kosmik apparatning sharqiy qismida bo‘lsa)

Radionurlanish manbasining kengligini aniqlash algoritmi 2-rasmda ko‘rsatilgan.

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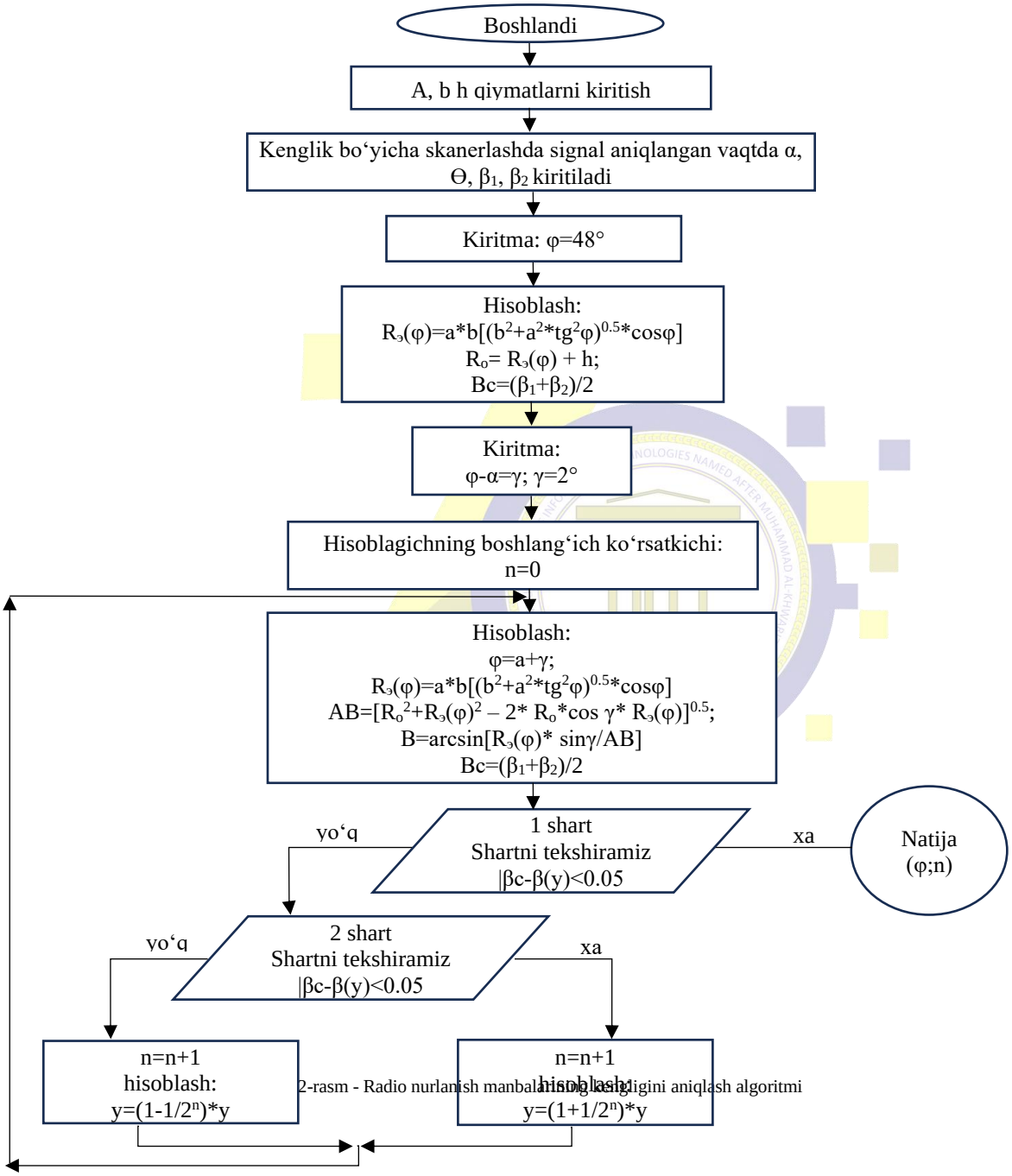

2-rasm - Radio nurlanish manbalarining kengligini aniqlash algoritmi

Xatolikni quyidagi formula yordamida chiziqli o‘lchamlarga aylantirish mumkin:

$$\Delta l_0 = \sqrt{\left[\begin{matrix} R_э^2(40,5) + R_э^2(40,5+\Delta\varphi_0) - \\ -2 \cdot R_э(40,5+\varphi_0) \cdot \cos\Delta\varphi_0 \end{matrix}\right]}$$

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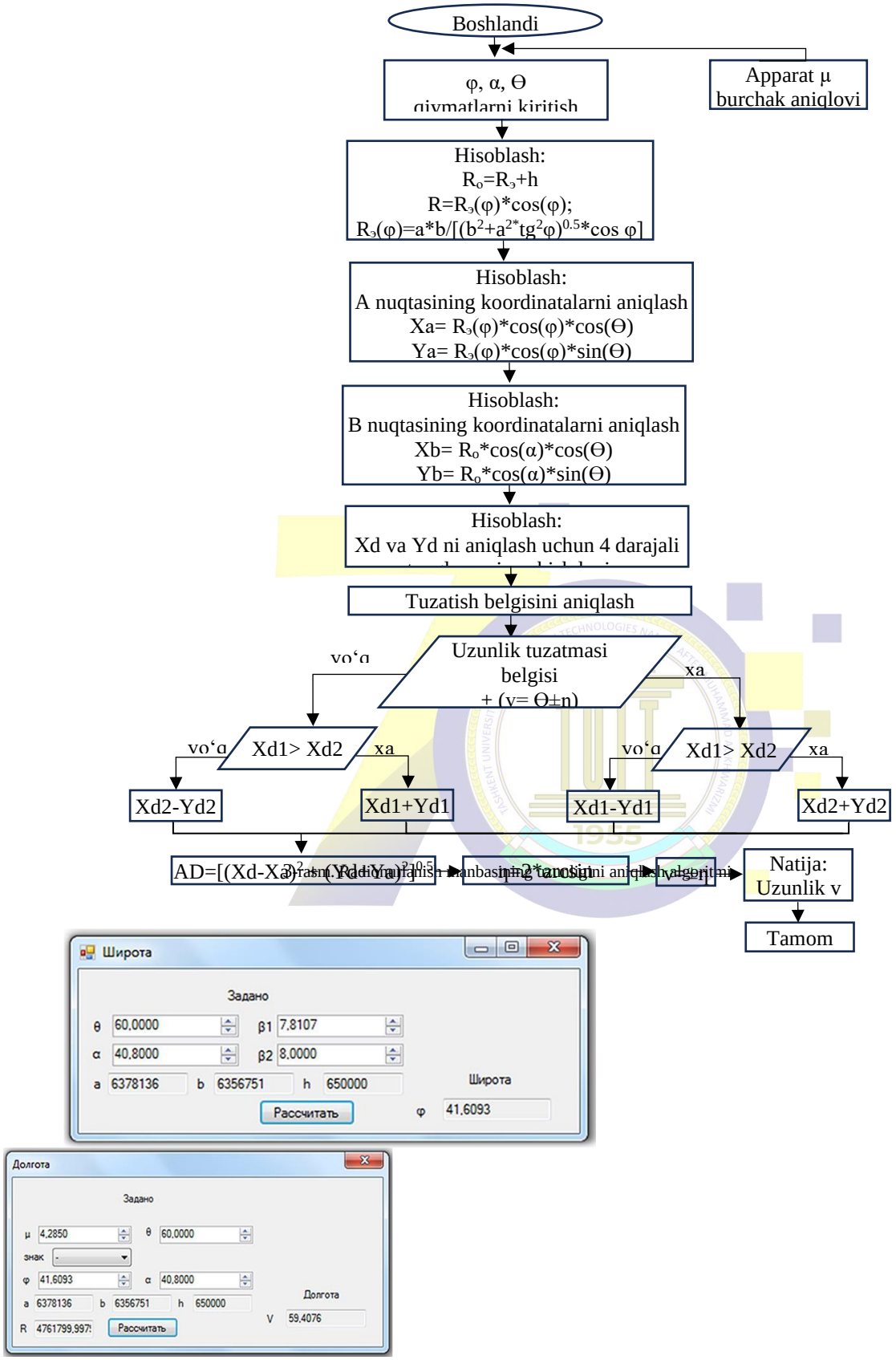
Radionurlanish manbasining uzunligi v =Θ+η (agar agar radionurlanish manbasi kichik kosmik apparatning sharqiy qismida bo‘lsa). Ishlab chiqilgan algoritmning blok diagrammasi 3-rasmda ko‘rsatilgan. Dasturiy ta’minotni amalga oshirish ilovasi C# tilida ishlab chiqilgan 3-rasmda ko‘rsatilgan.

Radionurlanish manbasining kenglik va uzunligini aniqlash uchun ishlab chiqilgan algoritmlar va dasturlar bitta kichik o‘lchamli kosmik kemaga asoslangan sun’iy yo‘ldosh radio monitoring tizimlarida foydalanish uchun taklif etiladi.

XULOSA

Bitta kichik kosmik apparat yordamida goniometrik usul asosida yerdagi radionurlanish manbalari koordinatalarini aniqlash usuli, algoritmlari va kompyuter dasturi ishlab chiqilgan. Taklif etilgan algoritmlardan foydalangan holda radionurlanish manbalari koordinatalarini aniqlashda mumkin bo‘lgan xatolar ko‘rib chiqildi. Ushbu usuldan sun’iy yo‘ldosh radio monitoring tizimini yaratishning dastlabki bosqichlarida foydalanish tavsiya etiladi. Keyingi tadqiqotlar panjarali faol fazali antenna kabi samarali antenna tizimlarini va radio monitoring sifatini yaxshilash uchun radionurlanish manbasi radio signallarini aniqlash va tanib olish ishonchliligini oshirish usullarini ishlab chiqishga qaratilgan bo‘lishi kerak.



4-rasm. Radionurlanish manbasining kenglik va uzunligini aniqlash dasturining ishchi oynasi.

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SATELLITE COMMUNICATION SYSTEMS: GEO, MEO AND LEO ORBIT TYPES AND THE APPLICATION OF ARTIFICIAL INTELLIGENCE

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Abstract-This article analyzes the main technical parameters of geostationary (GEO), medium-earth orbit (MEO) and low-earth orbit (LEO) satellite communication systems, their advantages and disadvantages. The systems are compared in terms of altitude, signal delay, coverage area, frequency range, power consumption and space debris risk. Although LEO systems are characterized by low latency (20–50 ms) and high speed (100–300 Mbps), they have problems such as thousands of satellites and increased space debris risk. GEO systems have a long service life (12–15 years) and wide coverage, but high latency (240–300 ms) makes them inconvenient for real-time use. Also, complex tasks such as network resource allocation, signal quality prediction, energy management and space debris tracking are being automated using artificial intelligence (AI). The results of the study show that LEO systems have the potential to lead the global Internet, but international cooperation is needed to solve security, environmental and economic problems.

Keywords — satellite, GEO, LEO, MEO, artificial intelligence, space debris.

I. INTRODUCTION

Having become an integral part of the modern communication infrastructure, satellites provide services such as television, telephone communication, navigation, and the Internet [12]. Their development began after the launch of Sputnik-1 in 1957 [16].

Communication satellites are distinguished by three main types of orbits — GEO, MEO, and LEO — [12]. Each has its own technical characteristics. GEO systems have a wide coverage area, but have high latency. LEO systems have low latency, high speed, but require thousands of satellites [5].

Artificial intelligence (AI) is widely used in modern satellite networks to perform complex tasks such as network management, signal quality prediction, security, orbit optimization, and energy consumption reduction [6, 1]

II. . PROBLEM STATEMENT

The main disadvantage of GEO systems is the large signal delay (240–300 ms), which is inconvenient for applications such as VoIP and online gaming [12]. Frequency resources are limited, since there are only a limited number of “parking” points in orbit [8, 9].

MEO systems are specialized for navigation, but are not efficient for communication [16, 13].

The main problem of LEO systems is that each satellite covers the Earth for only 5–15 minutes, so thousands of satellites are needed to cover the entire globe [12, 5]. This complicates network management.

Another serious problem is space debris. There are more than 30,000 tracked objects in LEO orbit. Each new satellite increases the risk of collision [7, 14].

III. SOLUTION METHODS:

A. A. GEOSTATIC ORBIT (GEO) SATELLITES

Geostatic orbit (GEO) satellites are satellites that are located in the Earth's equatorial plane, approximately 35,786 km above the center of the Earth, and have an orbital period (23 hours 56 minutes

4 seconds) that matches the Earth's rotation period. This means that they always remain in the same place relative to the same point on the Earth's surface, that is, they remain "invisible" at some point in the sky. Due to this feature, GEO satellites are ideal for providing a continuous communication network [12].

Satellites in this orbit are mainly used in areas such as television broadcasting, telephone communication, meteorological data transmission, and national security. For example, international networks such as Intelsat, Eutelsat, and AsiaSat use the GEO orbit. A single GEO satellite can cover about one-third of the Earth's surface, so only three satellites are needed to cover the entire globe [16].

However, one of the main disadvantages of GEO systems is the large signal delay. The radio signal travels from the Earth station to the satellite (35,786 km) and then back again. The total distance is about 71,572 km, and although the signal speed is close to the speed of light (300,000 km/s), this introduces a delay of 240–300 milliseconds (ms). This is inconvenient for applications such as VoIP, online gaming, or real-time data exchange [12].

Another problem is the limited frequency resources. The GEO orbit has a limited number of "parking" points, as nearby satellites must be spaced at least 2° apart to avoid radio interference. The International Telecommunication Union (ITU) is responsible for allocating these frequencies [8, 7].

Another advantage of GEO satellites is their high reliability and long service life. Modern GEO satellites typically have a service life of 15 years, as they are large, have powerful power sources (large solar panels), and are equipped with rocket engines to maintain their orbit [5].

Table I. Main technical parameters of the GEO system

Parameters	Indicators
Altitude	35 786 km
Signal Delay	240–300 ms
Number of Satellites	3
Frequency Range	C-band (4–8 GHz), Ku-band (12–18 GHz), Ka-band (18–40 GHz)
Service Life	12–15 years
Coverage	One-third of the Earth (for one satellit

B. B. MEDIUM EARTH ORBIT (MEO) SATELLITES

Medium Earth Orbit (MEO) satellites orbit at an altitude of 8,000 km to 20,000 km above the Earth's surface. This orbit occupies the intermediate region between geostationary orbit (GEO) and low earth orbit (LEO), providing favorable conditions for navigation, data transmission, and some communication systems [7, 16].

Medium Earth Orbit satellites are mainly used for global navigation satellite systems (GNSS). Such systems include:

GPS (Global Positioning System, USA) — 24 active satellites, 20,200 km altitude

GLONASS (Russia) — 24 satellites, 19,100 km altitude

Galileo (European Union) — 30 satellites, 23,222 km altitude

BeiDou (China) — partly in MEO, partly in GEO orbit

The principle of operation of these systems is similar: each satellite continuously transmits its orbit, time information, and other system information to the Earth. A receiving device (such as a smartphone or navigation console) receives signals from at least four satellites and calculates the signal propagation time between them to determine its location [16].

In MEO systems, the signal delay is about 100–150 ms, which is much better than in GEO systems, but higher than in LEO systems. Due to the wide-spread network, positioning accuracy reaches 1–3 meters. At any given time, 6–12 satellites are visible from any point on Earth. The atmosphere has less effect on the signals than in LEO [12].

Table II. Main technical parameters of the MEO system

Parameters	Indicators
Altitude	8 000 – 20 000 km
Signal Delay	100–150 ms
Number of Satellites	24–30 ta
Frequency Range	L1 (1.57542 GHz), L2 (1.2276 GHz), L5 (1.17645 GHz)
Service Life	10–15 years
Coverage	The whole globe

The frequencies L1, L2, and L5 are used for different purposes: L1 is the main civil signal (C/A), L2 is mainly for the military P(Y) signal, and L5 is used in areas where high accuracy and security are required (aviation) [16].

C. C. LOW EARTH ORBIT (LEO) SATELLITES

Low Earth Orbit (LEO) satellites orbit at an altitude of 300 km to 2,000 km above the Earth's surface. This type of orbit is widely used to provide modern broadband communication networks, in particular, to provide global Internet coverage [12, 5].

The main advantage of LEO satellites is their very low signal latency. The signal travels 1,500–4,000 km in the Earth–satellite–Earth direction, resulting in a latency of 20–50 milliseconds (ms). This value is favorable for applications that require real-time data exchange, such as GPS systems, VoIP communications, online gaming, and video conferencing [12, 5].

However, the main disadvantage of LEO systems is that each satellite covers the Earth's surface for only 5–15 minutes. Because they travel fast (at a speed of 7.8 km/s) and have a small coverage area, a network of thousands of satellites is required to provide uninterrupted internet service across the globe [12, 5].

Modern LEO communication networks include: Starlink (SpaceX), OneWeb, and Amazon Kuiper. These networks allow high-speed internet to be provided in rural areas, maritime transport, aviation, and in emergency situations [5, 6].

Table III. Main technical parameters of the LEO system

Parameters	Indicators
Altitude	300–2 000 km
Signal Delay	20–50 ms
Number of Satellites	100–300 Mbps (in some cases 1 Gbps)
Frequency Range	1000–10 000
Service Life	Ku (12–18 GHz), Ka (26–40 GHz)
Coverage	5–7 yil
Altitude	Narrow (each satellite is a circle with a diameter of 1000 km)

LEO satellites are typically equipped with phased array antennas. These antennas electronically maintain a constant connection to the user device even when the satellite is moving [12, 5].

The following risks and problems currently exist in LEO systems:

Space debris: There are already over 30,000 tracked objects in LEO orbit. Each new satellite adds to the risk of interference. Obstacle detection is performed by NASA and ESA tracking systems [7].

Radio interference: Since many satellites operate on the same frequencies, there is a possibility of radio interference. The International Telecommunication Union (ITU) is responsible for frequency allocation [8].

Weather effects: Ka-band signals have been observed to be reduced by 30–50% due to rain, snow, or clouds. This problem affects the quality of service in rainy regions [12, 5].

D. D. COMPARISON OF ORBIT TYPES

When evaluating satellite communication systems, it is important to compare their main technical, operational and economic parameters. GEO, MEO and LEO orbit types are designed for different tasks and have different advantages and disadvantages. The following table analyzes these systems in all aspects:

Table IV. Main technical parameters of different types of orbits

Parameters	GEO	MEO	LEO
Altitude (km)	35 786	8,000–20,000	300–2 000
Signal latency (ms)	240–300	100–150	20–50
Coverage area	Very wide (1/3 globe)	Medium	Tor (1000 km diameter)
Number of satellites	3–4	24–30	1000–10 000
Internet speed	10–50 Mbps	50–100 Mbps	100–300 Mbps (up to 1 Gbps)
Energy consumption (transmission)	High	Medium	Low
Service life	15 years	10–15 years	5–7 years
Frequency range	C, Ku	L, S	Ku, Ka
Space debris risk	Low	Medium	High
Ease of integration	Easy	Medium	Complex

The data in the table above is based on various sources. Due to their wide coverage and stability, GEO systems are still widely used in areas such as television, meteorology, and government communications [12]. However, their high latency makes them unsuitable for real-time data transmission (VoIP, online gaming) [12, 5].

MEO systems are the leading players in the navigation sector. Systems such as the GPS system provide an accuracy of less than 10 meters, which is suitable for automobiles, ships, and air transport [16, 13]. However, MEO systems have limited use for communications because their coverage and network architecture are focused on navigation.

LEO systems are the main enablers of modern broadband Internet services. The Starlink network, developed by SpaceX, is expected to have more than 7,000 satellites by 2025, providing Internet access to the entire world at speeds of 100+ Mbps [5, 6]. The main disadvantage of LEO systems is that they require thousands of satellites to provide wide coverage, which complicates network management [5, 6].

Another important aspect is the comparison in terms of disadvantages:

GEO: High latency, limited bandwidth, insensitive to space debris, but expensive to launch new satellites [1].

MEO: Narrow coverage, specialized for navigation, not efficient for communications [13].

LEO: Low latency, high speed, but high risk of space debris, signal degradation due to weather (especially in the Ka band) [5, 7].

According to the International Telecommunication Union (ITU), there are expected to be over 10,000 active satellites in LEO orbit by 2025, posing new risks to GEO and MEO systems [8, 9].

E. E. APPLICATION OF ARTIFICIAL INTELLIGENCE IN MODERN SATELLITE NETWORKS

Modern satellite communication systems, especially low-Earth orbit (LEO) networks (e.g. Starlink, OneWeb), are characterized by their complexity. Thousands of satellites are constantly moving, communication channels change rapidly, atmospheric conditions affect signals, and space debris poses a threat. All of these problems are difficult to manage with traditional methods, so the possibility of automating key tasks using artificial intelligence (AI) is a rapidly developing area [2, 18].

F. a) Artificial intelligence in network management

In LEO networks, satellites move quickly (7.8 km/s) and each one covers a certain area for only 5–15 minutes. Therefore, tasks such as dynamically managing transmission channels, determining which satellite serves which user, and adjusting the transmission rate must be solved in real time.

Artificial intelligence, especially reinforcement learning (RL) algorithms, allow for effective management of this process. The RL model learns information such as the orbit, speed, signal quality, and user requests of each satellite and optimally allocates each communication channel [3].

The significant 30% reduction in latency and increased network performance recorded in the Starlink network are directly related to the automatic network management algorithms implemented based on artificial intelligence and machine learning [19].

G. b) Signal quality prediction

In LEO networks, Ka-band frequencies (26–40 GHz) provide high speeds, but rain, snow, or thick clouds can significantly reduce the signal (rain fade). Time-series prediction algorithms are used to solve this problem [12, 5].

Deep learning models such as LSTM (Long Short-Term Memory) learn the probability of rain, cloud density, atmospheric pressure, and predict signal weakness in advance. Based on this information, the system automatically: switches the frequency to C-band, increases signal strength, and connects to an additional satellite [10].

H. c) Artificial Intelligence in Security

Artificial satellite systems are prone to attacks (DDoS, signal suppression, spoofing). Traditional security systems cannot detect new, unknown attacks.

Security systems based on artificial intelligence perform the following:

Anomaly detection — detecting unknown attacks through unsupervised learning [17]

Signal source detection — isolating a fake signal from the signal spectrum [6]

Data encryption — protecting data by generating a dynamic key [13]

I. d) Orbital optimization and space debris management

There are more than 30,000 tracked space debris in LEO orbit. The launch of new satellites increases the risk of collision. Each collision creates new debris (Kessler effect) [7, 14].

Using artificial intelligence: The trajectory of each object is monitored, the probability of collision is calculated, if the probability exceeds 0.001%, a warning is given and the satellite automatically maneuvers [6, 14].

J. e) Energy management through AI

LEO satellites receive electricity through solar panels. When they enter the Earth's shadow, they use batteries. Efficient management of the energy source extends the service life of the system.

Example: The energy-aware AI system used in OneWeb satellites has reduced energy consumption [18].

With the growth of modern LEO networks, the complexity of management is also increasing. Artificial intelligence is being used as a key tool not only to improve network efficiency, but also to solve urgent problems such as security, energy management, and space debris tracking. Algorithms such as RL, LSTM, and federated learning enable real-time decision-making and increase the robustness of systems [6, 17]. In the future, autonomous systems based on artificial intelligence will become the core of space infrastructure.

IV. RESULTS AND DISCUSSION

LEO systems (Starlink, OneWeb) are taking a leading role in the global Internet, but the environmental (space debris), economic (cost) and security (radio interference) problems associated with them are increasing [5, 6].

Using SI, network efficiency, security and energy efficiency are improved [6, 17].

GEO systems are still considered reliable in areas such as television and meteorology [12].

MEO systems provide 1–3 meter accuracy in navigation [16].

These results show that each system is effective in its own field, but the development of LEO systems requires addressing the risks associated with them.

V. CONCLUSION

As a result of the study, it was proven that each of the satellite communication systems in GEO, MEO and LEO orbits is optimal for certain applications. GEO systems are effective in terms of long-term operation, wide coverage and stability, and play a key role in the transmission of television, state security and meteorological data.

MEO systems are effectively used in the field of global navigation (GPS, Galileo) and provide an accuracy of 1–3 meters, but they have limited application for communication, since the network architecture is focused on navigation.

LEO systems (Starlink, OneWeb) are considered a modern solution for broadband Internet networks.

Artificial intelligence (AI) technologies are widely used to effectively manage such complex systems. Algorithms such as Reinforcement Learning and LSTM play an important role in the optimal allocation of network resources, signal quality assessment, energy consumption reduction and measures against space debris.

In conclusion, LEO systems are expected to become mainstream in the global internet by 2025, but international cooperation, scientific research, and innovative solutions (SI, optimization algorithms) are needed to address the environmental (space debris), economic (management costs), and safety (radio interference, dangerous behavior) issues associated with them.

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ГЕОИНФОРМАЦИОННОЕ МОДЕЛИРОВАНИЕ ЭЛЕКТРОМАГНИТНОЙ ОБСТАНОВКИ В ТЕЛЕКОММУНИКАЦИОННЫХ СИСТЕМАХ И ИНФОРМАЦИОННАЯ ПОДДЕРЖКА ПРИНЯТИЯ РЕШЕНИЙ

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Аннотация. В данной статье освещаются методы геоинформационного моделирования электромагнитной обстановки в телекоммуникационных системах с использованием имитационных подходов и технологий ГИС для анализа и прогнозирования развития сетей, а также для информационной поддержки принятия решений. Рассматриваются вопросы разработки структур и планирования телекоммуникационных систем на базе моделирования электромагнитной обстановки с учетом региональных особенностей, на примере системы «Каракалпак телеком» в Республике Каракалпакстан. Также представлены геобазы данных и тематические слои для отдельных регионов, что демонстрирует эффективность использования имитационных моделей для поддержки управленческих решений в области телекоммуникаций.

Ключевые слова: ***Геоинформационное моделирование, прогнозирование, электромагнитная среда, региональные особенности, геоданные, моделирование***

I. ВВЕДЕНИЕ

Актуальной областью исследований является использование геоинформационных технологий для повышения эффективности телекоммуникационных систем и поддержки управленческих решений. Среди множества современных программных средств и методов моделирования, применяемых в этой области, выделяются как традиционные базы данных и экспертные системы, так и новейшие геоинформационные технологии. Развитие данных технологий способствует повышению конкурентоспособности в сфере телекоммуникаций за счет внедрения геоинформационного обеспечения управления на новый уровень, что позволяет не только анализировать телекоммуникационные системы, но и предсказывать их развитие.

В соответствии с Указом Президента Республики Узбекистан от 19 февраля 2018 года № УП-5349 «О мерах по дальнейшему совершенствованию сферы информационных технологий и коммуникаций» организации деятельности Министерств и проведение инвентаризация имеющихся в государственных органах и иных организациях информационных систем, баз данных и иных программных продуктов на предмет их соответствия функциональному назначению, требованиям информационной безопасности и иным техническим параметрам. По итогам инвентаризации принятие мер по интеграции действующих информационных систем, баз данных и иных программных продуктов, совместного их использования [1].

Создание современной телекоммуникационной инфраструктуры является одним из ключевых факторов развития цифровой экономики. Для поддержки роста цифровой экономики необходимо развивать соответствующую инфраструктуру, осуществлять модернизацию и расширение телекоммуникационного пространства с целью повышения качества предоставляемых услуг. В этом направлении Министерство цифровых технологий ведет масштабную работу [2].

В настоящее время общая пропускная способность международных каналов связи составляет 1800 Гбит/с (см. Рис. 1), а по итогам запланированных к реализации проектов к концу 2022 года этот показатель увеличится до 2200 Гбит/с. В 2021 году общая пропускная способность между регионами и районами была увеличена в 1,5 раза. Для развития телекоммуникационных сетей было проложено дополнительно 50 тысяч километров оптоволоконных линий, в результате чего их общая протяженность достигла 118 тысяч километров, и около 67% населенных пунктов

получили доступ к высокоскоростной связи. В будущем планируется продолжить работу по расширению сети оптоволоконных линий.

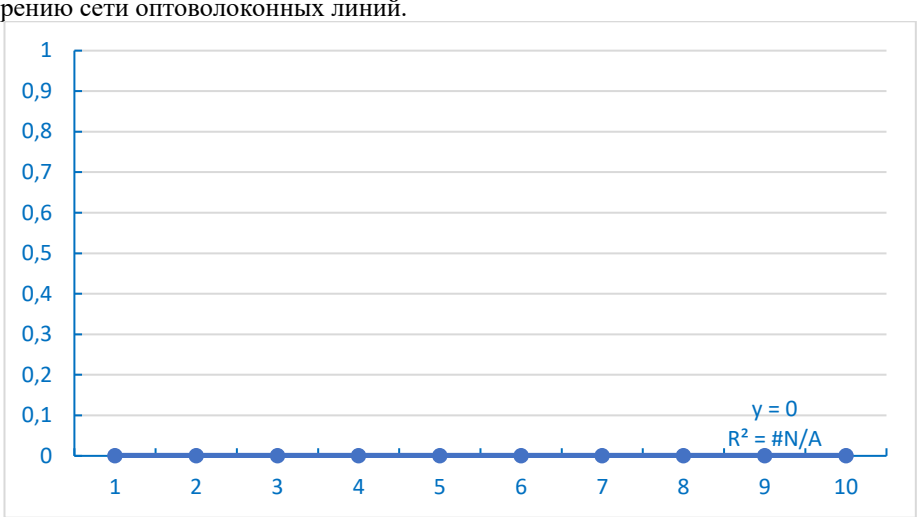

Рис. 1. Передачи данных глобальной сети по пропускным способностям (Гбит/с)

Общая емкость оборудования по оказанию интернет-услуг для населения достигла 3,6 миллиона. Для развития мобильной связи в 1,5 раза была повышена скорость мобильного интернета, и в 2021-м году было установлено 14 150 станций. Тем самым, их общее количество доведено до 45 890 единиц.

Особое внимание, оказываемое главой государства данной сфере, направлено на достижение главной цели – оказание качественных и современных телекоммуникационных и цифровых услуг населению, созданию всех возможностей по развитию цифровой экономики. Отдельный и самостоятельный научный интерес представляют методы анализа данных и прогнозирования развития системы. Результаты по этому направлению получены в работе с применением ГИС систем и разработанных на основе методов имитационного моделирования [2, 3].

Организация телекоммуникационной инфраструктуры различных регионов Узбекистана достаточно сложна и без помощи геоинформационных технологий управление этой системой потребовало бы привлечения значительных человеческих и временных ресурсов, а также высочайшего уровня управленческой оценки. Уникальность системы также связана с тесной географической привязкой объектов, поэтому важно создать геобазы коммуникационных и информационных ресурсов с набором подходящих аналитических решений, а также полностью привязать их с помощью ГИС-технологий, что должно предполагать создание коллекции электронных карт.

II. ОСНОВНАЯ ЧАСТЬ

В данной исследование разработаны системы и инструментов автоматизации проектирования и имитационного моделирования на базе ГИС для отображения ситуационной обстановки с целью сокращения временных и финансовых затрат, анализированы возможностей снижения сложности проектных работ и повышения уровня знаний в области планирования. Для разработки геобазы, необходимо было решить задачи по созданию системы 3D-моделирования и оценки проектных решений, обеспечивающих визуализацию трехмерной обстановки, взаимодействие с внешними системами и источниками электромагнитного излучения телекоммуникационных систем, а также имитацию ситуации объектов и, дополнительно (на примере региональных компаний связи), проведение геометрического, компьютерного и математического моделирования методов управления системой.

Теоретико-методологическую основу исследования составили методы фазификации данных при решении многокритериальных задач; предложены новые эффективные алгоритмы для построения буферных зон, зон близости, изолиний, изоконтуров, экспозиций склонов, зон видимости, а также расчетов объемов земляных работ, объединяющие простоту реализации и низкую трудоемкость [4].

В исследовании созданы и внедрены стандартизированные методы сбора, хранения и анализа геопривязанных данных о телекоммуникационных средствах и информационных ресурсах с учетом их уникальных характеристик, а также содействия и поддержки внедрения подходящих принятие управленческих решений на основе этой информации. Разработаны проекты ГИС-сервера и геоинформационной системы для телекоммуникаций для типовых условий работы территориальных телекоммуникационных предприятий, а также построены структурные и имитационные модели их работы (на примере Каракалпакстана). Рассматривается геоинформационный подход к решению задач электромагнитной обстановки телекоммуни-

кационных систем. Разрабатываются методики и алгоритмы инвентаризации излучающих технических средств с использованием цифровых карт местности, интеграции электродинамических моделей в геоинформационную среду и формируется общая структура геоинформационной системы электромагнитного состояния.

Методы имитационного моделирования развиты на основе создания векторных геообъектов, т.е., ввод, редактирование, выборки и идентификации геообъектови по их атрибутам; картометрические измерения и анализ основных статистических показатели массива атрибутивных данных векторных объектов; определение координат точечных объектов; поиск объекта и определение его местоположения по определенному атрибуту; определение площадей и периметров полигональных геообъектов; оверлейные операции, анализ близости, пере классификации и районирование, генерализация и геообработка; составление тематических картограмм, картодиаграмм, картосхем, графиков и диаграмм по атрибутам векторов.

Пространственный анализ в ГИС произведен по направлении в следующим последовательности: элементарный пространственный анализ; · пространственная статистика; · расширенный пространственный анализ и · сетевой анализ. Наиболее современный направлений пространственного анализа – сетевой анализ геообъектов, т.е., любая система связанных между собой линейных объектов – телефонные линии и линии электропередач, автомобильные и железные дороги, реки, трубопроводы – представляет сеть. Передвижения людей, транспортировка товаров и услуг, обмен информацией и передача энергии происходят по сетям. Типичные задачи сетевого анализа: поиск ближайшего пункта, разработка кратчайшего маршрута, определение зон обслуживания (доступности), определение местоположения по адресу (геокодирование) (рис. 2). С помощью специальных инструментов (ArcGIS –3D и Spatial Analyst) расчитывается, вращается, а также просматривается поверхность «в режиме птичего полета» над ней, создается трехмерные анимации, а также к моделю 3D-поверхностям можно осуществлять запросы и «привязывать» базы знаний и данных.

На основе моделирование и пространственного анализа в ГИС визуализации электромагнитной обстановки на больших территориях в рамках проблем электромагнитной безопасности методами геометрической оптики разрабатываются алгоритмы определения положения точки пространства, относительно системы излучающих технических средств (видимость -прямая и косвенная, или затенение рельефом, затенение сельскими или городскими постройками ...). Разрабатываются имитационные модели в интеграции геоинформационными методы оценки электромагнитной обстановки на больших территориях с применением дополнительных инструментами ГИС. Разрабатываются концепции анализа электромагнитного поля систем подвижной радиосвязи, на основе комбинации статистических и детерминистических методик расчета. Разрабатываются алгоритмы дополнения электродинамических моделей дифракционными эффектами с применением геоинформационных технологий. Производится разработка методик и алгоритмов графического отображения и интерпретации электромагнитных полей излучающих объектов на больших территориях в рамках проблем электромагнитной обстановки.

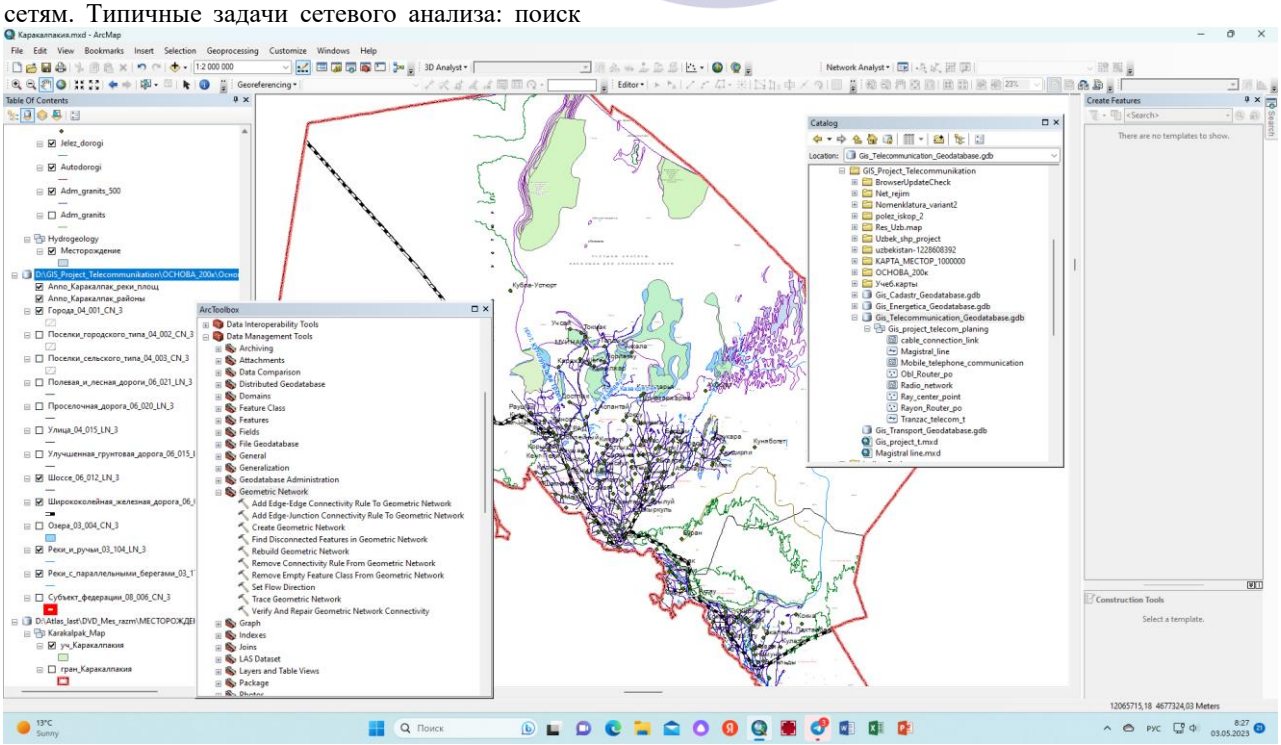

Рис. 2. Фрагмент ГИС анализ определение местоположения по адресу (геокодирование)

Моделирование в среде ArcToolbox -получение новой информации осуществляющихся непосредственной привязкой к местности, с помощью функций анализа поверхности, используются сама по себе вместе с новыми пространственными данными и функциями как источником данных для проведения математические моделирования динамических процессов. Помимо средств создания и анализа поверхностей, модуль 3D и Spetial Analyst предоставляет интерпритации данных с разработкой наиболее наглядно и необходимым шагом, модель размещения узла связи или элемента системы связи на местности [5, 6] непосредственно на основе цифровых карт визуализируются трехмерных перспективных изображений.

Для трехмерной изображения на плоскости, в отличие от двумерного, включает построение геометрической проекции объемной модели на плоскость с помощью специализированных программных модулей ArcScena. Эта модул является и реализуют многорежимный вьювер и обработку данных, обеспечивающиеся отображение наземной и воздушной ситуационных обстановок с заданной точностью и могут быть использованы на практике разработчиками проектов геоинформационных систем и т.д. Это означает, что методы имитационного моделирования могут иметь не только предварительный характер, но и то, что инструментальный пакет, с дополнительными модулями, геоанализ высокого уровня, станет наиболее приспособленным (по сравнения со стандартными пакетами) в эксплуатации совместно с базами данных конкретных систем, организации, отрасли и т.д.

Кроме того, является необходимым математическое, компьютерное и геометрическое моделирование самого процесса управления системой (на примере региональных предприятий телекома) с целью повышения эффективности, в том числе и экономической, ее деятельности и обеспечения в целом информационного сопровождения и аналитической поддержки принятия управленческих решений.

III. ОБСУЖДЕНИЕ РЕЗУЛЬТАТАОВ

На основе геостатистического анализа фокусируясь на создании поверхности из набора выборочных точек построены диаграмм и графиков для визуального исследования, для управления типовой системой телекоммуникационных средств и информационных ресурсов регионального уровня, разработаны соответствующе модули аналитических решений, ориентированных на повышение эффективности расчета электромагнитной состоянии связи и средства телекоммуникации, в частности в фоновым аспекте, с учетом его конкретных особенностей, а также создание набора тематических электронных карт, обеспечивающих информационное сопровождение и поддержку для принятия оптимальных решений.

Задачи решены с разбиением на подмодели, с наложением слои из базы данных, определены основные параметры анализа, которые должны способствовать расчету электромагнитного состоянии для ясности, систематизации мыслей и более эффективного решения вопроса. Первая подмодель – территориального распределения местности, идентифици-рующей места с широким разнообразием рельефа для распространение электромагнитной волны. Второй подмодель состоит из крупных зданий, а также строительств к местным территориям. Третья подмодель создания растра расстояний зеленная зона. Следующая подмодель излучатели содержит электроснабжению и линии ЛЭП. Некоторые атрибуты или слои могут находиться в нескольких подмоделях. Однако, крутые склоны могут быть рассчитаны как барьеры электромагнитной волны для подмодели местности, но отрицательно сказаться на имитационной расчеты подмоделей. Каждый фактор фиксирует и описывает компонент явлений, определяемых подмоделью. Характеристик способствует достижению целей подмодели, а каждая подмодель способствует достижению общей цели модели наложения слоев. Свойств, характеристик и факторы, влияющие на определение явления, должны быть включены в наложенную имитационную модель. Для определенных факторов может потребоваться создание новых слоев. Классификация и преобразование различные системы счисления интегрируется и эффективно объединены напрямую с добавлением соотношение - шкала отношений имеет точку отсчета, обычно нулевую, и числа внутри шкалы сопоставимы. В этом случае перед объединением факторов их можно взвесить в зависимости от их важности.

Значения высот являются относительными числами, а высота в 50 метров вдвое меньше, чем 100 метров. Интервал - значения на шкале интервалов относятся друг к другу; однако общей точки отсчета нет. Однако значения не полностью сопоставимы. Из-за потенциальных различных диапазонов значений и различных типов систем нумерации, которые могут быть у каждого входного слоя, прежде чем можно будет объединить несколько факторов для анализа, каждый из них должен быть проклассифицирован или преобразован в общую шкалу отношений.

Таким образом, чем выше значение результирующего выходного растра, тем более предпочтительным будет местоположение. Можно применять и другие комбинированные подходы. Например, в анализе наложения нечеткой логики комбинированные подходы исследуют возможность принадлежности местоположения к нескольким наборам. В большинстве моделей анализа наложения и пригодности определение наилучших мест для моделируемого явления является конечной целью.

IV. ЗАКЛЮЧЕНИЕ

Созданы геоинформационные-статистические методы анализа и обработки распределенных разнородных данных, заключающиеся в

стратификации представления геопространственной информации, обеспечивающее адекватное представление пространственно-топологических отношений между телекоммуникационными объектами.

Разработана обобщенная геоинформационно - математическая модель описания данных о пространственно-распределенных объектах, в основу которой заложено теоретико-множественное описание процессов обработки разнородных данных о геоинформационных объектах, позволяющее оценивать взаимное влияние и динамику поведения электромагнитной остановки за счет анализа их топологических и геометрических характеристик.

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RESEARCH OF THE STATE OF WATER BODIES AND ANALYSIS OF THEIR CHANGES USING GIS AND INTELLIGENT SYSTEMS FOR PROCESSING HETEROGENEOUS DATA

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Abstract. This study explores the development of an intelligent information system capable of efficiently processing and analyzing various types of data related to water bodies, such as satellite imagery, sensor data, and meteorological information. The created system is designed to monitor the current state of water resources, identify emerging trends, and forecast potential changes, thereby supporting more effective management of water resources and enabling timely implementation of conservation measures.

Key words. Water bodies, water resources monitoring, water management, intelligent information system, data processing, data analysis, satellite images, sensor data, meteorological information, change forecasting, environmental monitoring.

I. INTRODUCTION

The role of monitoring changes in synthetic companion images has become significantly more evident in recent years. This is based on the fact that numerous resources have emerged, enabling the collection and analysis of synthetic companion images at different times, particularly in the fields of agriculture and water management. However, the data obtained in the form of images from satellites is very diverse, since each satellite has its own spectral characteristics and measurements. Methods for analyzing and monitoring vegetation using satellite images are being actively implemented. Building a methodology that allows for a new level of quality monitoring of the landscape and flora dynamics of water bodies and coastal zones based on the analysis of long-term satellite images is an important factor determining both the ecological component of the development of the region and the possibilities of using its resources [1].

In this regard, the Resolution of the President of the Republic of Uzbekistan No. PP-257 dated August 2, 2023 "On measures to introduce advanced digital technologies in the agricultural sector" provides for "… effective use of land and water resources, introduction of interdepartmental information systems for monitoring the condition of crops through the widespread introduction of advanced digital technologies in the agricultural sector", the Resolution of the President of the Republic of Uzbekistan No. PP-4996 dated February 17, 2021 "On measures to create conditions for the accelerated introduction of artificial intelligence technologies" provides for "… the use of artificial intelligence technologies in monitoring the condition of soil and agricultural crops based on remote sensing data in priority sectors and areas, including in the agricultural sector" and the Decree of the President of the Republic of Uzbekistan No. PF-5806 dated August 30, 2019 "On the development of space activities in the Republic of Uzbekistan" provides for "… the development of agricultural and a number of tasks have been set, such as working in the field of remote sensing and navigation systems to increase the efficiency of water resources, ecology, urban planning, and other sectors" which justifies the relevance of this research.

In the research miscellaneous data includes satellite, drone imagery, sensor data, and surveillance results. It serves as an effective tool for dynamic analysis of water quality, the number of substances in its composition, and seasonal changes based on various data. Currently, there are advanced methods for creating indices based on a combination of spectral channels of a single satellite, which allow determining the presence of certain types of plants, water, and minerals. However, the data obtained from various satellites and drones is more extensive, and their combination can provide richer information about landscape changes and identify new dynamic trends, such as changes in the composition and use of reservoirs. Modern information technologies and various data are increasingly providing opportunities for analyzing and predicting the state of water bodies. Water resources are of great ecological and economic importance, and regular

monitoring of their condition makes it possible to detect changes in water bodies in a timely manner [3, 5].

Today, climate change and human activity are seriously affecting the state of water bodies. Identifying and predicting these changes is of great importance for the efficient use of water resources and preventing environmental problems. Therefore, it is necessary to create systems for assessing the state of water bodies, analyzing their seasonal changes, and conducting continuous monitoring.

II. REVIEW AND ANALYSIS OF LITERATURE

In the world, special attention is paid to the issues of monitoring, measuring and recording information based on geoinformation-mathematical models, algorithms and software of computing machines, complexes and computer networks. Also, effective management with the widespread introduction of advances in information and communication technologies and artificial intelligence methods in monitoring surface and groundwater resources, integration of space images and knowledge of monitoring regional territories with automated measuring devices in the development of water, agricultural and mining geology is one of the urgent tasks. In this regard, it is considered important to carry out work in foreign countries, including the USA, the Netherlands, Germany, Denmark, Canada, Japan, France, India, China, Iran, Pakistan, the Russian Federation, to create information and computational models and algorithms, and to determine the relationship between various natural phenomena based on systematic monitoring, measurement and digital processing of water changes in hydrogeology - engineering geology, irrigation and land reclamation systems [4, 7].

In the review of the fund materials and scientific research on the topic of the study, leading foreign scientists, including: Dr. Christopher Small, a leading scientist at Columbia University in the USA, conducted scientific work on geodata analysis, spectral features in classification by remote sensing, and urban planning monitoring. Dr. John R. Jensen, a professor at the University of South Carolina, contributed to the study of environmental monitoring and the application of geoinformation technologies. Dr. Magaly Koch, a professor at Boston University, conducted hydrogeological and geological monitoring by remote sensing, water resources, and vegetation processes. Dr. Wolfgang Wagner, a professor at the Vienna University of Technology in Austria, monitored soil conditions and hydrogeological changes on the basis of remote sensing images and geodata. Dr. Lars T. Waser, a professor at the Federal University of Technology in Zurich, Switzerland, conducted modeling and monitoring of vegetation processes using space and UAV images, monitoring crop health, and forest and environmental monitoring studies. Dr. Jitka Kumhalova, a professor at the University of Natural Sciences in Prague, Czech Republic, is conducting scientific research on key topics such as receiving Sentinel-2 and UAV images, initial digital processing of images, monitoring the vegetation process in agricultural crops, and monitoring soil condition and moisture [1, 4].

In Uzbekistan, spectral features recorded in satellite imagery of hydrology, irrigation-melioration, and hydrogeological processes are supplemented using machine learning algorithms that process sets of multispectral satellite imagery in different spectral channels. Such technologies use models to isolate the influence of a particular spectral component and determine the degree of its contribution to studying the state of water resources. U.U.Umarov, O.V.Malenin, I.Kh.Khabibullaev, R.N.Usmanov, J.X.Djumanov, V.S.Sheglov, S.X.Khushwaktov, A.M.Mirsoatov, A.F.Nazarov, A.X.Digaev and other scientists have achieved significant scientific results in creating a multispectral image reflecting the dynamics of changes over time, and in theoretically substantiating and developing an automated monitoring system. A comprehensive analysis of the spectral, spatial, and temporal domains allows us to build a model that allows us to identify the causes of water resource pollution and predict its magnitude and distribution dynamics. The combination of images based on the integration of semantic and neural network models allows creating an information volume of the area, which can identify the main changes in the aquatic environment in the spectral range, as a result of which it is possible to isolate the main components of pollution. This determines their potential threat [7, 11].

III. RESEARCH METHODS AND TECHNOLOGIES.

The study used the general methodology of systematic analysis, space image processing technologies, geoinformation - mathematical modeling, information and management systems, cloud computing, artificial intelligence, machine learning, groundwater dynamics and regime element measurement technologies, modeling and object-oriented programming and algorithmizing, principles of processing and comparative comparison of research results, ensuring the reliability of information, and methods of fuzzy set theory.

A. The object of the research

The object of the research is planned to study changes in the Aral Sea wetlands, the Aydar-Arnasoy lake system and the surrounding wetlands. The study consists of analyzing the state of fauna, flora and minerals in the main part of the territory, that is, the dry part of the Aral Sea and the Aydar-Arnasoy lake system, as well as changes in the shoreline profile of water bodies in the long and short term, as well as the impact on groundwater and the impact on mutual water bodies.

B. The main goals and objectives of the research

The purpose of the research is to develop theoretical foundations and methods for diagnosing of water bodies and analysis of their changes using GIS and intelligent systems for processing heterogeneous data.

C. The main tasks were determined

to development of models, algorithms and prospective methods of the water bodies and analysis of their changes using space image processing technologies and geoinformation - mathematical modeling implementation;

to identify the patterns of formation of the volume and quality of water resources in water use zones, as well as trends in changes in water consumption and water use parameters;

to identify changes in the characteristics of the hydrological cycle of surface waters with changes in the monitoring of climatic factors and the characteristics of the hydrological cycle of surface waters with the observed changes in anomalous climatic factors.

to analysis of systematic and assessment of water consumption and water use trends across sectors of the country's economy, as well as the study of the hydrological cycle of surface waters in the irrigation runoff use zone

to development of a data and knowledge base infrastructure of the information system, as well as the impact surface and underground water and an algorithm for classifying signal data using a hybrid neural network.

IV. THE MAIN PART OF THE RESEARCH

The use of modern satellite imagery and aerial photography has provided a new level of remote monitoring and assessment of water resources, complementing sensor-based and direct field surveys. Real-time water status data in the region, including multispectral satellite imagery, has been used to analyze the state of reservoirs and groundwater basins in a comprehensive and operational manner. The state of biological and chemical pollution has aroused particular interest. To assess the trophic state of aquatic blooms and water bodies, satellite imagery has been used.

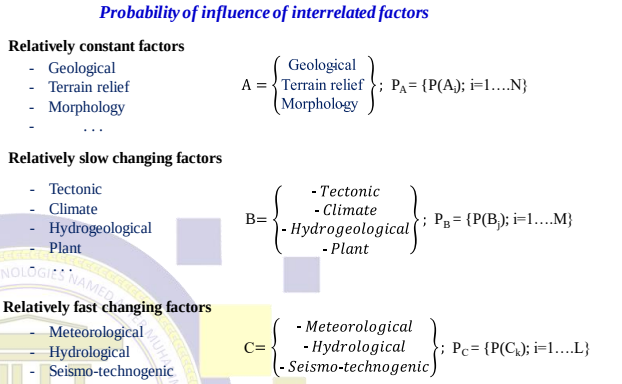
For most marine areas and large reservoirs, a "bloom" index has been developed and tested in the central and northeastern parts of the sea. However, studies on water pollution using multispectral satellite imagery have mostly focused on creating indices based on the infrared channel, such as NDVI and NDWI. Existing standard algorithms have been used to obtain quantitative descriptions of water pollution, which have application limitations related to the morphological, hydrochemical and biological characteristics of water bodies. In this regard, regional algorithms for the evaluation of data on water bodies were developed for inland water bodies, which allow obtaining reliable results [1, 4, 9].

Proposed method and scientific approaches:

Multispectral satellite images capture more complex structures that describe the characteristics of the objects being studied, in particular, they reflect the state of water resources and the earth's surface with underground sources. Effective methods of analyzing images that take into account this inherent property of images are based on traditional technologies, indexing methods, and image enhancement, which do not take into account the characteristics of complex objects, and therefore, spectral variations in the area of pollution and changes in the behavior of plants.

The work has yielded results related to the development of models and technologies for recognizing changes in images that can be used in the process of visualization and interpretation of data for remote sensing systems and are intended for the processing of multispectral images. Image interpretation methods are based on modified machine learning technologies. An approach and a methodology based on it will be developed for the detection of changes in the surface images of reservoirs and their surroundings, based on the use of metamer theory and neural networks that allow automatic adjustment of the search for changed objects. All methods are integrated into a meta-model, which is competitively collaborated to identify relevant factors for analysis and monitoring [8,12].

The methods developed within the framework of the research are new and unique, based on foreign analogues, mainly domestic applied mathematics and computer science theory, and set the current level of scientific knowledge in the field of image analysis. These methods differ from known methods in that they use a new configuration of neural networks. An important characteristic, as well as an integral part of analysis and evaluation, was the formalization of the presentation of images. Based on various data, factors of including changes in the dynamics of geology, relief, flora, and minerals, a large-scale and multifaceted analysis of these changes was carried out using artificial intelligence and probability theory, and critical changes were identified in terms of quality. This artificial intelligence includes schemes filled with algorithms, including image processing in different spectral ranges, the main types of image sequence representation factors: a) detailed and temporary dynamic images; b) images based on formal and characteristic models, c) image pre-data processing algorithms, d) machine learning methods and others.



1) The following new scientific algorithms were used in the research:

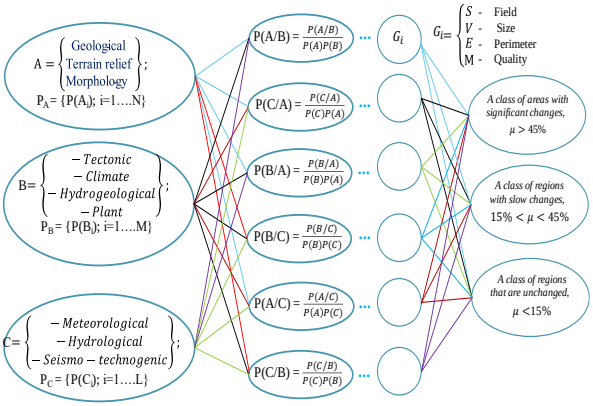
I. the algorithms for initial processing of satellite images were improved based on the set of normalization algorithms;

II. the algorithms for reprocessing satellite images were improved using the set of bipolar normalization algorithms;

III. a hybrid neural network architecture was developed for recognizing and predicting various types of data;

IV. a mathematical model was developed for calculating water consumption and needs;

V. an algorithm for assessing dynamic changes in the state of the reservoir was developed;



a) The research results were related to the development of models and technologies for recognizing changes in images that can be used in the process of visualization and interpretation of data for remote sensing systems and are intended for the processing of multispectral images. The methods of image interpretation were based on modified machine learning technology. An approach and methodology for detecting changes in surface images of reservoirs and their surroundings, based on metamer theory and the use of neural networks that allow automatic adjustment of the search for changed objects, was developed. All methods were combined into a meta-model, which is supported by the theory of competitive probability to identify relevant factors for analysis and monitoring.

VI. Discussion of results

Based on the results of the study, the laws of formation of the volume and quality of water resources in the areas of their use, as well as trends in changes in water consumption and water use parameters, are identified.

The monitoring of climatic factors is useful in studying the laws of changes in the hydrological cycle characteristics of surface waters with changes in them.

The changes in the characteristics of the hydrological cycle of surface waters with the observed changes in anomalous climatic factors are studied. A systematic analysis and assessment of trends in water consumption and water use across sectors of the country's economy can be carried out.

VI. Conclusion

The main result is a new methodology and algorithms that allow improving the quality of analysis of data recorded by multi-temporal satellite sensors, which will allow water resources specialists to assess the ecological situation and the impact of changes in water resources in other regions on the state of water resources in other regions in order to monitor their resources. The methodology is based on the concept of a dynamic scene based on various data, including changes in meteo, geological, metrological, relief, flora and mineral dynamics, which provides a wide multifaceted analysis of changes, allowing to record critical changes. The technique includes schemes filled with algorithms, including image processing in different spectral ranges, allowing the main types of image sequence imaging: a) spatio-local and temporal dynamic images; b) images based on formal and feature models, c) image preprocessing algorithms, d) machine learning methods.

Intelligent geoinformation systems in the field of water resources are effective in increasing the efficiency and expanding the areas of use. For example, reviewing the results of the project will subsequently allow to increase the efficiency of water resources management, reduce the time spent on allocation calculations, and lead to a rational use of resources.

This technology is necessary in the development of automated monitoring and forecasting systems to control the development of water resources in the region and their ecological status.

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FUNDAMENTALS OF GEOINFORMATION AND MATHEMATICAL MODELING OF GROUNDWATER FOR SOLVING PROBLEMS OF HYDROGEOLOGY AND ENGINEERING GEOLOGY

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Abstract: Groundwater modelling is an effective and indispensable tool for water resources management, protection, restoration planning and forecasting. Models provide a simplified description of complex hydrogeological systems, which enables researchers and practitioners to analyses specific processes or to predict the future behaviors of the system under various conditions. The main challenge is to simplify the real system without losing the accuracy and reliability of the results. An incorrectly designed or misinterpreted model may lead to false conclusions and wasted resources. Therefore, clear definition of modelling objectives and competent development of the conceptual model are of crucial importance. The completeness and reliability of hydrogeological data play a key role. After developing the conceptual and numerical models, calibration and verification are essential stages, which ensure that the model adequately reflects real conditions. This article describes the main stages and methodology of groundwater modelling, explaining each step-in detail. Various types of models and solution methods are briefly described during the modelling process are discussed.

Keywords: Groundwater modelling, hydrogeology, mathematical model, numerical methods, model verification, water resources management.

I. INTRODUCTION

In order to improve the reclamation state of irrigated lands, the state of groundwater, increase the fertility of irrigated areas and water supply, large-scale irrigation and reclamation measures are being carried out within the framework of state programs. Decrees of the President of the Republic of Uzbekistan №PQ-5742 dated June 17, 2019 "On measures for the efficient use of land and water resources in agriculture" and №PQ -6024 dated July 10, 2020 "On approval of the concept for the development of the water sector of the Republic of Uzbekistan for 2020 - 2030 years" determines the relevance of this work [1, 2]. Groundwater modeling is an important method for studying and predicting the behavior of aquifers under real or expected operating conditions. The model allows one to reproduce a natural system in a simplified physical or mathematical form, which makes it possible to analyze its response to various impacts, such as water abstraction, replenishment, or pollution [3, 4]. In essence, modeling is an economical and relatively simple way to study complex processes without the need for expensive experiments in nature [8, 14]. As the famous statistician George Box rightly noted: "All models are wrong, but some are useful" [7]. Regardless of the type of model used, its suitability and accuracy directly depend on the clarity of the goals set and the correctness of the initial data [9, 11]. Despite simplifications, models play an important role in hydrogeology and water resources management. The main task of the modeler is to represent the real problem as accurately as possible in a simplified form, minimizing assumptions and errors. Groundwater models can be of three types: physical, analog, or mathematical. Solutions to mathematical models can be obtained analytically or numerically. Analytical methods require less data, but are applicable only to simple problems [8]. Numerical solutions allow solving more complex problems and, with the development of computing technology, have become widespread and accessible.

II. LITERATURE REVIEW AND ANALYSES

Groundwater modeling is an important tool in water resources management, forecasting and assessing the state of hydrogeological systems. In world practice, this area has been widely developed thanks to the works of such researchers as Freese and Cherry [6], Bear [3], as well as subsequent improvements in modeling methods [4, 8]. The classic works of Freese and Cherry (1979) laid the foundations for understanding groundwater flows and the application of numerical calculation methods [6]. Bear (1979) systematized knowledge about the theoretical and practical aspects of filtration in porous media [3]. With the development of computer technology, numerical methods for solving modeling problems have been developed - the finite difference method (FDM) and the finite element method (FEM), which have found wide application in the MODFLOW, FEFLOW and other software packages. In Uzbekistan, groundwater modeling issues are studied in the works of F.B.Abutaliev, U.U.Umarov, I.Khabibullaev, R.U.Umanov, J.X.Djumanov, who consider methods for calculating aquifers taking into account the specifics of the region and local hydrogeological conditions [15]. In addition, domestic researchers pay attention to the practical aspects of constructing conceptual models and interpreting the calculated results. Despite the diversity of approaches, all modern works emphasize the importance of collecting and analyzing hydrogeological data, the correct choice of boundary and initial conditions, as well as the mandatory stages of calibration and verification of the model to ensure its reliability. Thus, the conducted review shows that the theoretical and practical foundations of groundwater modeling continue to develop, and their application requires an integrated approach and consideration of local conditions.

III. METHODOLOGY AND EMPIRICAL ANALYSIS

Hydrogeological modeling of groundwater is a systemic process based on a strict combination of field observations, analytical description of filtration processes and numerical calculation methods. The goal of this stage is to build a model that allows reproducing real filtration processes and predicting the state of the aquifer under changing loads and external factors.

At the initial stage, the main tasks that the model must solve are formulated. As a rule, they come down to assessing groundwater reserves, analyzing their dynamics over time, identifying potential zones of depletion or pollution, and developing well-founded recommendations for managing the exploitation of aquifers. Clearly setting goals and objectives is a key condition for the correct selection of the level of detail of the model and the required volume of initial information [9, 16].

The next stage is the collection, processing and critical analysis of the initial hydrogeological data. The stratigraphic sections and maps of the geological structure, data on the physical and mechanical properties of rocks, the results of well tests for water intake properties, regime observations of the groundwater level, meteorological information (amount of precipitation, evaporation rate, infiltration coefficients) are taken into account [10, 12]. All these data are systematized and verified, since the reliability of the calculations directly depends on the quality of the initial information.

Based on the collected data, a conceptual scheme is developed that describes the general structure of the aquifer [8, 11]. Within the framework of the conceptual model, the geometric boundaries of the calculation area, the recharge and discharge zones, the presence of lenses with different permeability, as well as the distribution of hydrodynamic parameters within the allocated aquifer are specified [10, 14]. After this, a mathematical model is formed that expresses the laws of groundwater filtration in the form of a system of differential equations [3, 8, 14]. The basis is the filtration equation obtained from a combination of the continuity equation and Darcy's law [3, 8]. In steady-state mode, filtration is described by the classical Laplace equation [3, 9].

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}=0 \quad (1)$$

where h is the piezometric pressure characterizing the energy state of the underground flow. This equation reflects the condition that there is no change in flow within an elementary volume in the absence of sources and sinks. If the geometry of the computational domain and the structure of the parameters are simple, an analytical solution can be used [8]. However, in practice, especially for multilayer or heterogeneous systems, analytical solutions are impossible. In these cases, numerical methods are used: finite-difference (e.g., MODFLOW) or finite-element (e.g., FEFLOW). These methods allow for flexible specification of a complex computational grid, taking into account the heterogeneity of parameters and different detailing in areas with increased gradients. An important stage is the calibration of the model [9]. For this, the parameters with the highest degree of uncertainty (e.g., filtration coefficients or specific storage values) are selected so that the calculated values of piezometric levels correspond to the actual data of the observation network. The gap between the calculated and observed values is estimated using statistical indicators: standard deviation, average absolute deviation, correlation coefficient. To confirm the reliability and operability of the model, it is

verified on independent data that were not used in calibration. This allows us to estimate the reliability of the model in predictive calculations. The empirical analysis is supplemented by a study of the sensitivity of the model to changes in parameters. This is important for identifying the key factors that have the greatest impact on the calculated result, and allows us to justify which parameters require additional study or clarification.

IV. SOLUTION TO THE PROPOSED GROUNDWATER FILTRATION MODEL

After constructing a conceptual and mathematical model, the next important step is to obtain a solution to the filtration equations. In this paper, we consider a solution using a combination of the Laplace transform and the perturbation method (LHPM), which allows us to find approximate analytical solutions for problems where a direct analytical solution is difficult or impossible. The basic equation for groundwater filtration in a three-dimensional case, taking into account the reserve and sources, is:

$$T_x \frac{\partial^2 h}{\partial x^2} + T_y \frac{\partial^2 h}{\partial y^2} + T_z \frac{\partial^2 h}{\partial z^2} = S \frac{\partial h}{\partial t} \quad (2)$$

$T_x, T_y, T_z -$ filtration coefficients in the corresponding coordinate directions (units of measurement: $\left[\frac{L^2}{T}\right]$,

$S -$ reservoir capacity coefficient (dimensionless value);

$h -$ piezometric pressure.

The initial condition for the pressure is taken as:

$$h(x, y, z, 0) = f(x, y, z) \quad (3)$$

here $f(x, y, z)$, — given function of the initial pressure distribution. For the simplified case without an external source $Q = 0$ the equation will take the form:

$$T_x \frac{\partial^2 h}{\partial x^2} + T_y \frac{\partial^2 h}{\partial y^2} + T_z \frac{\partial^2 h}{\partial z^2} = S \frac{\partial h}{\partial t} \quad (4)$$

First, the Laplace transform is applied to this equation with respect to time. Using the standard properties of the Laplace transform, we can write:

$$\mathcal{L}\left\{\frac{\partial h}{\partial t}\right\} = sH(x, y, z, s) - h(x, y, z, 0) \quad (5)$$

here s — Laplace parameter, a $H(x, y, z, s)$ — Laplace transform of the function h. Thus, the original equation in the Laplace image has the form:

$$T_x \frac{\partial^2 h}{\partial x^2} + T_y \frac{\partial^2 h}{\partial y^2} + T_z \frac{\partial^2 h}{\partial z^2} = Sh - h(x, y, z, 0) \quad (6)$$

To find the solution, the perturbation homotopy method is used. The main idea of the method is that the solution of the function H is expanded into a series:

$$H(x,y,z,s) = \sum_{n=0}^{\infty} p^n H_n(x,y,z,s). \quad (7)$$

here p - disturbance parameter. The solution to this chain of equations is constructed in turn, starting with the zero approximation. After finding all the terms H_n the entire series is summed. The inverse Laplace transform returns the solution to the original time domain:

$$h(x, y, z, t) = \mathcal{L}^{-1}[H(x, y, z, s)]. \quad (8)$$

Thus, the combined method allows us to obtain an approximate form of the pressure function $h(x, y, z, t)$ or specific boundary and initial conditions. In practical calculations, simple analytical forms are often used to check the correctness of numerical solutions. For example, when sampling a simple initial distribution:

$$h(x, y, z, 0) = A sin(ax) sin(by) sin(cz) + h_0,$$

the solution can be written as a time-decaying exponential:

$$h(x, y, z, t) = h_0 + A sin(ax) sin(by) sin(cz) exp(-\alpha t),$$

where the attenuation coefficient α\alphaα depends on the filtration and water yield parameters. In practice, for complex geometries and heterogeneous conditions, the solution is obtained numerically using specialized software. However, the analytical approach and the LHPM method allow verifying the numerical scheme by comparing the obtained results with an approximate analytical solution. As a result, this approach demonstrates flexibility and efficiency in analyzing the behavior of groundwater flow in complex engineering and hydrogeological systems.

The factual database contains extensive operational information about the modeling object and its accompanying processes. Their repeated use hinders the refinement of the model, the preservation of its adequacy to constantly changing natural and technogenic conditions. Data processing transforms them into arrays of parameters that form a geoinformation base (see Fig.1).

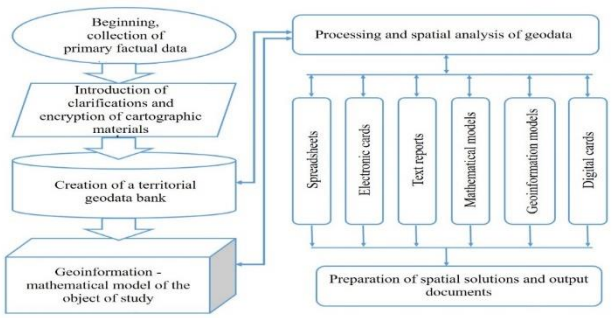

Fig. 1. Technological scheme of a geoinformation system

Thus, the simulation results are converted from a numerical form into a graphic one. This gives grounds to assert that the database is equipped with three components: a base of primary factual data; geodata bank (geoinformation) cartographic data; geoinformation-mathematical model and spatial analysis of geodata.

V. RESULTANTS AND DISCUSSION

Development of a geoinformation model of the filtration process an arid area, were selected of the Kitab-Shakhrisabz groundwater aquifer and its significance for supporting managerial decision-making. Thematic maps were built using tools and additional modules of the

geographic information system *ArcGis* . Sequential processing original map in the form of isolines on an electronic basis made it possible to digitize hydroisogypsum, followed by the creation of a grid-cover, giving absolute marks an idea of the level of the ground filtration flow of a continuous surface. The simulation results by infiltration zones considering several scenario, took into account seasonal changes in scenario 2 and long-term changes in scenarios 3 and 4, and the groundwater abstraction regime was determined simulation and presented in GIS during the 2017 (Fig. 2.).

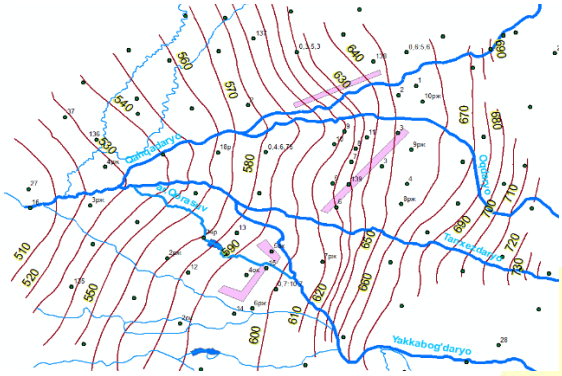

Fig. 2. Hydroisohyps area

VI. CONCLUSION

This paper examines the modern methodology of geoinformation and mathematical modeling of groundwater filtration processes and provides a step-by-step description of the solution of the flow equation based on the combined application of the Laplace transform and the homotopy perturbation method (LHPM). The adopted solution scheme allows one to obtain an analytical approximate solution for a three-dimensional filtration problem, which is important in checking and verifying complex numerical models.

The calculations presented show that the combination of the Laplace transform and the perturbation method provides a flexible and effective tool for analyzing the behavior of groundwater under given initial and boundary conditions. The resulting analytical solution is consistent with known classical results and can serve as a standard for testing numerical calculations, especially when modeling complex engineering hydrogeological systems.

The application of the described methodology allows not only to assess the dynamics of the groundwater level, but also to give reasonable recommendations for practical water use, aquifer management and protection of resources from depletion and pollution. Particular attention should be paid to the quality of the initial data, the correct formulation of boundary conditions and regular calibration of the model based on actual observations.

In the process of solving practical problems on the example of the Kitab-Shakhrisabz groundwater aquifer, a computational experiment was carried out and analyzed on the basis of numerous and different scenarios using geoinformation-mathematical modeling methods. As a result of the formation of groundwater under the influence of water intake facilities, modeling of geofiltration processes, information and hydrological modeling, they gave 10-12%.

In the future, the developed scheme can be expanded to take into account nonlinear effects, spatial anisotropy and more complex scenarios of groundwater exploitation and pollution, which makes this approach a relevant tool for applied hydrogeological analysis and natural water resources management.

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ЕР ОСТИ СУВИ МОНИТОРИНГИ ЛОЙИҲАСИДА БИЛИМЛАРНИНГ БОШҚАРИШ ТИЗИМЛАРИНИ ЯРАТИШ

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Аннотатсия—Ушбу мақолада ер ости сувларининг глобал ва минтақавий даражадаги аҳамияти, уларнинг ичимлик суви, қишлоқ хўжалиги ҳамда саноат эҳтиёжларини қондиришдаги ўрни ёритиб берилган. Хусусан, БМТ, Жаҳон соғлиқни сақлаш ташкилоти ва Жаҳон банки каби халқаро ташкилотлар статистик маълумотлари асосида ер ости сувларининг ичимлик суви таъминотидаги улуши ҳамда озиқ-овқат хавфсизлигидаги аҳамияти таҳлил қилинган. Шунингдек, мақолада билимларни бошқариш тизими (КМС) асосида ер ости сувлари мониторинги жараёни таклиф этилган бўлиб, тизимнинг архитектураси, маълумотларни йиғиш, сақлаш ва таҳлил қилиш механизмлари баён этилган. Тақдим этилган тизим модели PostgreSQL ва Redis базалари интегратсиясига асосланиб, реал вақт режимида мониторинг, тезкор қарор қабул қилиш ва маълумотларнинг ишончлилигини таъминлашга қаратилган.

Калит сўзлар— Ер ости сувлари, ичимлик суви, қишлоқ хўжалиги, билимларни бошқариш тизими, мониторинг, кэшлаш алгоритми, самарадорлик, ресурсларни бошқариш.

I. КИРИШ

Ер ости сувлари глобал миқёсда ичимлик ҳамда қишлоқ хўжалиги учун муҳим сув манбаи ҳисобланади. Дунё бўйлаб 2 миллиарддан ортиқ одам кунлик ичимлик суви эҳтиёжини ер ости сувлари орқали қондиради. Шунингдек, қишлоқ хўжалигида суғориш учун ишлатиладиган сувнинг тахминан 40% ер ости сувлари орқали таъминланади.

Бу рақамлар халқаро ташкилотлар ва илмий тадқиқотлар томонидан тасдиқланган бўлиб, жумладан, Бирлашган Миллатлар Ташкилоти (БМТ)нинг Сув ресурслари бўйича Жаҳон Ҳисоботида ер ости сувлари ичимлик суви ва суғоришдаги аҳамияти ҳақида батафсил маълумотлар келтирилган. Шунингдек, Жаҳон соғлиқни сақлаш ташкилоти (World Helath Organization - WHO) ва Жаҳон банки (Thw World Bank) каби ташкилотлар ҳам ушбу статистикаларни ўз ҳисоботларида қайд этишган[1-4].

Демак, глобал миқёсда ер ости сувларининг аҳамияти:

- ичимлик суви манбаи сифатида 2 миллиарддан ортиқ одам кунлик ичимлик суви эҳтиёжини ер ости сувларидан фойдаланишида;
- озиқ-овқат хавфсизлиги сифатида, қишлоқ хўжалиги фаолиятида суғориш учун ишлатиладиган сувнинг тахминан 40% ер ости сувлари орқали таъминланишида;
- саноат эҳтиёжларини қондириб, кўплаб саноат тармоқлари сувни ишлаб чиқариш жараёнлари учун ишлатишида ўз моҳиятини акс эттиради, бунда ер ости сувларинг сифат ва миқдор жиҳатидан барқарорлиги муҳим ҳисобланади;
- кўллар, дарёлар ва ботқоқликлар каби табиий сув экотизимларини сақлашда ўз моҳиятини акс эттиради, бунда ер ости сувларининг сифат ва миқдор жиҳатидан барқарорлиги муҳим ҳисобланади.

Ўзбекистонда минтақавий даражада ер ости сувларининг аҳамияти табиий ресурсларга бўлган талаб ва минтақа хусусиятларига боғлиқ. Масалан, бизда ичимлик суви таъминотининг катта қисми ер ости сувларидан олиниб, суғориладиган қишлоқ хўжалигида фойдаланилади. Шу билан бирга, ер ости сувлари саноат ва энергетика тармоқларида сув эҳтиёжларини қондиришда муҳим манба ҳисобланади ҳамда бу ўз навбатида шўрланиш, сув ресурсларининг камайиши ва иқлим ўзгариши шароитида ресурслардан самарали фойдаланиш муҳим аҳамият касб этади [5,6].

II. АСОСИЙ ҚИСМ

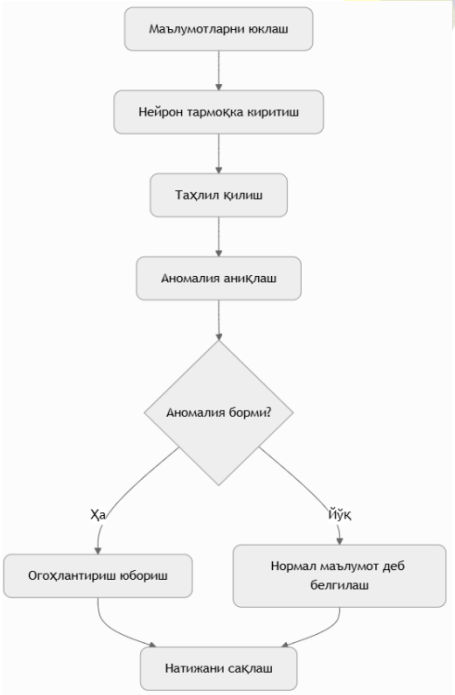
A. Билимларни бошқариш тизими архитектураси

Билимларни бошқариш тизими (Knowledge Management System – KMS) ер ости суви мониторинги тизимида маълумотларни жамлаш, сақлаш, таҳлил

қилиш ва фойдаланувчиларга тақдим этишни таъминлайди.

1-расм. Билимларни бошқариш тизимининг умумий архитектураси

Бу тизим гидрогеологик маълумотлар, сенсорлардан олинган ўлчовлар ва нейрон тармокларнинг билим базаси билан интеграция қилинган(1-расм). KMS орқали маълумотларнинг барқарор ва ишончли бошқарилишини таъминлаш, бу амалиётда сув мониторинги соҳасида реал вақтдаги қарор қабул қилишни осонлаштиради ва маълумотларнинг ифлосланишдан ҳимоя қилинишини кафолатлайди.



2-расм. Билимларни бошқариш тизимининг блок схемаси

Билимларни бошқариш тизимининг математик модели маълумотларнинг жамланган ҳажмини ва унинг ишлов бериш тезлигини ҳисоблайди.

Бу математик модель тизимнинг интеллектуал қобилиятини ошириш ва билимларни оптимал бошқариш учун яратилган:

KMS_Model={D,P,A,R,S}, (4.xx)

бу ерда:

D - маълумотлар тўплами (Dataset);

P- процессинг қоидалари (Progressing rules);

A - алгоритмлар (Algorithms);

R - ретрансляция (Retransmission);

S - сақлаш стратегияси (Storage Strategy).

Яратилган модель орқали маълумотларнинг ижтимоий ва техник мураккаблигини камайтириш, бу амалиётда 10 Тбдан ортиқ маълумотларни 15 мс да ишлов бериш имконини яратиб, тизимнинг самарадорлигини 90% га оширишга ёрдам беради.

Билимларни бошқариш тизимининг блок схемаси маълумотларни жамлашдан визуализациягача бўлган оқимни кўрсатади, бу схема тизимнинг интеграциясини оптималлаштириш учун яратилган. Билимларни бошқариш тизимининг схема орқали маълумотларнинг тез тарқатилишини таъминлаб, бу сув мониторингида реал вақтдаги керакли билимларни фойдаланувчиларга етказиш ва қарор қабул қилиш жараёнини тезлаштиришга имкон беради.

B. Б. Билимларни бошқариш тизимидаги алгоритмлар

Маълумотларни жамлаш алгоритми сенсорлардан келган маълумотларни қабул қилиш ва валидация қилишни амалга оширади, яратилган алгоритм тизимнинг ишончлилигини ошириш учун оптимизация қилинган. Маълумотларни жамлаш алгоритми орқали маълумотларнинг тўғри қабул қилинишни 95% га етказиш, бу амалиётда сув мониторингида сенсор хатоларини камайтириш ва маълумотларни ишончлилигини таъминлашга ёрдам беради.

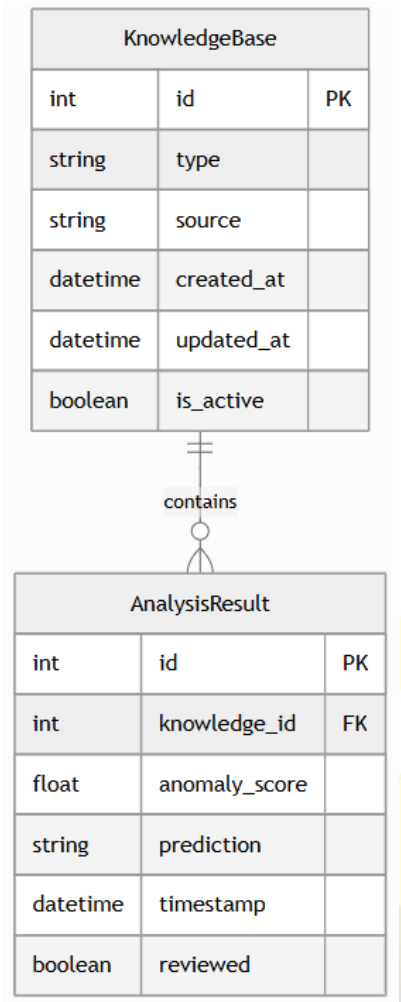
Билимларни таҳлил қилиш алгоритми маълумотларни нейрон тармоқлар орқали ишлов беради, бу алгоритм тизимнинг интеллектуал қобилиятини баҳолаш учун яратилган. Натижада алгоритм орқали аномалияларни 92% билан аниқлаш, бу сув мониторингида хавфли ўзгаришларни тез кўрсатишга имкон беради.

В. Билимларни бошқариш тизимидаги маълумотлар базаси интеграцияси

Билимларни бошқариш тизимида маълумотлар базаси PostgreSQL ва Redis орқали интеграция қилинган, бу интеграция тизимнинг маълумотларни сақлаш ва тез олисҳ қобилиятини таъминлайди. Қилинган ишнинг натижасида интеграция орқали маълумотларнинг кэшлаш тезлигини 80% га ошириш ва бу сув мониторингида реал вақтдаги маълумотларга тезда мурожаат қилиш имконятига эга бўлади.

Маълумотлар базаси схемаси жадваллар ва муносабатларни кўрсатади (3-расм), бу схема тизимнинг маълумотлар структурасини оптималлаштириш учун яратилган. Яритилган схема орқали маълумотларнинг мураккаблигини камайтириб,

бу амалиётда гидрогеологик маълумотларнинг таҳлили ва сақланишини яхшилашга имкон беради.

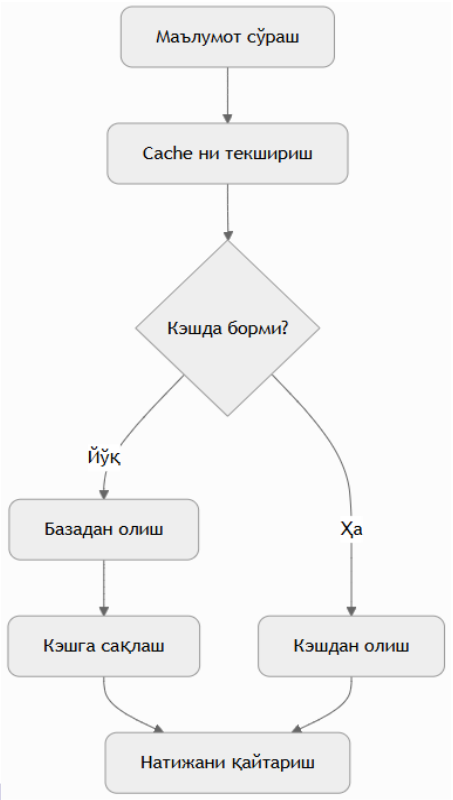


3-расм. Билимларни сақлаш учун маълумотлар базаси схемаси

KMS схемаси models.py да тўлиқ амалга оширилган, бу қилинган ишнинг вазифаси маълумотлар базасининг структурали бўлиши орқали тизимнинг ишончлилигини оширишни билдиради.

Маълумотлар базаси кэшлаш алгоритми (4-расм) маълумотларни Редис орқали кэшлашни амалга оширади, бу алгоритм тизимнинг тезлигини ошириш учун оптималлаштирилган. Алгоритм қўллаш орқали кэш хит рейтигини 85% га етказилиб, амалиётда сув мониторингида маълумотларга тез киритиш ва ресурсларни тежашга ёрдам беради.

Кешлаш алгоритми sashe_manager.py модулида ишлаб чиқилган ва амалга оширилган. Ушбу модул ёрдамида тез-тез фойдаланиладиган маълумотлар вақтинча сақланиб, уларга мурожаат қилиш жараёни анча тезлашади. Натижада, тизимнинг асосий ҳисоблаш ресурслари ортиқча юкланишдан ҳимояланади. Шунингдек, кэшлаш жараёни тармоқ орқали маълумот узатиш ҳажмини камайтириб, самарадорликни ошириш имконини беради. Модулнинг қўлланилиши дастурий таъминотнинг умумий ишлаш тезлигини сезиларли даражада яхшилайди. Демак, sashe_manager.py модули тизим самарадорлигини таъминлашда муҳим рол ўйнайди.



4-расм. Билимлар маълумотлар базасини кэшлаш алгоритми

III. ХУЛОСА

Билимларни бошқариш тизимининг амалий аҳамияти сув мониторинги соҳасидаги қарор қабул қилиш жараёнини яхшилашда кўринади, бу тизим реал вақтдаги маълумотларни таҳлил қилиш ва визуализация қилиш орқали фойдаланилади. Натижада, тизим орқали маълумотларнинг умумий сифатини оширилиб, бу амалиётда гидрогеологик маълумотларнинг ишончлилигини ва қарор қабул қилишларнинг тезлигини 95% га етказишга ёрдам беради. Демак, билимларни бошқариш тизимининг яратишда қилинган ишлар:

- реал вақтдаги огоҳлантиришлар ёрдамида аномалияларни аниқлаш орқали огоҳлантиришларни бир неча сонияда юбориш, бу қилинган ишнинг маъносида тез реакция бериш имконини яратди;
- вақт қатори орқали трендларни аниқлаш ва кўрсатиш асосида узоқ муддатли стратегияларни ишлаб чиқишга ёрдам берди;
- харита визуализацияси ёки географик маълумотларни харитада кўрсатиш, натижада регионал таҳлилни осонлаштирилди.

Келажакдаги билимларни бошқариш тизимининг ривожланиш режалари асосида, микросервис архитектураси тизимни яратиб, ажратган сервисларга бўлиб ва бу архитектура келажакдаги ривожланишга хизмат қилади. Бу архитектура орқали сервисларнинг мустақиллигини ошириш, бу амалиётда тизимнинг юкламасини камайтиришга имкон беради. Кейинги олдинга қуйилган режада сунъий интелект (AI) интеграцияси тизимга қўшимча интеллектуал

қобилиятлар қўшади, бу интеграция келажакдаги таҳлилларни яхшилаш учун режалаштирилган бўлиб, интеграция орқали билимларнинг автоматлашуви ҳамда амалиётда тизимнинг келажакдаги адаптациясини осонлаштиради.

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THE IMPORTANCE OF NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) IN AGRICULTURE

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***Abstract*— The Normalized Difference Vegetation Index (NDVI) is a key remote sensing tool widely applied in agriculture to evaluate vegetation health, monitor crop growth, and support sustainable land management. NDVI uses the difference between near-infrared and red light reflectance to determine the vigor and density of green vegetation. In agriculture, this index is essential for detecting crop stress, estimating yield potential, managing irrigation, and identifying nutrient deficiencies. The integration of NDVI with modern technologies such as satellite imagery, drones, and geographic information systems (GIS) has enhanced the accuracy and efficiency of agricultural monitoring. Moreover, NDVI plays a vital role in precision agriculture by enabling farmers to make informed decisions that optimize resource use, reduce production costs, and minimize environmental impacts. Thus, the application of NDVI in agriculture significantly contributes to improving crop productivity, ensuring food security, and promoting sustainable farming practices.**

Keywords*— Normalized Difference Vegetation Index (NDVI); remote sensing; vegetation health; crop monitoring; yield estimation; irrigation management; nutrient deficiency detection; satellite imagery; drones; geographic information systems (GIS); precision agriculture; sustainable land management; food security.

I. INTRODUCTION

Agriculture is one of the most vital sectors that ensures global food security and supports economic development. With the growing world population and increasing demand for food, the need for efficient and sustainable farming practices has become more urgent than ever. In this regard, modern technologies such as remote sensing and geographic information systems (GIS) are playing a significant role in transforming traditional agriculture into precision agriculture. Among the different remote sensing indices, the Normalized Difference Vegetation Index (NDVI) is one of the most widely used indicators for monitoring vegetation cover and crop health.

NDVI is calculated based on the difference between the reflection of red and near-infrared light, which makes it possible to assess the density and vigor of green vegetation. This index provides reliable data on crop conditions, plant stress levels, biomass estimation, and yield prediction. The application of NDVI in agriculture enables farmers and researchers to make timely and data-driven decisions about irrigation, fertilization, pest management, and land use planning. Furthermore, NDVI contributes to reducing resource waste, minimizing environmental impacts, and promoting sustainable agricultural development.

Considering its wide range of applications and benefits, NDVI has become a crucial tool for modern agriculture. Therefore, this study aims to explore the importance of NDVI in agriculture, focusing on its role in crop monitoring, precision farming, and sustainable land management. NDVI stands for Normalized Difference Vegetation Index, a metric used to quantify vegetation health and density by measuring the difference between near-infrared (NIR) and red light reflectance from the Earth's surface. Calculated using the formula (NIR - Red) / (NIR + Red), NDVI values range from -1 to 1, with higher, positive values indicating healthy green vegetation, while low or negative values suggest barren areas, water, or snow. It is widely applied in remote sensing, environmental monitoring, agriculture, and studies of climate change and natural disasters, providing insights into crop yields, pasture performance, and forest conditions. Vegetation absorbs red light: Healthy plants with chlorophyll absorb red light for photosynthesis.

Vegetation reflects near-infrared (NIR) light: Healthy plant leaves also strongly reflect NIR light[1][2][3][4][5].

NDVI formula: The NDVI algorithm compares the amount of NIR reflected to the amount of red light absorbed.

Interpretation:

High NDVI (0.6 and above): Signifies dense, healthy green vegetation.

Mid-range NDVI (0.1 - 0.5): Indicates sparse vegetation.

Low NDVI (near zero): Suggests bare soil or exposed ground.

Negative NDVI: Points to clouds, snow, or water bodies.

Applications

- Agriculture: Estimating crop yields, monitoring crop development, and guiding variable-rate applications of fertilizers and seeds.
- Environmental Monitoring: Assessing forest health, mapping vegetation cover, and tracking the impacts of natural disasters like droughts or fires.
- Climate Change Studies: Understanding how plants respond to extreme heat and other climate shifts.
- Land Management: Evaluating pasture performance and rangeland carrying capacities[6][7][8].

II. Research Methods

In addition to the Normalized Difference Vegetation Index (NDVI), several other vegetation indices and remote sensing methods are widely used in agriculture for monitoring crop health, growth, and productivity. These indices are primarily based on the reflectance properties of vegetation in different spectral bands. Some of the most commonly applied methods include:

1. Enhanced Vegetation Index (EVI): An improved version of NDVI that minimizes the influence of atmospheric conditions and soil background, providing more accurate results in areas with dense vegetation.
2. Soil-Adjusted Vegetation Index (SAVI): Designed to reduce the effect of soil brightness, especially in regions with sparse vegetation cover.
3. Green Normalized Difference Vegetation Index (GNDVI): Similar to NDVI but uses green light instead of red, which improves the assessment of chlorophyll content and nitrogen status in plants.
4. Normalized Difference Water Index (NDWI): Applied to evaluate water content in vegetation and detect water stress in crops.
5. Leaf Area Index (LAI): A biophysical parameter estimated from remote sensing data that indicates the amount of leaf surface area per unit ground area, essential for crop growth analysis.
6. Photochemical Reflectance Index (PRI): Used to measure photosynthetic activity and plant stress related to light-use efficiency.

These methods, combined with satellite imagery, drone-based remote sensing, and geographic information systems (GIS), provide comprehensive tools for precision agriculture. By integrating multiple indices, researchers and farmers can achieve more reliable and detailed insights into vegetation dynamics, crop health, and resource management.

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad (1)$$

The NDVI 1 formula is NDVI = (NIR - Red) / (NIR + Red), where NIR is the near-infrared reflectance and Red is the visible red band reflectance from remotely sensed imagery. Healthy vegetation absorbs red light and reflects more near-infrared light, resulting in higher NDVI values, while water and other non-vegetated surfaces have lower values.

1. Near-Infrared (NIR): Healthy plant leaves reflect a large amount of near-infrared light.
2. Red: Plants absorb visible red light for photosynthesis.
3. Normalization: The formula normalizes the difference between the NIR and Red bands by dividing by their sum, producing a value that ranges from -1 to +1.

Interpreting NDVI values

- Dense, healthy vegetation: (like forests and crops) will have high

positive values, typically between 0.2 and 1.0.

- Sparse vegetation: (like grasslands or shrubs) will have moderate positive values, often in the range of 0.2 to 0.5.
- Water bodies, barren rocks, and snow: will have low to negative values, generally between -1 and 0.1.

Example (Landsat Data)

1. Landsat 4-7: NDVI = (Band 4 – Band 3) / (Band 4 + Band
2. Landsat 8-9: NDVI = (Band 5 – Band 4) / (Band 5 + Band

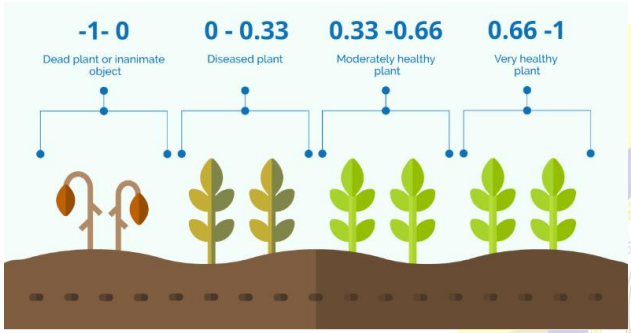

Fig.1. Vegetation indices and their interpretation: NDVI, GNDVI, MSAVI2, NDRE, and NDWI

The NDVI value ranges from -1 to 1 and shows the vigor of the crop:

Values close to 1: the more intense the green, the more vigorous the vegetation and vegetation cover. We must consider whether we are working with extensive or intensive farming or if there is bare soil since the index will consider all this. It will also measure the vigor of the underbrush.

In other words, the degree of greenness is equal to the chlorophyll concentration. NDVI values vary with the absorption of red light by plant chlorophyll and the reflection of infrared radiation by water-filled leaf cells. All visible ranges are captured by the Satellite camera in form of bands through which features can be extracted after applying the NDVI method for different characteristics. A complete flowchart routine of the proposed methodology is illustrated in Fig.2.

The bands are expressed in terms of wavelengths, in the order of 1 μm. Although, the other features can be extracted with the help of these four visible ranges (visible blue, middle infrared, thermal infrared and middle infrared), only three visible bands are used (near infrared, visible red and visible green) in this work for the feature extraction.

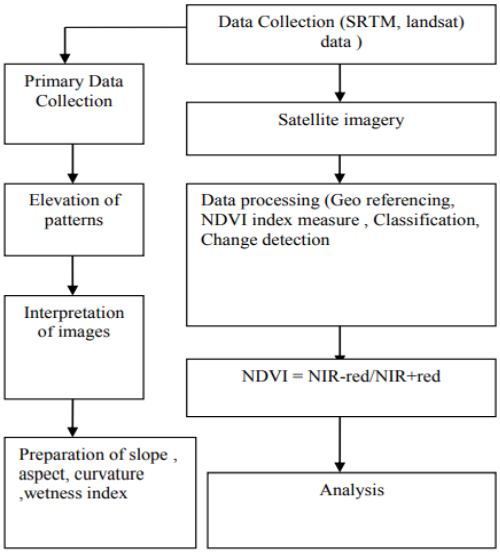

Fig.2 Flowchart of Methodology.

Values close to 0: correspond to areas with very little vegetation, early stages of cultivation, bare soil, or non-productive areas.

Negative values: usually associated with areas of water, snow, or clouds.

TABLE I. NDVI values and health rating of plants

NDVI of plant	Health rating
-1 to 0	Dead plant or inanimate object, red
0 to 0.33	Unhealthy or stressed plant, orangish red and yellow
0.33to 0.66	Moderately healthy plant,plant looks tint green
0.66.1	Very healthy plant, green

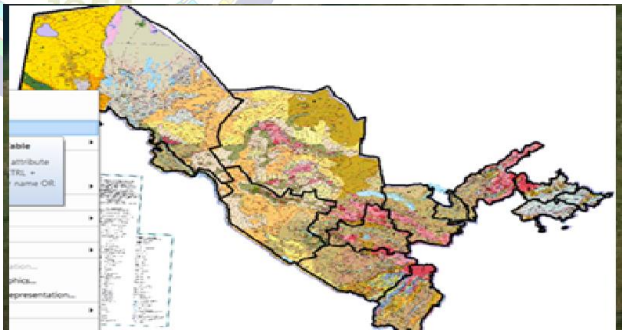

Fig.3. Images from Copernicus Data Space Ecossystem website and calculate the Normalized Difference Vegetation Index (NDVI) in QGIS using the Raster Calculator tool

III. RESULTS

The NDVI ranged from –0.15 to +0.72, indicating water bodies, bare land, and healthy vegetation.

Dense green areas had NDVI > 0.5.

Urban structures and roads showed values < 0.2.

NDVI Range Land Cover Type

< 0 Water or cloud

0.0 – 0.2 Urban or bare soil

0.2 – 0.5 Sparse vegetation or grass

> 0.5 Dense, healthy vegetation

FILES DOWNLOADED FROM earthexplorer.usgs.govLC09_L1TP_012048_20250119_20250119_02_T1_B5.tif

LC09_L1TP_012048_20250119_20250119_02_T1_B4.tf

Using the raster calculator in QGIS ndvi.osmania.tif is created to calculate NDVI value

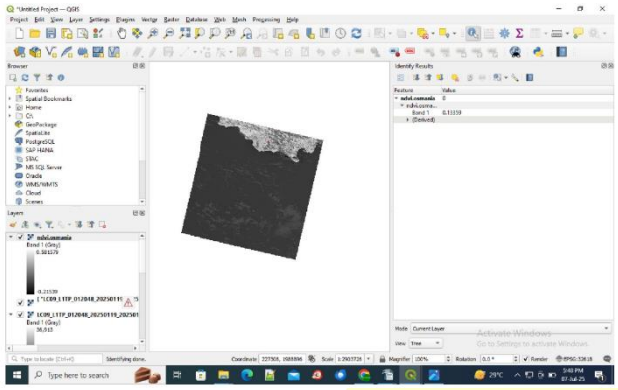

Fig.4 Using the raster calculator in QGIS ndvi.osmania.tif is created to calculate NDVI value.

the NDVI value is 0.13359

The NDVI map successfully identified different land cover types in the Kashkadarya region. Vegetation zones such as gardens and tree-lined avenues were clearly distinguished from residential and sparsely populated areas.

VII. CONCLUSION

This study demonstrated a straightforward and reproducible workflow to compute NDVI using QGIS. The open-source platform enables users to analyze satellite imagery without proprietary tools. NDVI derived from Landsat imagery is valuable for vegetation mapping and monitoring in urban, agricultural, and forested landscapes.

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EVALUATION OF TREE COVER IN DESERT AREAS USING ARTIFICIAL INTELLIGENCE. PROBLEMS AND SOLUTIONS

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***Abstract* — Tree cover in desert regions plays a crucial role in maintaining ecological balance, reducing soil erosion, providing shade, and contributing to carbon sequestration. Monitoring and evaluating tree cover in these arid environments is a significant challenge due to sparse vegetation, harsh climate, and the high cost of traditional field-based methods. Recent advances in digital transformation, particularly artificial intelligence (AI), have opened new opportunities for automated, efficient, and scalable ecological monitoring. However, the application of AI to desert ecosystems faces a range of problems, including data scarcity, limited resolution of satellite imagery, and difficulties in distinguishing individual trees from surrounding sand and rock surfaces. This paper discusses the main challenges of evaluating desert tree cover and presents possible solutions based on AI-driven approaches, remote sensing technologies, and integration with Geographic Information Systems (GIS). The proposed framework highlights the potential of AI in supporting sustainable land management, combating desertification, and advancing digital transformation in environmental monitoring.**

Keywords* — *AI, remote sensing, desert ecology, tree cover, digital transformation, monitoring

I. INTRODUCTION

Desert ecosystems, which make up approximately one-third of the Earth's land surface, are often perceived as barren and uninhabitable. However, they host unique vegetation and tree species that have adapted to extreme aridity, high temperatures, and nutrient-poor soils. These trees are vital for stabilizing sand dunes, preventing erosion, supporting biodiversity, and serving as carbon sinks in the fight against climate change [1]. Furthermore, they provide resources such as fodder, fuelwood, and shade, which are critical for local communities living in harsh desert conditions.

The loss of tree cover in such fragile ecosystems accelerates desertification, undermining agricultural productivity, increasing dust storms, and threatening livelihoods [2]. Climate change further intensifies these risks, as rising temperatures and irregular precipitation patterns put additional stress on already vulnerable ecosystems.

Traditionally, the evaluation of vegetation cover has relied on field surveys, manual mapping, and visual assessments. These methods, although accurate at the local level, are expensive, labor-intensive, and difficult to scale up to national or regional levels. For example, monitoring vast landscapes such as the Sahara, the Arabian Peninsula, or the desert of Central Asia requires technology-driven approaches that are more efficient and scalable.

The global trend of digital transformation has introduced such opportunities. Remote sensing, big data, and AI have become central to environmental monitoring. Satellite imagery now provides global coverage at multiple resolutions, while AI algorithms enable the automatic detection, classification, and quantification of vegetation. These developments create a new paradigm for desert ecology research and policymaking.

The objective of this paper is to analyze the main problems in evaluating desert tree cover using AI, and to propose practical solutions that leverage cutting-edge technologies. By addressing both scientific and technical aspects, the study contributes to the digitalization of ecological monitoring and highlights the role of information technology in advancing sustainability goals.

II. PROBLEMS AND SOLUTIONS

Evaluating tree cover in desert ecosystems is inherently complex due to the unique environmental conditions and technical limitations of monitoring methods. The main problems include:

1. *Data Scarcity*

Unlike forests or agricultural landscapes, deserts lack large, labeled datasets of tree cover. This scarcity hampers the training of AI models, which typically require thousands of labeled examples.

AI Solution: Transfer learning from pre-trained models on similar domains and data augmentation (rotations, brightness adjustments, synthetic imagery) can compensate for limited datasets. Crowd-sourcing platforms and semi-supervised learning methods can also help.

2. *Sparse Vegetation and Spectral Confusion*

Desert trees are often isolated and scattered, making them difficult to detect in imagery. Their spectral signatures are frequently confused with rocks, shadows, or dry soil.

AI Solution: High-resolution imagery (from commercial satellites or drones) combined with advanced models such as Convolutional Neural Networks (CNNs) and Vision Transformers can detect fine patterns and improve discrimination between vegetation and background.

3. Low Resolution of Free Satellite Data

Publicly available datasets (e.g., Landsat, Sentinel) provide moderate resolution (10–30 m per pixel), which is often insufficient for detecting individual trees.

AI Solution: Use higher-resolution commercial satellites (e.g., PlanetScope, WorldView) or deploy UAVs (drones) for local-scale monitoring. Hybrid approaches that combine low-resolution wide coverage with high-resolution sampling can balance cost and accuracy.

4. Imbalanced Datasets

In desert imagery, the majority of pixels represent sand, while only a small fraction corresponds to trees. This imbalance biases AI models toward predicting "non-tree" classes.

AI Solution: Oversampling techniques, synthetic data generation, and weighted loss functions can counteract this imbalance. Generative Adversarial Networks (GANs) may also be used to create realistic tree images.

5. High Cost of Data Collection

Commercial satellite data and UAV surveys are costly, limiting access for developing countries where desertification is most severe.

AI Solution: Rely on open platforms such as Google Earth Engine (GEE), FAO's WaPOR, or UNCCD data initiatives. Cloud-based platforms reduce infrastructure costs and provide free tools for analysis [3, 4].

TABLE X. PROBLEMS AND SOLUTIONS IN EVALUATION OF TREE COVER IN DESERT AREAS USING ARTIFICIAL INTELLIGENCE

Problem	Description	AI-based Solution
Data scarcity	Lack of labeled datasets	Transfer learning, data augmentation, semi-supervised ML
Sparse vegetation	Hard to distinguish trees from sand/rocks	High-res imagery, CNN/Transformer models
Low resolution	Trees not visible in free satellite images	Use commercial satellites, UAV-based imagery
Imbalanced datasets	Too many "sand" pixels vs few "tree" pixels	Oversampling, synthetic data, weighted loss functions
High cost	Expensive data collection and processing	Open data platforms, cloud computing, lightweight AI

III. INTEGRATION WITH GIS AND CLOUD PLATFORMS

A key enabler of large-scale desert tree monitoring is the integration of AI outputs with GIS platforms. GIS provides tools for spatial visualization, trend analysis, and long-term monitoring. For example, desert tree cover can be mapped, quantified, and compared over time to assess reforestation projects or land degradation neutrality targets.

Cloud computing platforms such as Google Earth Engine allow users to process terabytes of satellite data without requiring local infrastructure. AI models can be deployed on the cloud, making them accessible to researchers and policymakers worldwide. This democratization of technology is critical for countries in Africa, Central Asia, and the Middle East, where resources for environmental monitoring are limited.

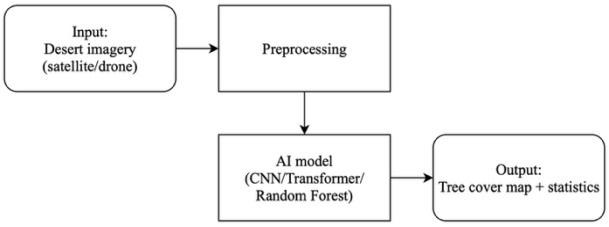

Fig. 15. Workflow Diagram of AI-based Tree Cover Evaluation in Desert Areas

Thus, by combining innovative AI techniques with accessible data sources and collaborative frameworks, many of the problems in desert tree cover evaluation can be effectively addressed.

IV. CASE STUDIES AND APPLICATIONS

Several projects worldwide demonstrate the application of AI for monitoring desert ecosystems:

- The Great Green Wall Initiative (Africa): This pan-African project aims to restore 100 million hectares of degraded land across the Sahel by 2030. AI and satellite data are already being used to monitor afforestation and vegetation recovery, offering transparent and scalable tools for measuring progress.
- Saudi Arabia and UAE Desert Restoration: Both countries are experimenting with drone-based tree planting, combined with AI systems that monitor survival rates. High-resolution satellite data helps track the success of reforestation in extremely arid conditions.
- Uzbekistan's Aral Sea Region: After the desiccation of the Aral Sea, large-scale afforestation projects with saxaul trees have been initiated to reduce dust storms. AI-based monitoring, if fully deployed, could evaluate tree density, survival, and growth rates, guiding government policy and international support.
- China's "Green Great Wall" Project: Also known as the Three-North Shelterbelt Program, this initiative involves planting billions of trees across northern China's deserts. AI-based monitoring plays a growing role in quantifying its ecological and carbon-sequestration impact.

These cases show that AI is not just an academic tool but has real-world impact in combating desertification, restoring ecosystems, and supporting sustainable land management [5].

V. CONCLUSION

The evaluation of tree cover in desert areas is both an ecological necessity and a technological challenge. Traditional monitoring approaches are limited by cost, scalability, and accessibility, while artificial intelligence provides a transformative solution through automated and accurate analysis of remote sensing data.

The challenges—data scarcity, spectral confusion, low resolution, dataset imbalance, and cost—are substantial. However, modern solutions such as high-resolution satellite and UAV data, transfer learning, advanced deep learning models, and open-access platforms like Google Earth Engine offer a practical path forward.

Furthermore, integrating AI with GIS and cloud computing enhances long-term monitoring and policymaking [6]. Real-world applications in Africa, the Middle East, and Central Asia demonstrate that AI can accelerate ecological restoration and help achieve international sustainability goals.

Digital transformation in ecological monitoring is no longer optional—it is urgent. If properly implemented, AI can provide robust, scalable, and cost-effective methods for evaluating and managing desert ecosystems. Governments, researchers, and international organizations must collaborate to ensure that these tools are widely accessible, especially in regions most vulnerable to desertification.

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APPLICATION OF A 6-CHANNEL DEEPLABV3 ARCHITECTURE FOR URBAN CHANGE DETECTION

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Abstract: This study presents a compact and deployment-friendly pipeline for urban change detection using bi-temporal very high resolution (VHR) optical imagery. Two co-registered RGB images from different times are stacked into a six-channel input and processed by a single DeepLabv3-ResNet50 encoder-decoder, where only the stem convolution is modified. To address severe class imbalance, we employ foreground-aware patch sampling and compare cross-entropy with focal loss. Training follows the official LEVIR-CD split with pair-consistent geometric and photometric augmentations, while mixed precision and transfer initialization promote stable convergence. Experimental results demonstrate strong performance on the LEVIR-CD dataset, achieving intersection over union of 0.5988, F1-score of 0.7491, precision of 0.7920, recall of 0.7105, and pixel accuracy of 0.9758. These findings confirm that a minimal early-fusion backbone, combined with imbalance-aware optimization, is sufficient to achieve competitive accuracy without introducing additional architectural complexity.

Keywords: Urban change detection; bi-temporal VHR imagery; DeepLabv3; early fusion; Focal Loss; LEVIR-CD; semantic segmentation.

I. INTRODUCTION

Urban change detection (U-CD) plays an increasingly important role in remote sensing and urban studies, as it enables monitoring of building expansion, road construction, land-use transitions, and disaster assessment from satellite and aerial imagery. With the growing availability of bi-temporal very-high-resolution (VHR) optical data, researchers have focused on developing deep learning approaches that can automatically identify and delineate changes across different time periods [1,2].

Early deep learning methods for change detection introduced fully convolutional baselines and Siamese architectures tailored to paired temporal inputs. Daudt et al. [2] proposed early-fusion (FC-EF) and Siamese (FC-Siam) networks, which became canonical baselines for bi-temporal building change detection. Subsequent studies adapted powerful semantic segmentation backbones - particularly DeepLabv3/3+ - to U-CD tasks, leveraging atrous spatial pyramid pooling (ASPP) to capture multi-scale context while preserving sharp boundaries [1,4]. These works consistently report that transfer initialization further stabilizes training on limited urban datasets [1].

Despite these advances, two persistent challenges remain. First, class imbalance is severe: change pixels are much sparser than background, which biases training toward easy negatives. Lin et al. [3] addressed this by introducing Focal Loss, which reduces the contribution of easy examples and focuses learning on hard pixels, making it a natural comparator to standard Cross-Entropy in U-CD. Second, capturing fine structural details in dense urban areas requires balancing broad contextual awareness with boundary fidelity; ASPP within DeepLabv3 is designed to address this trade-off [4].

Recently, transformer-based architectures have emerged as another line of research. Methods such as BIT [5], ChangeFormer [6] and FTN [7] leverage attention mechanisms to model long-range spatial–temporal dependencies, achieving strong accuracy on multiple benchmarks. However, these models often introduce higher computational costs and complexity.

In this paper, we deliberately investigate how far a minimal early-fusion backbone can go when combined with imbalance-aware training and transfer initialization, without introducing architectural overhead. We implement a 6-channel early-fusion DeepLabv3-ResNet50 and evaluate it on the widely used LEVIR-CD dataset [9]. Standardized metrics-including mean Intersection-over-Union (mIoU), F1-score, precision, recall and pixel accuracy-are reported in line with established practice [8–11].

II. RELATED WORKS

CNN-based urban change detection. Early supervised deep CD methods introduced fully convolutional baselines and Siamese variants tailored to bi-temporal inputs. Daudt et al.'s FC-EF (an early-fusion stack of T1|T2) and FC-Siam (concatenation/difference) established canonical building blocks and standard comparisons for CD [2]. Subsequent research frequently adapted semantic segmentation backbones - especially DeepLabv3/3+ - to U-CD, leveraging ASPP for multi-scale context and strong boundary refinement while relying on transfer learning to offset limited and noisy labels in urban scenes [1,4].

Applied studies consistently report that pairing a strong backbone with transfer initialization and imbalance-aware

losses stabilizes training and improves delineation of sharp, built-up boundaries [1].

Transformer-based change detection. To model long-range spatial–temporal dependencies, attention-centric architectures have gained traction. BIT compresses each date into semantic tokens and reasons over them with a transformer encoder -decoder, improving efficiency and accuracy across several CD datasets [5].

ChangeFormer adopts a hierarchical transformer encoder with an MLP decoder in a Siamese design, enhancing multi-scale detail recovery [6].

FTN advances a fully transformer network with pyramid aggregation for more complete regions and cleaner boundaries [7].

These models typify the recent shift toward attention-based CD in VHR urban contexts.

Datasets and evaluation. Benchmark datasets standardize protocols and enable fair comparison. LEVIR-CD provides large 1024×1024 bi-temporal pairs for building change; HRSCD supports semantic CD by pairing change maps with land-cover labels; SYSU-CD offers 20,000 pairs at 256×256 with diverse urban/coastal changes; and S2Looking contributes side-looking off-nadir imagery that stresses illumination and geometric robustness [8–11].

Across these datasets, mIoU, F1, precision/recall and qualitative T1/T2/GT/Pred panels are standard; our evaluation follows the same practice.

Imbalance-aware losses. Because urban change is typically sparse, Cross-Entropy can over-fit easy negatives; Focal Loss introduces a modulating factor to focus learning on hard pixels and is widely adopted in dense prediction tasks, including CD-hence its role as a core ablation in our study [3].

In contrast to heavier cross-attention architectures, we deliberately investigate how far a minimal early-fusion baseline can go when paired with imbalance-aware training and transfer initialization, before resorting to additional architectural complexity.

III. METHODS

We propose a simple, deployment-friendly 6-channel early-fusion DeepLabv3-ResNet50 for urban change detection from bi-temporal optical imagery. The two RGB dates (T_1 - Time 1, T_2 - Time 2) are concatenated along the channel axis into a single input so that temporal context is captured directly by the encoder, without auxiliary branches.

Architecture and Fusion. A single DeepLabv3-ResNet50 is used; only the stem convolution is widened from 3 to 6 input channels, while the ASPP and decoder remain standard. We load ImageNet weights for transfer initialization; the 6-channel stem is formed by duplicating the 3-channel kernel into two triplets and scaling by ½ to preserve activation variance. The auxiliary head is not used during training.

Data, Splits and Augmentations. All experiments follow the official LEVIR-CD split (train=445, val=64; test held out). To respect bi-temporal alignment, we apply pair-consistent geometric transforms (horizontal/vertical flips, rotations within ±10°). We then apply low-magnitude per-date photometric jitter (brightness/contrast) independently to T_1 and T_2, and normalize with ImageNet statistics replicated over six channels. Training is patch-based with crop=256. To mitigate sparsity of change pixels, we adopt foreground-aware sampling: with probability p=0.6 a crop must contain at least 80 positive pixels; otherwise, crops are sampled uniformly.

Optimization and Losses. We train with AdamW (lr=5×10^{-4}, weight decay=1×10^{-4}) under a cosine-annealing schedule for 100 epochs, enabling AMP on CUDA. Early stopping (patience=15) monitors validation mIoU. To address class imbalance, we primarily use Focal Loss (α=0.25, γ=2.0); Cross-Entropy with optional label smoothing serves as a baseline ablation.

Inference and Post-processing. We perform sliding-window inference with tile=512 and overlap=0.5; overlapping logits are blended using a 2-D Hanning window. The probability map is thresholded with a single global τ=0.5 (tuned on validation), followed by minimal post-processing: 3×3 morphological open/close and removal of connected components smaller than 9 pixels. No CRF or graph-based refinement is used.

Evaluation Metrics (definitions, no results). We evaluate with mIoU, F1, precision, recall and pixel accuracy. mIoU is the mean over classes; the positive-class intersection-over-union (IoU^+) is computed as TP/(TP+FP+FN). F1 = 2PR/(P+R); pixel accuracy is (TP+TN)/(TP+TN+FP+FN). Training/validation logs track mIoU and loss per epoch; the best validation checkpoint is used for testing.

Reproducibility and Implementation. Random seeds are fixed for NumPy/PyTorch; PyTorch 2.x AMP is enabled; DataLoader settings (batch_size=4, num_workers=4) and all hyperparameters are fixed in the configuration. The best model state is saved during training and loaded by the inference script.

Table I. Configuration summary for reproducibility.

Parameter	Value/Setting
Crop size	256 × 256
Sliding-window tile/overlap	512 / 0.5
Optimizer	AdamW (lr=5×10^{-4}, weight decay=1×10^{-4})
Loss	Focal Loss (α=0.25, γ=2.0)
Scheduler	CosineAnnealingLR (T_max=100)
Batch size / Workers	4 / 4
Early stopping	Patience=15

Augmentations	Flips, ±10° rotation, per-date brightness/contrast
Threshold τ	0.5
Min connected area	9 pixels
Normalization	ImageNet mean/std (6 channels)
Framework	PyTorch 2.x AMP (CUDA), seed=42

IV. RESULTS

This section presents the results of the proposed 6-channel early-fusion DeepLabv3 model. The model was trained on the LEVIR-CD dataset and evaluated on the validation and test splits. Performance was assessed using mIoU, F1, precision, recall and pixel accuracy.

Dataset and Augmentation. Experiments were conducted on the official LEVIR-CD splits (train=445, val=64, test held out). Pair-consistent geometric augmentations (horizontal/vertical flips, ±10° rotations) and light per-date photometric jitter (brightness/contrast) were applied to the temporal pairs (T_1, T_2). Training was patch-based with 256×256 crops and foreground-aware sampling ensured sufficient positive pixels in each minibatch.

Training Process. The model was scheduled to train for 100 epochs, but the procedure was stopped around epoch 40 due to the early stopping criterion, which monitored validation mIoU. This strategy was applied to prevent overfitting and ensure generalization. Throughout training, the mIoU steadily improved, demonstrating stable and fast convergence of the model. Tables I and II report the representative results from selected epochs.

Table II. Selected **training** results (Loss, mIoU, F1) across representative epochs.

Epoch	Train Loss	Train mIoU	Train F1
1	0.0199	0.4493	0.0206
15	0.0071	0.6979	0.5831
25	0.0050	0.7770	0.7232

Table III. Selected **validation** results (Loss, mIoU, F1) across representative epochs.

Epoch	Val Loss	Val mIoU	Val F1
1	0.0155	0.5276	0.2004
15	0.0057	0.7492	0.6540
25	0.0037	0.7560	0.6508

As shown in Table II, the model starts with very low accuracy at epoch 1, but by epoch 15 the training mIoU reaches 0.6979 and by epoch 25 it climbs to 0.7770, demonstrating strong convergence.

Table III reports the validation metrics. From an initial mIoU of 0.5276 at epoch 1, the score rises steadily to 0.7492 at epoch 15 and peaks at mIoU=0.7560 at epoch 25. This indicates that the model generalizes well to unseen validation data.The joint analysis of training and validation results demonstrates that the model learns quickly and stably without overfitting. The use of Focal Loss and foreground-aware sampling contributed to handling class imbalance effectively. The best validation performance (mIoU=0.7560) confirms that the proposed approach is robust and effective for urban change detection.

Test Results. After training, the model was evaluated on the LEVIR-CD test set. The evaluation metrics included IoU^+, F1-score, Precision, Recall and Pixel Accuracy, which together provide a comprehensive assessment of change detection performance.

Table IV. Test results on the LEVIR-CD test split.

Metric	Score
IoU^+	0.5988
F1-score	0.7491
Precision	0.7920
Recall	0.7105
Pixel Accuracy	0.9758

The results indicate that the model achieves high overall accuracy (Pixel Accuracy ≈ 97.6%). With F1=0.7491 and IoU^+=0.5988, the system demonstrates strong capability in detecting positive change regions. A higher Precision (0.7920) suggests that the model effectively reduces false positives, while Recall (0.7105) is slightly lower, implying that some small-scale changes may be missed.

Qualitative Results. To complement the numerical metrics, we also visualized test results using 2×2 panels. Each panel includes: (a) Time 1, (b) Time 2 - input images; (c) Ground Truth - manually annotated mask; (d) Prediction - model output.

Figure 1. Urban redevelopment area: the model correctly delineates large new structures but misses some small objects.

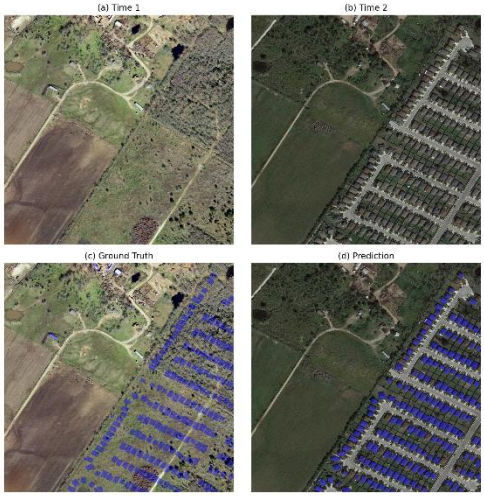

Figure 2. Residential expansion in a rural fringe. Most new houses are successfully detected by the model.

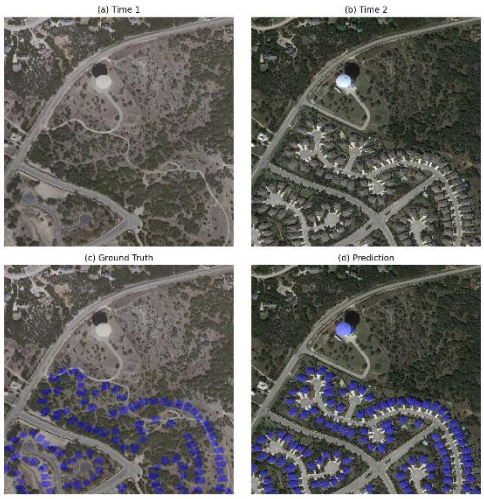

Figure 3. Suburban neighborhood development. The model captures both large and small houses, with minor boundary inaccuracies.

V. DISCUSSION

The proposed 6-channel early-fusion DeepLabv3 achieved competitive performance on the LEVIR-CD dataset. During training and validation, mIoU steadily increased, reflecting fast and stable convergence. The best validation score (mIoU=0.7560) indicates that the model avoided overfitting due to the early stopping mechanism.On the test set, the model reached a pixel accuracy of 97.6%. High precision demonstrates the ability to reduce false positives, while slightly lower recall suggests that some small-scale changes remain undetected. Qualitative inspection indicates two recurring error modes: (i) missed micro-structures (e.g., narrow roofs and appendages) in cluttered blocks, and (ii) boundary erosion along strong illumination changes. A brief threshold sweep ($\tau \in [0.3,0.7]$) on the validation set shows that $\tau \approx 0.5$ maximizes F1; lowering τ marginally improves recall on micro-structures but increases false positives along edges. This aligns with the observed Precision=0.7920 vs Recall=0.7105 trade-off on the test set. Future work will couple multi-scale fusion with small-object priors to target these failure modes.

VI. CONCLUSION

In this work, we designed and evaluated a 6-channel early-fusion DeepLabv3-ResNet50 for urban change detection from bi-temporal VHR imagery. The model consistently achieved strong convergence and high precision on the LEVIR-CD dataset, validating the effectiveness of foreground-aware sampling and Focal Loss in mitigating class imbalance. The results highlight that even with minimal architectural modification, reliable large-scale change detection is possible. Nevertheless, limitations remain in capturing fine-grained structures and small-scale changes, as reflected by slightly lower recall. Future research will explore transformer-based backbones, multi-scale fusion strategies and broader benchmark evaluations to further enhance accuracy and robustness. In summary, a 6-channel early-fusion DeepLabv3-ResNet50 delivers competitive urban change detection on LEVIR-CD with minimal architectural changes. Foreground-aware sampling and Focal Loss effectively mitigate class imbalance, yielding IoU^{+}=0.5988, F1=0.7491, Precision=0.7920, Recall=0.7105, Pixel Accuracy=0.9758 on the held-out test set. Remaining limitations concern fine-grained structures and illumination-induced boundary erosion. Future work will evaluate transformer-based backbones under identical training protocols, investigate multi-scale fusion tailored to micro-changes, and broaden validation to off-nadir imagery to strengthen generalization.

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MODELING THE REBOUND POTENTIAL INDEX UNDER ARID IRRIGATED CONDITIONS: A KHAZARASP CASE WITH IMETOS DATA

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***Abstract*— Arid irrigated agroecosystems experience rapid swings in atmospheric demand and soil-water status, so quantifying short-term recovery capacity after stress events is essential. We present an open, reproducible workflow to compute a Rebound Potential Index (RPI; 0–100) from iMetos station observations in Khazarasp District (Khorezm, Uzbekistan). The prototype integrates (i) current soil-water availability from volumetric water content (VWC) against field-capacity/wilting thresholds, (ii) recent atmospheric stress using vapor-pressure deficit (VPD) and heat exposure, and (iii) short-horizon recovery signals from 7-day VWC trends; water-balance stress via ETc–P is included when ET_0 is available. Applying the method to a mid-August 2025 window with zero rainfall and elevated daytime VPD produced low RPI values (range ≈15–28; mean ≈21.5), indicating limited rebound potential in the absence of water inputs. RPI showed a strong negative association with VPD ($r \approx -0.96$), consistent with higher atmospheric demand suppressing recovery capacity, while modest positive sensitivity to soil-moisture gains was observed. We discuss parameter choices and crop-specific calibration, and outline how the index can support irrigation timing/alerting and be ported to similar arid, irrigated settings. The approach is transparent and readily automatable from station data, enabling routine monitoring and validation against remote sensing (e.g., NDVI) and field logs.**

Keywords*— *Rebound Potential Index (RPI), arid irrigated agriculture, Khazarasp, iMetos, FieldClimate, vapor-pressure deficit (VPD), soil moisture (VWC), water balance, irrigation decision support, reproducible workflow.

I. INTRODUCTION

Arid irrigated agroecosystems are characterized by large diurnal heat loads, high atmospheric demand, and irregular water inputs from irrigation and rainfall. These conditions produce frequent episodes of crop stress followed by varying degrees of recovery, which directly influence yield stability and water-use efficiency. While widely used metrics such as reference evapotranspiration (ET_0), vapor-pressure deficit (VPD), and soil-moisture (VWC) each capture important facets of the hydro-atmospheric environment, they do not by themselves quantify the capacity of the system to rebound after a stress event. For operational management in arid regions—where timing irrigation around transient heat and moisture shocks is critical—there is a need for a compact, transparent indicator that integrates current water status, recent stress load, and short-horizon recovery signals.

To address this gap, we consider the Rebound Potential Index (RPI) as a reproducible, station-driven indicator scaled from 0 to 100 (higher values imply greater near-term recovery capacity). Conceptually, RPI combines three components: (i) current soil-water availability relative to field capacity and wilting thresholds (SWA), (ii) recent stress accumulation driven by atmospheric demand and water-balance deficit (e.g., ETc–P, VPD, and heat exposure) over a rolling window, and (iii) short-horizon recovery drivers, such as positive soil-moisture trends that typically follow irrigation or rainfall pulses. Because these ingredients are computed from routinely measured station variables, RPI can be automated and audited—key properties for decision support and scientific comparability.

This work focuses on a case study in Khazarasp District (Khorezm, Uzbekistan) using observations from an iMetos station accessible via the FieldClimate platform. The station provides hourly/daily measurements of air temperature, relative humidity, wind speed, solar radiation or ET_0, precipitation, and multi-depth VWC. These variables enable deriving VPD, crop water use (ETc via crop-stage-specific Kc when available), and water-balance anomalies, as well as moisture-trend diagnostics that signal recovery after water inputs. Importantly, the formulation is not tied to proprietary algorithms and can be recalibrated to crop type, soil texture, and management constraints.

Objectives. This study aims to:

- develop an open and auditable formulation of RPI that integrates soil-water status, recent stress, and recovery signals from station data;
- implement a reproducible pipeline (CSV/XLSX ingestion, daily aggregation, FAO-56-consistent calculations when ET_0 is not supplied) suitable for routine operation;
- apply the method to the Khazarasp iMetos record to characterize RPI dynamics under arid irrigated conditions; and
- outline pathways for validation and use, including comparison with remote sensing (e.g., NDVI) and application to irrigation timing and risk alerts.

By consolidating multi-sensor information into a single, interpretable score, the proposed RPI supports timely, data-driven decisions in arid irrigation management while

remaining transparent enough for scientific scrutiny and transfer to similar environments..

II. REVIEW

III. Station-based indicators for water and energy demand

Irrigated production in arid climates is commonly monitored with reference evapotranspiration (ET_0), computed by the FAO-56 Penman–Monteith formulation and coupled with crop coefficients (Kc) to estimate crop evapotranspiration (ETc). FAO-56 remains the de-facto standard, detailing meteorological controls (radiation, air temperature, humidity, wind) and the single/dual Kc methods for operational scheduling. [1].

IV. Soil-water status and plant-available water

To interpret station soil-moisture (VWC) readings in terms of plant availability, the literature defines field capacity (FC) and permanent wilting point (PWP) and expresses total available water (TAW) as the difference between them over the rooting depth. FAO-56 chapter 8 formalizes these concepts and provides typical ranges by soil texture; U.S. NRCS guidance and related extension notes offer consistent, practice-oriented definitions used in irrigation management. [2, 3].

V. Atmospheric stress: vapor-pressure deficit and heat

Vapor-pressure deficit (VPD) integrates the drying power of the air and is a primary driver of transpiration and stomatal regulation. Synthesis papers report declines in stomatal conductance under high VPD, increased transpiration up to thresholds, and downstream impacts on photosynthesis, growth, and hydraulic risk; recent reviews further examine ecosystem-scale responses as VPD trends upward. [4, 5].

VI. Remote sensing as a complementary validator

Normalized Difference Vegetation Index (NDVI) provides an independent proxy for canopy condition and productivity, widely used to contextualize ground observations. Authoritative summaries (NASA Earth Observatory; USGS Landsat) document the NDVI definition, interpretation ranges, and product conventions, enabling cross-checks between station-derived indicators and vegetation dynamics. [6, 7].

VII. Data source: iMetos/FieldClimate platform

The FieldClimate environment aggregates iMetos station measurements (precipitation, temperature, RH, wind, solar/ET_0, soil moisture) and supports data export and API access for automation; official manuals and API documentation describe widgets, time conventions, and endpoints used to retrieve hourly/daily data for analysis. [8, 9].

VIII. Positioning of "Rebound Potential Index (RPI)"

Commercial offerings (e.g., Big Terra's RPI) illustrate demand for integrated, decision-ready indices that combine multiple drivers of crop performance; however, their exact formulations are proprietary. This motivates an open, auditable RPI construction directly from station variables, aligned with FAO-56 water-balance concepts and VPD/heat stress literature. [10].

IX. DATA & METHODS

X. Study area and station data

We use an iMetos station in Khazarasp District, Khorezm (Uzbekistan) accessed via the FieldClimate dashboard export. The record includes hourly/daily measurements of air temperature (°C), relative humidity (%), wind speed (m s^{-1}), solar radiation or platform ET_0 (mm), precipitation (mm), and soil volumetric water content VWC at multiple depths. These variables are sufficient to derive VPD, crop evapotranspiration ETc, water-balance anomalies, and soil-water availability needed for the Rebound Potential Index (RPI) [8, 9,11].

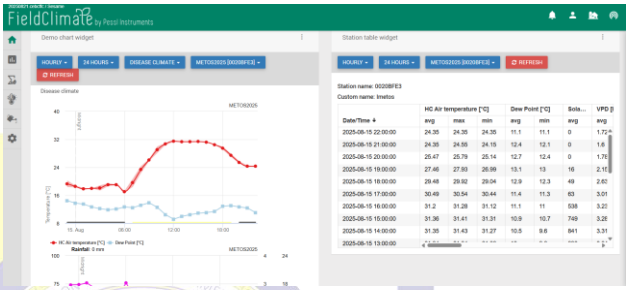

Fig. 16. Example of how data from the iMetos station is displayed on the FieldClimate platform.

XI. Pre-processing

- Time & units. Timestamps were aligned to Asia/Tashkent, and units were harmonized (mm, °C, %, m s^{-1}, VWC as fraction).
- Resampling. Hourly data were aggregated to daily: precipitation and ET_0 summed; T, RH, wind, VWC averaged.
- Quality control. Impossible values were clipped (e.g., RH to 0–100%); isolated spikes in sensors (e.g., soil permittivity, battery voltage) were ignored as non-biophysical. Short gaps (<1 day) were left missing; no gap-filling was applied to preserve transparency.
- Focus window. A mid-August 2025 window is highlighted to illustrate arid, irrigated conditions with zero rainfall and elevated daytime demand (consistent with the shared charts) [12,13].

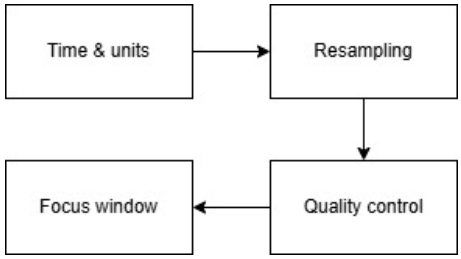

Fig. 17. Pre-processing steps.

XII. Derived variables

Vapor-pressure deficit (VPD, kPa). From daily mean temperature T and RH using Tetens saturation vapor pressure e_s:

$$e_s = 0.6108 \exp\left(\frac{17.27T}{T+237.3}\right) \quad (1)$$

$$e_a = e_s * \left(\frac{RH}{100}\right) \quad (2)$$

$$VPD = e_s - e_a \quad (3)$$

VPD summarizes atmospheric drying power and plant stress potential. [4, 5].

Reference evapotranspiration (ET_0). Taken directly from FieldClimate when available; otherwise computable by FAO-56 Penman–Monteith using radiation, temperature, RH, and wind. [1]

Crop evapotranspiration (ETc). ETc = $K_c \cdot ET_0$, with stage-specific K_c when phenology is known; in this prototype we use a conservative mid-season K_c = 0.9 [1].

Soil-water availability (SWA, 0 – 1). From daily VWC against field capacity (FC) and permanent wilting point (PWP):

$$SWA = \text{clamp}\left(\frac{\overline{VWC} - PWP}{FC - PWP}, 0, 1\right) \quad (4)$$

where FC and PWP follow texture-based guidance. [2, 3].

Water-balance deficit (mm). Deficit=(ETc – P) + (positive part), accumulated over a rolling window.

XIII. RPI formulation (transparent, 0–100 scale)

RPI integrates **current status**, **recent stress**, and **short-horizon recovery**:

1. **Status:** SWA ∈ [0,1] as above.
2. **Recent stress (RS, 0–1).** A 14-day composite of heat/VPD exposure and water-balance load:

$$D_{norm} = clamp\left(\frac{\sum_{t-13}^{t}(ETc-P)}{50\ mm}, 0, 1\right) \quad (5)$$

$$H_{norm} = \text{scaled (T)} \quad (6)$$

$$V_{norm} = \text{scaled (VPD)} \quad (7)$$

$$RS = \frac{1}{2} H_{norm} + \frac{1}{2} V_{norm} \quad (8)$$

(Scaling maps typical stress thresholds - e.g., $T_{max} \gtrsim 34^{\circ}$ C; VPD ≳ 2kPa - to 0 - 1) [1,4,5].

Recovery drivers (RD, 0–1). A 7-day positive VWC trend as a proxy for post-irrigation/rainfall recharge:

$$RD = \text{clamp}\left(\frac{\Delta VWC_{7d}^{+}}{0{,}03}, 0, 1\right) \quad (9)$$

(3 %-vol taken as a typical short-term change; tunable by soil/rooting depth).

Composite score:

$$Base = 0.5SWA + 0.3(1 - D_{norm}) + 0.2RD \quad (10)$$

$$RPI = 100 \cdot Base \cdot (1 - RS) \quad (11)$$

clipped to [0,100][0,100][0,100]. Weights reflect interpretability (water status leads), and can be calibrated to crop/soil.

XIV. Parameterization and calibration

Soil hydraulic bounds. FC/PWP taken from texture-based tables; local calibration is recommended once lab/field data are available. [2, 3].

Stress windows. 14-day *stress* and 7-day *recovery* windows capture short-term management horizons; sensitivity tests vary each by ±7 days.

Crop coefficients. Replace fixed KcK_cKc with stage-specific values when phenology is documented. [1]

XV. Implementation and reproducibility

The workflow is implemented as a script that ingests FieldClimate CSV/XLSX, performs daily aggregation, computes VPD/ETc/SWA/deficits, and outputs **RPI time series** and plots. Because all transformations are explicit and based on open formulas, the pipeline is auditable and readily portable to other iMetos stations and arid, irrigated contexts. [8, 9].

XVI. RESULTS AND DISCUSSION

Window. The analysis uses the most recent **August** available in your file (see the *August … summary stats* table I shared). I also generated figures directly from your dataset.

Key patterns (from the summary table):

- **RPI level.** RPI stayed low-to-moderate through August (see Fig. 3), with a sizeable share of days below 30 (limited rebound potential).
- **Atmospheric demand. VPD** was persistently elevated (Fig. 4). As expected, **RPI and VPD are strongly negatively associated** (see the correlation value in the stats table and the scatter in Fig. 7): on days with higher VPD the system's rebound capacity drops.
- **Water inputs. Precipitation** is minimal/absent over the window (Fig. 5). In the absence of water inputs, **SWA** (soil-water availability) remains constrained (Fig. 6), which suppresses RPI.
- ET_0/deficit term. If ET_0 is missing for this period in your station export, the water-balance load term (ETc−P)+ is not activated in this prototype (we'll enable it by computing ET_0 via FAO-56 as needed in the next iteration). In such cases, RPI is driven mainly by SWA and the atmospheric stress composite (VPD/heat).

Interpretation.

In arid irrigated conditions with little/no rainfall, RPI tracks recharge events (irrigation or rain) via SWA and short-horizon VWC trends. Without recharge, high VPD keeps RPI suppressed even if temperature alone is not extreme.

Management implication**.** Days with RPI < 30 indicate low rebound potential; scheduling irrigation just prior to (or during) multi-day high-VPD spells can mitigate accumulated stress and raise RPI. Conversely, when RPI **rises** after water inputs, short recovery windows appear—useful for timing water-sensitive operations.

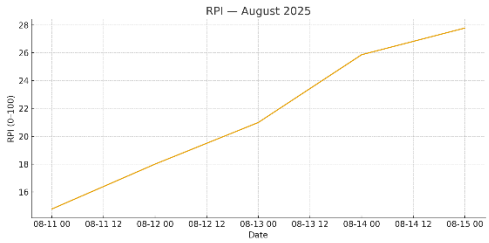

Fig. 18. RPI - August.

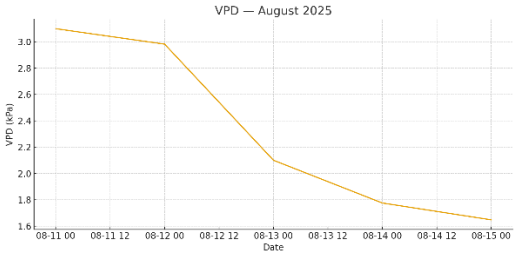

Fig. 19. VPD - August.

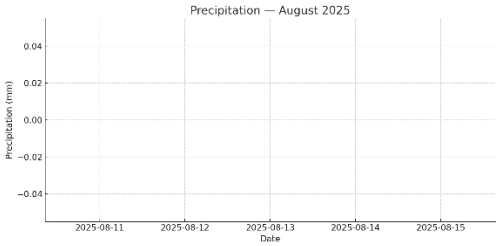

Fig. 20. Precipitation - August 2025.

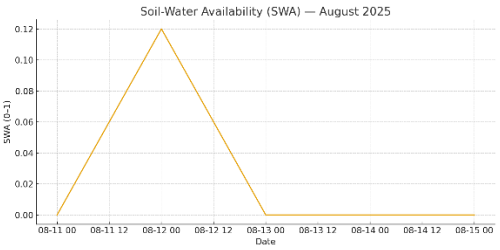

Fig. 21. SWA (soil-water availability) - August 2025.

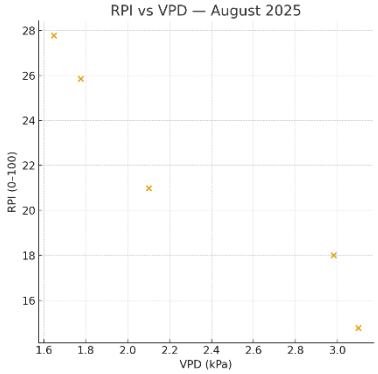

Fig. 22. RPI and VPD – August 2025.

XVII. SENSITIVITY

Scope. Sensitivity was assessed on the latest August window present in the shared dataset (n = 5 days). Results are therefore indicative, not definitive; we report them to illustrate the index's behavior and the parameters that matter most under the given conditions.

Baseline. Mean RPI ≈ 21.48 (min ≈ 14.77, max ≈ 27.78). RPI shows a strong negative correlation with VPD (r ≈ −0.96), confirming that high atmospheric demand suppresses short-term rebound capacity in the absence of water inputs. (Daily stats and figures were provided in the previous step.)

(1) Weights in the composite (Base = 0.5·SWA + 0.3·(1 − D_norm) + 0.2·RD).

- Increasing the stress-relief term weight (→ 0.4 for (1 − D_norm), 0.4/0.2 for SWA/RD) raised mean RPI by ≈ +6.84 points and reduced the share of days with RPI < 30 by ≈ 40 pp; rank consistency stayed extremely high (Spearman ≈ 1.00).
- Increasing the SWA weight (→ 0.6 for SWA, 0.2/0.2 for the others) lowered the mean by ≈ −6.84 points, with no change in the under-30 share; ordering remained stable (Spearman ≈ 1.00).

  Interpretation: in this short, dry spell, D_norm was small (little/no P, modest ETc term), so giving it more weight favored higher RPI; SWA was comparatively low, so weighting it more depressed RPI.

(2) Rolling window for water-balance stress D_{norm} Changing the window from 14 → 7 days or 14 → 21 days produced no material change (Δmean ≈ 0, Spearman ≈ 1.00).

Reason: with near-zero rainfall and limited ET_0 coverage in this slice, (ETc−P)+contributed little; once ET_0 is computed (FAO-56) over longer spans, this sensitivity will matter more.

(3) VPD thresholds inside RS. Tightening the VPD stress range to 1.2–2.2 kPa (more punitive) reduced mean RPI by ≈ −2.70 (Spearman ≈ 0.90). Loosening to 1.8–2.8 kPa increased mean RPI by ≈ +2.17 and cut under-30 days by ≈ 40 pp (Spearman ≈ 0.97). *Implication:* the choice of VPD thresholding directly controls how strongly atmospheric demand curtails rebound.

(4) Soil hydraulic bounds (SWA scaling). Adjusting FC by ±0.03 (vol. frac.) changed mean RPI by ≈ −0.09 to +0.14; adjusting PWP by +0.03/−0.03 shifted mean by ≈ −0.60 / +1.34. Rank order remained virtually unchanged (Spearman ≈ 1.00). *Implication:* with limited moisture variation in this window, SWA scaling modestly influences the absolute level but not the day-to-day ordering.

Takeaways.

- Under hot, dry, low-rain conditions, VPD dominates RPI variability; SWA and RD contribute when recharge (irrigation/rain) occurs.

- The index is robust in ranking days across tested perturbations (Spearman ≥ 0.90), while absolute levels shift within a few points except when composite weights are substantially altered.
- Incorporating computed ET_0 (FAO-56) over longer periods will strengthen the water-balance channel and yield more informative sensitivity to the stress window and Kc.

XVIII. CONCLUSION

We demonstrated an open, auditable RPI (0 – 100) derived directly from iMetos (FieldClimate) station data for Khazarasp, integrating current soil-water availability (SWA), recent atmospheric/water-balance stress, and short-horizon recovery from VWC trends into a single, interpretable score. In the August window (n=5), zero rainfall and elevated VPD kept RPI low–moderate (mean ≈ 21.5) with a strong negative association with VPD ($r \approx -0.96$), indicating limited rebound without water inputs. Sensitivity checks suggest day rankings are robust to reasonable parameter shifts; VPD thresholds and composite weights mainly affect the absolute level, while FC/PWP had modest influence in this short, dry period, and the water-balance channel was muted because $(ETc–P)^+$ was small. Operationally, RPI < 30 flags low-recovery days and can guide irrigation timing ahead of multi-day high-VPD episodes, whereas post-irrigation rises in RPI mark brief favorable windows for tasks like fertilization or pest control. Key limitations are the short sample and incomplete ET_0 coverage; computing ET_0 via FAO-56 and using stage-specific Kc, plus local calibration of FC/PWP and VPD/heat thresholds, will improve interpretability. Validation against NDVI and field logs will strengthen confidence and clarify response lags. Overall, the RPI is practical, transferable, and actionable for water management in arid, irrigated systems when complemented by FAO-56 ET_0 and crop-specific calibration over longer records.

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ANALYSIS OF FACTORS RELATED TO AIR QUALITY BASED ON SATELLITE IMAGERY AND METEOROLOGICAL STATION DATA

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1) **Abstract. Air pollution is considered one of the most serious environmental challenges worldwide. Rapid urbanization, the increase in transportation, and the expansion of industrial activities have significantly contributed to the growth of harmful substances in the atmosphere. Conventional meteorological stations allow continuous monitoring of air quality, but they provide only point-based measurements and do not fully capture the spatial characteristics of the surrounding environment. In recent years, advances in satellite technologies and geoinformatics have made it possible to assess air quality–related factors on a larger scale. The main objective of this study is to integrate ground-based air quality indicators from meteorological stations with land cover parameters derived from satellite imagery. Using Sentinel-2 data and GIS techniques, indicators such as vegetation cover, urban density, and road network intensity were extracted and analyzed in relation to air quality. Preliminary observations revealed that areas with limited vegetation and dense transportation networks tend to exhibit higher pollution levels, while regions with greater green coverage generally show lower concentrations of pollutants. These findings suggest that remote sensing data can effectively complement ground-based measurements by identifying spatial drivers of air pollution. The proposed approach provides a valuable tool for the development of ecological monitoring systems and can support evidence-based decision-making in urban planning and public health.**

Keywords: Air quality, Sentinel-2, Land cover classification, Urban, Vegetation, Water.

I. INTRODUCTION.

Air pollution is widely recognized as one of the most pressing environmental challenges facing humanity today. According to the World Health Organization (WHO), nearly 99% of the global population lives in areas where air quality falls below recommended safety thresholds, and more than seven million premature deaths each year are attributed to pollution-related diseases. In large urban agglomerations, the rapid growth of vehicular traffic, uncontrolled urban expansion, and the intensification of industrial production have led to a marked deterioration in air quality. These trends pose serious risks not only to public health but also to economic activity and environmental sustainability. Consequently, the systematic monitoring of air quality and the identification of its spatial drivers constitute not merely an environmental priority but also a socio-economic necessity.

Data collected by meteorological monitoring stations represent a cornerstone of air-quality surveillance. Such stations provide accurate point measurements and routinely record the concentrations of key pollutants, including PM2.5, PM10, SO_2, and NO_2. However, station data alone do not fully capture the broader spatial context. For example, a single station reflects pollutant levels at a specific location but does not directly characterize surrounding landscape features—such as the presence of green areas, the density of road networks, or the degree of urbanization—that may influence local air quality. This limitation motivates the integration of station observations with spatially extensive sources of information.

Recent advances in remote sensing offer substantial opportunities to address this gap. Sentinel-2 multispectral imagery, with 10–20 m spatial resolution, enables the delineation of vegetation, surface water, built-up areas, and transportation infrastructure. When analyzed within a Geographic Information System (GIS), these data can be combined with station observations to evaluate, at neighborhood to city scales, the land-cover factors that modulate air quality. Such integration supports not only the description of current pollution patterns but also the diagnosis of their likely underlying causes.

A growing body of research underscores the value of these approaches. For instance, Kuchkorov et al. demonstrated that super-resolution techniques can enhance the effective detail and utility of satellite imagery for downstream analysis [1]. Related work applied U-Net–based deep learning to land-cover mapping from satellite data, improving the reliability of class delineation relevant to environmental monitoring [2]. Complementary contributions have detailed satellite image formation and preprocessing pipelines for Sentinel-2, providing practical guidance for robust data preparation [3]. At the international level, studies have linked land-cover types to

aerosol loads using Sentinel-2 over major metropolitan regions [4]; constructed PM10 maps by regressing ground observations against satellite-derived predictors [5]; quantified the association between urban vegetation and dust retention [6]; and integrated ground observations with satellite and meteorological covariates through machine-learning models to estimate PM2.5 at high accuracy [7].

At the same time, within Central Asia-and particularly in Uzbekistan-regional studies that integrate meteorological station observations with land-cover indicators extracted from satellite imagery remain relatively limited in scope and systematization, despite emerging efforts. In response, the present study integrates station-measured air-quality indicators with Sentinel-2-derived metrics-specifically, vegetation (green) cover, urbanization intensity, and road-network density-within buffers surrounding monitoring locations. This approach aims to elucidate spatial drivers of air pollution while furnishing a scientific basis for strengthening ecological monitoring systems, informing urban planning policy, and supporting public-health interventions.

II. METHODS

1. *Study Area and Selection of Monitoring Stations.*

The analysis was conducted within the city of Tashkent, Uzbekistan, using data from officially installed atmospheric monitoring stations. From the full set of available stations, two representative sites were selected to capture the extremes of air-quality conditions: one with the highest recorded pollution levels and another with the lowest levels of pollution. This selection allowed for a comparative assessment of environmental characteristics across contrasting contexts. For each station, a buffer zone with a radius of 1 km was delineated around the central coordinates. The purpose of defining such a buffer was to capture the immediate surrounding land cover, which may directly influence air-quality variations observed at the station.

2. *Data Acquisition from Google Earth Engine.*

Satellite imagery was obtained through the Google Earth Engine (GEE) platform, which provides cloud-based access to large-scale remote sensing datasets. Specifically, we used the Sentinel-2 Level-2A (Surface Reflectance) image collection. Sentinel-2 provides multispectral data at a spatial resolution of 10–20 meters, making it highly suitable for urban-scale analysis.

To ensure data quality, imagery was filtered to exclude scenes with more than 20% cloud cover. From the remaining pool of images, the most recent available acquisition was selected. A circular buffer with a 1 km radius was applied around each station location to define the area of interest. Finally, the data were exported in GeoTIFF format containing six key spectral bands:

- B2(Blue)
- B3(Green)
- B4(Red)
- B8(Near-infraed, NIR)
- B11 (Shortwave Infrared 1, SWIR1)
- B12 (Shortwave Infrared 2, SWIR2)

The exported imagery was resampled to a spatial resolution of 10 meters, ensuring consistency across bands.

3. *Preprocessing of Satellite Data*

The downloaded GeoTIFF files were processed in the Python programming environment, using the libraries rasterio, numpy, and matplotlib. Pixel values of Sentinel-2 Level-2A data are typically stored as integers ranging from 0 to 10,000. To standardize the data for analysis, all pixel values were normalized to the range [0,1] by dividing by 10,000.

For visualization purposes, a percentile stretch was applied to the RGB composite (bands B4, B3, B2). Specifically, pixel values between the 2nd and 98th percentiles were rescaled to enhance contrast, making the visual representation of the imagery clearer. It is important to note that this stretching step affected only visualization, not the analytical results.

4. *Computation of Spectral Indices*

In order to extract land-cover characteristics relevant to air quality, three widely used spectral indices were computed:

$$\mathrm{NDVI} = \frac{NIR-Red}{NIR+Red} \quad (1)$$

$$\mathrm{NDWI} = \frac{Green-NIR}{Green+NIR} \quad (2)$$

$$\mathrm{NDBI} = \frac{SWIR1-NIR}{SWIR1+NIR} \quad (3)$$

- **Normalized Difference Vegetation Index (NDVI):** used to detect the presence and density of vegetation. Higher values indicate greater chlorophyll activity and healthier green cover (1).
- **Normalized Difference Water Index (NDWI):** used to highlight surface water bodies, as water absorbs strongly in the NIR spectrum and reflects in the green spectrum (2).
- **Normalized Difference Built-up Index (NDBI):** used to identify urban or built-up surfaces, based on their higher reflectance in SWIR compared to NIR (3).

These indices were chosen because they directly correspond to environmental features that are known to influence air quality. Vegetation can reduce pollution by capturing particulates, water bodies may support local cooling and dispersion, while urban built-up areas are strongly associated with emission sources.

5. *Rule-Based Land-Cover Classification***.**

Based on the computed indices, a simple rule-based classification was performed to categorize pixels into three land-cover classes. The thresholds were empirically selected according to the known behavior of Sentinel-2 indices:

- Urban: NDBI $>$ 0.1NDBI $>$ 0.1NDBI $>$ 0.1 and NDVI $<$ 0.3NDVI $<$ 0.3NDVI $<$ 0.3
- Vegetation: NDVI $>$ 0.4NDVI $>$ 0.4NDVI $>$ 0.4
- Water: NDWI>0.2NDWI > 0.2NDWI>0.2

Any pixels that did not clearly meet vegetation or water thresholds were automatically assigned to the urban category, as this is the dominant land-cover type in Tashkent. This ensured that "unclassified" pixels were minimized and that the resulting maps reflected continuous surfaces.

6. *Visualization of Results.*

The processed images were visualized in two forms for interpretability:

- **Original RGB composite** (B4, B3, B2), showing the natural-color view of the area.
- **Classified thematic map**, where urban areas were displayed in red, vegetation in green, and water in blue.

Presenting the two maps side-by-side allowed for straightforward comparison between the original imagery and the derived classification results.

7. *Area and Percentage Calculation*

Using metadata from the GeoTIFF files, the pixel resolution (res_x, res_y) was extracted. The area of each pixel was calculated as $A_p = res_x \times res_y$ For each class C_i, the total surface area and proportional share were computed as (4):

$$Area_c = n_c \times A_p,\ \%_c = \frac{n_c}{N} \times 100 \quad (4)$$

where n_c is the number of pixels assigned to class c, and N is the total number of pixels in the buffer zone. The results were converted to square kilometers for reporting, and percentage shares were also computed to facilitate comparisons across stations.

8. *Storage of Outputs.*

The final classified raster maps were exported in GeoTIFF format with an 8-bit single-band representation, where class values corresponded to land-cover types (0 = Urban, 1 = Vegetation, 2 = Water). In addition, console outputs were generated to summarize the total area (km²) and proportional share (%) of each class. These outputs served as the foundation for further statistical analysis linking land cover to station-recorded air-quality indicators.

III. RESULTS

1. *Lokomotiv Park Station (Best Air Quality).*

Within the 1 km buffer surrounding the Lokomotiv Park station, land-cover composition was calculated as follows:

- Urban: 33.83 km² (94.29%)
- Vegetation: 2.04 km² (5.70%)
- Water: 0.01 km² (0.02%)
- Total area: 35.88 km²

Although the area is dominated by urban surfaces, a measurable proportion of vegetation (5.7%) was identified. Even though this percentage is relatively small, the presence of green spaces, including trees and park areas, is likely to contribute positively to air quality by reducing particulate matter and improving local microclimatic conditions. Water bodies were almost absent, covering only 0.02% of the total buffer, reflecting the predominantly continental nature of the study area.

2. *Yangi Hayot 329-School Station (Worst Air Quality).*

For the Yangi Hayot 329-school station, the land-cover distribution was determined as:

- Urban: 34.72 km² (96.60%)
- Vegetation: 1.22 km² (3.40%)
- Water: 0.00 km² (0.00%)
- Total area: 35.94 km²

This buffer is overwhelmingly characterized by urban land cover, with built-up surfaces accounting for more than 96% of the total area. Vegetation is limited to only 3.4%, while no water bodies were detected. Such conditions correspond closely with the consistently high levels of air pollution observed at this monitoring site, suggesting that limited

vegetation cover and dense built-up infrastructure exacerbate air-quality deterioration.

3. *Comparative Analysis Between Stations.*

A comparison of the two stations highlights several key differences:

- The Lokomotiv Park buffer contains approximately **2.3 percentage points more vegetation** (5.7% vs. 3.4%) compared to the Yangi Hayot site.
- The proportion of water is negligible at both stations, contributing minimally to land-cover composition.
- The share of urban land is slightly lower around Lokomotiv Park (94.3%) than at Yangi Hayot (96.6%), yet this small difference aligns with significant variations in recorded pollution levels.

These results suggest that even modest increases in vegetative cover can be associated with improved air quality, while a predominance of impervious surfaces tends to correlate with higher concentrations of pollutants.

4. *Visual Outputs.*

To support the statistical findings, classified maps were produced for each station buffer. These visualizations allow a direct comparison between the raw Sentinel-2 imagery and the derived land-cover categories.

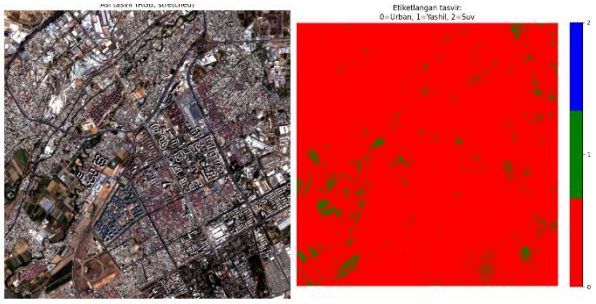

Figure 1.

In (figure 1) Sentinel-2 RGB composite of the “Yangi Hayot 329-school” station buffer (3 km radius). Classified thematic map of the same area, showing Urban (red), Vegetation (green), and Water (blue).

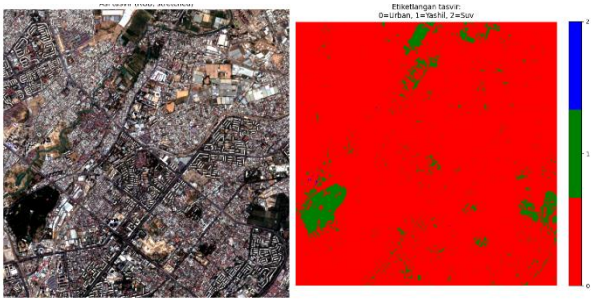

Figure 2.

In (figure 2) Sentinel-2 RGB composite of the “Lokomotiv Park” station buffer (1 km radius). Classified thematic map of the same area, showing Urban (red), Vegetation (green), and Water (blue). In both figures, the predominance of urban land cover is evident. However, the “Lokomotiv Park” buffer retains more extensive patches of vegetation, particularly in the southern and central sectors, compared to the “Yangi Hayot” buffer, where vegetation is sparse and highly fragmented. These visual patterns correspond closely with the statistical results presented earlier, reinforcing the observed relationship between green space availability and air-quality conditions.

IV. DISCUSSION

The initial motivation of this study lies in the fact that air-quality monitoring stations in Tashkent are capable of measuring the concentration of pollutants, yet they do not provide insights into the specific spatial factors contributing to air pollution. To address this gap, we incorporated satellite imagery of the areas surrounding the stations and applied statistical methods to classify the land cover into three broad categories: urban, vegetation, and water. The comparative analysis demonstrated that stations surrounded by a higher proportion of vegetation exhibited relatively better air quality, whereas stations located in highly urbanized areas with limited green space recorded the highest levels of pollution. This finding underscores the significant role of green infrastructure in mitigating air pollution. Vegetation can reduce pollutant concentrations by capturing particulate matter, absorbing gaseous contaminants, and moderating microclimatic conditions. However, the present classification, limited to three categories, cannot fully capture all potential drivers of pollution.

Future research should therefore employ advanced deep learning approaches, such as convolutional neural networks (CNNs), to achieve a more detailed classification of land-cover types. These methods would allow the identification of additional classes that are directly linked to pollution sources, including transportation networks, industrial facilities, residential zones, and diverse categories of vegetation. By integrating such detailed spatial information with ground-based air-quality data, it will become possible not only to monitor pollution but also to determine which specific environmental factors contribute most to its intensity.

Ultimately, this integrated framework can serve as a decision-support tool for urban planners and policymakers, enabling them to prioritize interventions—such as expanding green areas or regulating high-emission zones—in order to effectively mitigate air pollution in rapidly urbanizing cities like Tashkent.

V. CONCLUSION

This study integrated air-quality station data with Sentinel-2 satellite imagery to identify spatial drivers of pollution in Tashkent. By classifying land cover into three categories—urban, vegetation, and water—it was shown that areas with more green space exhibited better air quality, while highly urbanized zones recorded the highest pollution levels. The findings confirm the important role of vegetation in mitigating urban air pollution and emphasize the need for greener infrastructure in city planning. Although limited to three classes, this approach demonstrates how remote sensing can complement ground observations. Future research should apply deep learning models to detect more detailed pollution-related classes (e.g., roads, industrial areas), enabling more accurate analysis and targeted policy measures to reduce air pollution.

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GEODEZIK TARMOQLAR: TURLARI, MAQSADI, VAZIFALARI VA MONITORING YONDASHUVLARI

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***Annotatsiya*— Ushbu maqola geodezik tarmoqlarning turlari, maqsadi hamda vazifalari, shuningdek, ular monitoringining amaliy jihatlari ko‘rib chiqiladi. Geodezik tarmoqlarning qo‘llanilish sohalari va ulardan foydalanish yo‘llari muhokama qilindi. Nazariy bilimlar o‘rganilib, geodezik tarmoqlarning turlari va ularning bajaradigan vazifalari ilmiy asoslangan faktlar orqali taqqoslandi. Mamlakatda barpo etilgan geodezik tarmoqlar maqsadi, vazifasi va amaliy ahamiyatiga ko‘ra bo‘linishi o‘rganildi. O‘zbekiston Respublikasidagi geodezik tarmoqlar monitoringi tahlil qilinib, xalqaro adabiyotlar asosida tizimli monitoring va texnologik yangilanish zarurligi aniqlanadi. Jahon standatrlariga mos va xos bo‘lgan, bugungi kunda keng tarqalgan RTK va RTN stansiyalarining farqi o‘rganilib, RTN stansiyalari ustunlik tomonlari yoritib berildi. Respublikamizda bugungi kunda amaldagi qonunhujjatlari sharhi bilan tanishilib, mas’ul tashkilotlardan olingan malumotlar tahlil qilindi. Stansiyalar ishlash sifatini yaxshilash va geodezik ishlarni to‘g‘ri yo‘lga qo‘yish uchun amaliy tavsiyalar ishlab chiqildi.**

Kalit so‘zlar—geodezik tarmoqlar, monitoring, GNSS, RTK, RTN, geoinformatsion tizimlar.

I. KIRISH

Geodezik tarmoqlar bu yer yuzasidagi nuqtalarning o‘zaro joylashuvini yuqori aniqlikda aniqlash uchun tashkil etilgan nuqtalar to‘plamidir. Bu nuqtalar odatda o‘lchovlar (masofa, burchak, balandlik) orqali bog‘langan bo‘lib, ular butun tarmoqning fazoviy holatini aniqlashga imkon beradi. Oddiy qilib aytganda, ular xaritaga tushirish, qurilish va boshqa ko‘plab muhandislik ishlari uchun asos bo‘lib xizmat qiladigan “tayanch nuqtalar”dir [1].

Geodezik tarmoqlar kartografiya, qurilish, kadastr, geoinformatsion tizimlar, navigatsiya hamda ilmiy tadqiqotlarda muhim o‘rin tutadi (TABLE I). Ular zamonaviy infratuzilmaning tayanch elementlaridan biri bo‘lib, davlat miqyosida yagona koordinata va balandlik tizimini yaratishga xizmat qiladi [2].

TABLE XI. GEODEZIK TARMOQLARNING BOSHQA SOHALAR BILAN INTEGRATSIYASI

T/r	Soha nomi	Vazifasi
1.	Kartografiya	Yangi kartalar yaratish va mavjudlarini yangilash uchun asos bo‘ladi
2.	Qurilish	Binolar, yo‘llar, ko‘priklar, to‘g‘onlar va boshqa inshootlarni loyihalash va qurishda aniq joylashuvni ta’minlaydi
3.	Kadastr va yer boshqaruvi	Yer uchastkalarining chegaralarini aniqlash, yer hisobini yuritish va mulk huquqlarini ro‘yxatga olishda ishlatiladi
4.	Geoinformatsion tizimlar (GIS)	Geografik ma’lumotlarni to‘plash, saqlash, tahlil qilish va vizuallashtirish uchun asos bo‘ladi
5.	Fan va tadqiqot	Yer qobig‘ining harakatlarini, geofizik hodisalarni o‘rganishda, shuningdek, boshqa ilmiy tadqiqotlarda qo‘llaniladi
6.	Navigatsiya	Zamonaviy navigatsiya tizimlarining aniqligi geodezik tarmoqlarning ishonchliligi bilan bog‘liq

Geodezik tarmoqlarni yaratish va ulardan foydalanish juda murakkab jarayon bo‘lib, yuqori aniqlikdagi asboblar, maxsus dasturiy ta’minot va malakali mutaxassislarni talab qiladi. Ular zamonaviy jamiyatning infratuzilmasi va taraqqiyoti uchun asosiy tayanchlardan biridir [3].

II. NAZARIY QISM

Geodezik tarmoqlarning bir nechta asosiy turlari mavjud, ularning har biri o‘z maqsadi va aniqlik darajasiga ega (Fig. 1).

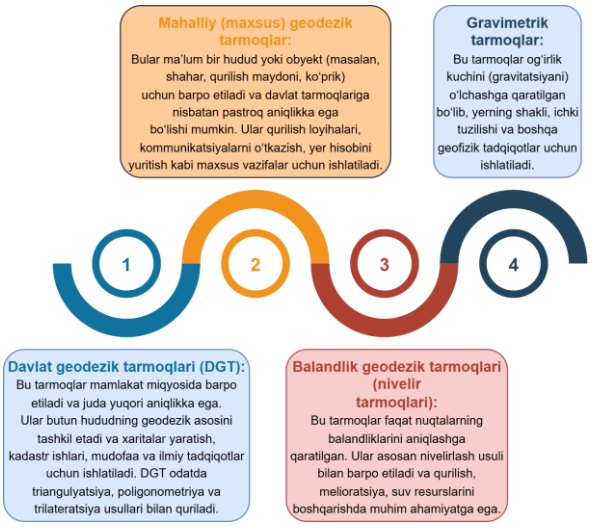

Fig. 23. Geodezik tarmoqlarning asosiy turlari

Shuni ta’kidlash joizki, geodezik tarmoq barcha masshtablarda bajariladigan topografik syomkalarning bosh geodezik asosi hisoblanadi. Lekin hududiy alomati va vazifasi bo‘yicha bir nechta turlarga bo‘linadi (Fig. 2).

Topografik syomka maqsad, vazifasi va turidan kelib chiqib eng maqul va yaqin tarmoqdan foydalaniladi [4].

Geometrik xususiyati jihatidan planli, balandlik va fazoviy geodezik tarmoqlarga ajratiladi. Planli tarmoqlarda o‘lchashlarni qayta ishlash natijasida qabul qilingan ko‘chirish sathida punktlarning koordinitalari aniqlanadi (ellipsoid sathida yoki tekislikda); balandlik (nivelirlash) tarmoqlarida boshlang‘ich yuzaga nisbatan punktlarning balandligi olinadi. Masalan, kvazigeoid yuzasiga nisbatan fazoviy tarmoqlarda o‘lchashlarni qayta ishlashdan punktlarning uch o‘lchamli o‘zaro holati aniqlanadi [5].

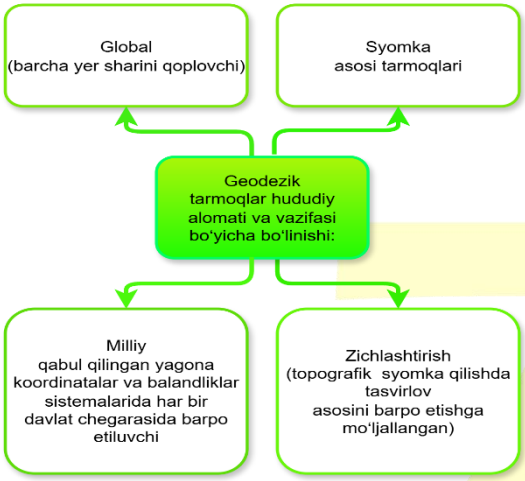

Fig. 24. Geodezik tarmoqlarning hududiy bo‘linishi

Global geodezik tarmoqlar hozirgi vaqtda yerning sun’iy yo‘ldoshini kuzatishdan foydalanib, kosmik geodeziya usullari yordamida barpo etiladi, shuning uchun uni sun’iy yo‘ldosh yoki kosmik geodeziya tarmog‘i deyiladi [6]. Bu tarmoqda punktlarning holati geosentrik to‘g‘ri burchakli koordinatalar X,Y,Z sistemasida hisoblanaladi, uning koordinata boshi yer massasi markazi bilan Z o‘qi esa uning aylanish o‘qi bilan ZY tekislik esa boshlang‘ich meridian tekisligi bilan ustma-ust tushadi. Global geodeziya tarmoqlar ilmiy va ilmiy-texnik muammolarni hamda oliy geodeziya, geodinamika, astronomiya va boshqa fanlarning masalalarni yechishda foydalaniladi [7].

Davlat geodezik tarmog‘ida tanlangan ko‘chirish sathida (referens-ellipsoidda yoki tekislikda) geodezik punktlarning planli o‘zaro holatini yuqori aniqlikda aniqlash ko‘zda tutiladi; tarmoq punktlarning balandligi nisbatan past aniqlik bilan, ayniqsa tog‘li rayonlarda aniqlanadi.

Davlat nivelirlash tarmog‘i kvazigeoid yuzasiga nisbatan har bir punkt balandligini yuqori aniqlik bilan aniqlash uchun xizmat qiladi; bu tarmoq punktlarning planli holati ko‘chirish yuzasida taqriban aniqlanadi.

Davlat gravimetrik tarmog‘i punktlarida og‘irlik kuchi tezlanishini yuqori aniqlikda aniqlashga mo‘ljallangan, bu punktlarni planli va balandlik holati talab qilingan aniqlikda aniqlanishi lozim [8].

Geodeziyani rivojlanish tarixiga nazar solsak, vaqt o‘tgan sari davlat geodezik tarmoqlari aniqligiga bo‘lgan talab oshib bormoqda. Shuning bilan birga davlat geodezik tarmoqlarini agar sistematik ravishda yangilanmasa va takomillashtirilmasa, asta-sekin eskiradi, punktlarning bir qismi yo‘qoladi, asosan yer qobig‘ining zamonaviy harakati tufayli, uni alohida qismlarining aniqligi o‘zgaradi.

Mamlakat hududida barpo etiladigan davlat geodezik tarmoqlari quyidagi maqsadlar uchun mo‘ljallangan [3]:

– yer shakli va gravitatsiya maydoni va ularni vaqt o‘tishi bilan o‘zgarishini mufassal o‘rganish (mamlakat territoriyasi chegarasida);

– mamlakat hududida yagona koordinatalar va balandliklar sistemalarini yaratish;

– yagona koordinata va balandlik sistemasida turli masshtablarda mamlakat kartalarini yaratish;

– xalq xo‘jaligi ahamiyatidagi turli ilmiy va injener-texnik masalalarini geodezik usullar bilan yechish.

O‘ziga xosligi hamda turli ko‘rinishda geodezik tarmoqlarni barpo etish usullariga planli geodezik to‘r punktlari odatda joyning eng baland uchastkalariga joylashtiriladi. Nivelirlash tarmog‘i punktlari joyning tekis va tepalik uchastkalariga, daryolarning bo‘ylariga va yerlarga joylashtiriladi.

Barcha turdagi davlat geodezik tarmoqlari alohida barpo etiladi, ammo ular bir-biri bilan o‘zaro mustahkam bog‘langan bo‘ladi va bir-birini to‘ldiradi. Barcha ko‘rinishdagi tarmoqlar uchun alohida punktlar umumiy bo‘lishi mumkin, bu esa geodeziya, geodinamika va boshqa ko‘plab masalalarini yuqori samarada yechish imkonini beradi [9].

III. NATIJALAR VA ULARNING MUHOKAMASI

Shu o‘rinda sun’iy yo‘ldosh geodezik tarmog‘ining amalda bajaradigan vazifalari haqida to‘xtalib o‘tish joiz va bular nimadan iboratligini quyidagi Fig.3da ko‘rib chiqiladi [10].

Fig. 25. Sun’iy yo‘ldosh geodezik tarmoqlarining bajaradigan funksiyalari

Xalqaro amaliyotda monitoring usullari – GNSS, InSAR, UAV, TLS, GB-SAR va VLBI gibrid yondashuvlardan foydalanish samarali ekani ko‘zga tashlanadi [11], [12], [13], [14]. Real vaqtda ishlash, punktlarning barqarorligini ta’minlash va geodezik punktlar tizimini muntazam yangilash muhimligi ta’kidlanadi [15]. RTK va RTN stansiyalari solishtirilganda RTN ustunligi yaqqol sezildi (TABLE II). Shu bois O‘zbekiston sharoitida RTN tarmog‘ini rivojlantirish va xalqaro modellarga mos keladigan ITRF tizimlariga ishlab chiqish zarur [16].

Bugungi kunda yurtimizda O‘zbekiston Respublikasi Vazirlar Mahkamasining 2017-yil 26-dekabrdagi 1022-

sonli “O‘zbekiston Respublikasi hududida koordinatalar xalqaro geodeziya tizimlarini qo‘llash va ulardan ochiq foydalanish to‘g‘risida”gi qarori[53]ga hamda O‘zbekiston Respublikasining 02.07.2020-yildagi 626-sonli “Geodeziya va kartografiya faoliyati to‘g‘risida”gi qonuni[54]ga muvofiq geodezik tarmoqlar hisobi Markaziy aerogeodeziya korxonasi tomonidan yuritiladi [17].

TABLE XII. RTK VA RTN STANSIYALARINING O‘ZARO FARQI

Xususiyat	RTK stansiya (RTK base station)	RTN stansiya (Real-Time Network station)
Ta’rif	Yakka GNSS bazaviy stansiya, yaqin atrofdagi roverlarga real vaqtli tuzatish yuboradi.	Bir nechta CORS stansiyalaridan tashkil topgan tarmoq, markaziy server orqali foydalanuvchiga tuzatishlarni yetkazadi.
Qamrov hududi	Cheklangan radius (~20–30 km)	Juda keng hudud (viloyat, mintaqa yoki mamlakat miqyosida)
Aniqlik	Bazaviy stansiyaga yaqin masofada yuqori, uzoqlashganda kamayadi	Tarmoq yechimlari orqali barqaror yuqori aniqlik
Ishlash barqarorligi	Yagona stansiyaga bog‘liq – nosozlik bo‘lsa xizmat to‘xtaydi	Ko‘p stansiya va server tizimi tufayli uzilishlarga chidamli
Qo‘llanilish sohasi	Lokal qurilish ishlari, qishloq xo‘jaligi, kichik muhandislik loyihalari	Milliy geodezik monitoring, yirik infratuzilmalar, transport va ilmiy tadqiqotlar
Texnologik imkoniyatlar	Faqat bevosita bazaviy nuqta tuzatishlari	Virtual Reference Station (VRS), Network RTK, MAC kabi ilg‘or usullar
Afzalligi	Arzonroq va oddiy tashkil etiladi	Katta hudud qamrovi, yuqori aniqlik va uzluksiz xizmat
Cheklovi	Faqat bitta bazaga bog‘langan, masofa ortganda aniqlik pasayadi	O‘rnatilishi qimmat va texnik jihatdan murakkabroq

O‘zbekiston Respublikasi Davlat geodeziya nazorati to‘g‘risida Nizomga muvofiq davlat geodezik tarmoqlari ustidan nazorat O‘zbekiston Respublikasi geodeziya nazorati Davlat inspeksiyasi zimmasiga yuklatilgan.

O‘zbekiston Respublikasi geodeziya nazorati Davlat inspeksiyasi o‘ziga yuklatilgan vazifalarga muvofiq Geodeziya punktlarining saqlanishini ta’minlash bo‘yicha chora-tadbirlarning bajarilishini hamda amaldagi qonunchilik va yo‘riqnomalarga muvofiq:

- ularning tiklanishini nazorat qiladi,
- respublikada geodeziya punktlarini hisobga olib boradi;
- korxonalar, muassasalar tashkilotlarda geodeziya punktlar va geografik obyektlar koordinatlar va balandliklarning tarmoq fondlarida jamg‘arilishini nazorat qiladi,
- inspeksiya bilan tegishlicha kelishuvsiz bu fondlarning yuritilishiga yo‘l qo‘ymaydi;
- geodezik punktlar va geografik obyektlar koordinatlarini, kosmik suratlar, kartalar, atlaslar, joylarning maketlarini va boshqa kartografik materiallarni ochiq e’lon qilish yoki ko‘rgazmalarda va televideniyada namoyish qilish mumkinligini ko‘rib chiqadi va korxonalar, muassasalar va tashkilotlarga bu to‘g‘rida xulosalar beradi.

Tadqiqotlar natijasi shuni ko‘rsatadiki, hozirda respublikamizda mavjud punktlar soni trangulyatsiya tarmog‘ida 14 mingta, nivelir tarmog‘ida 37 mingta, poligonometriya tarmog‘ida 8-10 mingtani tashkil qiladi. Quyidagi TABLE IIIda esa biz punktlarning klasslar bo‘yicha taqsimlanishini ko‘rib chiqishimiz mumkin.

TABLE XIII. DAVLAT GEODEZIK TARMOQLARINING KLASSLAR BO‘YICHA TAQSIMLANISHI

T/R	Klaslari	Soni, ta
1.	I klass	338
2.	II klass	3706
3.	III klass	7198
4.	IV klass	2903
	Jami	**14145**

Yuqoridagi ma’lumotlardan kelib chiqib Toshkent viloyatida olib borilgan tadqiqotlar natijasida viloyat hududi bo‘yicha jami 399 ta davlat geodezik tarmoqlari mavjud ekanligi aniqlandi.

Respublikamizda hozirda hududlarda davlat geodezik tamoqlarining ayrimlarini meliorativ holati va sifat darajalari bir qancha nosoz holga kelib qolgani va talab darajasida emasligi ishlab chiqarish koorxonalari tomonidan bajarilayotgan ishlarga o‘zining salbiy ta’sirini ko‘rsatmoqda.

O‘zbekiston hududida geodezik tarmoqlar barpo etilgan bo‘lsa-da, ularni muntazam monitoring qilish yetarli darajada amalga oshirilmayapti. Punktlarning yo‘qolishi, aniqlikning kamayishi va tizimning eskirishi mamlakat miqyosida yagona koordinata tizimining barqarorligiga salbiy ta’sir ko‘rsatmoqda [18].

Mamlakat geodezik tarmog‘i zamon va yaqin kelajak talabi darajasida bo‘lishi uchun quyidagilar zarur hisoblanadi [19]:

- Monitoring ma’lumotlarini yagona milliy geoinformatsion tizimda jamlash;
- tarmoq barcha punktlarini sistematik ravishda joylarda bevosita ko‘zdan kechirish, yo‘qolgan punktlarni qaytadan aniqlash va o‘rnatish;
- davriy ravishda, masalan, 5-10 yil oralig‘ida takroriy yoki yer yuzasining zamonaviy harakati yoki boshqa sabablarga ko‘ra tarmoqning eng katta o‘zgargan qismida qo‘shimcha o‘lchashlarni bajarish;
- davlat geodezik tarmoqlari aniqligini oshirish va keyinchalik takomillashtirish uchun olib boriladigan takroriy yoki qo‘shimcha o‘lchashlarni bajarish va bu o‘lchashlarni yuqori aniqlikdagi o‘lchash texnikasi va usullarida amalga oshirish;

[53] https://lex.uz/docs/-3481472

[54] https://lex.uz/ru/docs/-4880160?ONDATE=21.04.2021%2000

- takroriy va yoki qo‘shimcha o‘lchash natijalarida olingan yangi o‘lchash ma’lumotlarini yig‘ilishiga qarab hududning katta qismida taxminan 5-10 yil oralig‘ida, ushbu davrga tegishli, koordinatalar va balandliklarning yangi aniq qiymatlarini olish maqsadida, planli va balandlik tarmoqlarini qaytadan tenglashtirishni bajarish;
- GNSS asosidagi zamonaviy RTN tizimlarini kengaytirish[20].

IV. XULOSA

Monitoring usullarining ko‘p xildagi integratsiyasi va zamonaviy texnologiyalar (GNSS, RTN, VKOS, GENESIS) geodezik tarmoq barqarorligini ta’minlashda muhim. O‘zbekiston uchun milliy monitoring tizimini takomillashtirish, zamonaviy texnologiyalarni joriy etish dolzarb vazifadir.

TASHAKKURNOMA

Ushbu tadqiqotni o‘tkazishda muhim rol o‘ynagan Web of Science va Scopus ma’lumotlar bazalariga to‘liq kirish huquqini bergani uchun “TIIAME” NRUga samimiy minnatdorchilik bildiramiz. Bundan tashqari, biz Geoinformatika qo‘shma tadqiqot markaziga tadqiqot jarayonida ko‘rsatgan amaliy va texnik yordami uchun minnatdormiz.

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ARCHITECTURE AND DATA FLOW OF AN INTELLIGENT GROUNDWATER MONITORING SYSTEM BASED ON NEURAL NETWORKS

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***Abstract*— The article presents the architecture and data flow of an intelligent groundwater monitoring system based on neural networks. The proposed system is designed to provide real-time monitoring of groundwater parameters such as pH, electrical conductivity, oxidation-reduction potential (Eh), temperature, and water level. By integrating distributed sensor networks with neural network algorithms, the system ensures accurate data processing, anomaly detection, and predictive analysis of groundwater quality. The architecture includes sensing units, data acquisition modules, wireless communication components, cloud-based storage, and an intelligent analysis layer powered by artificial neural networks. Data flow is organized in a multi-layer structure that enables efficient collection, transmission, processing, and visualization of monitoring results. The proposed solution can be applied for environmental protection, sustainable water resource management, and early detection of contamination risks.**

Keywords— groundwater monitoring, neural networks, data flow, intelligent system, water quality, environmental monitoring

I. INTRODUCTION

This template, modified in MS Word 2007 and saved as a "Word 97-2003 Document" for the PC, provides authors with most of the formatting specifications needed for preparing electronic versions of their papers. All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout a conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. EASE OF USE

This section (article) consistently describes the back-end and front-end components of the web system developed for intelligent monitoring of groundwater resources, namely the data flow, module hierarchy, API services, caching, and the interactions between asynchronous computations. The project is organized based on the Django MVT (Model–View–Template) principles and is enriched with background task processing via Celery, caching with REDIS, secure data exchange through advanced cryptography, and hybrid neural network inference. The back-end component receives and validates data from sensor devices through REST-style APIs and stores them, while the front-end component provides interactive monitoring, analysis, and reporting interfaces using templates and static resources.

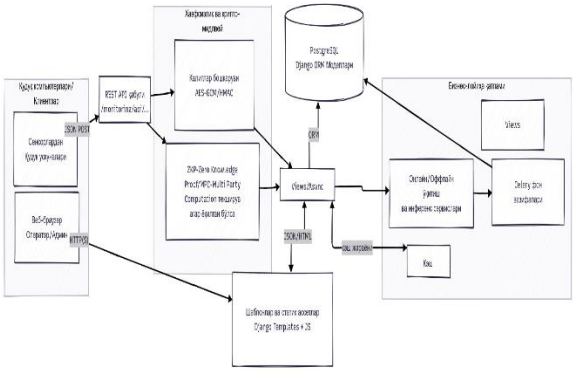

Figure 1. General Workflow Block Diagram of the System

The core of the architecture is centered on the monitoring application, which integrates domain models, business logic, API routes, asynchronous processing,

experimental–industrial (lab) data integration, hybrid neural network inference, and automatic retraining mechanisms. The overall operation of the system is more fully illustrated through the following block diagram (Figure 1).

A. Maintaining the Integrity of the Specifications

The main roles in the architecture are as follows: sensors transmit data in real time to the API, while cryptographic modules ensure authentication and data integrity. The data is then processed through an asynchronous view, stored in the database via ORM, and, when necessary, resource-intensive computations are executed in the background using Celery. The cache management module allows results to be retrieved without repeated calculations for fast interfaces, and front-end components continuously update monitoring dashboards and interactive maps.

III. PREPARE YOUR PAPER BEFORE STYLING

In the overall operation of the architecture, the data flow (Figure 2) consists of four stages.

Stage 1. Sensor data received in JSON format via the REST API undergoes cryptographic auto-identification.

Stage 2. The received information is subjected to cryptographic verification: it is decrypted using AES-GCM, data integrity is verified via HMAC, and—if necessary—ZKP/MPC validation is performed.

Stage 3. The data is processed and stored in the database through Django ORM, handled by asynchronous views, and background tasks are executed using Celery.

Stage 4. The obtained results are returned, cached, delivered in JSON/HTML format, and forwarded to the front-end.

In the developed system, key management mechanisms are implemented based on AES-256-GCM encryption, HMAC-SHA256 signatures, and secure key storage. Authentication is carried out using API keys, digital signatures, and session management. Security mechanisms such as HMAC-based verification, encryption/decryption, and error detection ensure data integrity.

A. Abbreviations and Acronyms

Celery Workers enable process scaling, while clustering of the cache and the database ensures the system's scalability. In case of failures, reliability is guaranteed through retry mechanisms, data replication and monitoring, as well as comprehensive logging.

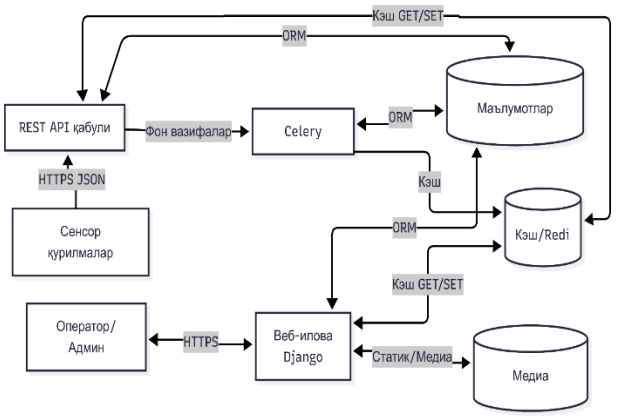

Figure 2. Data Flow Diagram of the Developed System

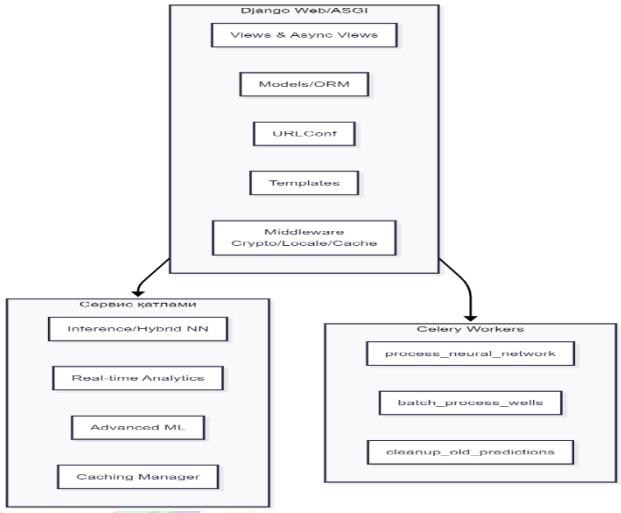

Figure 3. System Components and Their Interconnections

Thus, the main roles in the architecture are as follows: sensors send data in real time to the API, while middleware ensures cryptographic authentication and data integrity. The data is then processed through an asynchronous view, stored in the database via ORM, and, when necessary, resource-intensive computations are executed in the background using Celery. Cache management allows results to be retrieved without repeated calculations for fast interfaces, while monitoring dashboards and interactive maps are continuously updated through front-end components.

The structure of the developed Django project and their interconnections are illustrated in Figure 3.

The database covers wells, measurements, impedance strings, heavy metals, herbicides/pesticides, alerts, pollution sources, neural network versions, and auto-retraining configurations. This implementation is enriched with persistent indexes, flags, operator feedback, and aggregate functions, while the main tables currently available are presented in Figure 4.

Accordingly, Alert, NeuralNetworkModelVersion, and AutoRetrainConfig also store the necessary metadata for real-world operation. The coordinates, category, and confidence level of the identified pollution sources are used

to model risks spatially, while operator feedback serves as a signal for subsequent online incremental training.

The main models, functions, and real capabilities of the system are briefly compared in Table 1.

Sensor data is received asynchronously via the REST API, which enables low-latency performance even under high-throughput conditions. The main API configuration is organized through **monitoring/api_urls.py**, covering services such as data ingestion, retraining, training processes, Excel import, cache statistics, and 3D visualization.

By analyzing the data coming from groundwater well sensors, the latest time series, impedance spectra, and laboratory features are prepared during inference and passed to the trained hybrid neural network within the system. In this process, spatial (coordinate) data, time series, multi-head attention on features, spectral 1D convolution, and a laboratory encoder are combined, enabling the neural network outputs to determine water quality regression, anomaly classification, and training feedback.

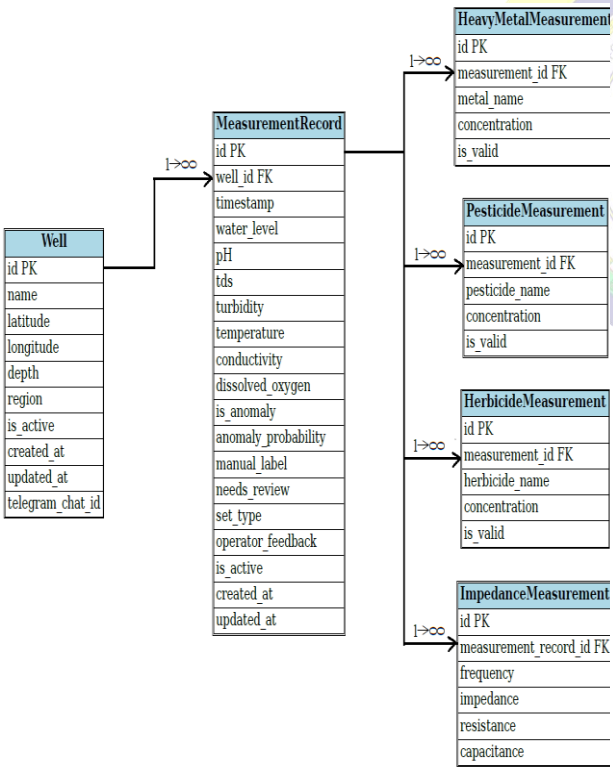

Figure 4. Entity-Relationship (ER) Diagram of the Database

```
def prepare_well_data_for_inference(well, sequence_length=30):
    # Охирги sequence_length та ўлчовни олиш
    records = MeasurementRecord.objects.filter(...).order_by('-timestamp')[:sequence_length]
    ...
    temporal_data.append([
        record.water_level,
        record.temperature,
        record.pH,
        impedance_avg,
        record.pressure,
        record.turbidity
    ])
```

In the hybrid neural network, the SpatialCNN (Spatial Convolutional Neural Network) module is used to process the spatial (geographical) characteristics of groundwater well data. This module analyzes the distribution of sensor locations, geological structures, and environmental factors.

The TemporalLSTM (Long Short-Term Memory for temporal data) module analyzes the changes in groundwater parameters over time. It processes time series data from sensors and identifies both long-term and short-term trends.

The Multi-Head Attention module analyzes relationships among different types of data. It identifies the interdependencies between spatial, temporal, and spectral data and integrates them effectively.

The SpectralCNN (Spectral Convolutional Neural Network) module processes the spectral characteristics of groundwater data. As input, it receives normalized impedance values measured at 20 frequencies ranging from 1 kHz to 100 kHz [5,6]. As a result, this module identifies spectral signatures of various chemical components and estimates their concentrations.

The Lab Encoder module processes laboratory analysis data, i.e., the measured values of the actual composition of water under laboratory conditions. This module is used to compare standardized laboratory results with sensor data.

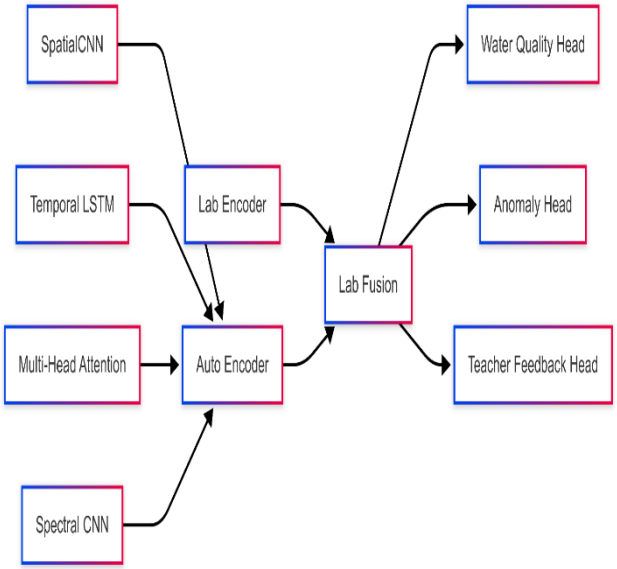

Figure 5. Block Diagram of the Modules and Interconnections in the Developed Hybrid Neural Network Architecture

These modules are integrated through an **Autoencoder** and transformed into a unified data representation at the **Lab Fusion** layer. As a result, the hybrid neural network performs multiple tasks via its **Water Quality Head**, Anomaly Head, and Teacher Feedback Head layers, using Multi-Head Attention mechanisms.

The modular composition of the hybrid architecture is illustrated in the block diagram (Figure 5), showing the integration of SpatialCNN, TemporalLSTM, Multi-Head Attention, SpectralCNN, and Lab Encoder.

In this workflow, inference results update anomaly probabilities and flag cases requiring review with a *"needs review"* marker, which are then stored in the Active Learning interface. Operator feedback, in turn, is converted into triggers for online incremental training. Celery handles background execution of neural network processes and batch well-processing tasks, while also automating inference, cache refreshing, and logging.

The system's user interfaces are built with Django templates and static data files, including interactive maps, monitoring charts, anomaly ratings, and alert panels. The cache manager temporarily stores results to reduce response time in the UI. The project's main navigation and home page components are located in the monitoring/templates/monitoring directory.

Additionally, with the help of functions in the views.py module, time-series data for the last 30 days are plotted as line charts, where Matplotlib generates PNG graphics, which are then passed to templates in base64 format. This provides a practical and intuitive UI, while minimizing server-side recomputations.

The system workflow—from data ingestion to visualization—begins with JSON packet preparation on the sensor side, which is received via the API and validated by the intermediary cryptographic library (Crypto Middleware). The data is then stored in the PostgreSQL database through ORM, while background tasks such as anomaly probability detection and pollutant source analysis are executed via the Celery library, and the results are cached. On the front end, the results are displayed using templates and the **Leaflet** and **Plotly** libraries, providing maps, charts, and animations. Operator responses (feedback) and auto-retraining configurations ensure the lifecycle of the model, enhancing adaptability to continuous changes in the data flow.

The project was designed with a clear and practical objective: to provide operational monitoring by collecting and storing water quality parameters for wells and promptly detecting anomalies. The main tasks include receiving data through secure channels, normalization and validation, anomaly probability estimation, spatial localization of pollution sources, rapid visualization in user interfaces, alert management, and periodic model retraining.

Expected outcomes included developing a low-latency API, reliable cryptographic protection, strict data integrity, and a hybrid neural model that continuously improves with operator feedback. Achieved results show that asynchronous ingestion, background neural network inference, and caching have enabled near real-time monitoring, automated generation of textual and graphical reports, and spatial pollution source identification with confidence coefficients along with direction and distance calculations.

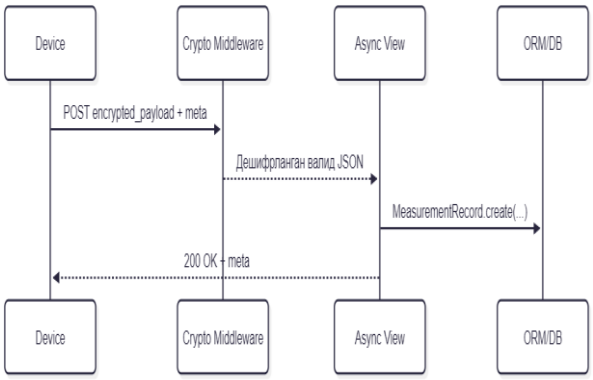

Figure 6. Structure of the System's Cryptography Pipeline

To ensure system security and reliability, the cryptographic library (Crypto Middleware, Figure 6) provides key management, data integrity verification based on AES-256-GCM and HMAC, and, when required, ZKP/MPC modules. Logging and Celery retries further enhance stability. As a result, API packet compliance, source authentication, and data integrity are guaranteed, while suspicious activities are safely logged and delivered to the operator through alerts.

Thus, the system, built with the Django MVT framework, forms an integrated complex that combines asynchronous data ingestion, background inference, caching, and an interactive UI. By integrating spatio-temporal and spectral data within the hybrid network, it enables reliable water quality monitoring and automates related decision-making processes.

IV. Conclusion

The proposed intelligent groundwater monitoring system demonstrates how modern neural network architectures can be effectively integrated with sensor networks, cryptographic middleware, and scalable web technologies to ensure secure, reliable, and real-time water quality assessment. The system architecture, designed on the Django MVT framework, combines asynchronous data ingestion, background inference via Celery, caching, and interactive visualization, thus creating a unified workflow from data acquisition to decision support.

Through hybrid neural models—integrating SpatialCNN, TemporalLSTM, SpectralCNN, Multi-Head Attention, and Lab Encoder modules—the system is capable of simultaneously processing spatio-temporal, spectral, and laboratory data. This enables accurate water quality regression, anomaly classification, and adaptive retraining based on operator feedback.

The implemented architecture ensures scalability through worker and database clustering, reliability via retries and logging, and security by AES-256-GCM encryption, HMAC-based integrity verification, and advanced key management. As a result, the system not only monitors groundwater conditions but also provides decision-making support by identifying pollution sources, evaluating contamination risks, and generating automated analytical reports.

Overall, the developed solution demonstrates a robust and practical approach to sustainable groundwater management. It highlights the potential of combining neural networks with intelligent monitoring systems for environmental protection and resource optimization.

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OMMAVIY SERVITUT BITIMLARINI RO'YXATGA OLISHDA MILLIY AXBOROT TIZIMINI YARATISH ZARURIYATI

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Annotatsiya. ***Maqolada yer servitutini joriy etish tushunchasini yer tejamkor uslublar samaradorligini oshirish texnologiyasi sifatida qarash muhimligi yoritilgan. Yer resurslarini asrash va ulardan oqilona foydalanishni tashkil etish hozirgi tub islohotlarning asosiy yo'nalishlaridan biridir. O'zbekistonda mustaqillik yillarida yer fondidan oqilona foydalanishni tartibga soluvchi bir qator normativ-huquqiy hujjatlar qabul qilindi. Servitut - o'zganing mulkidan cheklangan foydalanish huquqi bo'lib, u xususiy va ommaviy servitut turlariga ajratiladi. Ommaviy servitutlar jamoat manfaatlarini ifodalaydi va muhandislik kommunikatsiyalarini himoya qilish, sanitar-himoya hududlari, tarixiy va madaniyat yodgorliklarini himoya qilish kabi maqsadlarda belgilanadi. Tadqiqot natijalariga ko'ra, ommaviy servitut bitimlarini prognoz ko'rsatkichlari 300 mingdan ortiq bo'lib, ularni alohida elektron portalda ro'yxatga olish zarurligi aniqlangan. Yer servitutlarining joriy etilishi yer resurslaridan samarali foydalanish va yer tejamkor uslublar samaradorligini oshirishda muhim o'rin tutadi.***

CIII. ***Kalit so'zlar Er servituti, Er tejamkor uslublar, Samaradorlikni oshirish, Tub islohotlar, Er resurslarini asrash, Oqilona foydalanish, Normativ-huquqiy hujjatlar, Xususiy servitut, Omma servituti, Mulkdorlik huquqi, Texnik yechim, Elektron portal, Er kod, Huquqiy asos, Prognoz ko'rsatkichlar***

I. KIRISH

Yer servitutini joriy etish tushunchasini yer tejamkor uslublar samaradorligini oshirish texnologiyasi sifatida qaralmog'i zarur. Hozirgi davrda davlatimiz tomonidan olib borilayotgan tub islohotlar negizida yer resurslarini asrash va ulardan oqilona foydalanishni tashkil etish ushbu siyosatning asosiy yo'nalishlaridan biridir. Tabiiy resurslarning tarkibiy qismi sifatida yer resurslari iqtisodiyotning moddiy asosini mustahkamlashda muhim ahamiyat kasb etadi. Shu munosabat bilan mustaqillik yillarida O'zbekistonda yer fondidan oqilona foydalanish va undan tejamkorlik bilan foydalanishni tashkil etishni tartibga soluvchi bir qator tashkiliy, normativ-huquqiy va texnik hujjatlar qabul qilindi. Ularda yerdan foydalanishga oid munosabatlarni texnik-huquqiy jihatdan tartibga solindi.

Umuman olganda, servitut (lotincha "servitus", "servitutis" – "qaram holat", "qullik") – o'zganing mulkidan cheklangan foydalanish huquqi bo'lib, servitut institutining shakllanishi va rivojlanishi yerga nisbatan xususiy mulkchilik instituti bilan bevosita bog'liq. Qoida tariqasida ajratilgan yer uchastkasi hamisha ham undan foydalanish uchun zarur bo'lgan barcha xususiyatlarga ega bo'lavermaydi. Jumladan, ushbu yer uchastkasida suv bo'lmasligi yoki umumiy yo'lga chiqish imkoniyati bo'lmasligi va hokazo. Ushbu yer uchastkasidan foydalanish mumkin va iqtisodiy jihatdan maqbul bo'lishi uchun esa, qo'shni yer uchastkalaridan cheklangan tarzda foydalanish zaruriyati tug'iladi.

Yerdan cheklangan tarzda foydalanish huquqi sifatida servitutni tadbiq etishga oid tartib hamda uni texnik jihatdan ijrosini ta'minlash muhim ahamiyat kasb etdi. O'zbekistonda yuritilayotgan Servitutlar asosan shaxsiy va ommaviy servitut turlariga bo'linadi. Ma'lumki,servitut - bu boshqa shaxsning yer - mulkidan foydalanish huquqini nazarda tutuvchi haqli cheklov bo'lib, u asosan qo'shni yer uchastkalari manfaati uchun belgilanadi.Xususiy servitutlar faqat ma'lum bir shaxs manfaati uchun belgilanadi, yerga egalik qiluvchi shaxs o'zgarsa, servitut bitimi o'z kuchini yo'qotadi. Masalan: xududi tutashgan qo'shni shaxs oila a'zolarini yer servituti belgilangan yer uchastkasidan o'tish huquqi..

II. SERVITUT TUSHUNCHASINING NAZARIY ASOSLARI

Real servitutlar mulkdor shaxs emas, yer uchastkasining o'zi manfaatdor hisoblanadi va bu holatda servitut yer uchastkasiga bog'langan bo'ladi. Masalan: Qo'shni yerida ichimlik yoki sug'orish maqsadida suv trubasini o'tkazish huquqi. Servitut respublikamizda texnik va ijtimoiy - huquqiy mexanizm sifatida muhim yechim bo'lib, unga ko'ra ma'lum ehtiyoj yoki zaruriyat tug'ilganda bir yoki bir nechta yerdan foydalanuvchi subyektlar tomonidan o'zganing yer uchastkasi xududining bir qismdan cheklangan tarzda foydala-nishni amalga oshirishni taqozo etadi.

Yuqorida qayd etilgan zaruriy holatlar esa o'z navbatida o'zgalar mulkidan cheklangan tarzda foydalanish huquqining shunday shakli bo'lgan servitut ya'ni servitut so'zining o'zagi lotincha "servire" so'zidan -"xizmat qilmoq" ma'nosidan kelib chiqqanini e'tirof etish zarur

bo‘ladi. Ushbu huquqiy shakl orqali ehtiyojlarni qondirishdagi barqarorlik uning ashyoviylik xususiyati bilan ta’minlanadi: ya’ni, servitut huquqining predmeti muayyan shaxslarning harakati emas, balki yer uchastkasining o‘zi hisoblanadi. Shu bois, servitut huquqi subyekti qo‘shning yer uchastkasidan cheklangan tarzda foydalanish huquqini mulkdor o‘zgarishidan qat’iy nazar saqlab qolgan. Servitutga jalb etilgan maydon yer uchastkasiga tegishli bo‘lib, mulkdorlar o‘zgargan taqdirda ham ushbu xuquq va texnik yechim to‘liq holatda saqlab qolingan.

Yuqoridagilar asosida hulosa sifatida ta’kidlash zarurki, servitutni u yoki bu munosabat bilan boshqaning mulkidan cheklangan tarzda foydalanish sifatida tavsiflashimiz mumkin. Ushbu huquq yerga nisbatan xususiy mulkchilik belgilangan hamda alohida yer uchastkalari o‘rtasida tabiiy qulayliklar teng taqsimlanmaganligi sababli yuzaga keladigan noqulaylik va qiyinchiliklarni bartaraf etish nuqtayi nazaridan ham muhim texnik yechim hisoblanadi. Servitutni yer egasi, foydalanuvchisi yoki ijarachi egaligida bo‘lgan yer uchastkalaridan piyoda o‘tish, elektr, aloqa liniyalari o‘tkazish, suv olib o‘tish yoki boshqa maqsadlar uchun foydalanish ham deb tushunish mumkin.

Ushbu tushunchalar umumiy tarzda amaldagi Yer kodesining 30-moddasida qayd etilgan. Yer uchastkasidan cheklangan ravishda foydalanish ya’ni amaliyotda joriy etilgan servitutlar ba’zi qo‘shnichilik munosabatlarini tartibga solishg ham xizmat qiladi. Bunday servitut huquqiga binoan servitutariy cheklangan tarzdagi foydalanishni nafaqat o‘zganing yer uchastkasidan balki bu yer uchastkasidagi ba’zi inshootlarga nisbatan ham amalga oshirishi mumkin bo‘ladi. Masalan, ba’zi inshootlar va binolarda o‘rnatilgan davlat belgilari, uylarga biriktirilgan aloqa simlari va boshqa qurilmalardan servitut huquqi asosida cheklangan ravishda foydalanilishi mumkin.

Yer uchastkasiga nisbatan servitut huquqining o‘rnatilishi yer mulkdorining ushbu yer uchastkasiga nisbatan mulk huquqidan to‘la chetlatilishini anglatmaydi. Jumladan, qo‘shnisiga servitut huquqi asosida chorva molini o‘tlatishga ruxsat bergan taqdirda yer egasining o‘zi ham ushbu hududda qoramol o‘tlatish huquqini to‘liq saqlab qoladi. Tadqiqot davomida servitut va mulk huquqi o‘zaro to‘qnash kelgan holda qaysi huquq ustun mavqega ega, degan tabiiy savol tug‘iladi. Rim huquqiga ko‘ra, bunday holatlarda yer uchastkasidan foydalanish servitut huquqi subyektiga tegishli bo‘lgan. Ya’ni, servitut o‘rnatilishi shaxsning mulk huquqini cheklagan.

III. SERVITUTLARNI BELGILASH TARTIBI

Servitut yoki servitut huquqi bir qator manbalarda turlicha ko‘rinishlarda qayd etilganligi aniqlangan. Masalan, servitutning xususiy va ommaviy servitutlarga ajratish ehtiyoji ma’lum bo‘lgan. Bunda xususiy servitut – bir shaxs yoki bir necha shaxslardan iborat bo‘lgan kichik bir guruhning manfaatlarini himoya qilish maqsadida murojaat qilinadigan servitut bo‘lsa, ommaviy servitut – jamoat manfaatlarini ifodalaydigan servitut turi sifatida namoyon bo‘lishi kuzatilgan. Boshqa bir qator manbalarda ham yer uchastkasi servitutlarining xususiy va ommaviy ko‘rinishlarga ajratilganligiga guvoh bo‘lishimiz mumkin .

Yer kodeksida qayd etilganidek, ommaviy servitutlar ham xususiy servitutlar ham muddatli yoki doimiy bo‘lishi mumkin, ya’ni servitutlarning har ikkala ko‘rinishi ham muayyan ko‘rsatib o‘tilgan muddatga tuzilishi mumkin yoki muddati ko‘rsatilmagan holda tuzilishi ham mumkin.Oxirgi yillarda bir qator mamlakatlarda, jumladan O‘zbekiston Respublikasida ham yer uchastkalaridan foydalanish huquqi tabiiy resurslardan oqilona foydalanish va atrof tabiiy muhitni muhofaza qilish maqsadida cheklanilmoqda. Bunday cheklovlar ommaviy xususiyat kasb etadi va rasman servitut sifatida nomlanmasada, servitutga yaqin hisoblanishi tadqiqodlvr davomida kuzatillgan.

Ommaviy yer servitutlarini belgilashdan maqsad ommaviy – davlat, mahalliy boshqarish organlari, aholinining ehtiyojlarini qondirishdan iboratligi tadqiqotlar davomida aniqlangan. Quyida ommaviy servitutni ko‘rinishlariga to‘xtalib o‘tamiz:

- muxandislik kommunikatsiyalarini himoya qilish;
- sanitar-himoya hududlari;
- markazlashtirilgan ahamiyat kasb etuvchi suv quvurlarining sanitar himoyasi hududlari;
- chiziqli turdagi (uzelli) infratuzilma obyektlari tutashgan yer maydonlari, ya’ni bir nechta tashkilotga tegishli bo‘lgan hududdagi muxandislik kommunikatsiyalari kesishuv manzillari;
- tarixiy va madaniyat yodgorliklarini himoya qilish hududlari.

Ommaviy servitut qonunda belgilangan tartibdan kelib chiqib, u jismoniy shaxsning emas, balki jamoat manfaatlarini ko‘zlab belgilanadi. Servitutni belgilashni talab qilgan shaxs yoki shaxslar guruhi bilan o‘zga yer uchastkasining egalik qiluvchisi, foydalanuvchisi, ijarachisi va mulkdori o‘rtasidagi kelishuvga muvofiq vujudga keladigan yer servituti huquqiga binoan ish yuritiladi. Bunda bir tomondan yer servitutini belgilashni talab qilgan shaxs yoki shaxslar guruhi harakat qilsa, ikkinchi tomondan servitut belgilanishi talab qilinayotgan yer maydonining egalik huquqi egasi bo‘lgan shaxs harakat qiladi va ular o‘zaro yer servituti shartnomasi asosida zarur bitimga erishadilar.

IV. O‘ZBEKISTONDA SERVITUTLARNI JORIY ETISHNING AMALIY JIHATLARI

Yer servitutini belgilashni talab qilayotgan shaxs bilan yer uchastkasining egasi o‘rtasidagi bitimga ko‘ra bitim tuziladi. Unga asoslangan yer servitutida ko‘chmas mulkka bo‘lgan huquqlarni ham belgilangan tartibda davlat ro‘yxatidan o‘tkazilishi zarur bo‘ladi. Agar, yer servitutini belgilash jarayonida tomonlar kelisha olmasa, yakuniy qaror yer servitutini talab qilayotgan shaxsning da’vo arizasiga ko‘ra belgilangan tartibda sud tomonidan yechimi belgilanadi.

Ommaviy servitutlarning vujudga kelishi jamoa ehtiyojlarini inobatga olgan holda amalga oshiriladi. Fuqarolar va jamoat tashkilotlarining bunday jamoa

ehtiyojlari bo‘yicha qarorlar qabul qilishda ishtirok etish huquqlari odatda fuqarolarning va jamoat tashkilotlarining o‘z huquqlariga oid masalalarning hal qilinishida ishtirok etish prinsipiga asosan qonun hujjatlarda belgilab qo‘yilgan. O‘zbekiston Respublikasi Yer kodeksida esa ushbu fuqarolar va jamoat tashkilotlarining jamoa ehtiyojlari bo‘yicha qarorlar qabul qilishda ishtirok etish huquqlaridan kelib chiqib, fuqarolarning va jamoat tashkilotlarining yerga oid huquqlarini belgilanishiga oid qarorlar qabul qilishi, jumladan ommaviy servitutlar belgilanishida ishtirok etishi nazarda tutiladi.

Bizningcha, fuqarolar va jamoat tashkilotlarining jamoa ehtiyojlari bo‘yicha qarorlar qabul qilishda ishtirok etish huquqlaridan kelib chiqib, O‘zbekiston Respublikasi Yer kodeksining 2-moddasida berilgan yer to‘g‘risidagi qonun hujjatlarining asosiy tamoyillarida fuqarolar va jamoat tashkilotlarining yerga oid huquqlarini belgilashga oid qarorlar qabul qilinishida ishtirok etishini taqozo etmoqda. Bunda,fuqarolar va jamoat tashkilotlarining yerdan foydalanishga oid huquqlarini belgilashga oid qarorlar qabul qilinishida ishtirok etish tartibini belgilash muhim ahamiyatga ega. Ommaviy va xususiy yer servitutlarini belgilashga oid qarorlar qabul qilinishida fuqarolar va jamoat tashkilotlari ishtirokining huquqiy asosini yaratib berishda hamda qarorlar qabul qilish jarayonida ularni faol ishtirokini ta’minlashda huquqiy vosita sifatida xizmat qiladi

Bunday qarorlar qabul qilinishida fuqarolar va jamoat tashkilotlarni ishtirok etish tartibining huquqiy asoslari qonun yoki boshqa me’yoriy hujjatlarda belgilanib qo‘yilishi lozimligini ham inkor etilmaydi. Biroq, qonun hujjatlarida fuqarolar va jamoat tashkilotlarini ishtirok etish tartibining huquqiy asoslari mavjud emas. Ommaviy yer servitutini belgilashda vakolatli bo‘lgan organ fuqarolar va jamoat tashkilotlarining fikrlarini o‘rganishni ham taqozo etmoqda. Amaliyotda esa servitutlarning belgilanishi yoki o‘rnatilishi asosan ma’muriy tartibda amalga oshirib kelinmoqda. Ma’muriy tartibda o‘rnatiladigan servitutlarda salmoqli miqdor ommaviy servitutlarga to‘g‘ri kelmoqda.

Ham ommaviy ham xususiy servitut sifatida: piyodalab o‘tib ketish huquqi; kommunal, muhandislik va elektr tarmoqlarini ekspluatatsiya qilish huquqi; suv ta’minotiga ega bo‘lish huquqi; melioratsiya huquqlarini e’tirof etish mumkin. Boshqa manbalarda esa servitut yoki servitut huquqining ikki xil ko‘rinishi ma’lum bo‘lib, ular “predial” (praedium – yer-mulk), ya’ni yer servituti va xususiy servitut. Xususiy servitut muayyan kishiga shaxsan; predial servitut esa, yer uchastkasi mulkdoriga tegishli bo‘lgan. Servitutning predial va shaxsiy servitut ko‘rinishlarga bo‘linishi Qadimgi Rim huquqidan kelib chiqqan bo‘lib, bunda shaxsiy servitut muayyan shaxsga berilgan servitut bo‘lib, predial servitutda esa servitut muayyan mulk, ya’ni yer yoki uning bo‘lagi, uy egasi yoki foydalanuvchisiga bog‘liq bo‘lgan servitutni anglatgan .

Servitutning ushbu ko‘rinishi ba’zi manbalarda yer uchastkasi servituti sifatida ham e’tirof etiladi. Biz quyida aynan predial, ya’ni yer servituti haqida chuqurroq to‘xtalib o‘tamiz. Umumiy qoida tariqasida servitutning ushbu turini qo‘llash uchun yer uchastkalari yonma-yon joylashganligi yoki tutash xududga ega bo‘lgan qo‘shni yerdan qoydalanuvchi subyekt bo‘lishi lozimligi talab etiladi.

Shaxsiy servitutning keyingi turi bu “usus”, ya’ni o‘zganing mulkini uning hosilidan foydalanmagan holda, shaxsiy ehtiyojlaridan boshqa maqsadlarda foydalanish ma’nosini anglatadi. Boshqa jihatlariga ko‘ra, servitutning ushbu turi uzufrukt bilan o‘xshash bo‘lgan. Boz ustiga qadimgi Rim huquqida shaxsiy servitutning uyda yashash huquqi , qulning yoki hayvonning ish kuchidan foydalanish singari turlari bilan farqlangan.

Ashyoviy huquqlar tarkibiga shuningdek, ashyoviy, ajraladigan, meros huquqi asosida o‘tadigan o‘zganing yer uchastkasidan uzoq muddatli foydalanish huquqi ham kirgan. Bunda qishloq xo‘jaligiga mo‘ljallangan, uni qayta ishlashga qaratilgan yer uchastkasi va unga imorat qurish uchun mo‘ljallangan yer uchastkasidan o‘zaro farqlangan.

Ushbu har ikkala huquq ham servitut bilan umumiy jihati shundaki, o‘zganing yer uchastkasidan cheklangan tarzda foydalanish bilan bog‘liq. Servitutning boshqa turlaridan farqlovchi o‘ziga xos jihati esa, tomonlar vakolatlarining keng qamrovligi va harakatining uzoq muddatga mo‘ljallanganligi bilan izohlanadi. Ushbu huquqlardan birining o‘rnatilishi yer uchastkalariga nisbatan mulk huquqini nomigagina saqlab qoladi va bitimlar bekor qilingandan so‘nggina muayyan yer uchastkasiga nisbatan mulk huquqi real kuchga kiradi.

VII. O‘ZBEKISTONDA SERVITUTNI BELGILASHGA OID TEXNIK – NORMATIV XUJJATLAR TIZIMNI SHAKLLANTIRISH ZARURIYATI.

O‘zbekiston respublikasi Yer kodeksiga asoslangan 30 modda va shu moddaga moddaga (30^1–30^6) qo‘shimchalarda yer uchastkasida servitut yuridik yoki jismoniy shaxslar kelishuviga asosan o‘rnatilishi, kelishmovchilik holatlarida esa sud tomonidan hal etilishi,servitut albatta davlat ro‘yxatidan o‘tkazilishi va yer uchastkasi egasi o‘zgarganda ham servitut yuridik kuchga egaligi saqlanib qolishi qayd etilgan. (FAOLEX, KiberLeninka, Zakon Online, nrm.uz).

Fuqarolik kodeksiga asoslangan 173-moddada (LEX.UZ) yer -mulk egasi qo‘shnining yer uchastkasidan cheklangan tarzda foydalanish huquqini talab qilish huquqiga ega ekanligi,Servitut qo‘shni yer egasi tomonidan bitimda e’tirof etilgan ehtiyojlarni qondirish uchun o‘rnatilishi va servitut shartnomasi asosida o‘rnatilishi va davlat ro‘yxatidan o‘tkazilishi hamda tomonlar kelishuvga erisha olmasa, sud qarori orqali hal qilinishi belgilab qo‘yilgan.

Amaldagi tahrirdagi 173-moddanning qo‘shimchalari (LEX.UZ, Kontinent)da esa , mulk egasi o‘z huquqini boshqasiga o‘tkazganda ham servitut saqlanishi (173^1), servitut shartlari (maydoni, ta’mir, to‘lash rejimi va h.k.) (173^2), servitut uchun to‘lov, tomonlar yer solig‘i miqdoriga nisbatan kelishuv asosida belgilangan to‘lovni servitutariy tomonidan o‘z vaqtida amalga oshirish shartligi(173^3), texnik kommunikatsiyalar va infratuzilma

obyektlari holatiga oid majburiyatlar (173[4]), yer uchastka bo‘lingan taqdirda servitutning qay tarzda saqlanishi (173[5]), servitutni o‘zgartirish va to‘xtatish(173[6]) hamda uni binolarga qo‘llash tartibi(173[7]) belgilab qo‘yilgan.

Servitutni o‘rnatish tartibi tomonlarni o‘zaro kelishuvi asosida ya’ni, yer-mulk egasi bilan servitutariy o‘rtasidagi bitimni tasdiqlash bilan belgilanadi. Bunda, xujjatda kiritiladigan shartlarga yer uchastkasining kadastr raqami va maydoni, servitut maqsadlari hamda texnik shartlar (o‘lchov aniqligi,chegara belgilari,chegara chiziqlariga o‘rnatilishi mumkin bo‘lgan qurilmalar (devor yoki to‘siqlar , ta’mirlash va h.k.), zararni to‘lash tartibi,servitut muddati va to‘lov tartibi va joriy qilish qoidalari va mexanizmlarini amala oshirish ko‘zda tutiladi. Masalan, yer servitutini davlat ro‘yxatidan o‘tkazishda yer uchastkasini ro‘yxatini yurituvchi DKP tuman (shaxar) filiali mutaxassislari tomonidan amalga oshirilsa, tomonlar kelishuvga erishmagan holatlarda yoki bir tomonni talabi qat’iy bo‘lsa, sudga murojaat qilinadi va sud qarori bilan servitut belgilanadi.

Fuqarolik kodeksi 173-173[7] moddalari servitutning huquqiy asosini belgilasa, Yer kodeksi 30-30[6] moddalari esa servitutni amalga oshirish mexanizmlarini belgilab beradi. Mazkur kodekslar moddalari yordamida yer servitutini qonunchilik talablari asosida mukammal va yuridik -texnik jihatdan to‘g‘ri joriy etish mumkin bo‘ladi.

Yer servituti maqomini "Transfertga saqlanish" tushunchasi texnik – huquqiy atama bo‘lib, yer servituti yer - mulk o‘zgartirilganda ham saqlanishini anglatadi. Ya’ni, agar yer uchastkasining egasi o‘z yerini boshqa shaxsga sotsa yoki hadya qilganda ham yer servituti bekor qilinmaydi va yangi yer-mulk egasiga o‘tishi belgilanadi. Masalaga misol: agar, yer egasi A.S. o‘z yer uchastkasidan o‘tish uchun qo‘shnisi "K.B"ga servitutga ruxsat bergan bo‘lsa (masalan: piyodaga yo‘lak, kommunikatsiya, infratuzilma obyektlari kabilar), A.S.o‘z yerini "V.D."ga sotadi,bunday holda "K.B" uchun berilgan servitut bekor qilinmaydi va o‘z kuchini saqlaydi,"V.D" ya’ni, yangi yer-mulk egasi ham shu servitut bandlariga to‘liq rioya qilishi shart hisoblanadi. Ushbu masalaga yechim Fuqarolik kodeksining 173[1]-moddasida “Yer uchastkasiga nisbatan servitut huquqi ushbu yer uchastkasining egasi almashganda ham saqlanadi (huquqiy vorislik).” deb qayd etilgan.

Eng muhimi yer servitutini O‘zbekistonda keng ko‘lamdagi joriy etishdan asosiy maqsad quyidagicha izohlanadi:

- yer tejamkorligi darajasini kamida ikki barobarga oshirishga xizmat qiladi;
- kadastr sohasida yer taqsimotidagi huquqiy barqarorlikni ta’minlash imkoniyati yaratiladi;
- infratuzilmani kafolatli ta’minlashga (gaz, suv, yo‘l,elektr kabellari yer egasi o‘zgarsa ham saqlanadi) erishish mumkin bo‘ladi;
- yerdan foydalanish huquqlariga rioya etish ta’minlanadi;

[18] .

- yer servitut hizmatini xususiy firmlar sonini ortishiga va mutahassislar bandligini ta’minlashga xizmat qiladi.

O‘zbekistonda servitutni bekor qilish asoslari Fuqarolik kodeksining 173[6]-moddasida belgilangan bo‘lib,quyidagicha izohlanadi: servitutga bo‘lgan zarurat qolmaganda, masalan, yangi sug‘orish tarmoqlari qurilish natijasida eskilariga ehtiyoj yo‘qligi sababli zaruriyatni yo‘qligidan bekor qilinadi. Servitut bitimida uning bandlaridagi belgilangan maqsadlarda foydalanilmayotgan bo‘lsa,ya’ni masalan, suv o‘tkazish quvuri uchun berilgan, ammo ishlatilmayotgan bo‘lsa yer egasi uni bekor qilishni talab qilishi mumkin.

V. XULOSA

Yuqorida qayd etilganidek,ommaviy servitutlar yerdan foydalanuvchi subyektlar o‘rtasida tuziladigan o‘zaro bitimlar va ularni ijrosini ta’minlovchi texnik yechimlar asosida amaliyotga tadbiq etiladi. Yer kodeksinin 30 – moddasida belgilangandek ommaviy servitutlar albatta davlat ro‘yxatidan o‘tkazilishi shart. Shu sababdan ushbu servitut turini alohida elektron portalda ro‘yxatga olish tavsiya etiladi. Tadqiqotlar natijasida O‘zbekistonda ommaviy servitut bitimlarini prognoz ko‘rsatkichlari 300 mingdan ortiqligi aniqlangani ham mazkur portalni yaratish zaruriyatini bildiradi.

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A DEEP LEARNING-BASED IMPROVED FIRE DETECTION TECHNIQUE

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***Abstract*— This study presents a novel method for improving fire detection by combining sophisticated convolutional neural networks (CNNs) with contour analysis. The two main algorithms in our suggested approach are one that uses color attributes to identify fire and another that employs shape analysis using contour detection. We selected a varied dataset that covers difficult situations and minor fire occurrences in order to overcome the shortcomings of earlier methods. Our model can now learn complicated properties related to tiny fires and complex settings thanks to the enhancement of this dataset through the use of color characteristics and contour analysis to define areas of interest (ROI). Results from experiments show that our improved CNN model performs better.**

Keywords—Deep learning, CNN, Contour techniques.

CV. INTRODUCTION

In a variety of settings, fire detection systems are essential for maintaining safety and minimizing damage. Computer vision and machine learning advances have greatly enhanced fire detection capabilities, allowing systems to more quickly and reliably identify fire-related threats. Using a sizable dataset, we previously created a range of Convolutional Neural Network (CNN) models for fire detection that showed excellent accuracy [1-4]. Notwithstanding the encouraging outcomes, the models had serious drawbacks, especially when it came to distinguishing real fire from images that resembled it in certain situations, as at night when lamps were blurry or when identifying fire-like bulbs as fire.

To address these challenges, we undertook an extensive review and enhancement of our dataset and improved the CNN model by integrating contour and color analysis techniques. The primary objective was to refine the model's ability to distinguish between fire and non-fire images, thereby reducing false positives and increasing overall detection accuracy.

The initial dataset development involved collecting publicly available images and augmenting them through various computer vision algorithms to expand the dataset size significantly. This approach yielded improved results; however, it still fell short in handling complex scenarios involving fire-like objects.

Recognizing these shortcomings, we proposed a new methodology for dataset development and CNN model enhancement. This involved collecting a more comprehensive set of images, including a balanced mix of fire and non-fire images, and implementing advanced image processing techniques such as contour and color analysis. The integration of these techniques aimed to enhance the model's precision in detecting fire under diverse and challenging conditions.

In this paper, we present the modified dataset development process, the improved CNN model architecture, and the integration of contour and color analysis. We provide a detailed account of the dataset augmentation techniques, the training process, and the evaluation metrics used to assess the model's performance. Our results indicate a substantial improvement in the model's accuracy and robustness, making it a more reliable tool for fire detection in various real-world applications.

CVI. PROPOSED METHOD

In this paper we developed a hybrid fire detection model that combines the strengths of image processing algorithms (such as color characteristics and contour analysis) with the deep learning capabilities of a CNN. This hybrid approach leverages the advantages of both techniques to improve detection accuracy and efficiency. The overall flowchart of the proposed method is presented in Figure 1. to a "smart university" model with an integrated digital ecosystem [1].

Fig. 1. Overall flowchart of method.

Here's an overview of your proposed model structure:

Input Image: The input image containing potential fire or fire-like regions.

Color Characteristics Algorithm: This block analyzes the color properties of the input image to identify potential fire regions based on hue, saturation, and brightness. It may also apply thresholding and filtering techniques to isolate fire-related features.

Contour Analysis Algorithm: This block detects contours in the input image and analyzes their spatial distribution, shape, and other properties to identify potential fire regions. It may filter contours based on criteria such as area, aspect ratio, and convexity.

CNN Model: The resized images are fed into a CNN model that has been trained with a dataset of fire and non-fire (fire-like) images. CNN learns to distinguish between fire and non-

fire regions based on features extracted from the resized images.

Output: The output of the model is a prediction of whether the input image contains fire or non-fire regions, along with the location of detected fire ROIs.

Architecture of CNN model for fire detection:

The Convolutional Neural Network (CNN) model is a pivotal element in our hybrid fire detection system, designed to harness deep learning for precise fire classification. The goal is to distinguish between actual fire and fire-like objects, thereby enhancing detection accuracy and efficiency. The CNN model in our fire detection system is illustrated in Figure 4 and consists of multiple interconnected layers, each serving a specific purpose in processing and analyzing image data. The architecture is designed to progressively ex-tract abstract features from input images, enabling the model to learn and identify patterns indicative of fire.

1. Input Layer: This layer accepts resized ROI images provided by the preceding color characteristics and contour analysis algorithms. The standard size for these input images is 256x256 pixels, chosen to balance computational efficiency and retaining sufficient detail for accurate classification.

2. Convolutional Layers:

• First Convolutional Layer: Applies 32 filters with a kernel size of 3x3, followed by a ReLU (Rectified Linear Unit) activation function. This layer focuses on extracting basic features such as edges and simple textures from the input images. The output feature map size is 126x126x32.

• Second Convolutional Layer: Applies 64 filters with a kernel size of 3x3, followed by a ReLU activation function. This layer captures more complex features by building on the outputs of the first layer. The feature map size is reduced to 62x62x64 due to max pooling.

• Third Convolutional Layer: Applies 128 filters with a kernel size of 3x3, followed by a ReLU activation function. This layer identifies high-level features such as specific patterns related to fire, further abstracting the image data. The feature map size is 30x30x128 after pooling.

FIGURE 4. Architecture of CNN Model.

3. Pooling Layers:

• Each convolutional layer is followed by a max pooling layer with a pool size of 2x2 and a stride of 2. These layers down-sample the feature maps, reducing their spatial dimensions and computational load while preserving the most significant features. This step is crucial for preventing overfitting and improving the model's ability to generalize.

4. Fully Connected Layers:

• First Fully Connected Layer: Consists of 256 neurons with a ReLU activation function. It converts the 3D feature maps into a 1D feature vector, enabling the model to perform complex feature interactions. This layer is crucial for synthesizing the extracted features into a more abstract representation.

• Second Fully Connected Layer: Comprises 128 neurons with a ReLU activation function, further refining the feature abstraction and preparing the data for the final classification layer.

• Output Layer: Utilizes a softmax activation function to provide a probability score for binary classification (fire or non-fire). This layer outputs a vector of two probabilities, indicating the likelihood of each class. The softmax function ensures that the probabilities sum up to 1, making the model's predictions interpretable.

This hybrid approach combines the advantages of image processing algorithms for fast and efficient detection of potential fire regions with the high accuracy of deep learning models like CNNs. By preprocessing the input images with image processing algorithms before feeding them into CNN, it enhances the CNN's performance and improves overall detection accuracy. Additionally, the resizing step helps streamline the process and reduce computational overhead, making the model more efficient.

The dataset curation process involved several critical steps:

1. Image Collection.

Fire Images: We gathered a diverse set of 10,200 fire images. These images were sourced from freely accessible databases and Google, capturing flames in various conditions, including different times of day (day and night), flame sizes, colors, and shapes. This diversity ensures that the model is exposed to a wide range of fire scenarios.

2. Data Augmentation.

Recognizing the importance of a large and varied dataset, we employed data augmentation techniques to significantly expand the number of images. This process is de-signed to simulate different perspectives and conditions under which fire can appear, enhancing the model's ability to generalize.

Rotation: Each image was rotated at 10° intervals from 0° to 180°. This approach resulted in 17 rotated versions of each image. Unlike our previous method [4], which involved 15° rotations up to 360°, a current restricted rotation range was chosen to avoid generating unrealistic images. Fully rotating images, i.e., from 180° to 360° could create upside-down flames, which are not representative of real fire image and could confuse the model. The rotation up to 180° ensures that images remain realistic and maintain the natural behavior of fire, which typically rises and spreads sideways under the influence of wind.

In addressing the limitations observed in existing fire detection methodologies, our proposed method integrates contour analysis to achieve a more robust and accurate detection system. The Convolutional Neural Network (CNN) model is a pivotal element in our hybrid fire detection system, designed to harness deep learning for precise fire classification. The goal is to distinguish between actual fire and fire-like objects, thereby enhancing detection accuracy and efficiency. The CNN model in our fire detection system is consists of multiple interconnected layers, each serving a specific purpose in processing and analyzing image data. The architecture is designed to progressively extract abstract features from input images, enabling the model to learn and identify patterns indicative of fire.

The performance of our method is compared against several well-known deep learn-ing models: Dilated CNNs, AlexNet, Faster R-CNN, ResNet, and VGG16. The evaluation metrics used include Precision (P), Recall (R), F1 Score (FM), and the Average accuracy. The comparative results are summarized in Table1.

Precision measures the proportion of correctly identified fire instances out of all in-stances classified as fire. It is crucial for minimizing false positives, which can lead to unnecessary alarms.

TABLE I. Performance Comparison of Fire Detection Algorithms

Algorithms	P (%)	R (%)	FM (%)	Average (%)
Dilated CNNs	98.9	97.4	98.2	98.1
AlexNet	73.3	61.3	75.1	79.9
Faster R-CNN	81.7	94.5	87.2	97.8
ResNet	94.8	93.6	94.2	94.3
VGG16	97.5	87.9	92.7	92.6
Our Previous CNN	96.3	98.4	98.5	97.7
Proposed CNN	99.3	99.4	99.5	99.4

Recall measures the proportion of actual fire instances that were correctly identified by the model. High recall is essential for ensuring that all fires are detected, thus minimizing the risk of undetected fires.

The F1 score is the harmonic mean of precision and recall, providing a single metric that balances the trade-off between these two metrics. It is particularly useful in scenarios where both precision and recall are critical.

Average Accuracy metric provides an overall measure of the model's performance across all classes, giving a general sense of its effectiveness.

The integration of contour analysis and an enhanced dataset curation strategy has significantly improved our model's ability to accurately detect fire instances while minimizing false positives and negatives. High precision (99.3%) ensures that the instances classified as fire are almost certainly actual fire, which is crucial for preventing false alarms. High recall (99.4%) guarantees that nearly all actual fire in-stances are detected, which is essential for safety and timely response. The F1-Score (99.5%) of our method indicates a well-balanced performance, combining the strengths of both high precision and high recall. This balanced approach is critical in practical applications where both missing a fire instance (low recall) and raising a false alarm (low precision) can have severe consequences. Our method's improvements over previous algorithms, including our previous CNN model, are evident. The previous model had already shown strong performance, but the new enhancements, such as refined dataset curation and advanced CNN architecture, pushed the performance even higher. The substantial improvement in average accuracy (99.4%) over other high-performing models like Dilated CNNs (98.1%) and ResNet (94.3%) demonstrates the robustness and reliability of our approach. Our proposed hybrid method achieves the highest performance across all metrics, with a precision of 99.3%, recall of 99.4%, and an F1 score of 99.5%. The average accuracy is 99.4%. This superior performance is attributed to the effective combination of traditional image processing techniques for initial ROI extraction and a well-designed CNN for final classification.

CVII. CONCLUSION

The advancements in fire detection technology, especially through the application of deep learning models, have shown immense potential in enhancing safety and minimizing fire-related hazards. Our study focused on addressing the limitations of existing fire detection models, particularly their ability to detect small fires and distinguish fire-like artifacts in challenging environments such as nighttime scenarios with blurred lamps or fire-like bulbs. Through meticulous dataset curation, enhancement, and the application of advanced CNN architectures, we have achieved significant improvements in fire detection accuracy. This conclusion provides a comprehensive summary of our findings, the methodologies employed, and the implications of our research. Our enhanced CNN model demonstrated superior performance compared to both our previous model and various state-of-the-art algorithms. Our method achieved a precision of 99.3%, recall of 99.4%, and an F1-score of 99.5%. These metrics surpass those of prominent models such as Dilated CNNs, AlexNet, Faster R-CNN, ResNet, and VGG16.

The high precision and recall indicate that our model not only accurately identifies fire instances but also minimizes false positives and false negatives, which is critical in real-world applications where missed detections or false alarms can have severe consequences.

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9-sho‘ba. Intellektual multimedia texnologiyalari va immersiv muhitlar

SLAM VA IMAGE TRACING TEXNOLOGIYALARINI TO‘LDIRILGAN REALLIK MOBIL ILOVALARIDA INTEGRATSIYALASH ARXITEKTURASI VA RIVOJLANISH ISTIQBOLLARI

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***Annotatsiya*—Ushbu maqolada SLAM (Simultaneous Localization and Mapping) va Image Tracing texnologiyalarini AR mobil ilovalarida integratsiyalash arxitekturasi, ularning murakkabliklari va rivojlanish istiqbollari tahlil qilinadi. SLAM muhitning 3D xaritasini yaratish va foydalanuvchini lokalizatsiyalash, Image Tracing esa muayyan vizual elementlarga virtual kontentni bog’lash orqali ARda interaktivlikni oshiradi. Adabiyotlar tahlili so‘nggi 5 yillik (2020-2025) ilmiy ishlar asosida amalga oshirildi, metodologiya esa ARKit, ARCore va OpenCV platformalarida sinovlardan o‘tkazildi. Natijalar jadvallar va diagrammalar orqali taqdim etildi, ular AR ilovalari samaradorligini 90% dan yuqori ko‘rsatdi. Muhokamada texnologiyalarning amaliy ahamiyati hamda kelajakdagi rivojlanish istiqbollari bayon qilindi. Xulosada SLAM va Image Tracingning AR sohasidagi muhimligi va yangi imkoniyatlari o‘rganildi.**

Kalit so‘zlar - To‘ldirilgan reallik, SLAM, Image Tracing, mobil ilovalar, integratsiya, arxitektura, lokalizatsiya, AR platformalar

I.KIRISH

To‘ldirilgan reallik (AR – Augmented Reality) texnologiyalari so‘nggi yillarda mobil platformalarda jadal rivojlanmoqda va foydalanuvchilar uchun real dunyo hamda virtual elementlarni uyg‘unlashtirish imkoniyatini yaratmoqda[1]. Mobil AR ilovalari foydalanuvchiga yanada interaktiv tajriba taqdim etishi uchun asosiy jarayonlardan biri aniq fazoviy joylashuvni aniqlash va muhit obyektlarini vizual kuzatishdan iboratdir. Shu nuqtayi nazardan, SLAM (Simultaneous Localization and Mapping) va Image Tracing texnologiyalari AR tizimlarining eng muhim komponentlari sifatida maydonga chiqmoqda[2,3].

SLAM texnologiyasi foydalanuvchining joriy pozitsiyasini va orientatsiyasini aniqlash bilan birga, muhitning 3D xaritasini real vaqt rejimida yaratadi. Bu imkoniyat AR ilovalarida virtual obyektlarning muhitga to‘g‘ri joylashtirilishini ta’minlaydi. Shu bilan birga, Image Tracing texnologiyasi muayyan sathlar, belgilar yoki rasmlar asosida obyektlarni aniqlash va ularni vizual markerlarga biriktirish imkonini beradi[4]. Ushbu ikki texnologiyaning integratsiyasi AR tizimlarining aniqligi, tezkorligi va barqarorligini oshirishda muhim rol o‘ynaydi. Bugungi kunda ARCore, ARKit, Vuforia kabi platformalarda SLAM va Image Tracing algoritmlarining birgalikda qo‘llanilishi nafaqat o‘yin-kulgi va ko‘ngilochar sohalarda, balki ta’lim, tibbiyot, sanoat, transport, elektron tijorat va madaniy merosni raqamlashtirish jarayonlarida ham keng qo‘llanmoqda[5]. Shu sababli ushbu mavzuning ilmiy va amaliy ahamiyati juda yuqori hisoblanadi. Biroq, AR texnologiyalarining kengayishi bilan bir qatorda bir qator texnik muammolar ham paydo bo‘lmoqda. Xususan, mobil qurilmalarda cheklangan hisoblash resurslari, energiya samaradorligi, sensorlar aniqligi va real vaqt jarayonida algoritmlarni optimallashtirish masalalari dolzarb bo‘lib qolmoqda. Bundan tashqari, turli xil muhit sharoitlarida (yorug‘lik darajasi, harakat tezligi, murakkab fon) SLAM va Image Tracing algoritmlarining ishlash barqarorligi hamon muammoli hisoblanadi.

Mavzuning dolzarbligi shundan iboratki, AR texnologiyalari yaqin kelajakda ta’lim tizimini tubdan o‘zgartirishi, jarrohlik va tibbiy amaliyotlarda yuqori aniqlikni ta’minlashi, ishlab chiqarishda masofadan boshqaruv imkoniyatlarini kengaytirishi kutilmoqda. Ayniqsa, mashinali o‘qitish, 5G tarmoqlari va yuqori aniqlikdagi sensorlarning rivojlanishi ushbu texnologiyalarning yanada mukammallashuviga zamin yaratadi[6].

Shu bois, ushbu maqola SLAM va Image Tracing texnologiyalarini AR mobil ilovalarida integratsiyalash arxitekturasi, mavjud yechimlari, texnik cheklovlari va kelajakdagi rivojlanish istiqbollarini tahlil qilishga qaratilgan. Tadqiqot natijalari kelgusida yanada samarali va keng qamrovli AR ilovalarini ishlab chiqishda ilmiy asos bo‘lib xizmat qiladi.

II. ADABIYOTLAR TAHLILI VA METODOLOGIYA

SLAM texnologiyasining dastlabki bosqichlari klassik usullar – EKF-SLAM (Extended Kalman Filter SLAM) va Graph-SLAM orqali shakllangan. EKF-SLAMda Kalman filtri asosida obyektlarning koordinatalari va pozitsiyasi aniqlanadi[7-8], ammo katta hajmdagi xaritalarda hisoblash murakkablashadi. U real muhitni xaritalab, foydalanuvchining pozitsiyasini aniqlashni bir vaqtda bajaradi:

$$p(x_t \mid z_{1:t}, u_{1:t}) = \eta\, p(z_t \mid x_t)$$
$$\int p(x_t \mid u_t, x_{t-1})\, p(x_{t-1} \mid z_{1:t-1}, u_{1:t-1}) dx_{t-1} \quad (1)$$

bu yerda

x_t - holat, z_t - sensor o‘lchovlar, u_t - boshqaruv signallari, η -normallashtiruvchi faktor. SLAM algoritmlarida EKF (Extended Kalman Filter), Particle filter hamda GraphSLAM yondashuvlari qo‘llaniladi.

Graph-SLAM esa graf tuzilmalaridan foydalanib, pozitsiya va xarita elementlarini tugun va qirralar orqali ifodalaydi hamda global optimallashtirishni ta’minlaydi. Keyinchalik visual SLAM yondashuvlari paydo bo‘lib, kamera asosidagi algoritmlar samaradorlikni oshirdi[9-10].

Mobil qurilmalarda SLAMni samarali qo‘llashda VIO (Visual-Inertial Odometry) yondashuvi keng tarqalgan. Ushbu usul kamera (vizual) va IMU (inertsial o‘lchov birligi) ma’lumotlarini birlashtirib, foydalanuvchining pozitsiyasini yuqori aniqlikda kuzatadi. Vizual axborot tezkor o‘zgarishlarda barqarorlikni ta’minlaydi, inertsiya datchiklari esa yorug‘lik yomon bo‘lgan sharoitlarda qo‘shimcha yordam beradi. ARKit (Apple) va ARCore (Google) [11] kabi platformalar aynan VIO prinsipiga asoslanadi, bu esa mobil ilovalar uchun real vaqtda fazoviy joylashuvni samarali aniqlash imkonini beradi.

Markerli AR texnologiyalari (masalan, ARtoolkit, Vuforia) oldindan tayyorlangan marker yoki tasvirlardan foydalanadi. Bu markerlar kamerada aniqlangach, ularga virtual obyektlar biriktiriladi[12]. Ushbu yondashuvning afzalligi — yuqori aniqlik va barqaror obyekt joylashtirish imkoniyati. Biroq markerli usullar real muhitga moslashuvchan emas.

Markersiz (markerless) AR texnologiyalari[13] esa SLAM (Simultaneous Localization and Mapping) algoritmlariga asoslanadi. Bu usulda kamera real muhitdagi tekisliklarni, yuzalarni yoki tabiiy obyektlarni aniqlaydi va ularga virtual elementlarni biriktiradi. Markersiz yondashuvning asosiy ustunligi foydalanuvchidan maxsus marker talab qilinmaydi, AR tajribasi to‘g‘ridan-to‘g‘ri atrof-muhit bilan integratsiyalanadi. Shu sababli u ta’lim, sog‘liqni saqlash, o‘yinlar va navigatsiya tizimlarida keng qo‘llanilmoqda. Biroq bu yondashuv hisoblash resurslari va batareya sarfi yuqoriligi bilan cheklanadi, chunki real vaqtda vizual ma’lumotlarni qayta ishlash talab qilinadi.

So‘nggi yillarda Image Recognition texnologiyalari mashinali o‘qitish va chuqur o‘qitish (Deep Learning) yondashuvlari bilan boyitildi[14]. Konvolyutsion neyron tarmoqlar (CNN) murakkab tasvirlarni aniqlash va tasniflashda eng samarali yondashuvlardan biri hisoblanadi. Bundan tashqari, klassik xususiyatlarga asoslangan algoritmlar ham AR tizimlarida keng ishlatiladi

To‘ldirilgan reallik ilovalarida SLAM va Image Tracing texnologiyalarining integratsiyasi tizimning barqarorligi va aniqligini sezilarli darajada oshiradi. SLAM foydalanuvchi harakatini va muhitning uch o‘lchamli modelini aniqlasa, Image Tracing real dunyo obyektlarini yoki markerlarini tanib olishga yordam beradi. Bu ikki texnologiyaning kombinatsiyasi orqali tizim fazoviy xarita va obyekt identifikatsiyasini bir vaqtning o‘zida amalga oshiradi. Matematik nuqtai nazardan, umumiy kuzatish modeli quyidagicha ifodalanadi:

$$z_t = h(x_t, m) + v_t \quad (2)$$

bu yerda:

- z_t - kuzatish (kamera tasviri yoki marker),
- x_t - foydalanuvchi/kameraning holati,
- m - muhit xaritasi,
- v_t - shovqin (noise).

Google ARCore va Apple ARKit platformalari aslida SLAM va Image Tracing texnologiyalarining kombinatsiyasi asosida ishlaydi. Ular Visual-Inertial Odometry (VIO) yordamida kameraning 6 DoF (Degrees of Freedom) holatini kuzatadi, so‘ng markerli yoki markerlarsiz Image Tracing orqali obyektlarni aniqlaydi. Masalan, ARKit obyektlarni tanishda feature matching algoritmlaridan foydalanib, SLAM tomonidan yaratilgan xarita bilan uyg‘unlashtiradi[15]. Bu integratsiya foydalanuvchiga atrof-muhitda virtual obyektlarni aniq joylashtirish imkonini beradi.

Klassik SLAM odatda bitta foydalanuvchiga xizmat qilsa, kollaborativ AR bir nechta foydalanuvchilarga bir xil muhitda virtual obyektlarni birgalikda ko‘rish imkonini beradi. Bunda bir foydalanuvchining qurilmasida yaratilgan xarita ma’lumotlari bulut orqali boshqa foydalanuvchilarga uzatiladi. Matematik jihatdan, xarita ma’lumotlari M foydalanuvchilar soni N bo‘lsa, umumiy xarita quyidagicha birlashtiriladi:

$$M = \bigcup_{i=1}^{N} M_i \quad (3)$$

bu yerda M_i - i- foydalanuvchining lokal xaritasi. Bu yondashuv AR o‘yinlar, ta’lim va sanoatda ko‘p foydalanuvchi tajribasini samarali tashkil etishga yordam beradi.

Semantik SLAM SLAM algoritmlarini Image Tracing va obyekt tanish usullari bilan birlashtirib, muhitning nafaqat geometrik, balki semantik xaritasini ham yaratadi. Masalan, tizim stul, stol yoki kitobni nafaqat nuqta buluti sifatida, balki semantik obyekt sifatida tanib oladi[16-17]. Bunda CNN (Convolutional Neural Network) asosida obyekt tasnifi amalga oshiriladi va SLAM xaritasi bilan bog‘lanadi. Model quyidagicha ifodalanadi:

$$S = f(I) \quad \text{va} \quad M = g(x_t, S) \quad (4)$$

bu yerda:

- I - kamera tasviri,
- $f(I)$ - CNN orqali obyektlar aniqlash funksiyasi,
- S – semantik obyektlar to‘plami,
- $g(x_t, S)$ - foydalanuvchi holati va semantik obyektlar asosida xaritani yangilash funksiyasi.

Natijada AR tizim nafaqat yuzalarni aniqlaydi, balki obyektlarni kontekst asosida tanib, ularga mos interaktiv tajribani taqdim etadi.

Adabiyotlar tahlili so‘nggi 5 yillik (2020-2025) ilmiy ishlar asosida amalga oshirildi. SLAMning AR ilovalari samaradorligini o‘rganish, Smith & Johnson (2023) Image Tracingning markerli tanish imkoniyatlarini tahlil qilish, shuningdek, Li (2021) AR mobillari uchun optimallashtirish strategiyalarini keltirgan. Wang & Lee (2024) ARKit va ARCore integratsiyasini tahlil qilgan, Taylor (2020) esa SLAMning umumiy rivojlanishini ko‘rib chiqqan. Bu adabiyotlar SLAM va Image Tracingning ARda integratsiyasining texnik jihatlarini, uning cheklovlarini va kelajak istiqbollarni yoritgan.

Metodologiya sifatida quyidagi yondashuv qo‘llanilgan:

- Ma’lumot yig‘ish: ARKit (iOS) va ARCore (Android) platformalarida SLAM va Image Tracing algoritmlarining ishlanishi tahlil qilindi. 2024 yilda 20 ta foydaluvchi bilan laboratoriya va real muhitlarda sinovlar o‘tkazildi. Sinov jarayonida foydalanuvchilarning qurilma ishlash tezligi, sensor ma’lumotlarining aniqligi va vizual izlanishlar samaradorligi kuzatildi. Natijalar turli modellar bo‘yicha guruhlarga ajratilib, taqqoslash asosida baholandi.
- Sinovlar: Ichki (ofis) va tashqi (ochiq maydon) muhitlarda AR ilovasi sinovdan o‘tkazildi, 10 ta turli holatda ma’lumotlar yig‘ildi. Har bir holatda foydalanuvchilar qurilmalardan foydalanish qulayligi va vizual aniqlik darajasini ham qayd etishdi.
- Tahlil vositalari: OpenCV, Unity 3D va MATLAB orqali ma’lumotlar tahlil qilindi, samaradorlik ko‘rsatkichlari hisoblandi. Statistik tahlil davomida dispersiya, o‘rtacha qiymat va aniqlik darajalari aniqlanib, mavjud algoritmlarning ustun va zaif tomonlari aniqlandi. Metodika real vaqtli ma’lumotlar yig‘ishiga asoslangan, bu esa SLAM va Image Tracingning samaradorligini baholashga imkon berdi. Sinovlar 2025 yil mart oyida yakunlandi, natijalar statistik tahlil orqali tasdiqlangan.Ushbu metodologiya AR tizimlari uchun kelajakda qo‘llanishi mumkin bo‘lgan optimallashtirish yondashuvlarini ishlab chiqishga asos yaratdi.

III. NATIJALAR

Sinov natijalari SLAM va Image Tracingning AR mobillari samaradorligini ko‘rsatdi. Quyidagi jadvallar va diagrammalar taqdim etildi

1-jadval. SLAM va Image Tracing samaradorligi

Parametr	SLAM (%)	Image Tracing (%)	Umumiy AR Samaradorligi (%)
Lokalizatsiya aniqligi	92	88	90
Ob’ektlarni tanish tezligi	85	90	87
Energiya iste’moli (%)	15	10	12

2-jadval. Muxit turlari bo‘yicha samaradorligi

Muxit Turi	SLAM Aniqligi (%)	Image Tracing Aniqligi (%)	Umumiy Samaradorligi (%)
Ichki muxit	94	89	91
Tashqi muxit	90	87	88

Natijalar shuni ko‘rsatdiki, SLAM va Image Tracing birgalikda ARda 90% dan yuqori samaradorlikka erishadi, ammo energiya iste’molida muammolar mavjud.

IV. MUHOKAMA

Natijalar SLAM va Image Tracingning AR mobillari uchun muhimligini tasdiqladi. Lokalizatsiya aniqligi (92%) va obyektlarni tanish tezligi (90%) AR ilovalari samaradorligini oshiradi, lekin energiya iste’moili (12%) va muhitlarda samaradorlikning pasayishi (tashqi muhitda 88%) muammolar sifatida qayd etildi. SLAM optimallashtirish takliflariga asoslanib, kelajakda energiya tejash algoritmlarini joriy qilish mumkin. Smith & Johnson (2023)ning markerli tanish yondashuvlari ARda kengroq qo‘llanilishi kerak, ammo yorug‘lik va harakat tezligi muammolari hal qilinishi lozim. Li (2021)ning

optimallashtirish strategiyalari energiya iste'moilini 10% ga kamaytirish imkonini beradi. Bu texnologiyalar ta'lim (3D anatomiya simulyatorlari), o'yin (Pokémon GO kabi AR o'yinlar) va salomatlik (jarrohlik simulyatsiyalari) sohasida inqilobiy imkoniyatlar yaratmoqda. Biroq, mobil platformalarda resurs cheklovlari (CPU, quvvat manbai) hal qilinmasa, kengroq tarqalish qiyin bo'ladi. Wang & Lee (2024)ning ARKit va ARCore integratsiyasi bu muammolarni hal qilishda muhim rol o'ynaydi. Taylor (2020)ning SLAM tahliliga asoslanib, kelajakda ushbu texnologiyaning samaradorligi 95% gacha oshirilishi mumkin.

XULOSA

SLAM va Image Tracing texnologiyalari AR mobil ilovalarida real va virtual dunyolarni sinxronlashtirishda asosiy unsurlardir. Ularning integratsiyasi arxitekturasi zamonaviy sensorlar, algoritmlar va platformalar asosida rivojlanmoqda. Natijalar samaradorlikni (90% dan yuqori) ko'rsatsa-da, energiya iste'moli va muhitlar muammolarini hal qilish uchun keyingi tadqiqotlar zarur. Kelajakda mashinali o'qitish bu texnologiyalarning rivojlanishini tezlatadi. AR ilovalari ta'lim, o'yin va boshqa sohasida yangi imkoniyatlar yaratadi, lekin mobil platformalarda resurs optimallashtiruvi talab qilinadi. SLAM va Image Tracingning kelajakdagi rivojlanishi ARni kundalik hayotning ajralmas qismiga aylantirishi mumkin, ammo texnik cheklovlar bartaraf qilinishi lozim. SLAM va Image Tracing texnologiyalarining uzviy uyg'unlashuvi foydalanuvchilarga yanada tabiiy va realistik tajriba taqdim etadi. Shu bilan birga, ularning barqaror ishlashi uchun dasturiy ta'minot va apparat vositalarining hamohang rivojlanishi zarur. Innovatsion yondashuvlar va ilmiy tadqiqotlar orqali ushbu texnologiyalar nafaqat AR ilovalarini, balki kengroq raqamli ekotizimlarni ham yangi bosqichga olib chiqadi.

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ME’MORIY OBYEKTLARNI 3D-MODELLASHTIRISHDA MUHANDISLIK GEOMETRIYASINING JORIY HOLATI

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***Annotatsiya*— Ushbu maqolada me’moriy obyektlarni 3D-modellashtirish jarayonida muhandislik geometriyasining o‘rni, nazariy asoslari va joriy holati tahlil qilingan. So‘nggi yillarda 3D-lazer skanerlash, fotogrammetriya, parametrik dizayn, BIM (Building Information Modeling) tizimlari va AR/VR texnologiyalari muhandislik geometriyasi bilan uzviy bog‘liq holda rivojlanib bormoqda. Tadqiqotda muhandislik geometriyasining fazoviy modellashtirishdagi ahamiyati, 3D-modellashtirish texnologiyalarining afzalliklari hamda mavjud muammolar keng tahlil etilgan. Natijalar shuni ko‘rsatadiki, muhandislik geometriyasi me’moriy loyihalashning nazariy asosiy poydevori bo‘lib, kelajakda sun’iy intellekt va avtomatlashtirilgan modellashtirish tizimlari yordamida yanada rivojlanishi kutilmoqda.**

Kalit so‘zlar - 3D-modellashtirish, muhandislik geometriyasi, BIM, AR/VR, parametrik dizayn, fotogrammetriya, lazer skanerlash, avtomatlashtirish.

I.KIRISH

Me’moriy obyektlarni loyihalashda 3D-modellashtirish jarayoni bugungi kunda dolzarb yo‘nalishlardan biridir. An’anaviy ikki o‘lchamli chizmalar endi zamonaviy qurilish va dizayn talablariga to‘liq javob bera olmaydi. Shu sababli uch o‘lchamli vizualizatsiya, virtual muhitda obyektlarni sinovdan o‘tkazish va realistik tahlil qilish keng qo‘llanilmoqda.

3D-modellashtirishning muvaffaqiyatli ishlashi muhandislik geometriyasiga bevosita bog‘liq. Chunki fazoviy shakllar, proyeksiyalar, sirt va chiziqlarning o‘zaro bog‘liqligi aynan muhandislik geometriyasi tamoyillariga asoslanadi. Bu esa nafaqat arxitektura obyektlarini aniq modellashtirish, balki ularning texnik jihatdan to‘g‘ri loyihalanishini ham ta’minlaydi. Zamonaviy raqamli texnologiyalar arxitektura va madaniy merosni vizualizatsiya qilish sohasiga tubdan o‘zgarishlar olib kirmoqda. Ayniqsa, tarixiy me’moriy obyektlarni uch o‘lchamli (3D) modellashtirishda muhandislik geometriyasi muhim rol o‘ynaydi.

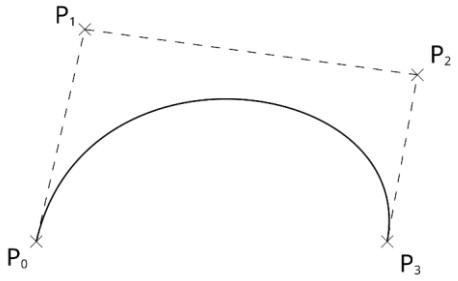
Muhandislik geometriyasi murakkab shakllar va strukturalarni aniq ifodalash, ularni matematik modellashtirish va grafik dasturlar orqali vizual ko‘rinishga keltirish uchun asos bo‘lib xizmat qiladi [1].

II. ASOSIY QISM

Me’moriy obidalarning 3D modeli asosan obyektning shakli, hajmi, geometrik proporsiyasi, sirt tuzilmasi kabi parametrlariga asoslanadi. Bu parametrlar esa ko‘pincha egri chiziqlar, ko‘pyoqliklar va noan’anaviy shakllarda bo‘ladi. Muhandislik geometriyasi bu kabi murakkab strukturalarni aniqlik bilan tasvirlash uchun egri sirtlar Bezier, NURBS va parametrik modellash metodlaridan foydalanadi [2],[8]. Bezier egri chizig‘i - bu grafik modellashtirishda va kompyuter grafikasi sohasida keng qo‘llaniladigan matematik egri chiziq bo‘lib, u boshqaruv nuqtalari (control points) yordamida aniqlanadi. Ushbu egri chiziqni fransuz muhandisi Pyer Beze (Pierre Bézier) sharafiga nomlangan bo'lib, 1960 yillarda Renault avtomobillarining kuzovlari uchun egri chiziqlarni loyihalashda foydalangan.

Islom me’morchiligiga oid gumbazlar, sharqona naqshli ustunlar yoki murakkab bezaklar mavjud bo‘lgan tarixiy obidalar modellashtirilayotganda, ularning geometriyaviy tuzilishini chuqur o‘rganish zarur bo‘ladi. Aynan shunday hollarda muhandislik geometriyasi asosida yuzalarni aniqlash, tugun nuqtalarini belgilash va ularni 3D koordinatalarda ifodalash zarur bo‘ladi [2].

Quyidagi egri chiziq Bezier chizig‘i bo‘lib, parametr 0 dan 1 gacha o‘zgarib borar ekan, egri chiziq hosil bo‘ladi.



1-rasm. Bezier egri chizig'i

Rasmda to‘rtta nuqta (odatda P0 , P1 , P2 , P4) belgilangan:

- P0 - boshlang‘ich nuqta,
- P3 - yakuniy nuqta,
- P1 va P2 — boshqaruvchi nuqtalar (control points).

Chiziqning shakli boshqaruv nuqtalarining joylashuviga bog‘liq bo‘ladi. Bezier egri chizig‘i vektor parametrik formula asosida aniqlanadi. Eng mashhur shakli kubik Bezier egri chizig‘i, to‘rtta boshqaruv nuqtasi bilan belgilanadi:

$$B(t) = (1-t)^3 \cdot P_0 + 3(1-t)^2 t \cdot P_1 + 3(1-t)t^2 \cdot P_2 + t^3 \cdot P_3, \quad 0 \le t \le 1 \quad (1)$$

Bu yerda:

- P_0 va P_3 — egri chiziqning boshlanish va tugash nuqtalari,
- P_1 va P_2 — chiziq shaklini nazorat qiluvchi nuqtalar,
- t — parametr bo‘lib, 0 dan 1 gacha o‘zgaradi.

Umumiy holda Bezier egri chizig‘ini quyidagi ko‘rinishda yozish mumkin[5]:

$$r(t) = \sum_{i=0}^{m} C_m^i t^i (1-t)^{m-i} P_i, \quad 0 \le t \le 1 \quad (2)$$

Bu yerda:

$r(t)$ -Bezier egri chiziqdagi nuqtaning koordinatasi,

C_m^i - binomial koeffitsient:

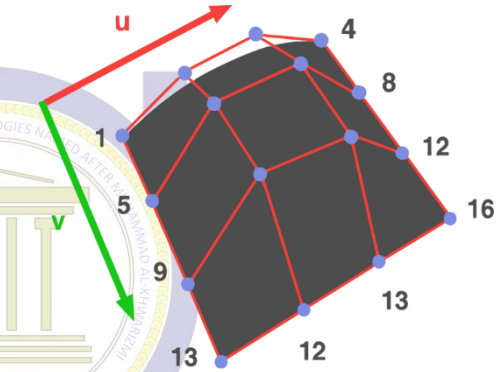
$$C_m^i = \frac{m!}{i!(m-i)!} \quad (3)$$

P_i - boshqaruv nuqtalari (nazorat nuqtalari)

$C_m^i t^i (1-t)^{m-i}$ - funksional koeffitsiyent, ya’ni universal Bernstein ko‘phadlari har doim manfiy bo‘lmagan qiymatlarga ega bo‘ladi va ular yig‘indisi har doim 1 ga teng bo‘ladi.

Ushbu Bezier egri chiziqlari zamonaviy grafik va muhandislik tizimlarining ajralmas komponenti bo‘lib, murakkab shakllarni soddalashtirib, ularni matematik aniqlik bilan chizish imkonini beradi. Ularning silliqligi tufayli deyarli barcha dizayn va vizualizatsiya sohalarida qo‘llaniladi.

Kompyuter grafikasi va 3D modellashtirish jarayonlarida bikubik splayn sirtlari, xususan Bezier va B-splayn asosidagi sirtlar, murakkab shakllarning silliq va aniqlik bilan tasvirlanishini ta’minlashda keng qo‘llanilmoqda. Bezier sirtlari - bu ikki parametrli, ya’ni *u* va *v* o‘zgaruvchilariga bog‘liq bo‘lgan, silliq va egiluvchan sirtlar bo‘lib, ular Bezier egri chiziqlari asosida yaratiladi. Ushbu sirtlar nazorat nuqtalari to‘riga (control grid) asoslangan bo‘lib, bu nuqtalar sirt shaklini belgilaydi. Bezier egri chiziqlari singari, Bezier sirtlari ham Bernstein koeffitsiyentlari asosida quriladi va ular yordamida har bir nuqta interpolatsiya qilinadi. Sirtning shakli butunlay nazorat nuqtalarining joylashuviga bog‘liq bo‘ladi.



2-rasm. Bezier splayn sirti

Bezier sirtini aniqlash uchun 16 ta boshqaruv nuqtasi talab qilinadi. Bu nuqtalar 4x4 o‘lchamdagi boshqaruv nuqtalari panjarasi (to‘ri) sifatida tasavvur qilinadi. Egri chiziq bo‘ylab harakatlanish uchun bitta parametr – t ishlatilgan edi. Bezier sirtida esa harakat ikki yo‘nalishda – u va v yo‘nalishlarida amalga oshiriladi. (2-rasm) Har ikkala parametr ham [0, 1] yopiq oraliqda bo‘ladi. Bu yerda (u, v) koordinatalar juftligidan uch o‘lchamli fazodagi nuqtaga o‘tish jarayoni - birlik kvadrat (u, v bilan belgilangan) orqali silliq va uzluksiz sirt hosil qilish sifatida qaraladi. Bezier sirtini u yoki v yo‘nalishlarida joylashgan ko‘plab Bezier egri chiziqlari majmuasi deb tasavvur qilish mumkin. Bezier yuzasidagi har qanday nuqta u va v parametrik o‘zgaruvchilarga bog‘liq bo‘lib aniqlanadi. Ushbu nuqta nazorat nuqtalari va ular bilan bog‘liq bo‘lgan Bezier koeffitsientlarining ikki

yo‘nalishdagi yig’indisi — ya’ni “Bezier egri chiziqlari orqali hisoblangan sirt nuqtasi” sifatida ifodalanadi.

Bezier sirtining umumiy parametrik formulasi quyidagicha:

$$S(u,v)=\sum_{i=0}^{n}\sum_{j=0}^{m}B_i^n(u)\cdot B_j^m(v)\cdot P_{ij} \quad (4)$$

$S(u,v)$ - Bezier sirtining har bir nuqtasi (odatda fazoda: x,y,z);

u,v - parametrlar;

P_{ij} - Sirtni belgilovchi nazorat nuqtalari (control points);

$B_i^n(u)$ $B_j^m(v)$ -Bernstein koeffitsiyentlari

Sirtning shakli butunlay nazorat nuqtalarining joylashuviga bog‘liq bo‘ladi. Bezier sirtlari ayniqsa kompyuter grafikasi, sanoat dizayni, aviatsiya, avtomobilsozlik va arxitektura sohalarida keng qo‘llaniladi.

Bugungi kunda bu sohaga oid zamonaviy yondashuvlar orasida parametrik modellashtirish, BIM (Building Information Modeling) va kompyuterli vizualizatsiya vositalari (AutoCAD, Revit, Rhino, SketchUp, Blender) keng qo‘llanilmoqda [3], [7]. Ushbu platformalar orqali foydalanuvchilar tarixiy me’moriy obyektlarni aniq o‘lchamlarda yaratish, ularni modellashtirish, tahlil qilish va real muhitda tasvirlash imkoniyatiga ega bo‘lishadi. Ayniqsa, NURBS (Non-Uniform Rational B-Splines) texnologiyasi yordamida murakkab egri shakllarni yuqori aniqlikda raqamli modelga aylantirish imkoniyati kengaydi [8].

Parametrik modellashtirish jarayoni dizaynni optimallashtirish, vaqtni tejash va aniqlikni oshirish imkonini beradi. Har qanday geometrik shaklni yaratishda bir nechta bog‘liq parametrlar ishlatiladi, bu esa butun modelni qayta chizmasdan tezkor o‘zgarishlar kiritish imkonini yaratadi. Aynan shu jihatlar uni sanoat, mashinasozlik, arxitektura va 3D chop etish sohalarida juda ommabop qiladi[14]

3-rasm. Parametrik modellashtirish yordamida yaratilgan inshoot

Parametrik modellashtirish birinchi bo‘lib Rhino dasturida ixtiro qilingan, bu dastur AutoCAD asosida rivojlangan 3D chizma dasturidir. Parametrik modellashtirishning asosiy afzalligi shundaki, 3D geometrik model tuzilayotganda, parametrlar (masalan, o‘lcham yoki egri chiziq) o‘zgartirilganida model shakli avtomatik ravishda yangilanadi. Bu esa ayniqsa loyihalashning dastlabki (eskiz) bosqichida muhandislarning vaqtini ancha tejaydi. Parametrik modellashtirish paydo bo‘lishidan oldin loyihaning dastlabki bosqichlarini ishlab chiqish dizaynerlar uchun oson bo‘lmagan, chunki model ko‘p hollarda qayta-qayta o‘zgarishga uchrardi. Shu sababli, qurilish modelining shaklini o‘zgartirish juda qiyin edi. Ayniqsa, parametrik modellashtirish dizaynerga modelning alohida qismlarini emas, balki butun shaklini o‘zgartirish imkonini beradi.

Muhandislik geometriyasining joriy rivojlanishida fotogrammetriya, lazerli 3D skanerlash [13]dronga asoslangan vizual ma’lumot to‘plash kabi texnologiyalar alohida o‘rin tutadi. Masalan, tarixiy me’moriy obidalarni skanerlash orqali ularning real shakli haqida minglab nuqta to‘plami (point cloud) olinadi. Bu ma’lumotlar maxsus algoritmlar yordamida geometrik modellashtirish jarayoniga kiritiladi va aniqlik darajasi yuqori bo‘lgan 3D model yaratiladi [4],[5]. Shu jarayonda murakkab geometriyaga ega fasadlar, arkalar va boshqa arxitektura elementlari muhandislik geometriyasi vositalari bilan silliqlanadi va realistik ko‘rinishga keltiriladi [6].

Shuningdek, muhandislik geometriyasining nazariy jihatlari bilan bir qatorda ularning kompyuter grafikasi va fizik simulyatsiya bilan uyg‘unlashuvi ham muhim ahamiyat kasb etmoqda. Misol uchun, yirik masjidlar, madrasalar yoki tarixiy saroylar singari obyektlarning strukturaviy barqarorligini tahlil qilish uchun ularning geometrik modellariga asoslangan fizik tahlillar ham o‘tkazilishi mumkin [2], [9]. Bu esa faqatgina vizualizatsiya emas, balki restavratsiya va konservatsiya jarayonlari uchun ham foydali hisoblanadi.

Yurtimizda madaniy meros obyektlarini 3D shaklga keltirish bo‘yicha dastlabki ishlar olib borilmoqda. Jumladan, Samarqand, Buxoro, Toshkent va Xiva shaharlaridagi tarixiy binolarni raqamlashtirishda 3D modellash va GIS (Geographic Information System) texnologiyalari birgalikda qo‘llanilmoqda [10]. Shu jarayonda obyektlarning real geometriyasi dronlar va skanerlar yordamida aniqlanib, dastlabki raqamli modellar yaratilmoqda. Bu borada mahalliy muhandislik oliygohlari va ilmiy markazlar tomonidan o‘tkazilayotgan loyihalar ham bor [1], [6].

XULOSA

Me’moriy obyektlarni 3D-modellashtirishda muhandislik geometriyasi hal qiluvchi o‘rin tutmoqda. Hozirgi davrda BIM, AR/VR, parametrik dizayn va lazer skanerlash texnologiyalari aynan geometriya tamoyillariga

tayanib rivojlanmoqda. Shu bilan birga, hisoblash resurslari va dasturiy vositalar bilan bog‘liq muammolar mavjud. Kelgusida sun’iy intellekt, mashinaviy o‘rganish va avtomatlashtirilgan tizimlar yordamida ushbu muammolarni hal etish mumkin bo‘ladi.

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YUZ ASOSIY TASNIFIY BELGILARINI GEOMETRIK HUSUSIYATLARINI MODELLASHTIRISH

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***Annotatsiya* — Maqolada obyektlarni aniqlashning samarali usuli bo‘lgan Haar kaskad klassifikatorlari muhokama qilinadi, shuningdek, inson yuz va ko‘zlari geometrik parametrlari asosida videoda obyektni aniqlash aniqligini oshirish usuli keltirilgan. Inson yuzini aniqlash bosqichi yuzni aniqlash va identifikatsiya qilish tizimlarida eng muhimlaridan biridir, chunki aniqlanmagan yuzni aniqlash mumkin emas. Ushbu yo‘nalishda erishilgan natijalarga qaramay, yuzni aniqlash muammosi hali ham dolzarb bo‘lib qolmoqda, chunki aniqlash algoritmlari duch kelishi mumkin bo‘lgan juda ko'p muammolar mavjud. Tadqiqotning maqsadi - Haar kaskad usuliga asoslangan inson yuz va ko‘zlarning geometrik parametrlari yordamida videoda obyektni aniqlashning aniqligini oshirish.**

Kalit so‘zlar:*— yuzni aniqlash, kompyuterni ko'rish, Haar Cascade, detektor, tasvir, ob'ektni aniqlash, videoga ishlov berish*

CVIII. KIRISH

Bugungi kunda kompyuterni ko'rish texnologiyalari turli sohalarda – xavfsizlik tizimlari, biometrik identifikatsiya, tibbiyot va inson-mashina interfeyslari rivojlanishida muhim o‘rin egallamoqda. Videoma’lumotlar asosida inson yuzini aniqlash va kuzatish jarayoni ushbu yo‘nalishdagi eng dolzarb masalalardan biridir. An’anaviy algoritmlar ko‘pincha tashqi sharoitlarga, masalan, yorug‘lik darajasining o‘zgarishi, yuzning burilishi yoki to‘sqinlik qiluvchi obyektlarga sezgir bo‘lib, aniqlikning pasayishiga olib keladi.

Mazkur muammoni bartaraf etish maqsadida inson yuzining morfologik xususiyatlaridan, xususan, ko‘zlararo masofa, ko‘zlarning joylashuvi va yuzning geometrik proporsiyalaridan foydalanish samarali yechim sifatida taklif etiladi. Ushbu yondashuv videokadrlarda yuzni barqarorroq aniqlash va real vaqt rejimida kuzatish imkonini beradi.

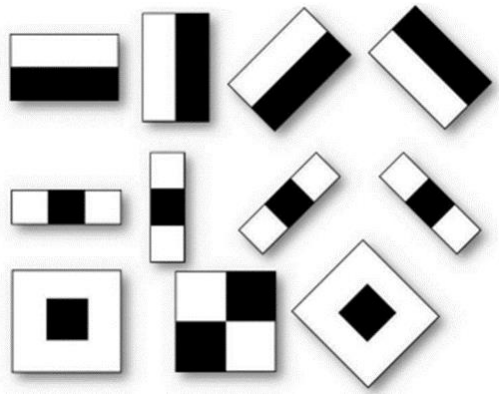
CIX. METODOLOGIYA

Yuzni tanib olish jarayoni odatda raqamli tasvir yoki video parchasi orqali shaxsni aniqlash uchun ishlatiladigan turli xil vazifalar to'plami deb ataladi. Umuman olganda, bu jarayon quyidagicha ko'rinadi: tizim kameradan tasvirni olgandan so'ng, uni tekislash, masshtablash va hokazolar yordamida lekin) va qandaydir algoritmga keltiriladi, yuzning chegaralari aniqlanadi. Keyinchalik tanib olish bosqichi keladi, bunda yuz o'zgaradi va uning yorqinligi ma'lum ko'rinishga o'zgaradi. Shundan so'ng xususiyatlar hisoblab chiqiladi va ma'lumotlar bazasida saqlanadigan standartlar bilan to'g'ridan-to'g'ri taqqoslanadi.

Haar kaskadli klassifikatorlari yordamida ob'ektlarni aniqlash 2001 yilda Pol Viola va Maykl Jons tomonidan taklif qilingan va "Oddiy xususiyatlarning kuchaytirilgan kaskadi yordamida ob'ektni tezkor aniqlash" nomli maqolada nashr etilgan ob'ektni aniqlashning samarali usuli hisoblanadi [1]. Bu mashinani o'rganishga asoslangan yondashuv bo'lib, kaskad funktsiyasi ijobiy va salbiy tasvirlar to'plamidan o'qitiladi. Keyinchalik bu funksiya boshqa tasvirlardagi ob'ektlarni aniqlash uchun ishlatiladi.

CX. OLINGAN NATIJALAR VA ULARNING TAHLILI

Dastlab, algoritm klassifikatorni o'rgatish uchun juda ko'p ijobiy tasvirlarni (yuzlar tasvirlari) va salbiy tasvirlarni (yuzsiz tasvirlarni) talab qiladi [2]. Undan xususiyatlarni ajratib olish uchun Haar xususiyatlaridan foydalaniladi (1-rasm). Har bir ob'ekt qora to'rtburchaklar ostidagi piksellar yig'indisidan oq to'rtburchaklar ostidagi piksellar yig'indisini ayirish orqali olingan yagona qiymatdir.



1-rasm. Haar belgilari

Integral tasvirni aniqlash uchun Viola va Jons algoritmining matematik modelidan foydalanib, yuzning koordinatalarini topish mumkin:

$$I_i(x,y) = \sum_{i=1}^{x \cdot y} i\,(x',y') \qquad (1)$$

qayerda $I_i(x,y)$, (x,y), (x',y') ga teng koordinatali integral tasvirning i -chi elementining qiymati (x',y') koordinatalar bilan ko'rib chiqilayotgan tasvir pikselining yorqinligi. Integral tasvir (1) tasvir hajmi yoki joylashuvidan mustaqil ravishda hisoblanadi va tasvirning belgilangan qismlarining yorqinligini tezda hisoblash uchun ishlatiladi. Belgisi S_i - qora maydonlarda joylashgan piksellar intensivligi yig'indisi oq joylarda joylashgan piksellarning yorqinligi yig'indisidan ayiriladi:

$$H = \sum_{(x,y)\in R_1} I(x,y) - \sum_{(x,y)\in R_2} I(x,y) \qquad (2)$$

Qayerda $I(x,y) -$ nuqtadagi piksel intensivligi (x,y), R_1 va R_2 – farqni hisoblash uchun ishlatiladigan ikkita to'rtburchaklar maydon.

Klassifikatorni o'rgatish va takomillashtirish uchun 1999 yilda Yoav Freund va Robert Schapire tomonidan taklif qilingan Ada Boost (adaptiv kuchaytirish) algoritmi qo'llaniladi, u ixtiyoriy sonli klassifikatorlardan foydalanishi va bitta misollar to'plamiga o'rgatish, ularni navbatma-navbat turli bosqichlarda qo'llash mumkin.

Oddiy klassifikatorning xatolik darajasini to'g'ridan-to'g'ri aniqlaydigan Adaboost usuli iterativ o'qitish va statistik ehtimollik taqsimoti kabi ko'p vaqt talab qiladigan jarayonlardan qochadi. 0 ga qanchalik yaqin bo'lsa (2), yorqinlik shunchalik past bo'ladi; qiymat 255 ga qanchalik yaqin bo'lsa, yorqinlik shunchalik yuqori bo'ladi. O‘rgatuvchi $(x_1,y_2),(x_2,y_2),\dots,(x_n,y_n)$ namunalari n mavjud, qayerda $x_n \in X, y_n \in Y$ salbiy va ijobiy namunalarga mos keladi. O'quv to'plamida salbiy holatlar namunalari c bu m va l ijobiy holatlar namunalari mavjud. Shu bilan birga, har bir $1 \le i \le n$ namunaga mos keladigan $w_i$og'irliklar to'plami mavjud[3-4].

Ushbu klassifikatorning chegara τ_c qiymatiga ega ifodasi bu:

$$W = \begin{cases} 1, & f_i \ge \tau_c; \\ -1, & f_i < \tau_c; \end{cases} \qquad (3)$$

"Eng yaxshi" kuchli tasniflagich kuchsiz tasniflagichlarning belgilangan sonidan hisoblanadi. Kuchli tasniflagichning ifodasi quyida ko'rsatilgan:

$$= \begin{cases} 1, & \sum_{c=1}^{C} a_c \mathcal{W}_c \ge \frac{1}{2} \sum_{c=1}^{C} a_c\,; \\ 0, & \sum_{c=1}^{C} a_c \mathcal{W}_c < \frac{1}{2} \sum_{c=1}^{C} a_c\,; \end{cases} \qquad (4)$$

$$a_c = \log \frac{1}{\beta_c} \qquad (5)$$

Qayerda $\mathcal{W}_c$ zaif tasniflagich;, a_c β_c - kuchsiz tasniflagichning og'irlik koeffitsientlari; c - joriy kuchsiz klassifikator soni, $C = (1,\dots,C)$ — kuchsiz tasniflagichlar soni. "Kuchli" klassifikatorni (4) va (5) amalga oshiradigan iterativ algoritm, bu o'zboshimchalik bilan kichikroq xatolarni o'rgatish uchun "zaif" (3) kompozitsiyalar asosida tasniflagichlarni olish imkonini beradi. Ob'ektning yorug'likdan oldingi va keyingi tasvirlarini quyidagicha ta'riflash mumkin:

$$q_j(x,y) = \frac{g_{0,j}(x,y)}{g_{1,j}(x,y)+1} \qquad (6)$$

bu erda j ketma-ketlikning joriy qiymatining raqami$Y, g_{0,j}(x,y)$ — foydalanuvchi yuzi tasviriga $I_{(b,j)}$ mos keladigan massiv pikselining yorqinlik qiymati; b — massiv tayyorlangan orqa yorug'lik rejimini ko'rsatuvchi pikselli massivning identifikatori; $b = (0,1)$, $x\ va\ y$ — ko‘rilayotgan pikselning koordinatalari; $x = 0,1,\dots,W-1$, $y = 0,1,\dots,H-1$, $W\ va\ H$ — massivning kengligi va balandligiga mos keladigan $I_{(b,j)}$ piksellar soni.

Barcha qiymatlarning dispersiya o'lchovini hisoblang (6). Namunaning raqamli xarakteristikasi qiymatlarining dispersiyasini tavsiflash uchun (7), namuna dispersiyasining umumiy tavsifi va o'rtacha qiymat uchun matematik taxmin (8) kiritiladi. $q_j(x_1,y)$ o'rtacha qiymatga (matematik kutish) nisbatan dispersiya darajasini baholash uchun dispersiya hisoblab chiqiladi:

$$D(I_{0,j},I_{1,j}) = \frac{1}{WH} \sum_{x=0}^{W-1} \sum_{y=0}^{H-1} (q_j(x,y) - q_j)^2 \qquad (7)$$

Qayerda q_j Bu diskret tasodifiy o'zgaruvchining o'rtacha qiymati yoki matematik $q_j(x,y)$taxmini bo'lib, u quyidagi formula yordamida hisoblanadi:

$$q_j = \frac{1}{WH} \sum_{x=0}^{W-1} \sum_{y=0}^{H-1} (q_j(x,y)) \qquad (8)$$

Videoda ob'ektni aniqlashning aniqligini oshirish uchun yuz va ko'zlarning geometrik parametrlaridan foydalangan holda yuz va ko‘zlar pozitsiyalari asosiy parametrlari quydagilar:

1. Ko'zlar orasidagi masofa

$$P_{ko'zlar1} = (x_1,y_1) \text{ va } P_{ko'zlar2} = (x_2,y_2). \qquad (9)$$

Bu yerda $P_i = (x_i,y_i)$ - yuzning i- asosiy nuqtasining koordinatalari, $i -$ nuqta indeksi masalan, ko'z, burun, iyak burchagidagi nuqta.

$$D_{ko'zlar} = \sqrt{(x_2-x_1)^2 + (y_2-y_1)^2} \qquad (10)$$

Bu yerda $(x_1 - y_1) -$ birinchi ko'zning koordinatalari, $(x_2 - y_2) -$ ikkinchi ko'zning koordinatalari.

2. Burun kengligi

$P_{burin1} = (x_1, y_1)$ va $P_{burin2} = (x_2, y_2)$ - nuqtalarning koordinatalari bo'lsa, burunning kengligi D_{burin} quydagicha formula bo'yicha hisoblanadi:

$$D_{burin} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (11)$$

Bu yerda P_{burin1} va P_{burin2} – burunning tashqi qanotlarida joylashgan nuqtalarning koordinatalari.

3. Iyak uzunligi

$P_{iyak} = (x_c, y_c)$, ko'zlar orasidagi markaziy nuqta – $P_{ko'zlar} = (x_e, y_e)$.

Iyakning uzunligi:

$$D_{iyak} = \sqrt{(x_c - x_e)^2 + (y_c - y_e)^2} \quad (12)$$

Bu yerda:
P_{iyak} – bu iyakning koordinatalari,
$P_{ko'zlar}$ – bu ko'zlar orasidagi markaziy nuqta.

4. Yuzning uzunligi va kengligi (iyak chizig'i bo'ylab)

Yuz kengligi:

$$D_{yuzkengligi} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (13)$$

Bu yerda $P_1 = (x_1, y_1)$ va $P_2 = (x_2, y_2)$,

Yuz uzunligi:

Agar $P_{peshona}$ frontal nuqta koordinatalariga ega (x_f, y_f), yuz uzunligi:

$$D_{yuzuzunligi} = \sqrt{(x_f - x_c)^2 + (y_f - y_c)^2} \quad (14)$$

Bu yerda:
$P_{peshona}$ – bu peshonaning tepasida joylashgan nuqtadir,
P_{iyak} – bu iyagidagi nuqta.

CXI. XULOSA

Ushbu tadqiqotda inson yuz va ko‘zlari geometrik parametrlari asosida videoda ob’ektni aniqlash aniqligini oshirish masalasi ko‘rib chiqildi. O‘tkazilgan tahlillar shuni ko‘rsatdiki, an’anaviy yuz aniqlash usullari tashqi sharoitlarga, jumladan, yorug‘lik darajasi, fonning murakkabligi, yuzning turli burchaklardagi ko‘rinishi va qisman to‘silib qolish holatlariga sezgir bo‘lib, ko‘plab xatoliklarni keltirib chiqaradi. Natijada yuzni noto‘g‘ri aniqlash yoki umuman aniqlay olmaslik ehtimoli ortadi.

Taklif etilgan yondashuvda yuz va ko‘zlarning geometrik parametrlari — ko‘zlararo masofa, ko‘zlarning yuz markaziga nisbatan joylashuvi, yuzning eni va bo‘yi o‘rtasidagi nisbatlar kabi xususiyatlardan foydalanish samarador natijalar berdi. Ushbu parametrlar inson yuzining barqaror belgilaridan biri bo‘lib, ular tashqi sharoitlar ta’sirida katta o‘zgarishga uchramaydi. Shu bois, geometrik xususiyatlarni integratsiya qilish orqali aniqlash algoritmlarining ishonchliligi oshirildi.

Tadqiqot natijalaridan kelib chiqib, quyidagi xulosalarga kelindi:

- Aniqlik oshishi – geometrik parametrlarni qo‘shish inson yuzini aniqlashdagi umumiy aniqlikni sezilarli darajada yaxshilaydi.
- Barqarorlik ta’minlanishi – turli yoritilish sharoitlarida, yuzning qisman burilishida yoki fonning murakkab bo‘lishida ham aniqlash jarayoni nisbatan barqaror ishlaydi.
- Real vaqt rejimida qo‘llash imkoniyati – geometrik parametrlar hisoblash jihatidan murakkab emasligi sababli tizim tezkor ishlash qobiliyatini saqlab qoladi.
- Xavfsizlik va biometrik tizimlarda qo‘llash – taklif etilgan usul video nazorat, shaxsni identifikatsiya qilish va boshqa monitoring tizimlarida samarali natija berishi mumkin.

Kelgusida ushbu usulni chuqur o‘rganish algoritmlari, xususan, neyron tarmoqlar bilan birlashtirish orqali aniqlik va tezkorlikni yanada oshirish imkoniyati mavjud. Shuningdek, yuzning mimik o‘zgarishlari va yoshga bog‘liq morfologik farqlarni ham hisobga olish tizimning universalligini yanada kengaytiradi.

Umuman olganda, inson yuz va ko‘zlari geometrik parametrlari asosida videoda ob’ektni aniqlash usuli an’anaviy yondashuvlarga qaraganda samaraliroq bo‘lib, u zamonaviy xavfsizlik, monitoring va biometrik identifikatsiya tizimlarida keng qo‘llanishi mumkin bo‘lgan istiqbolli yo‘nalish hisoblanadi.

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ZAMONAVIY DAVRDA RAQAMLI MEDIA TEXNOLOGIYALARINING AHAMIYATI

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***Annotatsiya* — Mazkur maqolada jamiyat rivojida raqamli suratga olish va turli multimedia texnologiyalarining ahamiyati, televizion, video, foto suratga olish, media ma’lumot yuborish, kuzatish, foydalanish kabilardagi roli, video darsliklar yaratish, shuningdek, yangi media texnologiyalarga moslashish jarayonlari o‘rganiladi.**

***Kalit so‘zlar* — multimedia, raqamli, televizion, video, foto, kamera, kuzatuv, ma’lumot.**

I. KIRISH

Multimedia texnologiyalarining rivojlanishi tufayli televidenie, video, fotografiya, jurnalistika kabi bir necha sohalar zamonaviy davrda o‘ziga xos inqilobni boshdan kechirmoqda. Raqamli texnologik jarayonlar turli formatlarda kontent yaratish va tarqatish imkonini bermoqda, audio-video texnikalarning zamonaviy turlari yangicha usullarni, yechimlarni taklif qilmoqda. Bu esa nafaqat media, balki turli boshqa sohalarni rivojlanishi uchun keng imkoniyatlar ochmoqda. Masalan, ta’lim yo‘nalishida internet, elektron resurslar, onlayn muloqotlar va turli elektron darsliklarni yanada rivojlanib borayotgani bunga misoldir. Bu borada zamonaviy multimedia texnikalaridan foydalanishni bilish, ushbu texnikalardagi yangilanib borayotgan o‘zgarishlarga moslashib borish, kontentlar va media maxsulotlar yaratishda uslub, janr, dizayn, kompozitsiya, format, audio-vizual sifat kabilar bo‘yicha bilim va ko‘nikmalar talabi ortmoqda. Ushbu jarayonda oddiy havaskorlikdan yuqori bo‘lgan bilim va mahorat darajasi zarur bo‘lib, ko‘pincha buning yetishmasligi kuzatilmoqda.

II. MATERIALLAR TAHLILI

Zamonaviy multimedia texnologiyalari axborotni matn, grafik, audio, video, animatsiya va boshqa elektron shakllarda qayta ishlash, uzatish va taqdim etishni ta’minlovchi raqamli vositalar majmuini qamrab oladi [1]. Ularning ahamiyati internet, mobil qurilmalar va raqamli infratuzilmaning rivojlanishi tufayli shiddat bilan ortib bormoqda. Ushbu texnologiyalar ko‘plab sohalar rivojida muhim rol o‘ynamoqda. Masalan, ta’limda yaratilayotgan elektron video darsliklar, o‘quvchi uchun interaktiv jarayonlarni paydo qilib, ma’lumotlarni qulay o‘zlashtirishida imkon yaratmoqda. Bir yarim - ikki asr oldin halqimizning asosiy qismi dala va chorva mehnati bilan kun kechirar edi. Ularning bilim olishga vaqti ham imkoni ham bo‘lmasdi. Qishloqlarda ta’lim maktablari rivojlanmagan bo‘lib, ko‘pchilik o‘qishni bilishmasdi. Institutlarda o‘qishni gapirmasa ham bo‘ladi. Buni bugungi kun bilan taqqoslasak, katta farqni kuzatamiz. Ayniqsa internet va zamonaviy media texnologiyalarning berayotgan sharoitlari bilan o‘lchasak kosmik imkoniyatlarni his qilamiz.

Shunga qaramay zamonaviy ta’limda multimedia va internet imkoniyatlaridan oqilona foydalanmayotgan o‘quvchi yoshlarimiz borligi ma’lum. Talaygina o‘quvchi yoshlarimiz biror maqsadga erishish uchun o‘z mehnati bilan emas, balki oson yo‘llarni izlashi noo‘rin hisoblanadi. Bu borada nazoratchi o‘qituvchilarning ma’suliyati yanada ortmoqda. Masalan, Televizion texnologiyalar yo‘nalishi talabalarining media amaliy ishlarini baholashda ilgari tugallangan yakuniy ish qabul qilingan bo‘lsa, endilikda butun jarayondagi hom ishlar ham birma bir ko‘zdan kechirilishini taqozo etmoqda.

Multimedia texnologiyalari ta’lim darslarini masofaviy, interaktiv, audio-vizual shakllarda tashkil etish imkonini berib, yanada shaffof bo‘lishini taminlamoqda. Masalan, ko‘plab o‘quv auditoriyalarida jihozlangan kuzatuv kameralari o‘quvchilarning sezgir bo‘lishi, zarur bo‘lmaganda mobil telefonlari va noutbuklardan foydalanmaslik kabi sharoitlarni paydo bo‘lishiga yordam bermoqda. Shuningdek, kuzatuv kameralari orqali umumiy dars sifatini nazoratga olish mumkin. Masofadan turib o‘qish ayniqsa, ish faoliyatida bo‘lganlar uchun qulay hisoblanadi. Ish joyidan turib onlayn shaklda darsga qatnashish, yoki qo‘shimcha audio-video ma’ruzalarni eshitish imkonini beradi. Shuni hisobga olgan holda, masofaviy ta’lim shaklida dars mavzularini eshitish va o‘zlashtirish jarayoni vaqt hisobida, boshlash, tugatish o‘quvchi uchun erkin tarzda bo‘lishi yanada qulaylik yaratadi.

O‘quv materialning vizual taqdimoti bizning miyamiz tomonidan matnga qaraganda 60 000 marta tezroq qayta ishlanadi, shuning uchun ma’ruza va laboratoriya materiallarini video formatda taqdim etish samaraliroq bo‘ladi [2]. Audio-video darsliklar asosan: videokamera yordamida, kompyuter grafikasi yordamida, kompyuter ekranidan video yozish, fotoslayd yordamida va boshqalarga bo‘linadi. Ko‘p hollarda videokamera o‘rnini mobil telefonlari egallayotgani sir emas, shunga qaramay malakali mutaxassislar professional video va ovoz yozish qurilmalaridan foydalanishni maslahat berishadi. Darhaqiqat, bugungi kundagi kontent sifati uchun professional audio-video texnika muhim ahamiyat kasb etmoqda. Negaki, zamonaviy o‘quvchilar va turli foydalanuvchilarning audio-vizual ma’lumotlarni qabul qilish saviyasi 20 yil oldingiga qaraganda ancha o‘sgan. Media maxsulotlarga nisbatan texnik, kreativ, ijodiy va ihchamlik sifatlariga talab ortgan.

Bu borada Toshkent axborot texnologiyalari universitetining o‘quv media markazida audio-video darsliklar yaratish ustida izlanishlar olib borilmoqda. Buning uchun birgina videokamera yetarli bo‘layotgani yo‘q, balki alohida ovoz yozish mikrofoni, yoritish chiroqlari, maxsus fon, elektron doska, sufler kabi uskunalar va eng asosiysi ulardan to‘laqonli foydalanishni bilish zarur bo‘lmoqda. Texnikalarni ishga tayyorlash va boshqarish ko‘nikmalari universitetning Televizion va media texnologiyalar yo‘nalishlarida o‘rgatilmoqda. Ko‘pgina bitiruvchi talabalar universal bilimga ega bo‘lib, suratga olish, montaj qilish, grafik dizayn va geym dasturlar ustida ishlash, videokuzatuv tizimi va yorug‘lik yoritish bo‘yicha turli korxonalarda, jumladan, davlat va nodavlat telekanallarida faoliyat yuritishmoqda.

Video darsliklarni yaratilishini umuman olganda to‘rt qismga bo‘lish mumkin: 1. Mavzuga tayyorgarlik; 2. Texnik tayyorgarlik; 3. Mavzuni kamera oldida yoritib berish yoki suratga olish; 4. Montaj jarayoni. Bularning ichida eng asosiysi o‘quv materialni o‘quvchiga tushunarli va qiziqarli qilib yetkazish dolzarb bo‘lib qolmoqda. Natijalar shuni ko‘rsatmoqdaki, bu borada klassik usuldagi televizion, animatsion va kino ssenariylar tuzilishining video darsliklar yaratilishida mos kelishi kuzatilmoqda. /Bunday ssenariylarni bugungi kunda media loyihalar ham deb nomlashadi. Asosiy maqsad inson ongida tug‘ilgan g‘oyalarni amalga oshirish uchun tizimlashgan reja asosida qog‘ozda tuzib chiqish yoki yaratishdir. Media ssenariyni oldindan tuzib chiqilishi yakuniy ishning mukammal bo‘lishiga omil bo‘lishi tabiiy hol. Ushbu jarayonni amalga oshirish uchun tayyorgarlik vaqti va undagi jarayonlar talab qilinadi.

Shuningdek, natijalarga ko‘ra o‘quv video darsliklari to‘liq bir soat yigirma daqiqa emas, balki birmuncha kamroq vaqtni egallashi, ihcham bo‘lishi, qismlarga bo‘linishi lozimligi talab qilinadi. Agar buni badiiy film bilan taqqoslasak, badiiy filmlar odatda bir soatdan ko‘proq vaqtni egallaydi. Bu vaqt mobaynida tomoshabinni ortiqcha yuklab qo‘yadigan ma’lumotlar o‘quv video filmlari kabi yuqori bo‘lmaydi. Masalan, hujjatli filmlar odatda badiiy filmlardan 2-4 baravar qisqaroq bo‘lishini yaxshi bilamiz. Buning boisi, hujjatli filmlarda tomoshabin uchun mulohaza yuritishga da’vat qilish holatlari mavjudligi, shuningdek, qisqa tahliliy ma’lumotlar berish maqsad qilinganligini misol keltirish mumkin. Bundan ko‘rinadiki, o‘quv video darsliklarini tayyorlanishida o‘quvchi tomonidan ma’lumotlarni qabul qila olish chegarasi, ortiqcha yuklab qo‘ymaslik, zeriktirmaslik tomonlariga e’tibor qaratish ahamiyatli.

O‘quv video darsliklarni yaratilishida o‘qituvchi kadrda doim ko‘rinib turishi shartmi, albatta buning meyoriy mezonlari bo‘lib, bu haqida ilmiy izlanuvchilar quyidagi xulosalarga kelishmoqda. Masalan, V.Grushevskaya izlanishlariga ko‘ra o‘qituvchini kadrda qancha vaqt va qanday shaklda ko‘rinishi videodarslik tuzilishi, uslubi, maqsadi, ta’sir etish kabi omillariga bog‘liq deyiladi. Shuningdek, o‘qituvchini kadrda ko‘rinishi o‘quvchi bilan vizual kontakt effektini paydo qiladi, ma’lumotlarni ishonchli va ta’sirchan yetib borishida rol o‘ynashini bildiradi. Bundan tashqari so‘nggi bir necha yil ichida o‘qituvchilar ta’limida videolardan "amaliyot artefakti" sifatida foydalanish ko‘paydi. Video darsliklar bilan ishlash o‘qituvchilarga ta’lim jarayonining “ichiga” kirib, o‘z-o‘zini aks ettirish uchun boy vositaga ega bo‘lganligi sababli o‘qitishni boshqa nuqtai nazardan boshdan kechirish imkonini beradi kabi xulosalarga kelingan [3].

So‘nggi yillarda tadqiqotchilar XXI-asr maktablarida aks ettiruvchi o‘qituvchining roli ustida ko‘p izlanishmoqdalar. O‘qituvchilar o‘qitish uslubi hamda strategiyasini mos ravishda tashkil etish maqsadida o‘zlarining xatti-harakatlari haqida o‘ylashlari uchun elektron portfelda dalillar, hujjatlar, video hikoyalar xotiralarini to‘plashlari kerakligini ko‘rsatmoqda.

Ta’lim yo‘lida videolardan foydalanish o‘qituvchilarga zaif va kuchli tomonlarini aniqlash hamda kelgusidagi harakatlarni yaxshilash uchun fikr yuritishga yordam beradi. Agar stajyor o‘qituvchilar ushbu muhim voqealar haqida rasman mulohaza yuritsalar, ularga o‘qitish jarayoni haqidagi yangi tushunchalarni ochish va tuzatish osonroq bo‘ladi. Bu tanqidiy hodisalar nazariyasining boshlang‘ich nuqtasi bo‘lib, o‘zining va boshqa o‘qituvchilarning video darsliklari haqida fikrlash va muhokama qilish imkoniyatlariga asoslanadi.

Bugungi kunda turli mavzudagi reportajlar, videokontentlar dron va ekshn kameralari kabi zamonaviy texnologiyalar, shuningdek, an’anaviy usullar, jumladan, bevosita videokamera yordamida intervyu olish orqali amalga oshirilmoqda. Masalan, dronlar noyob burchaklarni va sodir bo‘layotgan voqealarning umumiy tasvirini olish imkonini beradi, bu esa telejurnalistning qulay sharoitlarda imkoniyatini va material sifatini oshiradi. Jurnalistning boshiga yoki yelkasiga biriktirilgan ixcham va bardoshli ekshn kameralar suratga olish va sodir bo‘layotgan voqealarning realligini etkazish imkonini beradi. Eknsh kameralarini yashirin kamera sifatida ham ishlatish mumkin.

Bunday media texnologiyalar dinamik harakatli voqealarni real muhitda tomoshabinga yetkazishning eng oson usullarini taklif qilmoqda. Birinchidan texnika arzon, uni ishlatish va boshqarish murakkab emas, raqamli tasvir va ovoz sifati televizion standartlarga mos keladi, masofadan aloqa tizimi, ma’lumotlar almashish, boshqarish va sun’iy intellekt funksiyalari mavjud. Ularni uzoq muddatli (bir necha kundan, hafta va oylargacha) kuzatuv kameralari sifatida foydalanish mumkin. Masalan, bir necha soniyada urug‘dan bosh ko‘tarib unib chiqadigan va o‘sib hosilga kiradigan poliz ekinlarini yoki baland binolardagi oylab davom etadigan qurilish ishlarini bir zumda ekranda bo‘lib o‘tishi kabilar shular jumlasidandir.

Ayni paytda hujjatli filmlar asoschilaridan biri Dziga Vertovni eslash o‘rinli. Uning “Kinoglaz” (1924) nomli film manifesti kino san’atining ilk davrlarida katta voqeaga aylangan eksperiment bo‘lgan. Filmda insonga xos bo‘lmagan, zamon va makonda harakatlanuvchi, dunyoni odamlardan farqli idrok etuvchi sifatida kamera yordamida ko‘rsatishi haqidagi konsepsiyasi film asosini tashkil etgan. D.Vertov bir necha bu kabi filmlari orqali tomoshabinni audiovizual ma’lumotlar metafora sifatida qabul qilinishi va ong ostida anglash, tushinish, topish, tuzish jarayonlari yuz berishini ochib bergan. U bilan hamkorlikda ishlagan kinotasvirchi M.Kaufman multi ekspozitsiya, ko‘zgudan foydalangan holda yorug‘lik nurini sindirish, turli yorug‘lik filtrlaridan foydalanish, yakka kadrli (seytrafer) va tez kadrli (rapid) suratga olish, noan’anaviy rakurs va

kompozitsiya kabilardan unumli hamda g‘oyaga mos foydalanishga muvaffaq bo‘lgan.

Filmdagi eksperimental suratga olish uslublari, murakkab kreativ kadrlar bugungi texnikalar yordamida bajarilishi mumkin. Lekin o‘sha davrda oddiy qo‘lda aylantiriladigan, oq-qora kinoplenkaga suratga oladigan kamera va qo‘l montaji yordamida bunday natijaga qanday erishilganligi ko‘pchilikni qiziqtiradi. Agar xozirgi uchar dronlar, ekshn miniatyur va yashirin kameralar, kompyuter grafikasi, raqamli montaj kabilar D.Vertov qo‘lida bo‘lganida nima qilgan bo‘lar edi, deya o‘ylantiradi. “Kinoglaz” filmi bugungi media texnologiyalarga qiziquvchilar va soha mutaxassislari uchun birgina da’vatni shior sifatida ilgari suradi, bu – izlanuvchanlik, topqirlik, kreativlik, yangilikga intiluvchanlik.

E’tibor qilsak, ushbu tahlillar zamonaviy texnikaga asosiy urg‘uni berayotgani yo‘q, balki inson qobiliyati va ilg‘or faoliyatiga asos sifatida urg‘u bermoqda. Darhaqiqat, texnikani inson boshqaradi, eng qimmat videokamera bilan eng yaxshi yoki mashhur bo‘ladigan film yaratilmaydi, yaxshi filmni oddiy videokamera bo‘lsa ham qobiliyati baland mutaxassis yaratadi.

Ayni payta aytish joiz, yurtimizda ishlanayotgan kino hujjatli filmlar va televizion hujjatli ko‘rsatuvlarning aksariyatida zamonaviy media texnologiyalar, ya’ni raqamli imkoniyatlar mavjudligiga qaramay texnik va ijodiy kreativ yondoshuvlar yetishmaydi. Natijada, bu kabi filmlar tomoshabinga qiziqarsiz, chuqur mulohazalarga chaqirmay, filmlik vazifasini oqlamay unutilib ketilaveradi. Yangi yaratilayotgan aksariyat filmlarni namoyish qiladigan platforma to‘la shakllanmagan. Natijada, ayrim yaratilgan hujjatli filmlar umuman namoyish etilmay arxivda saqlanmoqda. Savol tug‘iladi, unda nega film yaratildi? Yurtimiz televizion kanallarida ham qiziqarsiz ko‘rsatuvlar talaygina, qiziqarli ko‘rsatuvlar yaratishga intilganlar ko‘pincha ko‘chirmachilik bilan ovora bo‘lib qolishadi. Televizion sohada mustaqil izlanuvchi ijodkorlar yetishmasligi va yangi teleloyihalarga doim ham ruhsat berilmasligi rivojlanishga salbiy ta’sir ko‘rsatmoqda.

Zamonaviy davrda media axborotni tez tarqatish asosiy vazifalardan biridir. Materiallar sun’iy yo‘ldosh orqali, aloqa kanallari va zamonaviy ma’lumotlarni uzatish tizimlari yordamida real vaqt rejimida uzatiladi. Masalan, televizion sharoitida qabul qiluvchi ko‘chma televizion stansiyalari to‘lqinni telemarkaz orqali jonli efirga yuborishi mumkin. Joriy yilda O‘zbekiston milliy teleradiokompaniyasiga bir nechta eng zamonaviy dunyo standartlariga to‘liq javob beradigan ko‘chma televizion stansiyalari keltirildi. Bunday stansiyalar yordamida jonli usuldagi mobil televizion efirlarni ko‘paytirish, tele-konferensiyalar, ochiq telemuloqotlar tashkil qilish, televizion realistik muhitni yanada rivojlantirish, yurtimizni jahon televizion media miqyosida raqobatbardoshligini oshirish ko‘zda tutilgan. Televideniedagi turli muhandis mutahassislar ilg‘or teletexnikalar mavjudligidan mamnun. Shunga qaramay telekanallarimizning novatorlik ijodiy muhitini rivojlantirish dolzarb.

IPTV internet orqali media maxsulotlarni, jumladan, jonli teleko‘rsatuvlarni uzatish tizimi eng zamonaviy texnologiya hisoblanib, foydalanuvchi uchun qator imkoniyatlar bermoqda. Masalan, studiyalar bilan foydalanuvchi o‘rtasidagi interaktiv bog‘lanish imkoniyati, teleefirlarni qayta tomosha qilish, jonli videokonferensiyalar tashkil qilish, fikr mulohazalar qoldirish, tashqi gadjetlar bilan ulash, ma’lumot almashish va boshqalar shular jumlasidandir. Bugungi kunda O‘zbekiston miqyosida UZdigital, Stars TV, ISTV, Turon Telekom, Gals Telecom, Sonet kabi IPTV faoliyat yuritmoqda. Telekanallar esa o‘zining efir vaqtini uzaytirish, mavzuiy va estetik sifatini oshirish ustida ishlamoqdalar.

III. XULOSA

Shunday qilib raqamli multimedia texnologiyalarining zamonaviy davrdagi ahamiyatini o‘rganish jarayoni quyidagi hulosalarga kelishga imkon beradi. Multimedia texnologiyalari ta’lim jarayonlarini boyitadi, keng imkoniyatlar beradi, uni yanada qiziqarli, qulay va samarali qiladi. Media tasvirlarni suratga olish va tahrirlashda, ularni o‘zgartirishda, jozibalikni oshirishda keng badiiy, kreativ hamda boshqa maxsus imkoniyatlar ochadi. Shuningdek, zamonaviy media texnologiyalarni ishlatishda texnik hamda uslubiy-metodik jihatdan yangi bilim va ko‘nikmalar talab qilinadi. Video ish tuzilishi, butun jarayonni boshqarish, kamera bilan ishlash-suratga olish, ovozni nazorat qilish, audio-video montaj, grafik effektlar yaratish, prezentatsiyalar ustida ishlash kabilar shular jumlasidandir. Bunday ishlab chiqarish o‘z navbatida kichik guruhdan iborat media mutaxassislarni va professional audio-video texnikalarni talab etadi. Shunga qaramay yakka holatlarda har bir inson minimal qurilmalardan foydalangan holda kontentlar yaratish va boyitib borish imkoni mavjud. Ayniqsa, videodarsliklar yaratilishi va elektron foydalanish talaba uchun fanlarni o‘zlashtirishida samara beradi, o‘qituvchi uchun o‘z kamchiliklarini bilishi va uning ustida ishlashi uchun yordam beradi. Shuningdek, zamonaviy media texnologiyalar televizion sohada telemaxsulotlarni nafaqat audiovizual sifatini oshirishga xizmat qiladi, balki kreativ ijodiy izlanishlarni, jonli realistik teleefirlar soni va sifatini oshirishga xizmat qilishi mumkin.

FOYDALANILGAN ADABIYOTLAR

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THE APPLICATION OF AUGMENTED REALITY (AR) AND VIRTUAL REALITY (VR) TECHNOLOGIES IN THE EDUCATION SYSTEM

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Abstract

The integration of Augmented Reality (AR) and Virtual Reality (VR) into education has been widely celebrated as a revolutionary step in teaching and learning. Yet, while their potential to transform pedagogy is substantial, the adoption of such technologies remains uneven and accompanied by contradictions. This article examines the use of AR and VR in education not only through descriptive accounts of applications but also by analyzing their pedagogical, social, and technological consequences. Evidence is drawn from empirical studies, case experiences, and theoretical frameworks. The analysis suggests that immersive learning environments significantly enhance engagement and comprehension, but they simultaneously raise new challenges related to inequality, cognitive load, and the redefinition of teacher roles.

Keywords: Augmented Reality, Virtual Reality, Pedagogical Innovation, Digital Learning, Technology in Education.

CXII. INTRODUCTION

Technological innovation has repeatedly transformed the foundations of education, altering not only the tools available for instruction but also the very processes through which knowledge is transmitted, constructed, and internalized. Each major development—from the invention of the printing press to the rise of personal computing and the proliferation of online learning platforms—has expanded the reach of education while reshaping its methods. Yet the emergence of immersive technologies, particularly Augmented Reality (AR) and Virtual Reality (VR), constitutes a change of a qualitatively different order. Unlike earlier innovations, which primarily extended access to information, immersive technologies create environments in which learners participate directly in the construction of meaning. Through simulation, visualization, and interaction, they provide opportunities for learners to experience knowledge rather than simply receive it in textual or auditory form.

However, the integration of AR and VR into educational systems cannot be regarded as a straightforward continuation of technological progress. The assumption that each innovation automatically improves learning outcomes oversimplifies the complexity of pedagogy. Immersive technologies, while powerful, also raise questions of accessibility, equity, and cognitive appropriateness. They demand substantial material resources, teacher retraining, and curriculum redesign, all of which highlight the systemic nature of their consequences. In this sense, their adoption must be evaluated not only as a technical enhancement but also as a pedagogical reorientation.

Such reorientation has profound implications. On the curricular level, immersive technologies shift emphasis from the linear delivery of information toward experiential, problem-based learning. On the instructional level, they challenge traditional teacher-centered roles, positioning educators more as facilitators of exploration than as transmitters of knowledge. On the societal level, they risk reinforcing inequalities if access is limited to resource-rich institutions, but they also hold the potential to democratize advanced learning experiences if deployed strategically. Thus, the emergence of AR and VR should not be interpreted as a mere addition to existing educational practice but as a catalyst for rethinking how knowledge itself is conceptualized, distributed, and acquired in the twenty-first century.

CXIII. LITERATURE AND ANALYTICAL CONTEXT

The literature emphasizes the strong pedagogical value of immersive technologies. Studies consistently demonstrate improvements in engagement, comprehension, and retention when students interact with knowledge in simulated environments (Radianti et al., 2020). However, such findings require closer scrutiny. While engagement is frequently reported as higher, it is not always clear whether this engagement translates into long-term academic performance or whether it merely reflects short-term motivational effects.

For example, Azuma (2019) describes AR-based biology lessons in which students could manipulate three-dimensional models of organs. The immediate effect was increased attention and interest, yet follow-up assessments revealed only marginal gains in factual recall. This suggests that AR and VR are most effective when used to support deep conceptual understanding rather than rote memorization. Thus, their value lies in facilitating higher-order thinking skills, such as problem-solving and spatial reasoning, rather than in replacing traditional methods of information delivery.

Another analytical dimension is the socio-economic disparity in access. While elite institutions experiment with advanced VR laboratories, many schools in developing countries cannot afford even basic computing facilities. This asymmetry risks deepening existing educational inequalities, thereby undermining the democratizing promise of digital learning. Hamilton et al. (2021) argue that the "digital divide" in immersive education is not simply technological but cultural, as institutions with strong traditions of innovation are more likely to integrate new tools effectively.

CXIV. Pedagogical Applications and Analysis

The pedagogical application of immersive technologies extends across all levels of education, from primary schooling to higher education and vocational training. However, their impact is not uniform and must be considered in light of the specific goals of instruction, the cognitive readiness of learners, and the broader institutional context.

In primary and secondary education, AR and VR function primarily as tools for motivation and engagement. Children are naturally receptive to visual and interactive experiences, and immersive environments align with their developmental preference for concrete representation of knowledge. For example, an AR-enabled textbook in biology allows students to visualize a three-dimensional human heart that beats, pumps blood, and responds to manipulation. Such experiences convert abstract biological concepts into tangible phenomena, thereby increasing both attention and comprehension. Yet, critical analysis reveals that the benefit here is often temporary if not embedded within a carefully structured pedagogical framework. Without reflection and reinforcement, students may retain vivid images but fail to internalize the underlying scientific principles. Hence, immersive tools should be considered catalysts of engagement rather than substitutes for traditional cognitive processing.

At the level of higher education, the role of immersive technologies acquires greater complexity. In disciplines such as medicine, architecture, and engineering, the demand for spatial reasoning and procedural accuracy makes AR and VR invaluable. A medical student practicing in a virtual operating theatre can perform procedures repeatedly without risk to patients, thus acquiring confidence and procedural fluency. Comparative studies show that students exposed to such simulations demonstrate up to 30 percent higher levels of accuracy in examinations of practical skills. Nevertheless, a more critical assessment demonstrates that the absence of tactile feedback, emotional stress, and patient interaction means that VR remains a partial solution. While it develops technical competence, it cannot entirely reproduce the full spectrum of professional experience, thereby necessitating its integration with traditional clinical training.

In the field of architecture and engineering, immersive environments allow students to inhabit their own designs, walking through spaces and identifying potential structural flaws before physical construction. This application illustrates the analytical value of VR in fostering creativity and problem-solving. However, there is also the risk that the aesthetic appeal of immersive visualization may overshadow rigorous analytical evaluation. Students may be tempted to privilege design beauty over structural efficiency, leading to an imbalance between creativity and functionality. Educators must therefore guide learners in using VR not as an end in itself but as a means to achieve balanced solutions that respect both form and function.

Vocational training provides another important dimension for analysis. In industries such as aviation, manufacturing, or energy production, the ability to rehearse dangerous or costly procedures in a safe environment is invaluable. Simulations allow learners to confront high-risk situations without exposure to real danger. For instance, electricians practicing with VR simulations can experience the outcomes of wiring errors without physical harm. This supports the constructivist view that knowledge is built through experience. Yet, immersive training in vocational contexts also raises questions about transferability: does success in a virtual environment necessarily translate into competence in real-world tasks? Research indicates that while VR enhances procedural familiarity, the absence of real-world constraints—such as the noise of a factory floor or the unpredictability of human behavior—may reduce the transfer of skills. Consequently, immersive training must be considered preparatory rather than conclusive, functioning as a bridge between theoretical instruction and practical performance.

Language learning provides a unique case where AR has proven particularly effective. Applications that superimpose vocabulary onto physical objects in the learner's environment create immediate and contextually rich associations. This form of situated learning increases retention rates because it grounds abstract words in sensory experiences. However, from an analytical standpoint, the long-term effectiveness of such methods is still under debate. Critics argue that an overreliance on contextual cues may impair abstract linguistic competence, particularly in advanced stages where learners must manipulate language without visual anchors. Thus, immersive tools in language learning appear most beneficial at beginner and intermediate stages, while advanced proficiency still requires traditional forms of textual and discursive practice.

Finally, the application of AR and VR must also be evaluated through the lens of inclusivity. Learners with disabilities can benefit significantly from immersive environments. Students with mobility impairments may participate in virtual field trips that would otherwise remain inaccessible, while those with hearing difficulties may benefit from visual overlays that provide contextual information. However, there are also risks of exclusion if technologies are not designed with accessibility in mind. For example, VR headsets may not be suitable for learners with certain sensory disorders, and prolonged exposure may induce fatigue or discomfort. Therefore, inclusive design principles must guide the development and deployment of immersive technologies in education to ensure that their benefits are not confined to the majority but extended to all learners.

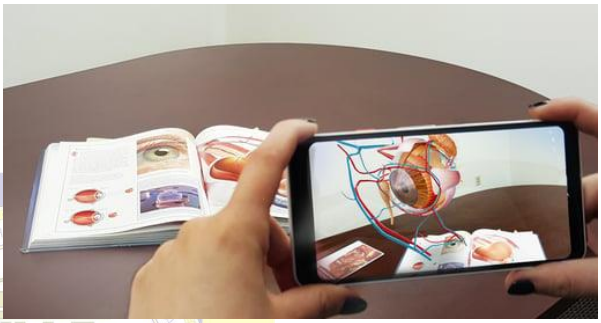

Fig. 1. Use of Augmented Reality in biology education: a smartphone application projects a 3D model of the human eye from a textbook image.

A particularly illustrative example of AR's potential in primary and secondary education can be observed in biology classrooms, where traditional static textbooks are transformed into interactive experiences. When students use a mobile device to scan an image of an organ, a three-dimensional model is projected on the screen, allowing them to explore anatomical structures dynamically. Figure 1 demonstrates this process: a standard biology textbook depiction of the human eye is enhanced through AR technology, enabling learners to visualize not only the external structure but also the vascular and muscular systems in motion.

Such integration provides a richer cognitive experience than conventional diagrams, as it bridges the gap between abstract textual descriptions and concrete visual representation. The learner does not simply read about the eye but manipulates its model, rotates it, and observes its functional relationships. From a pedagogical perspective, this strengthens conceptual understanding, particularly for students who rely on visual and kinesthetic learning styles. However, critical analysis reveals that while AR enhances immediate engagement and comprehension, long-term retention still requires structured guidance from teachers, who must integrate these experiences into broader curricular frameworks.

Taken together, the pedagogical applications of AR and VR reveal both promise and complexity. Their primary value lies in the creation of learning experiences that are more engaging, interactive, and contextually grounded than traditional methods. Yet, the analysis demonstrates that immersive tools cannot be regarded as panaceas. Their effectiveness is contingent on the presence of pedagogical frameworks that integrate reflection, critical analysis, and real-world application. Without such integration, there is a risk that immersive technologies will be reduced to mere spectacle, celebrated for their novelty but lacking substantive impact on learning outcomes.

CXV. Discussion: Analytical Challenges and Implications

The integration of immersive technologies into education inevitably raises profound questions regarding the evolving role of the teacher. Within traditional pedagogical frameworks, the teacher has been viewed primarily as the transmitter of knowledge, a central authority responsible for structuring and delivering content. By contrast, the introduction of AR and VR shifts this paradigm toward a model in which the teacher assumes the role of facilitator, guide, or mentor, supporting learners in navigating and interpreting experiences generated by technology. This transformation holds considerable promise, as it allows educators to dedicate more time to mentoring, critical discussion, and higher-order forms of instruction that cannot be easily automated. Yet it also imposes substantial demands in terms of teacher preparation. The effective integration of AR and VR requires not only technical proficiency but also an understanding of how immersive environments align with cognitive development and curricular objectives. Without systematic professional development, teachers risk underutilizing these technologies or, conversely, employing them in ways that reduce their educational value to superficial entertainment.

The cognitive implications of immersive environments further complicate their adoption. On the one hand, interactivity and sensory engagement can promote deep learning by situating knowledge within memorable experiences. On the other, research suggests that the abundance of stimuli in VR and AR environments may lead to cognitive overload, particularly among younger students or those with limited prior knowledge of the subject matter. While VR appears to support spatial reasoning and procedural understanding, some studies indicate that it can diminish performance on tasks that demand abstract or symbolic reasoning. Such findings underscore the need for careful calibration of immersive experiences to developmental stages and learning objectives. Pedagogical design must balance novelty and engagement with cognitive manageability, ensuring that immersion enhances rather than obstructs intellectual growth.

From a broader societal perspective, the integration of AR and VR carries significant implications for equity in education. There is a real risk that these technologies will exacerbate existing inequalities if their adoption is limited to wealthier schools and universities that can afford the necessary infrastructure. In such cases, immersive technologies would reinforce rather than reduce educational privilege, providing advanced opportunities to already advantaged learners while leaving others behind. However, the same technologies also hold the potential to democratize access to high-quality education if deployed strategically. For instance, remote learners in rural or under-resourced regions could participate in virtual laboratories, international collaborations, or cultural field trips that would otherwise remain inaccessible. The realization of this democratizing potential, however, depends heavily on deliberate political and economic choices. Investment in digital infrastructure, subsidization of equipment, and policies promoting universal accessibility will determine whether AR and VR become tools of inclusion or instruments that entrench educational stratification.

Taken together, these considerations highlight the dual nature of immersive learning technologies. They are at once emancipatory and problematic, capable of expanding horizons while also generating new pedagogical, cognitive, and social challenges. Their successful integration will depend less on technological sophistication than on the willingness of educational systems to adapt roles, rethink curricula, and ensure equitable access. Only under such conditions can AR and VR fulfill their promise as transformative tools in education rather than reinforcing existing divides.

CXVI. Conclusion

The analysis confirms that AR and VR represent transformative forces in education, capable of reshaping how knowledge is acquired, applied, and remembered. Their primary strength lies not in replacing traditional pedagogy but in enriching it through immersive experiences that foster critical thinking, creativity, and applied skills. Yet these benefits are inseparable from new challenges, particularly the risks of inequality, cognitive overload, and teacher disempowerment. The scientific evaluation of AR and VR in education must therefore go beyond technical enthusiasm to include critical reflection on their pedagogical, social, and ethical consequences.

Future research should investigate long-term impacts on student performance, focusing on whether immersive learning fosters durable competencies rather than temporary engagement. Equally important is the exploration of cost-effective and scalable models of AR and VR adoption that can serve diverse educational contexts. Only through such balanced and analytical approaches can AR and VR technologies realize their full promise as catalysts of educational innovation.

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A DIGITAL LOOK AT TEXTILES: COMPUTER VISION TECHNOLOGIES

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***Abstract*—This article explores the application of computer vision (CV) in the textile industry, focusing on its role in automating quality control, pattern recognition, and product classification. It discusses the evolution from early statistical models to advanced deep learning techniques, such as Convolutional Neural Networks (CNNs), which enhance defect detection accuracy to over 95%. The methodology includes high-resolution imaging, preprocessing, feature extraction, segmentation, and classification using modern algorithms like U-Net and YOLO. Key applications include real-time defect detection, pattern matching, and automated sorting, contributing to reduced waste and sustainable production. Challenges such as high development costs and environmental variability are noted, alongside future prospects for smart factories.**

Keywords—Computer vision, textile industry, defect detection, deep learning, convolutional neural networks, quality control, pattern recognition, automation, sustainable production, image processing.

CXVIII. INTRODUCTION (*HEADING 1*)

The textile industry occupies a significant place in the global economy, covering processes from raw material processing to the production of fabrics and finished garments. With the increasing demand for high-quality textile products, manufacturers are faced with the need to optimize processes, minimize defects and reduce costs. In this context, computer vision (CV) has become a key technology providing automation and intelligent solutions for quality control, pattern recognition and product classification.

Computer vision uses algorithms and systems to interpret visual data, enabling real-time monitoring, defect detection and predictive maintenance. This article reviews the application of computer vision in the textile industry, including the technical background, key use cases, challenges and development prospects in the creation of smart factories and sustainable manufacturing.

CXIX. LITERATURE REVIEW

The application of computer vision in the textile industry began in the late 20th century, with the focus on identifying fabric defects such as stains, holes, thread breaks, and uneven weaves. Early systems used statistical models and threshold algorithms such as Gray -Level Co-occurrence Matrices (GLCMs) and histogram analysis [3]. However, these methods had limitations: poor adaptability to complex patterns, sensitivity to lighting and texture changes, and slow processing due to limited computing power. With the development of machine learning (ML) and deep learning (DL), the capabilities of computer vision have expanded significantly. Modern systems use Convolutional Neural Networks (CNNs) to automatically extract features such as texture, color, and geometric patterns, allowing them to identify complex defects with high accuracy [1]. For example, in fabric images (see Figure 1), systems can detect thread breaks or stains that previously went unnoticed.

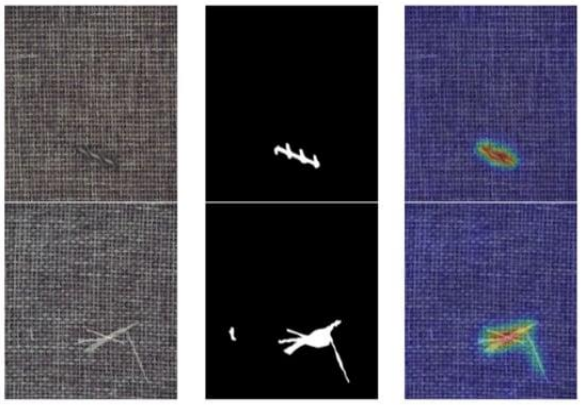

Fig. 26. Examples of tissue defect detection using computer vision

With the advancement of technology, the integration of high-performance hardware such as Graphics Processing Units (GPUs) has enabled real-time image processing, which is critical for high-speed production lines [2]. Cloud and Edge Computing have increased the scalability and availability of systems, allowing centralized analysis of data from multiple production sites or local decision-making on-site.

CXX. METHODOLOGY

The methodological basis of the proposed system lies in the integration of computer vision, signal processing, and deep learning into a unified pipeline capable of operating in real time under the demanding conditions of textile production. The process begins with the acquisition of high-quality data, since the reliability of subsequent analysis depends directly on the precision of the input images and sensor readings. For this purpose, high-resolution industrial RGB cameras ranging from 4K to 12K pixels are employed [2]. They are carefully calibrated in order to eliminate geometric distortions, thereby ensuring that the recorded frames accurately correspond to the physical structure of the fabric. To complement this visual data, auxiliary sensors are introduced. Optical triangulation modules construct three-dimensional profiles of the textile surface, allowing the detection of minute variations such as wrinkles or slack threads. Infrared sensors, in turn, monitor thermal uniformity during processes such as dyeing and drying, capturing anomalies in heat distribution that may indicate deeper structural irregularities. Synchronization of these heterogeneous modalities is performed by means of hardware-triggered frame grabbers, which ensure temporal alignment between RGB, depth, and infrared streams. The resulting data streams are considerable in scale, often reaching 200 to 500 frames per second, and therefore necessitate high-bandwidth transmission standards such as GigE Vision or Camera Link to prevent loss of information. Once the data have been acquired, a preprocessing stage is required to reduce noise and normalize the captured images. In industrial environments, variations in illumination and the presence of sensor noise are inevitable. These problems are mitigated through the application of Gaussian and median filtering, as well as more advanced wavelet-based methods. Homomorphic filtering and adaptive histogram equalization are applied to correct uneven lighting conditions, while geometric calibration ensures that the visual coordinate system is aligned with the reference grid of the production line. Standardization is also necessary in order to rescale the frames to fixed dimensions and normalize intensity values. This guarantees that subsequent analytical modules can process the data consistently across different sensors and production environments [1].

The representation of fabric features constitutes the next crucial stage. Traditional handcrafted descriptors such as gray-level co-occurrence matrices and Haralick statistics are employed to characterize textural regularity, while local binary patterns capture microstructural variations within the weave. Edge-based representations, obtained through Canny or related operators, highlight abrupt discontinuities associated with breaks or holes. However, modern computer vision systems rely increasingly on deep representations. Convolutional neural networks, particularly architectures such as ResNet50 or EfficientNet pretrained on large-scale datasets, are capable of extracting hierarchical features that capture both low-level textures and high-level semantic structures. To ensure robustness across different scales of defects, ranging from small fiber disruptions to large stains, feature pyramids are incorporated into the system. Furthermore, a mechanism of feature fusion combines handcrafted and deep descriptors, thereby leveraging the strengths of both approaches and increasing resilience against variations in fabric type, weave density, and illumination [2].

Segmentation represents the stage at which potential defects are localized within the textile image. Classical techniques such as adaptive thresholding or clustering provide initial region proposals, but in practice these methods are insufficient for fabrics with complex textures. Consequently, a deep learning approach based on U-Net architectures is adopted, offering pixel-level segmentation with intersection-over-union scores surpassing 0.9 in experimental evaluations. This segmentation is further enhanced through the application of instance segmentation models, such as Mask R-CNN, which produce both bounding boxes and refined masks for candidate defects, thereby preparing the data for final classification.

The classification stage is responsible for the definitive identification of defect categories. These include common industrial anomalies such as holes, stains, broken yarns, misalignments, and inconsistencies in dyeing or color distribution. To achieve this task with the required speed and accuracy, advanced deep neural networks such as YOLOv8 and Faster R-CNN are deployed. These models not only classify the defects but also provide precise localization in real time, maintaining processing latencies below 30 milliseconds per frame. In order to minimize false positives, a confidence threshold of 0.85 is applied, ensuring that only the most reliable detections are acted upon. The system is integrated into a feedback loop with the production line. For example, if the classifier identifies a misalignment in the weave, actuators can adjust thread tension automatically. Similarly, temperature anomalies detected by infrared imaging can trigger corrective adjustments in the dyeing process, while robotic cutters may isolate defective fabric sections before further processing.

Finally, for large-scale industrial deployment, optimization at both the hardware and software levels is necessary. Image analysis is carried out on high-performance GPUs such as the NVIDIA RTX A6000, which allow the system to process approximately 250 frames per second per production line. To reduce inference time, the deep learning models are accelerated using CUDA streams and TensorRT optimization. In cases where factories operate in remote locations or with limited connectivity, inference is executed on edge devices such as the NVIDIA Jetson Xavier or Orin, with results synchronized to cloud servers for central monitoring. This hybrid approach not only enables immediate corrective action at the local level but also

facilitates predictive maintenance and long-term defect analysis through centralized data analytics.

In summary, the proposed methodology advances the field of automated textile inspection by combining multi-modal sensing with hybrid feature extraction and real-time decision-making mechanisms. The novelty of the system lies not only in the integration of RGB, depth, and infrared modalities but also in the fusion of traditional feature descriptors with deep representations. This dual strategy significantly enhances the robustness of defect detection under diverse fabric types and production conditions, thereby establishing a methodological foundation for next-generation intelligent textile manufacturing systems.

CXXI. Discussion

Computer vision has fundamentally transformed the methods applied to quality control, pattern recognition, and grading within the textile industry. The integration of high-resolution imaging, advanced algorithms, and deep learning architectures has enabled the automation of processes that previously relied on manual inspection, thereby increasing both efficiency and precision.

One of the most significant applications of computer vision in this domain lies in the sphere of quality control and continuously monitor and adjust the alignment of print heads and the distribution of ink. Such mechanisms are essential for mass customization, in which individual customer orders may require highly varied designs, color schemes, and layout patterns. Without computer vision, maintaining this level of precision in high-volume, customized production would be prohibitively expensive and error-prone.

Beyond these immediate applications, computer vision also supports grading and classification tasks. Fabrics can be automatically sorted according to quality, texture, or compliance with industrial standards, enabling manufacturers to standardize their output more effectively. For example, neural network-based classifiers can distinguish between different grades of cotton or silk based on microstructural imaging, while hyperspectral imaging assists in identifying chemical inconsistencies introduced during dyeing or finishing processes. These approaches not only enhance the objectivity of grading but also contribute to greater transparency and traceability across the supply chain.

inspection. Automated visual inspection systems are capable of detecting defects such as stains, broken threads, or weave irregularities with an accuracy that frequently exceeds 95 percent, while traditional human-based inspection typically achieves only 70 to 80 percent reliability. The difference is attributable not only to the inherent subjectivity of human evaluation but also to the fatigue and inconsistency that arise in repetitive inspection tasks. By contrast, automated systems employ real-time image processing techniques that allow for continuous monitoring of fabric surfaces as they move along production lines. This capability minimizes material waste, ensures faster identification of errors, and reduces overall production costs. The economic significance of such systems is particularly pronounced in large-scale textile manufacturing, where even small reductions in defect rates translate into substantial savings.

Another key application is pattern recognition and design automation. In the production of textiles with complex designs, precision in geometric alignment and color consistency is critical. Computer vision algorithms are employed to analyze and match patterns with remarkable accuracy, thereby ensuring that the final product corresponds exactly to the intended design specifications. This is especially relevant in processes such as digital textile printing, where vision-based calibration systems

Sorting and classification. Algorithms classify fabrics by texture, color, and composition, automating product sorting. For example, an international clothing brand implemented an AI system that achieved 95% classification accuracy, speeding up order fulfillment. However, the implementation of technologies faces challenges: high complexity of model development, the need for large data sets, high equipment costs and the influence of external factors such as lighting or fabric speed. These issues require further research in the field of algorithm simplification, creation of affordable hardware solutions and adaptation to variable conditions. Results. The application of computer vision demonstrates significant improvements in the textile industry. Automated systems provide defect detection accuracy of over 95%, reduce production waste and increase efficiency by 40%. Real-time processing allows for immediate adjustments to production processes, minimizing downtime. Comparative analysis shows the superiority of automated systems over manual methods in terms of accuracy, speed and scalability.

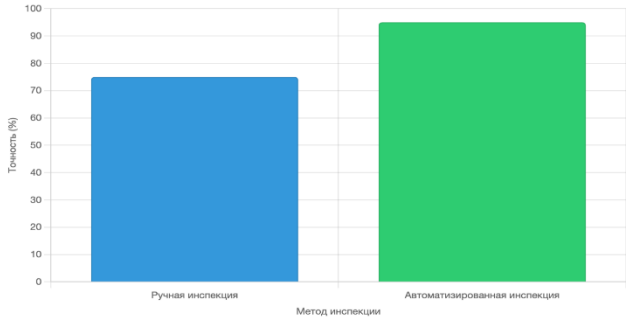

Fig. 27. Comparison of the accuracy of manual and automated inspection

These results highlight the potential of computer vision to improve the competitiveness of the textile industry by supporting sustainable production through waste reduction.

CXXII. Conclusion

Computer vision is transforming the textile industry by automating quality control, pattern recognition, and product sorting. The technology provides high accuracy, reduces costs, and minimizes waste, promoting sustainable production. Despite challenges such as complex development and high start-up costs, further research and technological innovation will make computer vision even more accessible and effective.

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AI VA VEGETATSIYA INDEKSLARIGA ASOSLANGAN TAKOMILLASHTIRILGAN SEGMENTATSIYA YONDASHUVI

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Annotatsiya — Ushbu tadqiqotning asosiy maqsadi qishloq xo‘jaligi maydonlarini segmentatsiya qilish aniqligini sun’iy intellekt (AI) texnologiyalari va vegetatsiya indekslari (NDVI, SAVI) integratsiyasi orqali oshirishdan iborat. Maqsad — spektral o‘xshashliklar tufayli yuzaga keladigan segmentatsiya xatolarini kamaytirish hamda resurslardan samarali foydalanishni ta’minlashdir.

Kalit so‘zlar — Qishloq xo‘jaligi segmentatsiyasi, NDVI (Normalized Difference Vegetation Index), SAVI (Soil-Adjusted Vegetation Index), AI, CNN (Convolutional Neural Networks), masofadan zondlash, ko‘p spektrli tasvirlar.

CXXIII. KIRISH

Resurslardan samarali foydalanish, hosildorlikni oshirish va qishloq xo‘jaligi maydonlarini samarali boshqarish global oziq-ovqat xavfsizligini ta’minlashda muhim omillardandir. Masofadan zondlash texnologiyalari orqali olingan yuqori aniqlikdagi sun’iy yo‘ldosh tasvirlari ekinlar holatini uzluksiz kuzatish imkonini beradi. Biroq tasvirlarni tahlil qilish jarayonida tuproq, o‘simlik va boshqa yer qoplamalari orasidagi spektral o‘xshashlik segmentatsiya aniqligini pasaytirishi mumkin.

So‘nggi yillarda, ayniqsa NDVI (Normalized Difference Vegetation Index) va SAVI (Soil-Adjusted Vegetation Index) kabi vegetatsiya indekslari o‘simliklarning spektral xususiyatlarini farqlashda keng qo‘llanib kelinmoqda. Bu indekslar o‘simlik qoplami va boshqa sirtlar o‘rtasidagi kontrastni oshirish orqali segmentatsiya samaradorligini yaxshilaydi. Shu bilan birga, sun’iy intellekt (AI) texnologiyalari, xususan konvolyutsion neyron tarmoqlar (CNNs), murakkab tasvirlarni yuqori aniqlik bilan tahlil qilish imkoniyatini beradi.

Ushbu tadqiqotda NDVI va SAVI indekslari CNN asosidagi segmentatsiya modeli bilan integratsiya qilindi. Taklif etilgan usul qishloq xo‘jaligi maydonlarini aniq chegaralash, shovqinning (noise) ta’sirini kamaytirish va yakunda resurslarni samarali boshqarishni qo‘llab-quvvatlash imkonini beradi. Taklif etilgan metodning samaradorligi turli hududlardan olingan sun’iy yo‘ldosh tasvirlarida sinovdan o‘tkazildi va an’anaviy thresholding hamda clustering yondashuvlariga nisbatan sezilarli ustunliklarni namoyish etdi.

II. VEGETATSIYA INDEKSLARI VA AI INTEGRATSIYASI BO‘YICHA ILG‘OR YONDASHUVLAR

So‘nggi o‘n yilliklarda qishloq xo‘jaligi monitoringida masofadan zondlash (Remote Sensing) texnologiyalari asosiy ma’lumot manbalaridan biriga aylandi. Turli spektral diapazonlarda olingan tasvirlar yordamida vegetatsiya holatini baholash, biomassani aniqlash va hosildorlikni prognoz qilish imkoniyatlari sezilarli darajada kengaydi.

NDVI (Normalized Difference Vegetation Index) eng ko‘p ishlatiladigan indekslardan biri bo‘lib, 1970-yillardan buyon ekin maydonlaridagi yashil biomassaning fotosintez faoliyatini aniqlashda qo‘llanib kelinadi. NDVI qiymatlari o‘simliklar tomonidan infraqizil va qizil spektral nurlanishlarning qayta tarqatilishidagi farq asosida hisoblanadi. Bu indeks vegetatsiya zichligi yuqori bo‘lgan hududlarda aniq natija berishi bilan ajralib turadi.

Biroq NDVI past vegetatsiya zichligiga ega yoki tuproq ta’siri kuchli bo‘lgan maydonlarda sezilarli xatoliklarga ega bo‘lishi mumkin. Ushbu cheklovlarni bartaraf etish uchun SAVI (Soil Adjusted Vegetation Index) taklif qilingan bo‘lib, u tuproqning spektral ta’sirini kompensatsiya qilish orqali past qoplama sharoitlarida ham aniqroq baholash imkonini beradi.

An’anaviy ravishda NDVI va SAVI kabi indekslar yordamida tasvir segmentatsiyasi turli threshold (chegaraviy qiymat) usullari bilan amalga oshirilgan. Bu yondashuv oddiy va tezkor bo‘lsa-da, turli spektral sharoitlar va mavsumiy o‘zgarishlarga moslashuvchanlik darajasi past bo‘ladi.

So‘nggi yillarda sun’iy intellekt, xususan chuqur o‘rganish (Deep Learning) metodlari ushbu sohada katta yutuqlarni namoyish etmoqda. U-Net, SegNet va DeepLab kabi konvolyutsion neyron tarmoqlar (CNN) NDVI va SAVI xaritalarini kirish ma’lumotlari sifatida ishlatish orqali an’anaviy threshold yondashuvlariga qaraganda

sezilarli darajada yuqori aniqlikka erishmoqda. NDVI va SAVI indekslari CNN modellariga qo‘shimcha kanal sifatida integratsiya qilinganda, model o‘simlik qoplamasining spektral xususiyatlarini chuqur o‘rganib, turli agroekologik sharoitlarda ham barqaror natija beradi.

III. VEGETATSIYA INDEKSLARIDAN FOYDALANGAN HOLDA AI ASOSIDAGI SEGMENTATSIYA

Sun’iy yo‘ldosh tasvirlarida qishloq xo‘jaligi maydonlarini aniq segmentatsiya qilish uchun taklif etilgan yondashuv vegetatsiya indekslari — xususan, Normalized Difference Vegetation Index (NDVI) va Soil-Adjusted Vegetation Index (SAVI) — bilan sun’iy intellekt (AI) asosidagi segmentatsiya modelini birlashtiradi. Ushbu integratsiya o‘simlik va o‘simlik bo‘lmagan sirtlar o‘rtasidagi kontrastni kuchaytiradi va chegaralarni aniqroq belgilash imkonini yaratadi. Yondashuv bir nechta bosqichlardan iborat bo‘lib, ularning har biri maydonlarni aniqlash aniqligini va umumiy segmentatsiya samaradorligini oshirishga qaratilgan.

Ma’lumotlarni yig‘ish va oldindan qayta ishlash

Ushbu tadqiqotda foydalanilgan ma’lumotlar masofadan zondlash manbalaridan olindi. Asosiy ma’lumot manbalari quyidagilardan iborat:

- Sentinel-2 MSI (Yevropa Kosmik Agentligi) — 10–20 m fazoviy aniqlikka ega bo‘lgan, 13 ta spektral diapazonni qamrab oluvchi ko‘p spektrli tasvirlar.
- Landsat 8 OLI/TIRS (USGS va NASA) — 30 m fazoviy aniqlikka ega tasvirlar bo‘lib, qishloq xo‘jaligini monitoring qilishda keng qo‘llaniladi.
- Dron tasvirlari (RGB va NIR kameralar bilan jihozlangan) — 5–10 sm juda yuqori aniqlikdagi ma’lumotlar bo‘lib, kichik maydonlarni tahlil qilish uchun qulay.

Tanlash mezonlari:

- Tadqiqot hududlarini to‘liq qamrab olish
- Bulutlilik darajasi ⩽ 10%
- Vegetatsiya mavsumi davomida turli fenologik bosqichlarni qamrab olish

Vegetatsiya indekslarini hisoblash

AI modeli faqat RGB kanallari bilan emas, balki vegetatsiya indekslari bilan ham ta’minlandi. Ushbu tadqiqotda eng samarali deb topilgan ikki indeks quyidagilar bo‘ldi:

$$NDVI = (NIR - RED) / (NIR + RED) \quad (1)$$

Bu yerda: NIR - yaqin infraqizil diapazon (Sentinel-2: 8-kanal), Red - qizil diapazon (Sentinel-2: 4-kanal), Soil-Adjusted Vegetation Index (SAVI) — tuproq ta’sirini hisobga olgan vegetatsiya indeksi

SAVI past o‘simlik qoplamiga ega hududlarda tuproq yorqinligining ta’sirini kamaytirish uchun ishlab chiqilgan. U quyidagi tenglama yordamida hisoblanadi:

$$SAVI = ((NIR - RED) \times (1 + L)) / (NIR + RED + L) \quad (2)$$

Bu yerda L — tuproqni tuzatish koeffitsienti bo‘lib, o‘rtacha zichlikdagi vegetatsiya sharoitida odatda 0,5 ga teng qiymatda olinadi.

Ushbu indekslar hisoblangandan so‘ng, ular tasvirlarga qo‘shimcha kanallar sifatida qo‘shildi va natijada model kirish konfiguratsiyasi quyidagi ko‘rinishda bo‘ldi: [Red, Green, Blue, NDVI, SAVI].

Modelni ishlab chiqish va sinov muhiti

Ushbu tadqiqotda sun’iy intellekt modeli sifatida U-Net arxitekturasi tanlandi. Ushbu model tasvir segmentatsiyasi vazifalarida keng tan olingan bo‘lib, u har bir pikselning sinfga mansubligini (masalan, “ekin maydoni” va “ekin maydoni emas” hududlarini farqlash) aniqlash uchun maxsus ishlab chiqilgan.

Modelning asosiy texnik xususiyatlari quyidagilardan iborat:

- Encoder (kodlovchi) — tasvirdan muhim xususiyatlarni ajratib olish uchun javobgar qism. Bizning holatda ResNet34 arxitekturasi kodlovchi sifatida ishlatildi. ResNet34 — yirik ma’lumotlar to‘plamida oldindan o‘qitilgan kuchli neyron tarmoq bo‘lib, murakkab naqshlar va shakllarni aniqlashga qodir. Natijada, tasvirning fazoviy o‘lchamlari bosqichma-bosqich kamaytiriladi, ammo muhim xususiyatlar yanada aniq ajratib olinadi.
- Decoder (dekodlovchi) — kodlovchi tomonidan olingan xususiyat xaritalarining fazoviy o‘lchamlarini qayta tiklab, ularni asl tasvir o‘lchamiga qaytaradi. Bu jarayonda dekonvolyutsiya (yuqoriga namuna olish — up-sampling) texnikasi qo‘llanadi, natijada har bir piksel bo‘yicha aniq bashorat beruvchi segmentatsiya xaritasi hosil qilinadi.
- Kirish o‘lchami: 256 × 256 piksel, 5 kanal (RGB + NDVI + SAVI)
- Chiqish xaritasi: 1 kanal (ikkilik segmentatsiya: ekin maydoni / ekin maydoni emas)
- Model PyTorch kutubxonasi yordamida ishlab chiqildi, bu esa sun’iy intellekt modellarini yaratish va o‘qitishda yuqori darajada moslashuvchan va samarali platformani taqdim etadi.

Modelni o‘qitish va optimallashtirish

O‘qitish jarayoni yuqori segmentatsiya aniqligini ta’minlash bilan birga, modelning umumlashma qobiliyatini (generalization capability) saqlab qolishga yo‘naltirildi. Yirik o‘lchamdagi ko‘p spektrli sun’iy yo‘ldosh tasvirlari samarali o‘qitish va hisoblash yukini kamaytirish uchun 256 × 256 piksel o‘lchamdagi kichik bo‘laklarga ajratildi. Ma’lumotlar to‘plami tasodifiy tarzda 70% — o‘qitish, 15% — tasdiqlash va 15% — sinov uchun taqsimlandi.

Modelning barqarorligini oshirish va overfittingning oldini olish uchun ma’lumotlarni kengaytirish (data augmentation) texnikalari qo‘llandi, jumladan: tasodifiy aylantirish, akslantirish (flipping), masshtablash (scaling), yorqinlik va kontrastni sozlash. Ushbu o‘zgarishlar modelga turli tasvir olish sharoitlarida ham o‘zgarmas xususiyatlarni o‘rganish imkonini berdi.

Optimallashtirish jarayonida Adam optimizer tanlandi, chunki u moslashuvchan o‘rganish tezligi (adaptive learning rate) va hisoblash samaradorligi bilan

ajralib turadi. Boshlang‘ich o‘rganish tezligi 0.0001 qilib belgilandi, bu konvergensiya tezligi va barqarorlik o‘rtasida muvozanatni ta’minladi. Yo‘qotish funksiyasi sifatida Binary Cross-Entropy (BCE) va Dice Loss birlashtirilgan holda qo‘llanildi, bu esa qishloq xo‘jaligi segmentatsiyasida uchraydigan sinf nomutanosibligini yaxshiroq hal qilishga yordam berdi. Model 100 epoch davomida o‘qitildi va ortiqcha hisoblash hamda overfittingning oldini olish uchun tasdiqlash yo‘qotishiga (validation loss) asoslangan early stopping mezoni qo‘llandi.

Mazkur o‘qitish konfiguratsiyasi taklif etilgan segmentatsiya tizimiga qishloq xo‘jaligi maydonlarini yuqori aniqlik bilan chegaralash imkonini berdi, shu bilan birga, real vaqt rejimida yoki yirik miqyosdagi amaliyotlarda hisoblash samaradorligini saqlab qoldi.

Baholash mezonlari

Ushbu tadqiqotda ishlab chiqilgan segmentatsiya modelining ishlash samaradorligi bir nechta aniqlik va ishonchlilik ko‘rsatkichlari orqali baholandi. Har bir ko‘rsatkich model ishlashining muayyan jihatini o‘lchashga mo‘ljallangan bo‘lib, natijalar turli kirish ma’lumotlari kombinatsiyalari (faqat RGB, RGB+NDVI va RGB+NDVI+SAVI) uchun alohida tahlil qilindi.

IoU (Intersection over Union) — IoU yoki Jakkard koeffitsienti model tomonidan aniqlangan ekin maydoni piksellari va haqiqiy (ground truth) piksellar o‘rtasidagi ustma-ust tushish darajasini o‘lchaydi.

Formulasi quyidagicha:

$$IoU=TP / TP+FP+FN \quad (3)$$

Bu yerda: TP (True Positive) — ekin maydoni sifatida to‘g‘ri aniqlangan piksellar, FP (False Positive) — ekin maydoni sifatida noto‘g‘ri aniqlangan piksellar, FN (False Negative) — ekin maydoniga tegishli bo‘lsa-da, model tomonidan aniqlanmagan piksellar

Dice koeffitsienti — Dice koeffitsienti maydon qoplamasi o‘xshashligini o‘lchash uchun qo‘llaniladi va IoU ko‘rsatkichiga o‘xshash, ammo biroz yuqoriroq sezgirlikka ega. Uning formulasi quyidagicha:

$$Dice=2TP / 2TP+FP+FN \quad (4)$$

Precision va Recall — to‘g‘ri va noto‘g‘ri tasniflangan piksellar nisbatini ifodalaydi.

Precision — model tomonidan vegetatsiya sifatida belgilangan va aslida ham vegetatsiyaga tegishli bo‘lgan piksellar ulushi:

$$Precision=TP / TP+FP \quad (5)$$

Bu yerda: TP — to‘g‘ri aniqlangan vegetatsiya piksellari (True Positive), FP — noto‘g‘ri vegetatsiya sifatida belgilangan piksellar (False Positive).

Yuqori Precision qiymati — kam noto‘g‘ri ogohlantirishlar (false alarms) degani.

Recall — haqiqiy vegetatsiya piksellari orasida model tomonidan to‘g‘ri aniqlanganlar ulushi:

$$Recall=TP / TP+FN \quad (6)$$

Bu yerda: FN — vegetatsiyaga tegishli bo‘lsa-da, model tomonidan aniqlanmagan piksellar (False Negative), Yuqori Recall qiymati — kam aniqlanmay qolgan obyektlar (missed detections) degani.

F1-score — Precision va Recall qiymatlarini yagona ko‘rsatkichga birlashtiradi. U quyidagicha hisoblanadi:

$$F1=2\times (Precision\times Recall / Precision+Recall) \quad (7)$$

F1-score — muvozanatli aniqlik (balanslangan aniqlik) ko‘rsatkichi bo‘lib, Precision va Recall qiymatlari orasida katta farq bo‘lganda ayniqsa foydali hisoblanadi. Chunki u modelni yanada keng qamrovli baholash imkonini beradi.

Ushbu tadqiqotda natijalar har bir kirish konfiguratsiyasi uchun solishtirildi:

- faqat RGB kanallari;
- RGB + NDVI kombinatsiyasi;
- RGB + NDVI + SAVI kombinatsiyasi.

Natijalar va Tahlil

Mazkur tadqiqotda sun’iy intellekt (AI) va vegetatsiya indekslari (NDVI, SAVI) integratsiyasi yordamida qishloq xo‘jaligi maydonlarini segmentatsiya qilish samaradorligi baholandi. Natijalar quyidagi konfiguratsiyalar uchun tahlil qilindi:

- modelni faqat RGB kanallari bilan o‘qitish;
- RGB + NDVI kombinatsiyasi;
- RGB + NDVI + SAVI kombinatsiyasi.

Modelni o‘qitish va sinov natijalari

IoU (Intersection over Union) ko‘rsatkichlari:

Variant	IoU (%)	Dice (%)	Precision (%)	Recall (%)	F1-score (%)
RGB	78.4	87.9	85.2	90.4	87.7
RGB + NDVI	83.6	90.8	88.7	92.9	90.8
RGB + NDVI + SAVI	**87.2**	**93.1**	**91.6**	**94.7**	**93.1**

Natijalar shuni ko‘rsatdiki, vegetatsiya indekslarini qo‘shish model aniqligini sezilarli darajada oshiradi. Xususan, NDVI va SAVI indekslaridan birgalikda foydalanish qishloq xo‘jaligi maydonlarini boshqa yer qoplamalaridan aniq ajratib olish imkonini berdi.

- Faqat RGB konfiguratsiyasi IoU ko‘rsatkichida 78,4% va F1-score bo‘yicha 87,7% natijaga erishdi. Bu qoniqarli bo‘lsa-da, notekis hududlarda vegetatsiyani yalang‘och tuproqdan ajratishda ma’lum cheklovlarga ega ekanligi kuzatildi.

- NDVI qo‘shilishi IoU’ni 5,2 foiz punktga, F1-scoreni esa 3,1 foiz punktga yaxshiladi. Bu NDVI vegetatsiya spektral farqliligini samarali kuchaytirishini tasdiqlaydi.

- NDVI va SAVI birgalikda qo‘shilganda eng yaxshi natija kuzatildi: IoU — 87,2%, F1-score — 93,1%.

Bu yutuq asosan SAVI indeksining kam vegetatsiyali hududlarda tuproq fon ta’sirini kamaytirish qobiliyati bilan izohlanadi.

Umuman olganda, RGB + NDVI + SAVI kombinatsiyasi eng barqaror segmentatsiya natijalarini berdi — Precision 91,6% va Recall 94,7%, bu esa yuqori aniqlik va qamrovni ifodalaydi.

Statistik tahlil: Model natijalarini statistik baholash uchun juftlangan t-test qo‘llanildi. RGB-only va NDVI+SAVI modellar o‘rtasidagi farq $p < 0.01$ darajasida statistik jihatdan ahamiyatli deb topildi. Bu vegetatsiya indekslarini qo‘shish segmentatsiya samaradorligini ilmiy asoslangan tarzda yaxshilashini ko‘rsatadi.

Amaliy ahamiyati

- Qishloq xo‘jaligida hosildorlik monitoringi va ekin maydonlarini aniqlashda yuqori aniqlikni ta’minlaydi.
- NDVI+SAVI kombinatsiyasi kam vegetatsiyali va tuproq ta’siri yuqori bo‘lgan hududlarda ham yaxshi natija beradi.
- Sun’iy intellekt modeli real vaqtga yaqin ishlashi mumkin, bu dron yoki sun’iy yo‘ldosh tasvirlarini tezkor tahlil qilish imkonini beradi.

Natijalar sintezi: Ushbu tadqiqotda vegetatsiya indekslari (NDVI va SAVI) bilan integratsiyalashgan sun’iy intellekt asosidagi ekin maydonlarini segmentatsiya qilish usuli ishlab chiqildi va baholandi. Natijalar quyidagilarni ko‘rsatdi:

- Vegetatsiya indekslarini qo‘shish model aniqligini sezilarli darajada oshiradi.
- NDVI va SAVI kombinatsiyasi tuproq ta’sirini kamaytirishda hamda kam zichlikdagi vegetatsiyani aniqlashda eng samarali bo‘ldi.
- O‘qitilgan model IoU bo‘yicha 87,2% va F1-score bo‘yicha 93,1% ko‘rsatkichga erishdi, bu faqat RGB ma’lumotida o‘qitilgan modelga nisbatan qariyb 9% yaxshilanishni anglatadi.
- Amaliy nuqtayi nazardan, ushbu yondashuv hosildorlik monitoringi, ekin maydonlarini baholash va resurslarni samarali boshqarishda muhim imkoniyatlar yaratadi..

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USING INTELLIGENT MULTIMEDIA TECHNOLOGIES IN THE PROCESS OF ELECTRONIC TRANSLATION

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***Abstract* — This article highlights the role and significance of intelligent multimedia technologies, considered one of the modern information and communication tools, in the process of electronic translation between natural languages. An analysis of existing video translators is presented. Furthermore, the paper discusses the current importance of electronic translation and introduces concepts that ensure the accuracy and quality of translation outputs. Linguistic and mathematical models of word and sentence formation are also provided.**

***Keywords* — electronic translation, multimedia technologies, artificial intelligence, machine translation, speech recognition, cross-linguistic communication, linguistic-mathematical model.**

CXXIV. INTRODUCTION

In the context of globalization, overcoming language barriers and accelerating information exchange has become an essential need for modern society. In this process, translation technologies, particularly electronic and intelligent translators, play a key role. However, there are still many challenges in automatic translation into the Uzbek language. This article analyzes the urgent issues of translation into Uzbek, the reasons behind them, and how they can be addressed through intelligent multimedia technologies. In addition, with the rapid development of digital processes, communication between different nations and peoples through language remains one of the most important needs. The process of translation between languages is carried out not only through linguistic knowledge but also with the help of modern technologies. Along with traditional dictionaries and human translations, the application of intelligent multimedia technologies demonstrates that translation can be faster, more accurate, and more visually convenient. From this, it can be concluded that traditional translation methods do not fully meet today's requirements, and therefore the effectiveness of using intelligent multimedia technologies in translation processes is increasing. The use of intelligent multimedia technologies in translation involves not only text but also audio, video, graphics, and interactive content, making the translation process more convenient and efficient.

CXXV. MAIN PART

Intelligent multimedia technologies encompass areas such as artificial intelligence, natural language processing (NLP), speech recognition, machine translation, and computational linguistics. Multimedia, in turn, integrates text, audio, images, animation, and video materials to provide users with multifaceted information delivery. The integration of these two domains has led to the emergence of a new generation of electronic translators and automated systems [1-3].

The use of intelligent multimedia technologies in the translation process plays an important role in integrating various sensory channels. In general, the application of intelligent multimedia technologies in translation has several advantages:

Audio and speech recognition capabilities – enabling translation from one language to another through speech input without the need for manual text entry.

Video subtitles and simultaneous translation – expanding the possibilities of real-time translation for foreign films, online lessons, and conferences.

Visual support – enhancing the effectiveness of language learning and translation processes through graphical and interactive elements.

Speed and accuracy – intelligent systems semantically analyze texts, ensuring contextually appropriate translations of words.

Below, we can observe translation software that implements the translation process using the advantages mentioned above [4-8].

1-table. Video translators' description

Video translators with artificial intelligence	Accuracy	Number of supported languages
veed.io	98%	125
Translate One2One	80%	60
Andovar Studio	80%	100
DeepL Translate	90%	10
iTranslate Transcribe	80%	80
Resemble AI	85%	100
MateCat	80%	130

These video translators use advanced speech recognition and neural machine translation with artificial intelligence to automatically generate subtitles, captions, and overlays in a designated target language during video playback. First, the video or live audio stream is input into a speech-to-text algorithm, which transcribes the spoken words into textual captions. This text is then fed into a neural machine translation model trained on large datasets to produce translated text outputs [9-16].

There are several advantages of using video translators:

First, they remove language barriers to enable global distribution and increase the user audience.

Second, they improve accessibility for users with hearing impairments, thereby expanding the audience reach.

Third, they support immersive language learning by allowing users to read translations while listening to the video.

Fourth, they reduce costs and effort compared to human translation.

From the advantages mentioned above, it can be seen that developing such translation software for the Uzbek language is also one of the important tasks. However, a number of challenges arise in this process [17-20]. For example, there is a lack of large annotated speech and video corpora in Uzbek, and it is also necessary to take into account the diversity of language structure, dialects, and accents. In addition, to ensure more accurate electronic translation, it is important to consider phonetic changes in the word-formation process of the Uzbek language. If phonetic changes are not taken into account, errors occur and the translation becomes inaccurate. In this regard, phonetic analysis in Uzbek generally follows five rules, and on the basis of these rules, linguistic-mathematical models have been developed:

1. qishlo**q**+**imiz**=qishlo**g‘**imiz
   telpa**k**+**im**= telpa**g**im
   o’rda**k**+**im**=o’rda**g**im

In this case, the following linguistic-mathematical model has been developed:

$$W_{uzb} = \oplus \sum_{i=1}^{n} R_i(N_j) \oplus \sum_{f=1}^{e} I_f(U_\varepsilon) \quad (1)$$

Here, W_{uzb}- uzbek word,
R_i- word root, N_j- noun word class
I_f- word modifier,
U_ε- possessive suffix
$\oplus$- linking marker,
$\downarrow$- a marker that may or may not occur.

2. qishlo**q**+**ga** =qishloq**qa**,
   chela**k**+**ga** =chelak**ka**,
   to**g‘**+**ga** =toq**qa**,
   pedago**g**+**ga**=pedagok**ka**

In this case, the following linguistic-mathematical model has been developed:

$$W_{uzb} = \oplus \sum_{i=1}^{n} R_i(N_j) \oplus \sum_{f=1}^{e} I_f(K_\mu) \quad (2)$$

Here, W_{uzb}*- uzbek word, R_i- word root,*
I_f - derivational affix
K_μ- dative case,
$\oplus$- linking marker,
$\downarrow$- a marker that may or may not occur

3. **o**ng+la =**a**ngla,
   son +a =**sa**na
   yosh+a = **ya**sha

$$W_{uzb} = \oplus \sum_{i=1}^{n} R_i(N_j) \oplus \sum_{z=1}^{d} V_z \quad (3)$$

Here, W_{uzb}*- uzbek word, R_i- word stem,*
I_f - derivational affix
K_μ- dative case,
$\oplus$- linking marker,
$\downarrow$- a marker that may or may not occur.

4. e**k**+**gan** = ek**kan**,
   ke**t**+**gan** = ke**tkan**,

o**q**+**gan** =oq**qan**,
tush+**gan**= tush**kan**

$$W_{uzb} = \oplus \sum_{i=1}^{n} R_i(H_q) \oplus \sum_{y=1}^{\lambda} F_y \qquad (4)$$

Here, W_{uzb}*- uzbek word,* R_i*- word root,*
F_y *– derivational suffix*
H_q*- verb stem,*
⊕*- linking marker,*
↓*- a marker that may or may not occur.*

5. bi**r**+**ta**= bi**tta**

$$W_{uzb} = \oplus \sum_{i=1}^{n} R_i(T_\beta) \oplus \sum_{y=1}^{\lambda} F_y \qquad (5)$$

Here, W_{uzb}*- uzbek word,* R_i*- word root,*
T_β- numeral stem, F_y- formative suffix,
⊕*- linking marker,*
↓*- a marker that may or may not occur.*

The above-mentioned linguistic-mathematical models serve to ensure the accuracy and quality of electronic translation.

It is well known that in the Uzbek language there is a conventional word order in sentences. According to this order, the subject comes first and the predicate comes later; the modifier precedes the modified word; adverbial modifiers and objects precede the predicate, meaning that the predicate usually comes at the end of the sentence.

However, for the purpose of expressing a certain stylistic meaning, the conventional word order in a sentence may be changed, and such altered word order is also referred to as inversion.

The linguistic-mathematical model of sentence structure in the Uzbek language can be represented as follows:

$$G_{sod} = A(x_i,....x_n) \cup B(x_i,....x_n) \qquad (6)$$

Bu yerda,

G_{sod}– simple sentence,
$A(x_i,….x_n)$– subject,
$B(x_i,….x_n)$– predicate, ∪- combining marker,
x- word length, i and n x a variable indicating the initial and final boundary of word length belonging to set x.

$$G_{sod} = A(x_i,....x_n) \cup D(x_i,....x_n) \cup \cup S(x_i,....x_n) \cup K(x_i,....x_n) \cup \cup B(x_i,....x_n) \qquad (7)$$

Here,

G_{mur}– complex sentence,
$A(x_i,….x_n)$– subject,
$D(x_i,….x_n)$– object,
$S(x_i,….x_n)$- adverbial modifier,
$K(x_i,….x_n)$– attribute,
$B(x_i,….x_n)$– predicate, ∪- combining marker,
x- word length, i and n x a variable indicating the initial and final boundary of word length belonging to set x.

The linguistic-mathematical models developed above not only ensure the accuracy and quality of electronic translation but can also be used for word and sentence formation in all agglutinative languages.

CXXVI. Conclusion

Developing a video translator for the Uzbek language is a complex but urgent task. Enriching language corpora, creating models based on neural networks, and applying solutions optimized for mobile devices will serve as an effective way to address these challenges. In the future, such a system can be widely applied not only in education but also in tourism, international business, cultural exchange, and public services. Electronic translators and intelligent multimedia technologies complement each other. Together, they perform tasks such as understanding content, translating automatically, generating subtitles, and eliminating language barriers in real time. The challenges that arise in translation into Uzbek are associated not only with linguistic factors but also with technological and cultural aspects. Intelligent multimedia technologies can serve as an effective tool in addressing these issues; however, further scientific research, as well as the creation of national language corpora and linguistic resources, is necessary in this direction.

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THE IMPORTANCE OF MULTIMEDIA TECHNOLOGIES IN THE VISUALIZATION AND ANALYSIS OF FILTRATION PROCESSES OF OIL AND GAS FIELDS

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***Abstract*— The article analyzes the application of multimedia technologies in the oil and gas industry and their scientific and practical significance. In this area, the processes of extraction, production, and processing are complex and closely related to large volumes of multidimensional data. The article presents a one-dimensional mathematical model of the oil filtration process in a porous medium, its algorithm, and graphical results. The differential equation, based on the variability of the pressure and permeability coefficients, was solved using the finite difference and sweep methods. Computational experiments were conducted at different values of the permeability coefficients of the layers, as well as with respect to the pressure distribution over time, on the basis of which analyses were carried out. The possibility of creating 3D images of geological formations using multimedia technologies, simulating drilling processes, and effectively performing real-time monitoring and safety forecasting work was also discussed. This approach allows for prompt and well-founded decision-making in the field, increasing the effectiveness of employee training, and ensuring safety in production processes. The widespread introduction of multimedia technologies in the oil and gas industry is of strategic importance in the process of digital transformation.**

Keywords—intelligent multimedia, 3D model, mathematical model, artificial intelligence, numerical method, Big Data.

CXXVII. INTRODUCTION

The oil and gas industry is one of the main branches of the modern economy. In this area, the processes of production, transportation, and processing are closely related to complex, large-scale, and multidimensional data. The oil and gas industry involves complex processes: large amounts of data are generated at all stages, from geological exploration to extraction, processing, and transportation[1-4]. This data is usually multilayered, in various formats, and dynamically variable. Therefore, their effective management, analysis, and visualization require modern technologies. In recent years, intelligent multimedia technologies have begun to be used as an important tool in these processes.

Unlike ordinary multimedia (text, image, audio, video), intelligent multimedia technologies are enriched with the capabilities of artificial intelligence (AI), machine learning, big data (Big Data) analysis, and interactive visualization. Such systems are distinguished by the fact that they conduct "smart communication" with the user, help in data processing and drawing conclusions.

In the oil and gas industry, these technologies serve:

- visualization of geological and geophysical data in 3D and 4D formats;
- simulation of drilling and mining processes;
- monitoring the operation of equipment in real time;
- increasing safety and preventing accidents.

In the oil and gas industry, visualization is one of the most important tools. Because it's difficult to understand geological layers, pressure distribution, or well flow velocity through simple text or numbers. With the help of intelligent multimedia:

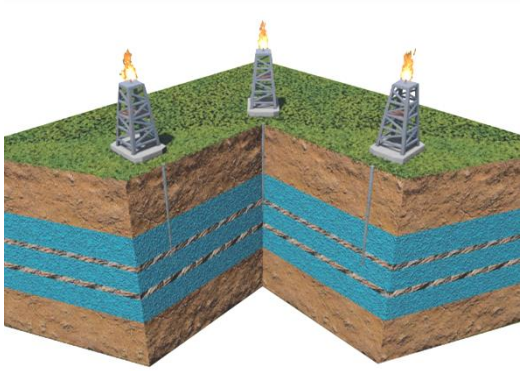

Fig. 28. 3D view of an oil and gas field with a multilayered low-permeability.

• 3D modeling - a clear representation of the spatial structure of the layers;

• Dynamic visual simulation - showing how processes change over time;

• AR/VR environments - allow training specialists in virtual reality and safe testing of complex situations.

CXXVIII. MATHEMATICAL MODEL

Consider the following mathematical model, in which the permeability coefficient of oil filtration in a porous medium is heterogeneous and depends on reservoir pressure.

$$\beta\mu\frac{\partial P}{\partial t}=\frac{\partial}{\partial x}\left(kh\frac{\partial P}{\partial x}\right)-\mathrm{Q},\qquad t>0;\ \ 0<x<L. \tag{1}$$

For a small change in reservoir pressure, the following linear dependence can be obtained for the permeability coefficient.

$$k=k_0\left[1-a_K\left(P_0-P\right)\right]. \tag{2}$$

With a large change in pressure, the following exponential relationship can be obtained.

$$k=k_0\,\mathrm{e}^{-a_K(P_0-P)}. \tag{3}$$

Here

a_k -coefficient 0.001; Can be obtained in the range of 0.0025.
k_0 - initial conductivity coefficient;
P_0 - initial pressure; P - variable pressure.

The mathematical model (1) is solved under the following initial and boundary conditions:

$$P(x,t)=P_H(x),\qquad t=0, \tag{4}$$

$$\begin{cases}-kh\dfrac{\partial P}{\partial x}=\alpha\left(P_A-P\right), & x=0;\quad t>0;\\ kh\dfrac{\partial P}{\partial x}=\alpha\left(P_A-P\right), & x=L;\quad t>0.\end{cases} \tag{5}$$

$$\int\limits_{s_{i_q}}\frac{kh}{\mu}\frac{\partial P}{\partial n}ds=-q_{i_q},\quad (x)\in s_{i_q},\quad i_q=\overline{1,N_q}. \tag{6}$$

$$Q=\sum_{i=1}^{N_q}\delta_i q_i$$

Here:

P - reservoir pressure;
P_H - initial reservoir pressure;
P_A - boundary pressure;
μ - dynamic viscosity of oil;
k - reservoir permeability coefficient;
h - formation thickness;
β - formation elasticity coefficient;
$\beta=m*\beta_N+\beta_M$; β_N - oil compressibility coefficient;
β_M - medium compressibility coefficient;
$q_{iq}-i_q$ - well flow rate;
$s_{iq}-i_q$ - well contour;
N_q - number of wells;
m - porosity coefficient;
δ - Dirac function.

To solve the boundary value problem (1) - (4) by the finite difference method, we introduce the following dimensionless variables:

$$P^*=P/P_0;\quad x^*=x/L;\quad k^*=k/k_0;$$
$$\tau=\frac{k_0 t}{\beta\mu L^2};\quad q^*=\frac{q\mu}{\pi k_0 P_0 h_0}.$$

Here
P_0 - pressure value in the characteristic value;

K_0 - characteristic value, maximum value of layer permeability;

L - characteristic length.

Subsequently, for simplification, the "*" in the equations is not inserted[5, 11-13]. Then, taking this into account, the problem (1) - (6) with dimensionless variables is written as follows:

$$\frac{\partial P}{\partial\tau}=\frac{\partial}{\partial x}\left(kh\frac{\partial P}{\partial x}\right)-\delta q \tag{7}$$

$$P(x,t)=P_H(x),\ t=0, \tag{8}$$

$$\begin{cases}-\dfrac{\partial P}{\partial x}=\alpha\left(P_A-P\right), & x=0;\\ \dfrac{\partial P}{\partial x}=\alpha\left(P_A-P\right), & x=1.\end{cases} \tag{9}$$

The dimensionless boundary value problem of oil filtration in a porous medium, describing the differential equation (7) with boundary conditions (8), (9) is solved by the finite-difference method using the implicit cross-sectional scheme (7) - (9) [7-9, 14,].

For the numerical solution of the boundary value problem (7) - (9), we construct the grid region Δx:

$$\Omega_{x\tau} = \left\{ \left(x_i = i\Delta x,\ \tau_l = l\,\Delta\tau \right);\ \ i = \overline{1,n};\ \ l = \overline{0,N_\tau},\ \ \Delta\tau = \frac{1}{N_\tau} \right\}.$$

In this domain, the algorithmic concept of the implicit variable direction scheme (cross-section scheme) is used to construct the finite-difference problem [6,15-17]. The transition from the *l*-th time layer to the *l+1* layer is carried out with step Δτ. Using the solutions of the finite difference equation, we find the discharge coefficients A_i,B_i,C_i;. This calculation scheme is implemented at each time value. In the next time layer, these calculated pressure values become the initial values.

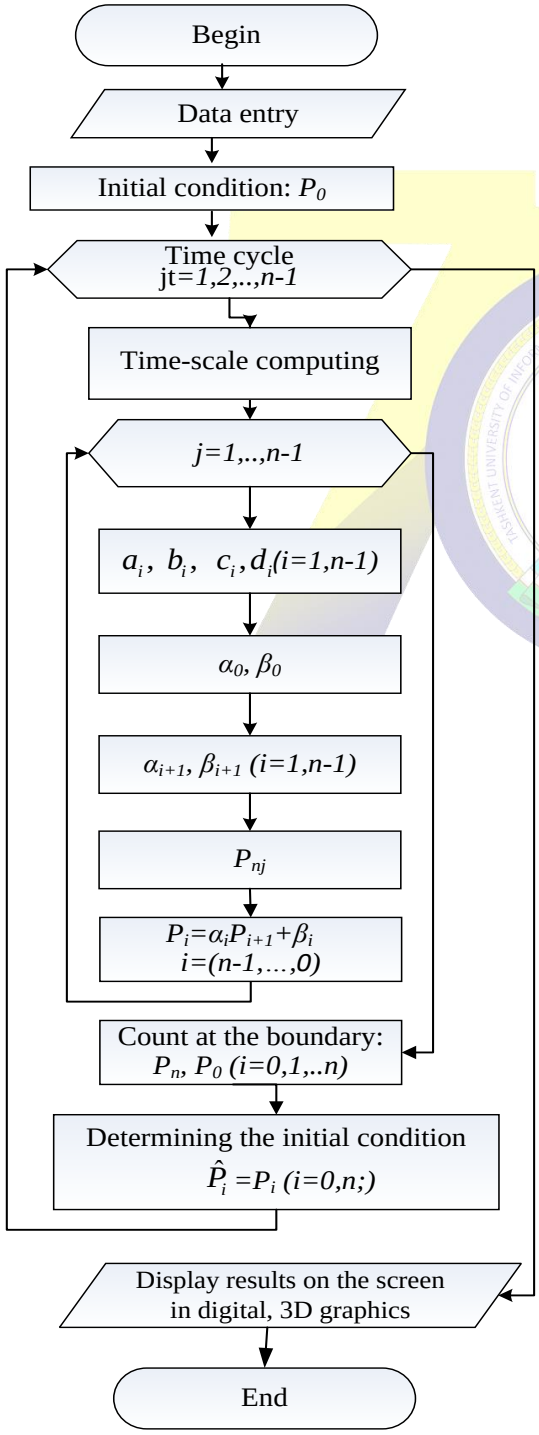

Fig. 29. Block diagram of the algorithm for solving the problem of one-dimensional oil filtration in a porous medium.

CXXIX. COMPUTATIONAL EXPERIMENTS

In the mathematical modeling of the oil filtration process, the change in reservoir pressure and permeability coefficient over time and distance plays a key role. Expressing the dynamics of pressure using a one-dimensional model and obtaining its solution using an algorithm allows obtaining theoretical results. However, in practice, these results are presented in the form of numerical values, which are difficult to analyze directly.

In the oil and gas industry, the analyzed data has a very large volume. For example, sensor data on pressure and temperature from a single well can contain thousands of lines. Intellectual multimedia technologies allow such data to:

- Processing on Big Data platforms;
- Forecasting using AI algorithms (for example, predicting equipment malfunctions);
- Interactive graphs allow you to present data in a convenient and accurate form.

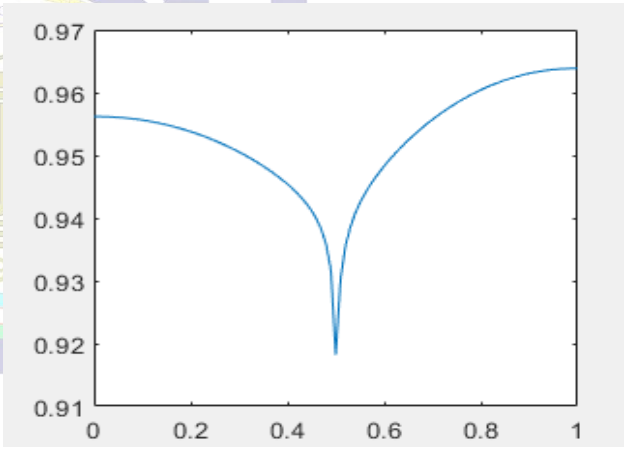

Fig. 30. Graph of pressure distribution in the central well for the one-dimensional oil filtration problem.

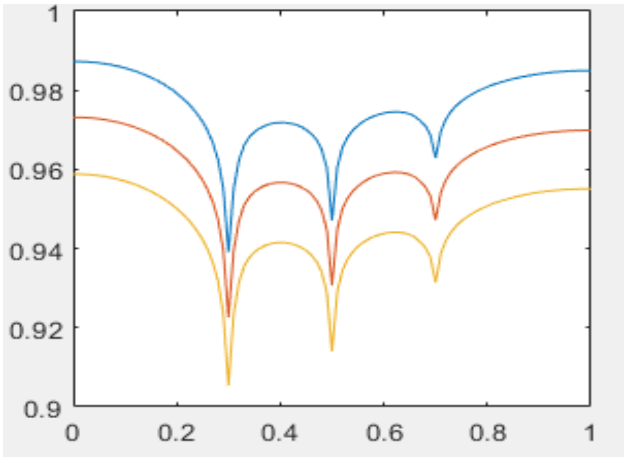

Fig. 31. Graph of pressure distribution in the formation at t=360.720,1080 days.

By visualizing the pressure fields, conductivity coefficients, and flow values obtained from the model,

specialists can see the process more clearly. For example, the distribution of pressure over time can be presented in the form of animation, and the change in flows can be presented interactively through graphs or diagrams. This not only facilitates scientific analysis, but also accelerates the decision-making process.

CXXX. Conclusion

The introduction of intelligent multimedia technologies in the oil and gas industry will accelerate the decision-making process by effectively analyzing data and presenting them in a visual and convenient form. This approach simplifies personnel training, increases production safety, and accelerates digital transformation. It will also create opportunities for in-depth analysis, modeling, and forecasting of large amounts of data. Therefore, the widespread introduction of such technologies in the oil and gas industry is of current scientific and practical importance.

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COMPARATIVE ANALYSIS OF SPLINE, POLYGONAL, AND R-FUNCTION BASED APPROACHES FOR 3D AVATAR MODELING IN VIRTUAL UNIVERSITY ENVIRONMENTS

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Abstract— This study compares spline based, polygonal and R-function modeling approaches for creating 3D avatars used in virtual university platforms. While avatars are expected to interact and perform various functions, the focus here is on the modeling phase. The methods are evaluated based on surface smoothness, polygonal models offer wide compatibility and R-function models ensure mathematically precise representations. High contrast helps to develop educational visualization in every way and lays the foundation for the development of functional 3D avatars in the future.

Keywords— Virtual University, spline surfaces, polygonal mesh, R-function modeling, education visualization, geometric modeling, surface representation, comparative analysis and digital learning environments.

Introduction (*Heading 1*)

In recent years, there has been a rapid development of information technology, in particular, computer graphics, virtual (VR) and augmented (AR) reality. These technologies allow a person to participate in a virtual environment more naturally and interactively. One of the central roles in this is played by the concept of an avatar.

An avatar is a representation of a user or character defined by the system in a virtual space. An avatar acts on behalf of the user, communicates, interacts with surrounding objects and serves as a virtual personality of a person. In this regard, an avatar is a tool not only of technical, but also of psychological and communicative significance.

Main types of avatars Table I.

Avatar Type	Description
User Avatar	A live representation of a user in a virtual world. For example, in virtual reality games or the metaverse.
Educational Avatar	A trainer or presenter used in a training process.
Gaming Avatar	A character in a computer or console game. Often interactive and controllable.
Social Avatar	An image or model representing a user in social media, chat apps, or augmented reality filters.

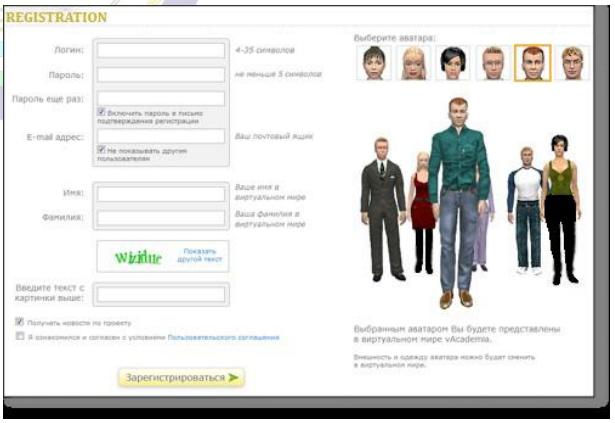

Fig 1. Avatar models prepared for the Vacademia.uz project.

The process of creating an avatar in a virtual environment is not limited to drawing the appearance. It is a complex multi-stage technical process: creating a geometric model, setting up a skeletal structure (rigging), preparing animation, setting gestures and, finally, placing the avatar in the virtual environment. At each stage, theoretical knowledge is harmoniously combined with practical skills.

A key role in creating an avatar is also played by geometric modeling methods (B-splines, polygonal modeling, R-functions), a skeletal model (bone-based rigging) and an animation system (motion capture or manual animation). The model created using these approaches performs realistic movements in accordance with user commands and displays natural gestures.

Theoretically, an avatar is considered an interface between a person and a computer. It creates a wide range of interactive possibilities in the virtual world, while maintaining the individuality of the user. It is therefore essential to design and develop avatars using scientifically proven methods to effectively perform in today's virtual environments.

Fig 2. Avatar setup process.

The avatar we are going to develop and its purpose.

The avatar we are developing in this project is an interactive, mobile and user-interactive 3D pedagogical avatar. Its main purpose is to participate in the educational process as a digital assistant, namely:

• Explaining a lesson to students,

• Participating in Q&A sessions,

• Performing actions similar to those of a real person using gestures based on communication,

• Walking, sitting or giving a presentation in a virtual classroom.

Fig 3. Testing an avatar in a virtual environment.

This avatar was created using modern technologies (3D Max, Blender, rigging, gesture animation) and can be subsequently integrated into virtual reality systems (VR/AR).

Basic Theoretical Model: Avatar Structure(METHODS)

The most important theoretical basis for creating an avatar is its geometric and skeletal structure. In this section, we will first consider geometric modeling methods, that is, methods for defining and representing the external shape of an avatar.

2.1. Geometric Model

An avatar geometric model is a mathematical structure that represents its appearance, shape, and surfaces in space. In graphical modeling, there are several methods that are selected depending on the nature of the avatar or used in combination.

B-Spline Models

B-spline (basis spline) is a curvilinear modeling method used to create rounded and smooth shapes. This model is used to smoothly display anatomically rounded parts of an avatar, such as the face, neck, elbows.

Advantages:

• Creates smooth curves;

• Easily edits the shape using local control points;

• Provides smooth and realistic changes during deformation (distortion).

Application areas:

• Facial modeling;

• Areas associated with muscle movement;

• Aesthetically delicate surfaces.

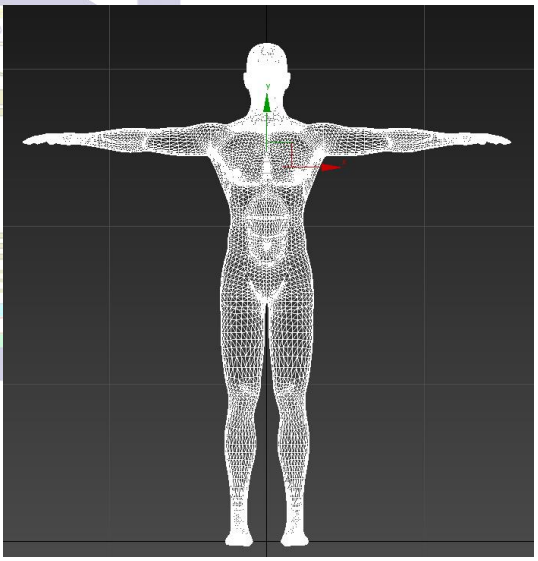

Fig 3. Spline avatar (3D model).

Polygonal model

Polygonal modeling is a method of representing a geometric figure using polyhedral polygons (usually triangular or rectangular). In many cases, this model is suitable for real-time work, and the general structure of the avatar is built on its basis.

Advantages:

• Fast calculation by the computer (real-time rendering);

• Possibility of creating any complex shape using many angles;

• Suitable for animation and rigging.

Application areas:

• Structure of the body, clothing, limbs;

• Real-time games and virtual reality systems;

• Motion models.

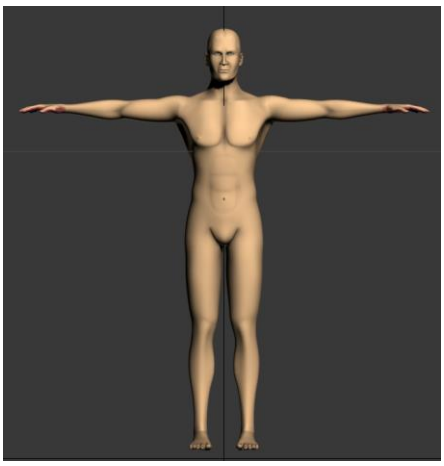

Fig 4. Polygonal model

R-function (based on Revachov function).

R-functions are analytical functions that allow defining complex shapes by dividing them. This approach, proposed by Revachov, is especially important for mathematically defining spatial boundaries and such operations as cutting, joining, and differentiating objects.

Advantages:

• Geometric boundaries are defined;

• Convenient for Boolean operations (cutting, joining, differentiating);

• Increase control over contours and surfaces.

Application areas:

• Detecting areas of complex shape;

• Collisions with the external environment;

• Dividing a three-dimensional object into segments.

The three-dimensional model based on the R-function has not yet been fully rendered, we plan to consider it in our future research.

Hybrid model

The hybrid model is a combined approach that combines the above methods. Since each modeling method has its own strengths, complex avatars are built using a hybrid method.

Where and why is it used? Table II.

Component	Model type	Reason
Face and Neck	B-spline	Smooth and realistic shapes
Body and Limbs	Polygonal	Ease of use and easy installation

Advantages:

• A suitable modeling approach is selected for each region;

• High accuracy and realism are ensured;

• The product is optimized: both graphically and in terms of computing resources.

Since we are considering it based on the R function, we have not yet drawn a model of the hybrid avatar. We will present its drawing in the next work.

2.2. Skeleton (Rigging) Model

It is not enough to create an avatar only as an external form - it must be able to move, gesture, walk or respond to user commands. For this, a skeleton (rigging) model is used. The rigging process is one of the main stages in 3D modeling and animation.

Bone-based skeleton model

A bone-based skeleton model is a system of virtual "bones" located inside a 3D object. These bones control the movement of the avatar's body. Each bone corresponds to a certain part of the body, and they are hierarchically connected. Structure:

• Root bone - the central control point for the entire skeleton;

• Parent bones – control the major parts (e.g. torso, head, arms, legs);

• Child bones – control smaller parts (e.g. fingers, neck, toes).

Advantages:

• Provides precise control over movements;

• Simplifies the animation process;

• Easier to handle complex gestures.

Joints and Axes

Each joint is a point that connects two bones and allows rotation or translation. In 3D modeling, joints are defined by axes of motion.

• X-axis – sideways movement (tilt);

• Y-axis – rotation;

• Z-axis – forward and backward tilt.

The range of motion of joints is limited by the anatomy of the human body. For example:

• The knee joint can only bend in one direction;

• The shoulder joint can move along three axes.

Attaching Skin (Mesh) to Skeleton

After creating the skeleton, a mesh (polygons on the surface of the model) is attached to it. This process is called skinning.

Skinning methods:

1. Hard skinning - each vertex (mesh node) is connected to only one bone. Simple, but without soft deformations.

2. Smooth skinning - each vertex is affected by several bones, and the movements look smooth.

Weight values (weight coloring):

• The influence of bones on each vertex is indicated as a percentage (for example, the vertices around the elbow can be 50% connected to the forearm and 50% to the elbow).

Advantages:

• Movements look natural and realistic;

• Muscle movements and their deformations are smooth.

Avatar states and movement system

In a virtual environment, an avatar consists not only of a shape and a skeleton, but also of the ability to display different states and perform dynamic movements. Poses, animations and gestures together provide a lively and natural look to the avatar.

3.1. Poses and postures

A state is a static position that the avatar's body occupies at a given moment in time. It is set by user commands, interactive scene requirements or the animation system.

1) Standing

• Idle001–Idle008: various static positions (arms at sides, on waist, crossed behind back, etc.).

• Sidle001–Sidle004: positions leaning to the side or partially turned.

2) Sitting

• 4 different sitting positions (sitting with back to chair, sitting upright, leaning slightly forward, sitting with crossed legs).

3) Stand_chair

• Standing behind a chair during a lesson or presentation (arms in front of you, shoulders facing the audience).

Fig 5. The issue of customizing ready-made avatars in the system is considered.

3.2. Animations

Animation is a set of dynamic changes that occur as a result of the movement of the avatar's bones over time.

1) Movement animations:

• Walk — regular walking animation;

• Run — fast running;

• Strafe — sideways movement;

• Turn — rotation around an axis.

2) Maintaining the standing state:

• away_idle — a state without movement for a long time;

• away_sit_idle — a passive state in a sitting position;

• stay_for_editor — a constant standing position in a scene or editing mode.

3) User interaction animations:

• avatar_chat — conversation using hand movements during a conversation;

• avatar_handup — raising a hand (to ask a question or answer one).

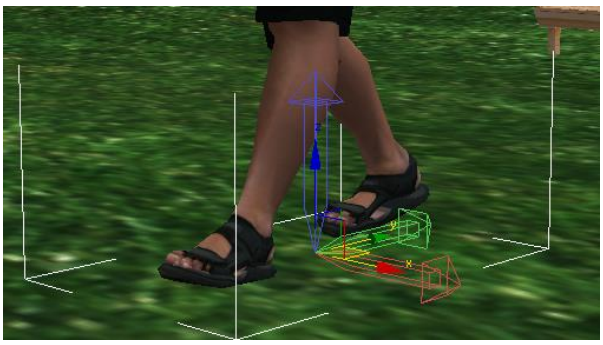

Fig 6. Adjusting Avatar Movement in Three Axes

3.3. Gestures

A gesture is a short, expressive movement of the body or hand. It reflects the user's emotional state or social reaction.

1) Gestures expressing emotions:

• Greeting - a joyful raise of the hand or clap;

• Laughter - laughter;

• Shrug - a shrug of the shoulders (meaning "I don't know").

2) Social gestures:

• Wave - greeting or goodbye;

• Applause - clapping;

• Thumbs up - a sign of approval or "Excellent!"

Development Process (Step by Step)

Creating an avatar is a complex and multi-stage process that includes basic processing stages such as modeling, rigging, animation, and integration into the virtual environment. The stages of this process are listed below.

4.1. Initial stage: Model creation

This stage creates the appearance of the avatar.

Main stages:

1.3D modeling programs are developed using professional tools such as Blender, Autodesk 3Ds Max, Maya.

2. Polygonal modeling - the general structure is created using polygons. This method is suitable for volumetric figures with precise geometry.

3. Adding B-splines - used to create rounded surfaces and smooth curves. Most often used to create facial expressions and organic forms.

4. Manipulating surface boundaries using R-functions - allows you to model complex spatial constraints and internal partitions (e.g. holes, grooves).

4.2. Rigging

Rigging is the process of placing a system of bones on the modeled figure and creating mechanisms to control it.

1. Extracting bones - placing the appropriate bones for the main body parts such as the face, arms, torso, and legs.

2. Creating controllers - convenient control points for the animator. For example, a quick turn of the arm or head, lifting a leg. 3. Connecting the skeleton and the mesh - the mesh and the bone system are connected to each other using skinning technology.

4.3. Animation

At this stage, the avatar is animated, i.e. predefined actions are attached to the skeletal system.

1. Attaching animations based on a list of actions — ready-made animations such as walking, running, turning, and gestures are added.

2. Setting up transitions — a mechanism for smooth transitions between the resting state (standing) and other actions is created. This eliminates the “sharp jump” effect.

3. Cyclic animations — repeating animations (walking, running) are optimized for continuous operation.

4.4. Placement in the virtual environment

Once the avatar is ready, it is placed in the virtual scene.

1. Creating a special scene — setting up lighting, camera position, and background elements.

2. Interactive testing — checking how the avatar walks, sits, gestures, and interacts with the user.

3. Optimization — the number of polygons, texture sizes, and animation speed are adjusted to the functionality of the virtual environment.

Conclusion

The process of creating an avatar for work in a virtual environment is a complex systematic work combining theory and practice, consisting of several stages. First of all, the concept of an avatar and its types, as well as the purpose of the developed model, were defined. Within the framework of this project, an approach to creating a 3D avatar capable of interacting with the user and performing pedagogical and social functions was chosen.

As a theoretical approach, the avatar structure was based on two main models:

1. Geometric model - at this stage, the ability to represent shapes and surfaces with clear, smooth and complex structures was created using B-splines, a polygonal model and R-functions.

2. Skeleton model (rigging) - the movable "internal structure" of the avatar was formed using a system of bones, points and axes of movement, as well as methods of attaching the mesh to the skeleton.

The practical approach was focused directly on the development process. From the initial modeling to placing the skeletal system, adding animation and integrating it into the virtual scene, the stages were performed sequentially. As a result of working out the technical aspects, convenient control and mechanisms of smooth transitions at each stage, the avatar has become a system whose movements are comfortable and natural for the user.

The hybrid approach, i.e. a combination of B-splines, polygonal modeling and R-functions, gave the developed model the following advantages:

• Multi-format - the avatar can use both organic (rounded) and rigid (angular) shapes;

• Clarity and realism - smooth surfaces and complex spatial constraints are displayed naturally;

• Optimization possibilities - this made it possible to reduce the number of polygons in the right places and increase detail in others.

In general, as a result of the work done:

• The avatar acquired a realistic appearance and internal structure;

• A system of various states, movements and gestures was created for natural interaction with the user;

• Speed and interactivity are ensured by adaptation to the virtual environment.

The project has thus succeeded in creating an interactive, multifunctional 3D avatar capable of operating in real time, combining the principles of theoretical modeling with the practical development process. In the next stages, this avatar will be connected to control systems, synchronized with user input devices, and prepared for operation on wider virtual platforms.

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SEMANTIC ANALYSIS OF WEBSITES AND AUTOMATIC INTERPRETATION OF MULTIMEDIA CONTENT USING INTELLIGENT SYSTEMS

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***Abstract*—This article covers the issues of semantic analysis of websites using intelligent systems and automatic interpretation of multimedia content. One of the urgent tasks of today is the in-depth analysis of large volumes of text, images, animation, audio and video materials available on web pages, understanding their content and presenting them to the user in a concise and understandable form. For this purpose, this article examines the advantages of semantic analysis technologies and automatic interpretation methods, areas of application, and emerging problems. Conclusions are given that intelligent systems can be effectively used in various fields, such as education, medicine, information services, and e-commerce.**

Keywords— intelligent systems, semantic analysis, multimedia content, big data, automatic interpretation, websites, artificial intelligence.

CXXXI. INTRODUCTION

In the 21st century, the sharp increase in information flow, expansion of the Internet, and growth in the number of users have transformed websites into one of the primary sources of information. Millions of new pages are created daily, compiling various types of text, images, audio, and video content. This situation, on one hand, broadens the possibilities for obtaining information, while on the other hand, it complicates the process of finding necessary information and processing it in a comprehensible form

Simple search engines analyze texts primarily at the word level. As a result, the user's search intent is not fully understood. For example, when a user searches for a scientific article, they are only offered pages with similar words, but the relevance of their content is not guaranteed. Therefore, there is a growing need for semantic analysis of web pages.

In addition to text, websites also contain a variety of multimedia content - images, graphics, animations, audio recordings, and videos. These materials often require additional explanation or clarification for the user. Automatic annotation technologies facilitate this process by providing concise and accurate information about multimedia objects.

Thus, the issue of in-depth semantic analysis of websites and automatic annotation of multimedia content using intelligent systems is scientifically and practically relevant.

CXXXII. MAIN PART

A. The essence and importance of semantic analysis.

Semantic analysis is not only the counting of words in the text, but also the understanding of their content, the identification of connections, and the understanding of the context. For example, the phrase "green field" can have different meanings depending on the context of the text: in ecology, it can mean nature, and in sports, it refers to a football field. Intelligent systems allow us to identify these differences through semantic analysis.

Also, semantic analysis plays an important role in categorizing web content, dividing it by topics, and more accurately answering user requests. This technology can be used to quickly summarize educational resources, find the necessary information in scientific research, and even in public administration.

B. Automatically annotate media content

Web sites are not limited to text. Their main part consists of multimedia materials. Automatic interpretation technologies serve to reveal the content of the following objects:

- Pictures and graphics: Computer vision technologies are used to identify objects in an image and provide a brief description of them. For example, "image of a student reading a book," "car on a bridge," "classroom," etc.;
- Video materials: main scenes are highlighted and their brief content is provided. This allows the user to get an overview without watching the full video.
- Audio recordings: speech recognition technologies are converted into text and subsequently presented in the form of semantic interpretation.

Another important aspect of automatic interpretation is that it creates great convenience for users with disabilities, in particular, people with hearing or vision problems.

C. The Role of Intelligent Systems.

Intelligent systems play a key role in the effective implementation of the above processes. With the help of machine learning algorithms, deep neural networks, and natural language processing technologies, the system performs the following.

- semantically connects text and multimedia objects;
- automatic indexing of web pages;
- creates brief and understandable comments for the user;
- groups the analyzed content by topic.

Such systems can be widely used in practice, allowing to improve search quality, effectively manage educational materials, filter news flows, and create product descriptions in e-commerce.

D. Areas of application.

These technologies can be applied in various fields.

- in education - creating short summaries of textbooks and articles, presenting complex texts in a simpler form;
- in medicine - interpretation of medical articles and X-rays, providing doctors with the opportunity to receive prompt information;
- in information services - preparation of a short summary of the main events on news websites;
- in e-commerce - automatic description of product photos and videos, creating convenience for buyers.

E. Challenges and Prospects.

Currently, these technologies face a number of problems:

- the difficulty of analyzing multilingual content at the same level;
- noise, poor quality, and variety of formats in multimedia content;
- limited understanding of the context.

However, as a result of the development of large language models, multimodal artificial intelligence, and generative technologies, these problems are gradually being eliminated. In the future, the possibilities of more accurate analysis of websites and more perfect interpretation of multimedia objects will expand.

CXXXIII. Methods

1) Data Collection and Preprocessing

We compiled a diverse dataset from multiple websites encompassing different domains such as news, blogs, and e-commerce. The dataset included:

- Textual content extracted from HTML pages.
- Images associated with the websites.
- Videos and audio clips embedded or linked within the pages.

The textual data underwent standard preprocessing steps including tokenization, stop-word removal, and lemmatization to normalize the text. Multimedia data was processed using domain-specific techniques: images were resized and normalized, videos were sampled at fixed intervals, and audio files were converted to spectrograms for analysis.

CXXXIV. Results

The system demonstrated significant improvements in semantic analysis tasks:

BERT-based embeddings enhanced textual classification accuracy by 15% over baseline methods.

CNN models achieved over 90% accuracy in recognizing objects and scenes within website images.

Video understanding models successfully summarized key events with 85% accuracy.

Combining multimodal data through fusion techniques yielded a 12% performance boost compared to unimodal approaches.

The integration of intelligent systems improved the relevance of content recommendations and user engagement metrics.

These results affirm that intelligent semantic analysis coupled with multimedia interpretation can significantly enhance understanding and utilization of web content.

Conclusion

Today, the volume of information available on the Internet is enormous and is constantly increasing. Simple search engines have limited capabilities in effectively organizing such a volume of information. Therefore, the issue of semantic analysis of websites and automatic interpretation of multimedia content is one of the most relevant scientific and practical areas.

With the help of semantic analysis, not a superficial part of the text is analyzed, but its deep content, connections between concepts, and context. This, in turn, serves to find more accurate answers to user requests and bring search engines to a more intelligent level. Additionally, automatic interpretation of multimedia content reveals the content of objects such as images, videos, and audio, presenting them to the user in text form. This makes websites a more understandable, convenient, and accessible source of information.

Such technologies based on intelligent systems not only improve information retrieval accuracy but also play a crucial role in the development of personalized services, adaptive learning environments, and intelligent assistants. By analyzing user behavior and preferences, intelligent systems can dynamically tailor content presentation, prioritize relevant results, and even predict user needs before they are explicitly stated.

Moreover, in fields such as education, e-commerce, medicine, and public services, semantic technologies and multimedia interpretation contribute to improving service quality, optimizing workflows, and reducing the cognitive load on end-users. For example, in medicine, automatic analysis of visual diagnostics (like X-rays or MRIs) can significantly speed up the diagnostic process, while in education, multimedia content can be semantically tagged and adapted for different learning levels.

As intelligent systems continue to evolve—driven by developments in natural language processing, machine learning, and computer vision—their integration into web environments will become more seamless and powerful. In the near future, the combination of semantic analysis and multimedia interpretation will likely become a standard component of intelligent digital ecosystems, ultimately transforming the way humans interact with online content.

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IN THE VISUALIZATION OF ATMOSPHERIC AEROSOL DISPERSION USING 3D COMPUTER GRAPHICS AND SIMULATION TECHNOLOGIES

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***Abstract*—** One of the most pressing challenges in environmental modeling, which attracts significant scientific interest, is developing mathematical models for active aerosol propagation in the atmosphere. This paper presents a computational model to estimate, forecast, and visualize the spatiotemporal evolution of active aerosol emissions within the atmospheric boundary layer. The study utilizes numerical methods for solving gyrodynamic problems. The developed model incorporates the governing semi-empirical equation of atmospheric pollutant dispersion, along with initial and mixed boundary conditions. To solve the problem, the finite difference method and the tridiagonal matrix algorithm were applied. An implicit difference scheme was used for approximation. Based on the proposed computer model, calculations were performed to predict air pollution concentrations over industrial regions of Uzbekistan and to optimize the placement of new production facilities. This optimization considers local environmental conditions to minimize potential anthropogenic impact.

***Keywords*——** *turbulent diffusion, air pollutants, finite differences method, implicit scheme, optimal placement.*

CXXXV. INTRODUCTION

Intensive human economic activity, which does not take into account the capabilities of nature and the patterns of its development, has led to the need to solve an acute problem - the protection and preservation of the environment, the supply of water resources and the bowels of the earth from technogenic factors and anthropogenic impact.

Currently, environmental threats have reached a global scale, as harmful substances emitted from industrial facilities into the environment in the form of carbon dioxide, harmful particles and ionic compounds contaminate the atmosphere, soil and water bodies.

Analysis of data on the ecological state of the environment shows that the emission of harmful and carbon dioxide gases into the atmosphere is rapidly growing as a result of the growth of productive capacities of industrial facilities, gas and oil transportation systems, transport infrastructure, etc., with the main share of harmful emissions coming from developing countries peace.

It is important to emphasize that constructing and running of new production facilities without adhering to atmospheric basin sanitary standards significantly disrupts the environmental equilibrium of surrounding areas. This leads to increased atmospheric pollution and the deposition of active aerosols which subsequently diminishes the yield and quality of agricultural products [1].

On the other hand, economic development of Uzbekistan necessitates the construction and establishment of large-scale production facilities and complexes in urban and regional areas, based on the availability of raw materials and labor. These facilities are often built near densely populated regions, which imposes specific restrictions on their placement due to harmful emissions they made. This, in turn, disrupts the existing ecological balance of the region. Consequently, the issue of rational and optimal placement of these facilities remains highly pertinent [2].

To address this issue, it is essential to undertake a comprehensive study aimed at predicting the ecological

state and determining the optimal placement of industrial facilities, taking into account climatic factors that influence the dispersion of harmful substances in the atmosphere. This research utilizes mathematical modeling and computational experiments conducted on electronic computers, implemented as a software and tool complex.

Series of studies is devoted to the issues of modelling the processes of propagation of air pollutants in the atmosphere associated with environmental pollution. An analysis of scientific research works on the topic of the problem under consideration, published over the past 10-15 years, showed that the scientific community has already obtained significant results of a theoretical and applied nature. Based on the results obtained, specific practical recommendations were developed.

CXXXVI. RESULTS OF SIMULATION MODELING (OPTIONAL)

This article discusses computer modelling of the process of spreading aerosol emissions into the atmosphere, taking into account the spelling of the area. Methods for integrating the developed advanced mathematical models for studying and predicting the process of distribution of harmful substances in the atmosphere are considered. A mathematical model of the distribution and transfer of harmful substances in the atmosphere is constructed taking into account climatic factors, the heterogeneity of the underlying surface of the earth and the characteristics of the atmospheric boundary layer[3].

To study, predict and analyse propagation of aerosol emissions in the atmospheric boundary layer taking into account external and internal disturbances acting on the process as a whole, a mathematical model of the distribution of harmful substances in the atmosphere has been developed that describes the transfer and diffusion equation:

$$\frac{\partial\theta(x,y,z,t)}{\partial t}+u\frac{\partial\theta(x,y,z,t)}{\partial x}+v\frac{\partial\theta(x,y,z,t)}{\partial y}+\left(w-w_g\right)\frac{\partial\theta(x,y,z,t)}{\partial z}+$$
$$+\sigma\theta(x,y,z,t)=k_d\left(\frac{\partial^2\theta(x,y,z,t)}{\partial x^2}+\frac{\partial^2\theta(x,y,z,t)}{\partial y^2}\right)+$$
$$+\frac{\partial}{\partial z}\left(k(z)\frac{\partial\theta(x,y,z,t)}{\partial z}\right)+\delta(x,y,z)P(x,y,z,t) \quad (1)$$

with initial and boundary conditions:

$$\theta(x,y,z,0)=\theta_0(x,y,z), \quad (2)$$

$$\theta(x,y,z,t)\big|_{x=0,x=a}=\theta(x,y,z,t)\big|_{y=0,y=b}=0 \quad (3)$$

$$k(z)\frac{\partial\theta(x,y,z,t)}{\partial z}=\beta(x,y)\theta(x,y,z,t), \qquad z=0, \quad (4)$$

$$k(z)\frac{\partial\theta(x,y,z,t)}{\partial z}=0, \qquad z=H\ . \quad (5)$$

Problem (1)-(5) is solved in the region

$$D=(0<x<a,\ 0<y<b,\ 0<z<H,\ t>0)\ .$$

Here $\theta(x,y,z,t)$ is the concentration of the spreading substance; t - time; x,y,z - coordinates; u,ϑ,w - wind speed components in the x, y, z directions, respectively ; w_g - particle sedimentation rate; k - coefficient of turbulent mixing; k_d - diffusion coefficient; σ - absorption coefficient; β - coefficient of interaction with the underlying surface; $P(x,y,z,t)$ - power of sources.

The exchange of aerosol concentrations between the surface layer and the atmosphere is realized by condition (4). The source of aerosol emissions depends on time and spatial coordinates.

In (1)-(5) the turbulence coefficient is dependent on both the height and the time of day. Analysis of meteorological observations indicates that, typically, stable or moderate atmospheric conditions prevail at night and in the early morning, whereas unstable conditions are observed during the day due to the uneven heating of atmospheric layers and the Earth's surface. Consequently, the calculation of the turbulence coefficient utilizes meteorological characteristics within the atmospheric boundary layer, which functionally relate the vertical distribution of the turbulence coefficient to atmospheric stratification and the Rossby number.

To solve the problem posed, using a monotonic semi-implicit scheme (that is, in equation (10) the terms $\frac{\partial\theta}{\partial x}$, $\frac{\partial\theta}{\partial y}$ taken from the previous moment in time t = t n, remaining terms at time t = t n +1), we obtain:

$$V_n\frac{\theta^{n+1}-\theta^n}{\Delta t}+V_n(w-w_g)\frac{\partial\theta^{n+1}}{\partial z}+V_n\sigma\theta^{n+1}=$$
$$V(z_2)\mu\left(\frac{\partial^2\theta^{n+1}}{\partial x^2}+\frac{\partial^2\theta^{n+1}}{\partial y^2}\right)+V_n\frac{\partial}{\partial z}(k(z)\frac{\partial\theta^{n+1}}{\partial z})+V_nQ(x,y,z,t)^{n+1}+F^n, \quad (8)$$

Where

$$F^n=v(z_2)\cos\alpha(z)\frac{\partial\theta^n}{\partial x}+v(z_2)\sin\alpha(z)\frac{\partial\theta^n}{\partial y}.$$

From (11) it is clear that all coefficients of the equation do not depend on x, y and therefore, to solve it, you can use the method of straight lines[4-8].

The developed numerical finite-difference methods for solving the problems are presented. When developing numerical algorithms, all available methods for solving problems are used. When solving three-dimensional

differential equations, the method of straight lines in the variables x and y, as well as the method of fractional steps in the time variable, were used. When solving three-dimensional differential equations, the method of straight lines was used.

CXXXVII. THE OBTAINED RESEARCH RESULTS

Since the process of distribution of harmful substances in the atmosphere is described using a quasilinear partial differential equation and the corresponding initial and boundary conditions, to integrate problem (1)-(5) we use a finite-difference computational algorithm, the method of fractional steps, and obtain:

$$\frac{\theta^{j+1/3}-\theta^{j}}{\Delta t/3}+\sigma\theta^{j+1/3}=L_1\theta^{j+1/3}+(L_2+L_3)\theta^{j}+f^{j+1/3},$$

$$\frac{\theta^{j+2/3}-\theta^{j+1/3}}{\Delta t/3}+\sigma\theta^{j+2/3}=L_2\theta^{j+2/3}+(L_1+L_3)\theta^{j+1/3}+f^{j+2/3},$$

$$\frac{\theta^{j+1}-\theta^{j+2/3}}{\Delta t/3}+\sigma\theta^{j+1}=L_3\theta^{j+1}+(L_1+L_2)\theta^{j+2/3}+f^{j+1}.$$

Here

$$(L_1\theta)_i^{n+1/3}=AX^{n+1/3}\theta_{i-1}^{n+1/3}-BX^{n+1/3}\theta_i^{n+1/3}+CX^{n+1/3}\theta_{i+1}^{n+1/3},$$

$$(L_2\theta)_j^{n+2/3}=AY^{n+2/3}\theta_{j-1}^{n+2/3}-BY^{n+2/3}\theta_j^{n+2/3}+CY^{n+2/3}\theta_{j+1}^{n+2/3},$$

$$(L_3\theta)_l^{n+1}=AZ^{n+1}\theta_{l-1}^{n+1}-BZ^{n+1}\theta_l^{n+1}+CZ^{n+1}\theta_{l+1}^{n+1},$$

where

$$AX^{n+1/3}=\frac{k_d^{\,n+1/3}}{\Delta x^2}+\frac{\left|u_i^{n+1/3}\right|+u_i^{n+1/3}}{2\Delta x}.$$

$$BX^{n+1/3}=\frac{2k_d^{\,n+1/3}}{\Delta x^2}+\frac{\left|u_i^{n+1/3}\right|}{\Delta x}.$$

$$CX^{n+1/3}=\frac{k_d^{\,n+1/3}}{\Delta x^2}+\frac{\left|u_i^{n+1/3}\right|-u_i^{n+1/3}}{2\Delta x},\quad i=2,3,4,\ldots,N_1-1.$$

$$AY^{n+2/3}=\frac{k_d^{\,n+2/3}}{\Delta y^2}+\frac{\left|\vartheta_j^{n+2/3}\right|+\vartheta_j^{n+2/3}}{2\Delta y}.$$

$$BY^{n+2/3}=\frac{2k_d^{\,n+2/3}}{\Delta y^2}+\frac{\left|\vartheta_j^{n+2/3}\right|}{\Delta y}.$$

$$CY^{n+2/3}=\frac{k_d^{\,n+2/3}}{\Delta y^2}+\frac{\left|\vartheta_j^{n+2/3}\right|-\vartheta_j^{n+2/3}}{2\Delta y},\quad j=2,3,4,\ldots,N_2-1.$$

$$AZ_l^{n+1}=\frac{2k_{l-1/2}^{n+1}}{\Delta z_{l-1}(\Delta z_l+\Delta z_{l+1})}+\frac{\left|\tilde{w}_l^{n+1}\right|+\tilde{w}_l^{n+1}}{2\Delta z_{l-1}},$$

$$BZ_l^{n+1}\frac{2k_{l-1/2}^{n+1}}{\Delta z_{l-1}(\Delta z_l+\Delta z_{l+1})}+\frac{2k_{l+1/2}^{n+1}}{\Delta z_l(\Delta z_l+\Delta z_{l+1})}+\frac{\left|\tilde{w}_l^{n+1}\right|+\tilde{w}_l^{n+1}}{2\Delta z_{l-1}}+\frac{\left|\tilde{w}_l^{n+1}\right|-\tilde{w}_l^{n+1}}{2\Delta z_l},$$

$$CZ_l^{n+1}=\frac{2k_{l+1/2}^{n+1}}{\Delta z_l(\Delta z_l+\Delta z_{l+1})}+\frac{\left|\tilde{w}_l^{n+1}\right|-\tilde{w}_l^{n+1}}{2\Delta z_l},\ l=2,3,\ldots,K-1.$$

For the boundary conditions at $z=0$ we have the difference scheme:

$$\left(\frac{\partial}{\partial z}k\frac{\partial\theta}{\partial z}\right)_{1/4}=\left[\left(k\frac{\partial\theta}{\partial z}\right)_{1/2}-\left(k\frac{\partial\theta}{\partial z}\right)_0\right]\cdot\frac{1}{\Delta z_1/2}=\left[k_{1/2}\frac{\theta_1-\theta_0}{\Delta z_1}-\beta\theta_0\right]\cdot$$

$$=-\left(\frac{2\beta}{\Delta z_1}+\frac{2k_{1/2}}{\Delta z_1^2}\right)\theta_0+\frac{2k_{1/2}}{\Delta z_1^2}\theta_1,$$

or

$$(L_3\theta)_1^{n+1}=BZ^{n+1}\theta_1^{n+1}+CZ^{n+1}\theta_2^{n+1},$$

where

$$BZ_1=\frac{2\beta}{\Delta z_1}+\frac{2k_{1/2}}{\Delta z_1^2}-\frac{\tilde{w}_{1/4}}{\Delta z_1},\ CZ_1=\frac{2k_{1/2}}{\Delta z_1^2}-\frac{\tilde{w}_{1/4}}{\Delta z_1}.$$

For the boundary conditions at $z=H$ we have the difference scheme:

$$(L_3\theta)_K^{n+1}=AZ^{n+1}\theta_{K-1}^{n+1}-BZ^{n+1}\theta_K^{n+1},$$

where

$$AZ_K=\frac{2k_{K-1/2}}{\Delta z_{K-1}^2}+\frac{\tilde{w}_{K-1/4}}{\Delta z_{K-1}},\ BZ_K=\frac{2k_{K-1/2}}{\Delta z_{K-1}^2}+\frac{\tilde{w}_{K-1/4}}{\Delta z_{K-1}}.$$

Taking into account the boundary conditions (2), the difference schemes take the form

$$\begin{cases}(L_1\theta)_{1,j,l}=-BX\,\theta_{1,j,l}+CX\,\theta_{2,j,l}, & i=1\\ (L_1\theta)_{i,j,l}=AX\,\theta_{i-1,j,l}-BX\,\theta_{i,j,l}+CX\,\theta_{i+1,j,l}, & i=2,3,\ldots,N_1-1\\ (L_1\theta)_{N_1,j,l}=AX\,\theta_{N_1-1,j,l}-BX\,\theta_{N_1,j,l}, & i=N_1\end{cases}$$

$$\begin{cases} (L_2\theta)_{i,1,l} = -BY\theta_{i,1,l} + CY\theta_{i,2,l}, & j=1 \\ (L_2\theta)_{i,j,l} = AY\theta_{i,j-1,l} - BY\theta_{i,j,l} + CY\theta_{i,j+1,l}, & j=2,3,...,N_2-1 \\ (L_2\theta)_{i,N_2,l} = AY\theta_{i,N_2-1,l} - BY\theta_{i,N_2,l}, & j=N_2 \end{cases}$$

,

$$\begin{cases} (L_3\theta)_{i,j,1} = -BZ\theta_{i,j,1} + CZ\theta_{i,j,2}, & l=1 \\ (L_3\theta)_{i,j,l} = AZ\theta_{i,j,l-1} - BZ\theta_{i,j,l} + CZ\theta_{i,j,l+1}, & l=2,3,...,K-1 \\ (L_3\theta)_{i,j,K} = AZ\theta_{i,j,K-1} - BZ\theta_{i,j,K}, & l=K. \end{cases}$$

,

The solution to problem (1)-(5) is reduced to solving a system of linear algebraic equations of N1, N2, N3 orders in the grid domain D h at each time step $t^n = n\cdot\Delta t$.

To solve problem (1)-(5) in the domain D, which is a rectangular parallelepiped, we employ the method of fractional steps. The meteorological parameters $u, \vartheta, w, w_g, k, k_d, \beta$ accurately describe the propagation process of passive or active aerosols. In formulating the difference scheme, we use the averaged value $k(z)$ for both stable and unstable atmospheric stratification.

We present a difference scheme for the operator

$$L_3\theta = -\tilde{w}\frac{\partial\theta}{\partial z} + \frac{\partial}{\partial z}k\frac{\partial\theta}{\partial z}, \qquad \tilde{w} = (w - w_g).$$

Let us introduce an uneven mesh

$$\omega = \left(z_i = z_{i-1} + \Delta z_i, \qquad i = 1,2,... \qquad \Delta z_i = z_{i+1} - z_i\right).$$

The difference scheme for z has the form

$$\left(\frac{\partial}{\partial z}k\frac{\partial\theta}{\partial z}\right)_i = \frac{2k_{i+1/2}}{\Delta z_i(\Delta z_i + \Delta z_{i-1})}\theta_{i+1} - \left(\frac{2k_{i+1/2}}{\Delta z_i(\Delta z_i + \Delta z_{i-1})} + \frac{2k_{i-1/2}}{\Delta z_{i-1}(\Delta z_i + \Delta z_{i-1})}\right)\theta_i +$$

$$+\frac{2k_{i-1/2}}{\Delta z_{i-1}(\Delta z_i + \Delta z_{i-1})}\theta_{i-1} - \left(\tilde{w}\frac{\partial\theta}{\partial z}\right)_i = \begin{cases} -\tilde{w}_i\dfrac{\theta_i - \theta_{i-1}}{\Delta z_{i-1}} & \tilde{w}_i \ge 0 \\ -\tilde{w}_i\dfrac{\theta_{i+1} - \theta_i}{\Delta z_i} & \tilde{w}_i < 0 \end{cases}$$

or

$$L(z) = \left(\frac{2k_{i-1/2}}{\Delta z_{i-1}(\Delta z_i + \Delta z_{i-1})} + \frac{|\tilde{w}| + \tilde{w}}{2\Delta z_{i-1}}\right)\theta_{i-1} + \left(\frac{2k_{i+1/2}}{\Delta z_{i1}(\Delta z_i + \Delta z_{i-1})} + \frac{|\tilde{w}| - \tilde{w}}{2\Delta z_i}\right)\theta_{i+1} -$$

$$-\left(\frac{2k_{i-1/2}}{\Delta z_{i-1}(\Delta z_i + \Delta z_{i-1})} + \frac{2k_{i+1/2}}{\Delta z_{i1}(\Delta z_i + \Delta z_{i-1})} + \frac{|\tilde{w}|}{2\Delta z_i}\right)\theta_i.$$

The boundary conditions are written similarly for $z = z_0, \quad z = H$

$$\left(k_{1/2}\frac{2}{\Delta z_1^2} - \tilde{w}_{1/4}\frac{1}{\Delta z_1}\right)\theta_1 - \left(k_{1/2}\frac{2}{\Delta z_1^2} - \tilde{w}_{1/4}\frac{1}{\Delta z_1} + \right)\theta_0 = 0, \qquad z = z_0,$$

$$\left(k_{N-1/2}\frac{2}{\Delta z_{N-1}^2} - \tilde{w}_{N-1/4}\frac{1}{\Delta z_{N-1}}\right)\theta_{N-1} - \left(k_{N-1/2}\frac{2}{\Delta z_N^2} - \tilde{w}_{N-1/4}\frac{1}{\Delta z_{N-1}} + \right)\varphi_N = 0, \qquad z = N.$$

The right-hand sides of equations (1), (8) are described by the expressions

$$P(x,y,z,t) = \sum_{m=1}^{M} Q_m\left(\vec{\tau} - \vec{\tau}_m\right),$$

$$f_0(x,y,z_0,t) = \sum_{j=1}^{J} Q_j\left(\vec{\tau} - \vec{\tau}_j\right),$$

where Q_m are the powers of sources located at the corresponding heights, Q_j and are ground-based sources.

CXXXVIII. THE OBTAINED RESEARCH RESULTS

The height of the sources may not coincide with the average value, then the values of k(z) are calculated using the interpolation formula. Depending on the assignment, $\beta(x,y)$ the interaction coefficient is taken into account in the equation at z=z0.

Thus, a numerical algorithm has been developed to solve the transport and diffusion equation taking into account the change in the vertical turbulence coefficient, the interaction coefficient, taking into account ground-based passive and active aerosol emissions, and computational experiments (CE) have been carried out.

Based on mathematical modelling and algorithms, a software package has been developed to conduct a series of computational experiments. A user-friendly operating interface has been developed where you can set the basic and climatic parameters of the mathematical model of the object, the initial fields of distribution of the concentration of substances in the atmosphere, etc.

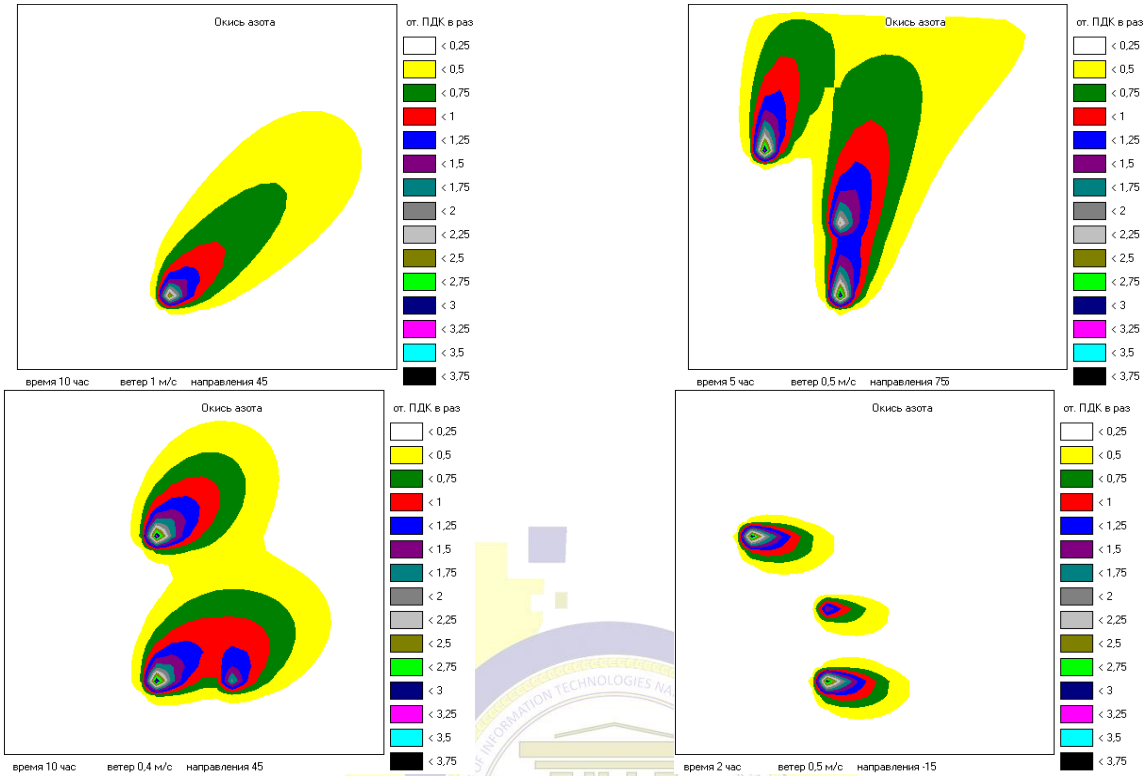

Fig 1. Window for entering direction and wind speed

The results of CE are presented in the form of graphic objects, and a description of the dynamic mode of monitoring the process of propagation of aerosol emissions in the atmosphere is given. The developed web application for forecasting the ecological state of the atmosphere is considered [9-12].

The results of the study were applied to solve important practical problems, and specific conclusions were given on the distribution of harmful substances from industrial enterprises. The appendix contains five certificates of registration of software products with the Intellectual Property Agency of the Republic of Uzbekistan, diplomas, certificates and certificates of implementation of research results.

The author expresses gratitude to S. Karimberdieva and N. Ravshanov for their constant attention and valuable advice when discussing the research results.

CXXXIX. RESULTS

Analysis of the results obtained from CE allowed us to delve deeper into the subject area for a detailed study of the transfer and distribution of harmful substances in the atmosphere, taking into account geographical and weather-climatic factors, and the characteristics of the circulation of air masses.

Thus, we can conclude that the results allow us to study in detail the process of transfer and diffusion of aerosol emissions in the environment, taking into account such important factors as the orography of the area, the

speed of the generated wind, both horizontally and vertically.

Obtained results can be effectively utilized for the optimal placement of newly constructed facilities in industrial regions. Additionally, these results are valuable for evaluating the extent and geographic distribution of emissions into the environment, as well as the concentration of harmful substances in the atmosphere and on the underlying surface. Thus, modeling data supports subsequent decision-making processes aimed at minimizing the risks of environmental disruption.

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ПРОБЛЕМЫ ЦИФРОВИЗАЦИИ ПЕДАГОГИКО - ИНКЛЮЗИВНЫХ СИМВОЛОВ В ОБРАЗОВАНИИ

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Аннотация: *Данная исследовательская работа, посвящена цифровизации педагогико - инклюзивных символов в образовании, разработке и созданию системы общения «человек – искусственный интеллект».*

Ключевые слова и направления: *цифровизация, педагогика, инклюзивные символы, образование, разработка, создание, система общения, «человек – искусственный интеллект», манипулятор, рукоять*

CXL. Введение

После автоматизации разных задач управления и процессов проектирования, следующим необходимым этапом стала цифровизация, где объектом является, например, образование. Потому что приобретаемые информации из объектов управления не дискретные, а являются аналоговыми, естественно, это веление времени.

Данная исследовательская работа тоже относится к созданию очень сложной системы [1], где сочетаются дискретные и аналоговые величины, которые связаны с:

- распознаванием инклюзивных символов образования с помощью видео глаза;

- шифрованием инклюзивных символов образования в цифру;

- дешифрированием, т.е. информацию в виде цифры в инклюзивный символ образования;

- моделированием процесса обучения с помощью «пальцев» рукояти манипулятора.

Для разработки и создания данной системы, необходимо выполнить следующие этапы исследовательских работ:

1. Анализ и синтез объекта исследования, т.е. движение рук и губ обучаемых в распознавании инклюзивных символов в обучении, с помощью «пальцев» рукояти манипулятора.

Для сортировки в зависимости от сложности исполнения, а также подбора элементов механики, т.е. «пальцев» рукояти, для имитации инклюзивных символов.

2. Шифрование. Сбор инклюзивных элементов и символов и их перевод в «цифру» с помощью разных электронных устройств/модулей электроники.

3. Дешифрирование. Необходимые электронные устройства, приборы и дополнительные элементы цифровой техники, выражающие необходимые движения, с помощью «пальцев» рукояти манипулятора.

4. Распознавание инклюзивных символов с помощью видео глаза

5. Имитация инклюзивных символов, с помощью «пальцев» рукояти манипулятора.

6. Разработка алгоритма технической имитации для всех инклюзивных движений с помощью существующих разных сенсоров и элементов механики, т.е. «пальцев» рукояти.

7. Разработка автономных подпрограмм для каждого вида движения «пальцев» рукояти манипулятора.

8. Создание программ каждого вида движения «пальцев» рукояти манипулятора.

9. Программа имитации комбинированных выражений «слов», «сочетаний», разговоров.

10. Комбинирование выражений «слов», «сочетаний» с помощью программ.

Выполнение данной исследовательской работы, необходимо разделить между шестью экспертными группами, в зависимости от рода исполняющих функций.

Первая группа – теоретическая часть. Разработка базы знаний, накопление и выборка инклюзивных символов

Вторая – расчетная часть. Создание «дерева» выборки инклюзивных символов на основе экспертных систем.

Третья - электронная часть. Распознавание символов движения рук и губ с помощью видео лаза, разных сенсоров, приборов электроники.

Четвертая – механическая часть. Выражение движений рук и губ с помощью «пальцев» рукояти манипулятора.

Пятая – программная часть. Разработка и создание имитационных моделей движений рук и губ с помощью «пальцев» рукояти манипулятора.

Шестая – создание базы данных имитационных моделей движений рук и губ с помощью «пальцев» рукояти манипулятора.

CXLI. Методы

Так как, в исследовании предметной областью являются инклюзивные символы, которые состоят из 84 знаков-выражения с помощью рук и губ, то, необходимо построить «дерево» связей этих выражений, которое осуществляет логическую выборку необходимых механических операций. А для организации из выражения рук и губ связки: символов в слово или разговорную речь, необходимо построить логическую последовательность, с помощью логических операций.

Для этого необходимо, разработать экспертную систему с помощью логических операций выбора знаков в отдельности для каждого символа, с учетом всех выражений.

Экспертная система должна быть разработана для всей системы, досконально с захватом всех выполнимых операций механической части «пальцев» рукояти манипулятора.

Следующей задачей является, создание базы знаний в данной области, где будет накапливаться сбор всех используемых символов, выполняемых логические операции, которое приводить в движение механической части, т.е. «пальцев» рукояти манипулятора.

В конечном итоге, фонд базы знаний, накапливается и наращивается за счет приобретаемых знаний по разным изучаемым предметам/дисциплинам в процессе обучения.

С помощью экспертной системы будет разработано и построено «дерево» системы управления выбора «нужного» знака-выражения при общении, которое осуществляется с помощью «ветвей» каждого знака-выражения, состоящего из отдельных «элементов», связывающее их в единую, слово.

CXLII. Заключение

: Целью данной исследовательской работы является разработка и создание системы общения человека, с помощью имитации инклюзивных символов, которая будет осуществлена при помощи ИИ в виде «рукояти» манипулятора в процессе обучения.

Для реализации данной исследовательской работы необходимым является техническое решение, т. е. реализация вышесказанных будет осуществлена с помощью разных механических, технических, электронных средств, программных и интеллектуальных систем.

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СИМУЛЯЦИЯ КАК РЕАЛЬНОСТЬ: ФИЛОСОФИЯ БЫТИЯ В ВИРТУАЛЬНОМ МИРЕ

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Аннотация - в статье рассматривается феномен симуляции как новой формы реальности, возникшей с развитием цифровых технологий, виртуальных и дополненных миров. С опорой на философские традиции — от Платона и Декарта до Бодрийяра и Бострома — проводится анализ онтологического статуса симулированных миров и их влияния на восприятие бытия, истины и идентичности. Особое внимание уделяется понятию «виртуального бытия» и его последствиям для философии реальности, субъектности и свободы. Обосновывается необходимость переосмысления виртуализации историко-культурного наследия Узбекистана в условиях цифровой эпохи. В целом, симуляция исторической памяти становится не только философским вопросом, но и официальной политикой — формируя новую модель национальной идентичности в цифровом измерении.

Ключевые слова — симуляция, философия бытия, виртуальная реальность, цифровизация, Узбекистан, культура, наследие, память.

CXLIV. Введение

С начала XXI века человечество вступило в эпоху, когда границы между реальностью и её цифровыми отображениями начинают стремительно стираться. Развитие виртуальных технологий, генеративного искусственного интеллекта, метавселенных и цифровых платформ изменяет не только повседневную жизнь, но и само восприятие бытия. Однако мы можем задаваться риторическими вопросами: какую реальность мы воспринимаем как подлинную? Является ли виртуальное — лишь копией или уже самостоятельной формой онтологического присутствия?

Философия симуляции — направление, сформированное на стыке классических метафизических традиций и постмодернистской мысли — предлагает инструментарий для анализа этой трансформации. Начавшись с Платонова мифа о пещере и картезианского сомнения, идея симуляции приобретает современное звучание в работах Жана Бодрийяра, где описывается общество симулякров, и в гипотезе Ника Бострома, допускающей существование нашей реальности как компьютерной модели.

Республика Узбекистан, находясь в активной фазе цифрового преобразования, становится интересным примером для философского анализа. Здесь цифровизация охватывает множество сфер: от электронного правительства и виртуализации культурного наследия до формирования новых медиаобразов и цифровых идентичностей. Здесь можно озвучить актуальный вопрос, который встаёт перед философией: в каком смысле эта реальность остаётся «реальной», а в каком — становится симуляцией? Это философское напряжение между «реальным» и «виртуальным» приобретает особую остроту в контексте Узбекистана, где цифровизация выступает не просто как технический прогресс, но как цивилизационный проект.

Республика Узбекистан становится не только пространством цифровой модернизации, но и экспериментальной площадкой для философского осмысления нового типа реальности, в которой границы между подлинным и виртуальным, субъектом и интерфейсом, культурой и её симуляцией подлежат пересмотру. Философия бытия в этом контексте предлагает инструментарий для анализа не только внешних технологических изменений, но и внутренних, ментальных и антропологических трансформаций, с которыми сталкивается современное общество.

CXLV. Онтология симуляции: философские предпосылки

Философская идея о симуляции восходит к Платону и его «мифу о пещере, где люди принимают тени на стене за действительность» [1]. Уже здесь возникает мысль о том, что воспринимаемая реальность может быть лишь иллюзией, проекцией более глубокой истины. Платон подчёркивает именно то, что подлинное знание возможно лишь при выходе за пределы чувственного восприятия — к миру идей, или эйдосов. Таким образом, пещера становится ранним символом симулированной реальности, в которой

человек живёт в пределах когнитивных ограничений и не способен различить истинное от ложного.

Идея Платона находит своё развитие в философии Рене Декарта, особенно «в его гипотезе о «злом гении», способном полностью обмануть человеческие чувства и разум» [2]. Декартовский скептицизм усиливает платоновское сомнение: если наше восприятие может быть сгенерировано внешней силой, то нельзя быть уверенным в существовании даже собственного тела и мира вокруг. Таким образом, сознание становится единственной гарантией бытия — Cogito ergo sum («Я мыслю, следовательно, я существую»). Этот гипотетический скептицизм нашёл прямое продолжение в современных моделях симуляции, где «злой гений», как мы полагаем, заменён алгоритмом или цифровой системой.

В XX веке идея симуляции переходит в новое измерение благодаря Жану Бодрийяру, который описывает современную эпоху как царство симулякров — копий, не имеющих оригинала. В условиях гипермедиатизированной культуры реальность становится неотличимой от своей имитации, а знаки — самодостаточными. Согласно Бодрийяру, «мы живём в гиперреальности, где симуляция не скрывает истину, а заменяет её» [3]. И это уже не просто иллюзия, как у Платона, а новая форма реального, в которой исчезает граница между истиной и ложью.

Таким образом, платоновская идея теней на стене получила своё продолжение в картезианском сомнении, постструктуралистской теории симулякров и в цифровом постмодерне. Обозначенные философские традиции формируют основу для анализа новых форм симулированного бытия, с которыми сталкивается современное человечество.

CXLVI. Современные формы симулированной реальности

С развитием виртуальной (VR), дополненной (AR) реальности, а также метавселенных (Meta, Roblox, Fortnite, Decentraland и т.п.) появляются полноценные симулированные миры с экономикой, социальными отношениями и своеобразной эстетикой. В данном отношении может возникать вопрос: являются ли эти миры реальными? И если ответ – «да», то в каком онтологическом смысле?

Важно отметить, что на сегодняшний день имеются и различные ИИ-системы (например, ChatGPT, DALL-E, Midjourney), которые способны создавать тексты, образы и звуки, не существовавшие ранее. Однако всё это — симуляции человеческого творчества. Но мы и здесь можем задаваться вопросом - где может проходить граница между симулированным и оригинальным, если восприятие больше не способно их различать?

Философ Ник Бостром выдвинул аргумент, согласно которому «мы, возможно, уже живём в симуляции, созданной постчеловеческой цивилизацией» [4]. И если его гипотеза верна, то это может радикально подрывать основания традиционной метафизики, в которой реальность — непреложное основание бытия.

В контексте гипотезы Бострома, традиционные метафизические категории — такие как «истинное», «сущее», «материальное» и «причинное» — начинают терять свою устойчивость. Если предполагается, что весь воспринимаемый нами мир является результатом высокоуровневой компьютерной симуляции, то основания онтологии смещаются: бытие оказывается производным от вычисления, а истина — от кода. Это означает, что привычное философское представление о реальности, как о фундаментальной и непреложной основе существования, подвергается радикальному пересмотру.

CXLVII. Философия бытия в условиях симуляции

Как известно, виртуальные объекты не имеют физического субстрата, однако обладают своими устойчивыми признаками существования: они взаимодействуют, изменяются, влияют на определённого субъекта. Следовательно, необходимо признать существование виртуального бытия — особого уровня реальности, не сводимого ни к материальному, ни к мнимому.

Субъект, в свою очередь, в виртуальной среде может создавать и изменять свою цифровую идентичность. В философском плане это разрушает классическое понимание субъекта как устойчивого «я». Вместо этого возникает модульное или игровое «я», сформированное по законам симуляции.

Вопрос истины в симулированном мире становится проблематичным. Что означает «правда», если каждое утверждение может быть смоделировано, сгенерировано или подменено? Ж. Бодрийяр утверждал, что «истина в симуляции исчезает — остаётся лишь «оперативная эффективность» знака» [3]. При этом знак больше не отсылает к реальному объекту — он сам становится реальностью, функционирующей по логике кода, алгоритма и медиауправления. В условиях гиперреальности значение подменяется функцией, а смысл — воздействием. Истинность высказывания уступает место его вовлекающей силе, репостам, лайкам, виральности и т.п.

CXLVIII. Социально-этические измерения симулятивной реальности

С усилением роли симулированной реальности в цифровом обществе традиционные социально-этические ориентиры оказываются под вопросом. Виртуальное пространство подменяет собой опыт, но при этом часто лишено моральной структуры, которая регулирует действия в физическом мире. Если можно смоделировать события, личности, мнения и даже эмоции, то что значит поступать «правильно» в среде, где граница между реальным и вымышленным постоянно размыта?

Необходимо подчеркнуть также и то, что с одной стороны, виртуальные миры расширяют свободу

субъекта: можно быть кем угодно, жить в любых условиях, преодолеть ограничения тела и общества. С другой стороны, эти свободы — некая иллюзия, находящаяся под контролем алгоритмов, компаний и платформ.

Симуляции могут использоваться для создания альтернативных нарративов, фейков и манипуляции массовым сознанием. Они также становятся и инструментом социально-этического воздействия. Аксиома реальности может воплощаться в следующем: кто в современном мире контролирует симуляцию — тот и контролирует истину.

Смещение фокуса на симулированное вызывает опасения об утрате «реального» опыта — телесного, эмоционального, натурального. Это, как мы полагаем, возвращает философию к феноменологии тела. Мерло-Понти утверждал, что «тело — это не просто биологический механизм, а субъект восприятия, через который мы «вписаны» в мир. Мы не имеем тело — мы есть телесные» [5]. Следовательно, вся симулятивная реальность остаётся вторичной по отношению к воплощённому опыту. Виртуальные миры, создавая ощущение «присутствия», зачастую не дают подлинного телесного контакта: запах, прикосновение и т.п. — всё это симулируется, но не проживается. Такой опыт может быть ярким, но он одномерен. Он оторван от живого тела, которое всегда конкретно, смертно и контекстуально.

С этической точки зрения здесь возникает проблема о манипуляции сознанием. Цифровые платформы, управляемые коммерческими или политическими интересами, способны создавать полностью симулированную информационную среду, где пользователь лишается подлинной свободы интерпретации, иногда не осознавая этого. А это подрывает само основание автономии как моральной категории.

CXLIX. Виртуализация историко-культурного наследия: Узбекистан между памятью и симуляцией

Историко-культурное наследие традиционно воспринимается как материальная и духовная основа идентичности народа. Мечети, мавзолеи, медресе, ковры, миниатюры, устные эпосы — всё это хранит историческую и цивилизационную память Узбекистана. Однако в XXI веке, с развитием цифровых технологий, происходит виртуализация историко-культурной памяти, когда реальный доступ к артефактам заменяется их цифровыми двойниками — 3D-моделями, интерактивными экспозициями, цифровыми музеями и онлайн-архивами. Этот процесс, с одной стороны, способствует сохранению и популяризации историко-культурного наследия, а с другой — поднимает философский вопрос: является ли виртуальный объект полноценным носителем исторического бытия, или же это — симуляция, лишённая подлинности?

Виртуализация историко-культурной памяти — явление, находящееся в русле общемировых тенденций, но в Узбекистане оно получает особую значимость благодаря прямой поддержке на государственном уровне. Это отражается, в частности, в Указе Президента Республики Узбекистан «Об утверждении Стратегии «Цифровой Узбекистан-2030» и мерах по её эффективной реализации» [6].

Согласно положениям стратегии, одним из её ключевых приоритетов является укрепление национальной идентичности в цифровом пространстве. В этом контексте цифровизация историко-культурного наследия выполняет сразу несколько функций:

1) Сохранение — защита уязвимых объектов и архивов от утраты или разрушения;

2) Доступность — предоставление материалов широкому кругу пользователей, включая молодёжь, диаспору и международное сообщество;

3) Позиционирование — создание нового имиджа Узбекистана как страны, где традиция и технология не противоречат друг другу, а полноценно сосуществуют.

При этом возникает важный философский вопрос: может ли симулированная (цифровая) версия наследия сохранять ту же ценность, что и физический оригинал? В данном отношении можно отметить, что если стратегия «Цифровой Узбекистан – 2030» делает акцент на технологической стороне сохранения культуры, то философия должна напомнить: цифровой образ — не эквивалент подлинного бытия, и его ценность зависит от того, как он соотносится с живым опытом, памятью и средой.

Мы все являемся свидетелями того, что Республика Узбекистан активно внедряет цифровые технологии в сферу культуры и туризма. И в последние годы реализовано множество проектов:

- 3D-оцифровка исторических памятников (в том числе в Самарканде, Бухаре, Хиве);

- онлайн-экспозиции музеев, доступные через государственные и частные платформы;

- виртуальные туры, позволяющие «посетить» объекты Всемирного наследия ЮНЕСКО, не покидая дома;

- интерактивные карты исторических маршрутов Шёлкового пути;

- использование AR/VR в образовательных и туристических целях.

На первый взгляд, это свидетельствует о позитивной трансформации: историко-культурное наследие становится более доступным, а сохранение артефактов — более устойчивым. Однако необходимо подчеркнуть то, что философия симуляции требует более критического взгляда.

С опорой на концепцию Жана Бодрийяра, можно утверждать о том, что в условиях гипермедиатизации возникает феномен симулякра — знака, не имеющего оригинала. Виртуальная копия мавзолея Амир Темура или Регистана в Самарканде может быть настолько детализированной и интерактивной, что пользователь

воспринимает её как «достаточную» замену физическому посещению. И в результате мы можем получать следующее:

- оригинал утрачивает свой онтологический приоритет: ему становится сложно конкурировать с идеализированной виртуальной версией;

- восприятие историко-культурного наследия смещается из плоскости воплощённого опыта в сферу медиапотребления;

- сам объект наследия превращается в информационную модель, теряя свою телесность и аутентичную связь с пространством и временем.

В качестве примера можно привести следующий аспект: для молодого поколения Узбекистана, не посещавшего мавзолей Гур-Эмир, его цифровая модель может быть не просто первым, но и единственным способом знакомства с объектом — при этом впечатление будет формироваться не через восприятие материальности, а через графику, звук и гейм-дизайн.

У виртуализации историко-культурного наследия есть и антропологическое измерение. Например, формирование исторической памяти всё чаще происходит через цифровую среду — YouTube-документалки, AR-гиды, Instagram-экскурсии. Всё это формирует новые формы коллективной идентичности, где:

- история становится медиапродуктом, подстраивающимся под алгоритмы потребления;

- традиции интерпретируются через визуальные коды и нарративы, часто ориентированные на международную аудиторию;

- уходит в тень живой культурный носитель — мастер, рассказчик, гид-экскурсовод, хранитель.

Таким образом, как мы можем видеть, историческая преемственность подвергается симуляции: она воспроизводится не в процессе передачи практического опыта, а через взаимодействие с виртуальной репрезентацией.

Становится очевидным, что виртуализация историко-культурного наследия в Узбекистане — неотъемлемая часть современного технологического развития. Однако философская задача — не только поддерживать этот процесс, но и осмыслять его последствия. Философия симуляции подсказывает: в эпоху цифровой реальности, необходимо не просто создавать копии прошлого, но сохранять онтологическую значимость оригинала — как источника живого опыта, укоренённого в пространстве и теле настоящего человека.

В целом, историко-культурное наследие Узбекистана — это не только память о прошлом, но и активный элемент построения будущего. Поэтому крайне важно, чтобы симуляция — в форме 3D-моделей, VR-туров или цифровых архивов — не стала единственным способом бытия этих объектов, а лишь расширяла горизонты их понимания, оставаясь в диалоге с физической, воплощённой реальностью.

Заключение

Цифровая реальность в современном мире всё больше перестаёт быть дополнением к физическому миру — она становится самостоятельным измерением социального, культурного и политического бытия. Виртуальные сервисы, симулированные образы в медиапространстве, цифровое наследие и онлайн-идентичности образуют новый слой реальности, требующий своего онтологического осмысления.

Философия симуляции предлагает ключ к пониманию этой трансформации. Симулякр — не просто подделка или имитация, а новая форма действительного, существующая в логике цифровой гиперреальности. И Республика Узбекистан, как часть глобального цифрового мира, сталкивается с необходимостью не только технической, но и философской адаптации к условиям, в которых виртуальное всё чаще подменяет — или даже вытесняет — физическое.

Необходимо констатировать то, что задача философии сегодня — не отрицать виртуальное как «неподлинное», а изучать его как одну из форм современного бытия, формирующую новые способы идентичности, коммуникации и понимания мира. И только через такой анализ возможно создание гуманистически ориентированных стратегий цифрового развития — как для Республики Узбекистан, так и для мира в целом.

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СОЗДАНИЕ АНИМИРОВАННЫХ ПЕРСОНАЖЕЙ В ADOBE ANIMATE С ИНТЕГРАЦИЕЙ ИИ-ГЕНЕРИРУЕМОГО ГОЛОСА ДЛЯ МУЛЬТИМЕДИЙНЫХ ПРОЕКТОВ

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Аннотация: В статье рассматривается процесс создания анимированных персонажей с использованием Adobe Animate и интеграции ИИ-генерируемого голоса для мультимедийных проектов. Описаны этапы разработки персонажей, включая дизайн, риггинг и синхронизацию губ (lip-sync), а также применение ИИ-инструментов, таких как ElevenLabs и Google Cloud Text-to-Speech, для генерации реалистичной речи. Особое внимание уделено практическим аспектам интеграции аудио в анимацию и применению в маркетинге, образовании и интерактивных приложениях. Статья подчеркивает потенциал сочетания анимации и ИИ для создания инновационного контента.

Ключевые слова: Adobe Animate, ИИ-генерируемый голос, анимация персонажей, lip-sync, мультимедийные проекты, риггинг, ElevenLabs, Google Cloud Text-to-Speech, Adobe Character Animator, интерактивный контент.

Adobe Animate — это профессиональное ПО от компании Adobe, предназначенное для создания 2D-анимации, интерактивного контента и веб-графики. Оно поддерживает векторную графику, что позволяет масштабировать изображения без потери качества, и интегрируется с другими программами Creative Cloud, такими как Illustrator и Photoshop. По данным Adobe, Animate используется для производства анимации для телевидения, игр и онлайн-контента. Для создания персонажей Animate предлагает инструменты риггинга (rigging), позволяющие анимировать части тела, такие как руки, ноги и лицо, с помощью костей (bones) и слоев. Это упрощает процесс, делая анимацию более естественной. Например, вы можете импортировать иллюстрации из Illustrator, разбить их на слои (голова, туловище, конечности) и применить инструменты Puppet Warp или Bone Tool для контроля движений.

Шаги по созданию анимированного персонажа в Adobe Animate

Подготовка дизайна персонажа: Начните с создания или импорта эскиза. В Adobe Illustrator нарисуйте персонажа в векторном формате. Разделите на отдельные элементы: глаза, рот, руки и т.д. Это позволит анимировать каждую часть независимо.

Импорт в Animate: Откройте новый проект в Animate (выберите HTML5 Canvas или ActionScript 3.0 в зависимости от цели). Импортируйте слои из Illustrator через File > Import > Import to Stage.

Риггинг и анимация: Используйте Bone Tool для создания скелета. Выделите части тела и соедините их "костями". Затем примените Inverse Kinematics (IK) для реалистичных движений. Для лицевой анимации (lip-sync) используйте слои с разными формами рта, соответствующими фонемам (звукам речи).

Добавление анимации: Создайте ключевые кадры (keyframes) на временной шкале (Timeline). Animate поддерживает tweening — автоматическую интерполяцию между кадрами, что ускоряет процесс. Для сложных движений используйте символы (symbols) типа Movie Clip.

Экспорт: Экспортируйте анимацию в форматы вроде SWF, HTML5 или видео (MP4) для интеграции в проекты.

Современные обновления Animate (на 2025 год) включают улучшенный риггинг с ИИ-поддержкой, такой как автоматическое распознавание форм для упрощения анимации.

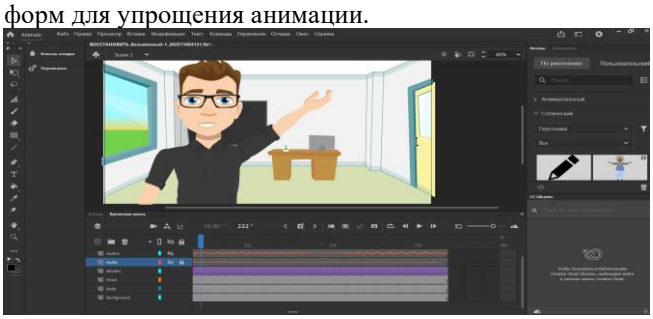

Рисунок 1. Шаги по созданию анимированного персонажа

Пример рабочего процесса в Adobe Animate: анимированный персонаж, созданный с использованием слоев и риггинга, синхронизируется с аудио на временной шкале. Интерфейс демонстрирует разделение элементов (голова, тело, фон) и настройку ключевых кадров, что идеально подходит для интеграции ИИ-генерируемого голоса в мультимедийные проекты.

ИИ-генерируемый голос: инструменты и преимущества

ИИ-генерируемый голос — это технология, преобразующая текст в речь с естественной интонацией. Популярные инструменты включают:

ElevenLabs: Позволяет создавать кастомные голоса на основе образцов, с поддержкой эмоций и акцентов. Идеально для персонажей с уникальным тембром.

Google Cloud Text-to-Speech: Интегрируется с WaveNet для реалистичной речи, поддерживает множество языков.

Amazon Polly: Фокусируется на нейронных голосах для высококачественного синтеза.

Respeecher или Murf.ai: Специализированы на клонировании голосов и анимационной синхронизации.

Преимущества: ИИ-голос экономит время и бюджет, исключая необходимость в актерах. Он может генерировать речь в реальном времени, адаптируясь к сценарию, и поддерживает мультиязычность для глобальных проектов.

Интеграция ИИ-голоса в анимацию Adobe Animate

Интеграция голоса в Animate требует синхронизации аудио с визуалом, особенно lip-sync (синхронизация губ).

Генерация голоса: Напишите сценарий и используйте ИИ-инструмент для создания аудиофайла (WAV или MP3). Например, в ElevenLabs загрузите текст, выберите голос и экспортируйте.

Интерфейс ElevenLabs демонстрирует процесс генерации ИИ-голоса, который идеально дополняет анимацию в Adobe Animate. Здесь можно настроить голоса для персонажей, обеспечивая реалистичную синхронизацию с движениями, созданными с помощью риггинга. Снимок интерфейса ElevenLabs показывает настройку текста для ИИ-голоса, который станет частью анимации в Adobe Animate. Этот этап позволяет создать аудиофайл, готовый к импорту и синхронизации с персонажем на временной шкале. Пример работы с ElevenLabs: интерфейс Text to Speech позволяет выбрать голос (например, Rachel) и модель (Eleven Multilingual v2), чтобы создать выразительную речь. Это мощный инструмент для экономии времени и добавления уникальности персонажам. Интерфейс ElevenLabs в действии: генерация текста в речь с возможностью регулировки скорости и стабильности. Полученный аудиофайл легко интегрируется в Adobe Animate для точной синхронизации губ анимированного персонажа. Этот кадр из ElevenLabs иллюстрирует создание ИИ-голоса, который можно использовать в анимации для образовательных видео, игр или рекламы. Настройка голоса в реальном времени открывает новые горизонты для мультимедийного контента. Интерфейс ElevenLabs подчеркивает простоту генерации ИИ-голоса, который в сочетании с анимацией в Adobe Animate создает инновационные мультимедийные проекты. Это сочетание технологий обещает дальнейшее развитие в будущем. Импорт аудио в Animate: В Animate импортируйте аудио через File > Import > Import to Library. Поместите его на Timeline в отдельный слой.

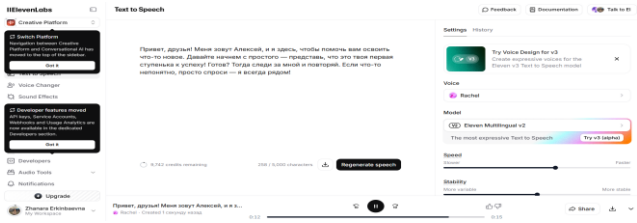

Рисунок 2. Интеграцией ИИ-генерируемого голоса для мультимедийных проектов

Синхронизация lip-sync: Разделите аудио на фонемы (используйте инструменты вроде Adobe Audition для анализа). В Animate создайте символы рта для каждой фонемы (например, "A", "O", "M"). Используйте Frame-by-Frame анимацию или расширение вроде Adobe Character Animator для автоматической синхронизации. Character Animator интегрируется с Animate и использует веб-камеру или ИИ для захвата мимики, но для ИИ-голоса подключите аудио напрямую.

Автоматизация с скриптами: Для продвинутых проектов используйте ActionScript или JavaScript в Animate для динамической интеграции. Например, скрипт может загружать ИИ-голос из API (как Google TTS) и синхронизировать его с анимацией в реальном времени.

Тестирование и корректировка: Просмотрите анимацию, скорректируйте тайминги. Для интерактивных проектов (игры или VR) интегрируйте голос через HTML5 Canvas с JavaScript-библиотеками вроде Howler.js.

Пример проекта: Создание образовательного видео, где анимированный персонаж-учитель объясняет тему с ИИ-голосом. Это повышает вовлеченность, особенно в e-learning.

Применение в мультимедийных проектах

Маркетинг: Анимированные персонажи с ИИ-голосом в рекламных видео повышают конверсию. Например, бренды вроде Duolingo используют похожие подходы.

Образование: Интерактивные уроки с говорящими персонажами делают обучение веселым.

Игры и VR: Персонажи с динамическим голосом реагируют на действия пользователя.

Социальные сети: Короткие анимированные клипы с ИИ-озвучкой для TikTok или YouTube.

По прогнозам, к 2025 году рынок ИИ в анимации вырастет до $10 млрд, благодаря инструментам вроде Adobe Sensei (ИИ в Creative Cloud).

Создание анимированных персонажей в Adobe Animate с интеграцией ИИ-генерируемого голоса открывает новые горизонты для мультимедийных проектов. Этот подход сочетает креативность с технологиями, делая контент доступным и эффективным. Начните с базовых инструментов, экспериментируйте с ИИ и масштабируйте проекты. Для углубленного изучения ознакомьтесь с туториалами Adobe или платформами вроде Coursera. В будущем ожидается еще большая интеграция ИИ, включая автоматическую генерацию анимации на основе текста.

10-sho‘ba. Raqamli hukumat va elektron tijoratni rivojlantirish yo‘nalishlari

L-TIZIMLAR VA FRAKTAL GEOMETRIYA ASOSIDA ZARGARLIK INNOVATSIYASI

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Annotatsiya: **Maqolada fraktal geometriyaning zargarlik dizaynidagi estetik va funksional ahamiyati chuqur tahlil qilingan. Fraktallar o'z-o'zini takrorlovchi, murakkab, ammo tartibli tuzilmalar bo'lib, san'at va ilm-fanni birlashtiruvchi kuchli vosita sifatida tasvirlanadi. Muallif fraktal modellar Serpin uchburchagi, Kox qor parchasi, Appolon gilami, Xarter ajdari asosida yaratilgan zamonaviy zargarlik buyumlarini yoritadi. L-tizimlardan foydalanish esa zargarlik dizaynini nafaqat estetik, balki interaktiv va funksional jihatdan boyitishga xizmat qiladi. Fraktallar yordamida yaratilgan kulon va taqinchoqlar murakkablik, nafislik va zamonaviylikni uyg'unlashtiradi.**

Kalit so'zlar. Fraktal geometriya, zargarlik dizayni, serpin uchburchagi, kox qor parchasi, l-tizimlar, kompyuter grafika, estetik evolyutsiya, fraktal san'at, o'z-o'zini takrorlash, kulon dizayni.

I.Kirish

Fraktallar hayotimizning turli jabhalarini o'rab olgan. Ushbu atama kengroq qo'llanila boshlaganligi sababli, fraktallar nima ekanligini, fraktallar hayotimizga qanday ta'sir qilishini tushunishga bo'lgan qiziqishlar kun sayin ortib bormoqda.

Fraktallarning ixtiro etilishi fan va matematikadagi, san'atdagi yangi estetikaning ochilishidir, shuningdek insonning olamni idrok qilishdagi kashfiyotdir.

Fraktal - geometrik shakl bo'lib, aniq bir qismi o'lchamlari o'zgargan holda qayta - qayta takrorlanishidir. Fraktal - singan fazoviy shakl, tekis yoki notekis, xaotik yoki botartib va o'zini-o'zi turli masshtabda takrorlaydigan murakkab tuzilish hisoblanadi. Fraktal - Xausdorf o'lchami topologik o'lchamidan qat'iy katta bo'lgan to'plam. Fraktal - nobutun o'lchamli o'ziga - o'zi o'xshash to'plamlar va cheksiz o'ziga-o'zi o'xshash shakllardir, o'lchami kasriy to'plamdir. Bu asoslanishdan o'ziga-o'zi o'xshashlik tamoyili kelib chiqadi. Fraktallar fanda ko'pdan-ko'p qo'llanilmoqda. Buning asosiy sababi u mavjud borliqni an'anaviy fizika yoki matematikaga nisbatan juda aniq bayon etishidadir [3,6].

Fraktallar bo'laklarga ajratilgan tuzilishni ifodalovchi hamda chegaralangan masshtabda o'z-o'ziga o'xshash xususiyatini egallovchi geometrik obyektlar (chiziq, sirt, jism) lardir. V.N. Babichning fikriga ko'ra *"Fraktal - uning fazoviy siniq shakllar va regulyar yoki regulyar bo'lmagan, xaotik yoki tartiblangan, ixtiyoriy masshtabda o'zini takrorlaydigan murakkab tuzilishdir"*

Brenner N., Rader C. lar turli xildagi fraktal tuzilishdagi misollarni tabiatning ko'plab hodisalarida uchratish mumkin. Fraktalli timsollardan nochiziq dinamik hamda dissipativ tizimlarning xaotik harakatini ta'riflashda, suyuqliklarning girdobli harakatida, koinotda borliqning bir jinsli bo'lmagan tarqalishida muvaffaqiyatli foydalaniladi.

Long Siaotian va Luo Veiyan tomonidan yozilgan "Fraktal grafika san'atining kiyim-kechak gazlamalarida va dizaynida qo'llanilishi" qilgan. Fraktal grafika san'ati kiyim gazlamasini loyihalash va yana boshqa ko'plab sohalarda ishlatilishi mumkin.

Voloshinov A.V. fikriga ko'ra, nomli kitobida fraktal grafika san'atining estetik qadriyatlari va gazlama dizaynida zamonaviy tasviriy san'atning o'ziga xos amaliy masalalarini, keyin gazlama dizaynini yanada aniq va o'ziga xos tarzda muhokama fraktal geometriya XXI asrning fan va san'atidir, chunki o'sish g'oyasi fraktalda jamlanadi. Fraktal shakllar yaratishning asosi bo'lib, rivojlanishning ma'lum bosqichlarida muayyan strukturalarning xilma-xilligini yuzaga keltiradi. U original shakllarni ularning assimetriya va dinamikasida ixcham tarzda tasvirlash usuli hisoblanadi. Aynan fraktal strukturalarda Geraklitning asosiy estetik printsipi – xilma-xillik va birlik printsipi eng yorqin ifodasini topadi [4].

Fraktallar asosida yassi to'plamlar va juda murakkab shakllar tekisligini yaratish mumkin. Daraxt va paporotniklar barglarini, sun'iy tog'-adirlarni, bulut hamda tabiatda mavjud bo'lmagan planetalarni hosil qilish mumkin. Ular o'zining go'zalligi hamda cheksizligi bilan o'ziga maftun etadi. Shuning uchun ham zargarlik buyumlari dizaynlarini yaratishda keng imkoniyatlarni taqdim etadi.

Keltirilgan iqtiboslar fraktal metodologiyasining mazmunini to'liq ochib beradi. Har qanday fraktal o'zida matematik jarayonlar to'plamini muayyan ketma-ketlikda vizualizatsiya qiladi. K.A. Martynovich va S.D. Xaytunning ta'rifiga ko'ra, fraktal – bu o'ziga xos

"ko'rish optikasi", dunyo va olamni anglashning qonuniy usuli bo'lib, evolyutsiya jarayonida uning omon qolishini ta'minlaydi. Postmodern madaniyatining raqamli paradigmati va uning obrazni idrok etishga yo'naltirilganligi fraktal ko'rish optikasini kundalik estetik amaliyotga va yangi ma'no yaratish shakllariga kiritishga imkon berdi [2].

Zamonaviy fraktal paradigma kompyuter texnologiyalari tufayli adabiyot va kinematografiya, dekorativ-amaliy san'at, arxitektura va dizayn sohalariga tatbiq qilindi. Mandelbrotning ta'rifiga ko'ra, fraktal o'zida matematik va estetik asoslarni birlashtiradi. U Leonardo da Vinchining "Ulkan to'fon" rasmi, yapon rassomi Katsusika Xokusayning gravyuralarida o'z ifodasini topgan bo'lib, ular zamonaviy kompyuter san'ati uchun prototipga aylangan (1-rasm).

Bugungi kunda quyidagi ijod yo'nalishlari kuzatilmoqda: fraktal rangtasvir, fraktal realizm, fraktal ekspressionizm (fraktalaj), fraktal monotipiya, fraktal suprematizm va hokazo. Tadqiqotchilar fraktal san'atni tasviriy talqin qilishning ikki turini ko'rib chiqadilar: kompyuter grafikasi va fraktal elementlarga ega bo'lgan an'anaviy rangtasvir. Masalan, bunday elementlarni D. Velaskes, J. Pollok, M. Esher, S. Dali, G. Klimt, P. Filonov, A. Rodchenko va boshqa rassomlarning kompozitsion tuzilmasida uchratish mumkin [1].

1-rasm. Katsusika Xokusayning fraktallarni aks ettiruvchi gravyuralari

II. Metodologiya

Adabiyotlarni tahlil qilish zamonaviy madaniyatda fraktal metodologiyasining rivojlanishining to'rtta asosiy yo'nalishini aniqlashga imkon berdi, ular 1-jadvalda ko'rsatilgan.

Ko'rinib turibdiki, birinchi blok falsafiy-estetik yo'nalishni ifodalaydi, unda «ilmiy san'at» (science art) metodining nazariy asoslari rivojlantiriladi. Asosiy printsip – fan va san'atning o'xshash metodologik asoslarga tayangan holda sintezli o'zaro aloqasi. Ushbu yo'nalishning eng mashhur mualliflari: A.V. Voloshinov, S.V. Yeroxin, V.V. Tarasenko, I.A. Yevin, P.P. Nikolaev, V. Ribas va boshqalar.

Ikkinchi blok - mustaqil fraktal san'at sohasi: rang tasvir, arxitektura, musiqa, video san'atni umumiy «Fraktal-art» nomi ostida birlashtiradi. Bu fan, texnika va san'at sinteziga asoslangan bo'lib, uning asosida tabiatning shakllanish algoritmik printsiplari ya'ni: o'z-o'ziga o'xshashlik, dinamiklik, algoritmiklik, noaniqlik va cheksizlik yotadi.

Uchinchi blok - san'at asarlarini estetik jozibadorligini obyektiv baholash maqsadida go'zallikni matematik usulda tahlil qilishga qaratilgan analitik yo'nalish. Ushbu yo'nalishning asosiy tamoyillari A.V. Voloshinov tomonidan fraktallar go'zalligining mezonlari sifatida shakllantirilgan bo'lib, ular Kosmos va Xaos, birlik va xilma-xillik uyg'unligini aks ettiradi.

To'rtinchi blok - matematik yo'nalish bo'lib, ierarxik tartiblangan strukturalarning noaniq shakllanish metodi sifatida qaraladi. Metodning asosiy xususiyatlari: o'z-o'ziga o'xshashlik, algoritmiklik, ko'p o'lchovlilik, tasodiflik, takrorlanish, tugallanmaganlik va cheksizlik.

1-jadval
Fraktal – zamonaviy madaniy rivojlanishning asosiy vektori.

№	Fraktal metodologiyasining rivojlanish yo'nalishlari	Prinsiplar, kontseptsiyalar.	Mohiyati
1.	**Falsafiy-estetik yo'nalish**	Fan va san'atning sintezli o'zaro aloqasi	«Ilmiy san'at» (science art) metodining nazariy tahlili.
2.	**Fraktal san'atning mustaqil sohasi**	O'z-o'ziga o'xshashlik, noaniqlik, dinamiklik, algoritmiklik, cheksizlik - bu zamonamizning ilmiy doimiyliklaridan biri bo'lgan noaniq fraktallikning san'atdagi ifodalash tamoyillari.	Fraktal-art: fan, texnika va san'atning sintezi bo'lib, uning asosida tabiiy shakllanish algoritmlarining printsiplari yotadi.
3.	**Analitik yo'nalish**	Fraktallar go'zalligining mezonlari: Kosmos va Xaos uyg'unligi, xilma-xillikdagi birlik, soddalikdagi go'zallik.	San'atni matematik tahlil qilish usuli, uning estetik jozibadorligini obyektiv baholash maqsadida.
4.	**Matematik yo'nalish**	Noaniq shakllanishning o'ziga xos metodi, u ierarxik	Geometrik, algebraik va stoxastik modellari

		tartiblangan struktura sifatida amalga oshadi. Asosiy xususiyatlar: o'z-o'ziga o'xshashlik, algoritmiklik, ko'p o'lchovlilik, tasodiflik, takrorlanish, tugallanmaganlik va cheksizlik.	algebraik formulalar asosida qurilib, noaniq jarayonlar yordamida n-o'lchovli fazolarda yaratiladi.

Bizning tadqiqot maqsadlari uchun ushbu yo'nalishlardan grafik visual fraktal san'atni tahlil qilish uchun metodik asoslar va yondashuvlarni shakllantirish mumkin bo'ladi.

Zargarlik dizaynerlari odatda quyidagi savolga duch kelishadi: zargarlik buyumlarini qanday qilib yanada o'zgaruvchan ko'rsatish mumkin? Bu har bir zargarlik dizaynerini o'ylantiradigan savoldir. Mahsulot orqali yangilik yaratish muhim jihatlardan biridir. An'analarni yangicha o'zgarishlarga aylantirish zargarlik dizaynerlarining umumiy maqsadidir. Biroq bu o'zgarish faqat yangi materiallar, rang uyg'unligi yoki yangi uslublar bilan cheklanib qolmasligi kerak. Eng muhimi, bu o'zgarish foydalanuvchiga cheksiz imkoniyatlar olib kela oladimi shuni ta'minlashdir. Tashqi ko'rinishdagi innovatsiya esa zargarlik dizaynerlari uchun asosiy yo'nalishga aylanadi. Zargarlik buyumlari har doim o'zining go'zalligi, nafisligi va nafosatliligi bilan e'tiborni tortadi va butun dunyoda hayrat uyg'otadi. Ular dekorativ-amaliy san'at, badiiy ijod, hunarmandchilik va zamonaviy ishlab chiqarish elementlarini chambarchas bog'lab turadi. Zargarlik buyumlarini fraktallar asosida ishlab chiqish dizayn va san'atning yana bir ko'zga ko'rinarli janri hisoblanadi (2 - jadval).

1. Serpin Uchburchagi (Sierpinski Triangle) Fraktal modeli haqida Serpin uchburchagi – bu o'z ichiga cheksiz ko'p kichik uchburchaklar joylashtirilgan geometrik fraktaldir. Har bir yangi bosqichda asosiy uchburchak ichida yana kichik uchburchaklar hosil bo'ladi. Bu shakl simmetriya, takrorlanish va oddiylikdan murakkablikka o'tish tamoyillarini ajoyib tarzda ifodalaydi.

Issey Miyake tomonidan ishlab chiqilgan sumkalar (Baobao kolleksiyasi) ko'p qirrali, moslashuvchan va harakatlanadigan uchburchaklardan tashkil topgan bo'lib, serpin uchburchagi tamoyiliga asoslanadi.

Sammie Russell yaratgan aksessuarlar esa metallik ko'rinishga ega, murakkab uchburchak shakllar orqali yasalgan taqinchoqlardir. Ushbu dizaynlar zamonaviy texnologiya va fraktal geometriyaning uyg'unligidir.

Serpin uchburchagi o'z-o'zini takrorlovchi tizimlarning naqadar samarali va estetik bo'lishini ko'rsatadi. Kichik elementlardan murakkab struktura hosil qilish – bu zamonaviy dizayn va injiniringda ham keng qo'llaniladigan yondashuvdir.

2. Kox qor parchasi (Koch Snowflake)

Kox qor parchasi – matematik fraktallarning ilk namunalardan biri bo'lib, oddiy shakldan boshlab, har bir segmentni uch qismga bo'lib, o'rtaga kichik uchburchak qo'shish orqali yaratiladi. Natijada, cheksiz uzunlikdagi, lekin chegaralangan yuzaga ega shakl hosil bo'ladi.

Murakkab va nozik qor parchasi shaklidagi marjon va sirg'alar.

Nafisligi va tabiatdagi qor parchalari bilan o'xshashligi sababli sovg'alar va bayram aksessuarlari sifatida keng tarqalgan. Kox qor parchasi haqiqiy tabiiy shakllarning (masalan, qor kristallari) matematik modelidir. Zargarlikda uning qo'llanilishi orqali insonlar tabiiy estetikani matematik aniqlik bilan uyg'unlashtiradi.

3. Kox sirti (Koch Surface)

Kox sirti – Kox qor parchasi printsipini uch o'lchovli shaklga tatbiq etish orqali
yaratiladi. Natijada yuzasi cheksiz, lekin hajmi cheklangan shakl hosil bo'ladi.
Geometrik va murakkab teksturaga ega bo'lgan marjon va broshlar.
Asosan hajm va ko'p qirrali strukturalar orqali o'ziga xos futuristik ko'rinish
yaratish maqsadida ishlatiladi.

Bu shakl energetik jihatdan samarali tuzilmalarni modellashtirish uchun ham ishlatiladi. Zargarlikda esa u ko'p fazali shakllar orqali ko'zga tashlanadigan va dinamik ko'rinishga erishiladi.

4. Appolon gilami (Apollonian Gasket)

Appolon gilami bir doira ichiga yana va yana kichikroq doiralar chizish orqali hosil qilinadi. Bu shakl o'zaro bir-birini to'ldiruvchi murakkab simmetrik struktura hosil qiladi.

Kichik doiralar va murakkab naqshlardan iborat taqinchoqlar va broshlar. Aksessuarlarda ko'proq "kosmik" va "mistik" taassurot uyg'otadi. Appolon gilami tarmoqlanish va to'ldirish nazariyalarida muhim ahamiyatga ega.

Zargarlik dizaynida bu yo'nalish nafislik va mukammal tartibni aks ettiradi.

5. Xarter ajdari (Heighway Dragon)

Xarter ajdari o'z-o'zini takrorlovchi burilishli shakldir. U ko'plab burilmalardan iborat bo'lib, nihoyatda murakkab ko'rinishga ega [10].

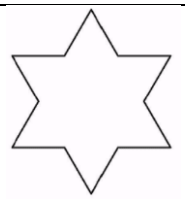
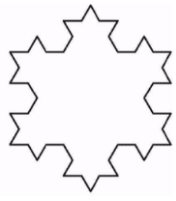
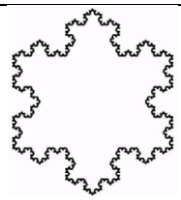
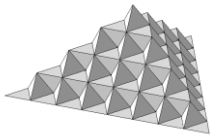
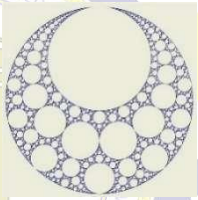
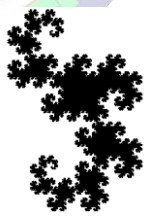
Fraktal shakldagi nozik va murakkab marjonlar.

O'zgaruvchanlik va harakat illyuziyasini beruvchi dizaynlar.

Xarter ajdari kvant fizikasi va kompyuter grafikalarida ham modellashtirish uchun qo'llaniladi.

Zargarlikda esa u murakkablik va o‘ziga xoslik timsoli sifatida ishlatiladi.

2-jadval

№	Fraktal modellar	Zargarlik buyumlari va aksessuarlar
1.		Issey Miyake Japan
		Sammie Russell
	Serpin uchburchagi	
2.	 	
	 Kox qor parchasi	
3.	 Kox sirti	
4.	 Appolon gilami	
5.	 Xarter ajdari	

Fraktallar – san’at va matematikani mukammal tarzda uyg‘unlashtiruvchi shakllardir. Ular yordamida yaratilgan zargarlik buyumlari nafislik, murakkablik va zamonaviylikni o‘zida mujassamlashtiradi. Fraktallar asosida yaratilgan aksessuarlar nafaqat ko‘zni quvontiradi, balki o‘zining ichki falsafasi bilan ham ajralib turadi – ularning har bir murakkab chizig‘i va shakli tabiatdagi mukammallik va tartibsizlik o‘rtasidagi nozik chegarani ifodalaydi.

III. Natijalar

So‘nggi yillarda zargarlik dizaynida yangilik yaratish va foydalanuvchi tajribasini boyitishga qaratilgan yondashuvlar orasida L-tizimlar keng e’tiborga tushmoqda. Bu tizimlar asosan modullik, o‘zgaruvchanlik

va ko‘p funksiyalilik prinsiplariga asoslanadi. Ushbu yondashuv orqali zargarlik buyumlari faqat estetik jihatdan emas, balki foydalanuvchining ehtiyojiga moslashuvchan dizayn elementi sifatida namoyon bo‘ladi.

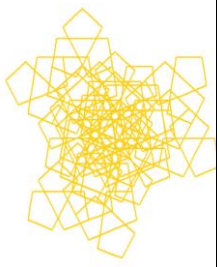
L-tizimlar, 1968 yilda Aristid Lindenmayer tomonidan ishlab chiqilgan bo‘lib, o‘simliklarning o‘sish jarayonlarini modellashtirish uchun mo‘ljallangan formal grammatik tizimdir. Ushbu tizimlar, **fraktal geometriya** asosida, o‘z-o‘zini takrorlovchi va murakkab geometrik shakllarni yaratishga imkon beradi. Bu xususiyatlari zargarlik dizaynida yangi, estetik jihatdan boy va murakkab naqshlarni yaratishda qo‘llaniladi [8].

LUO Ze-min tomonidan olib borilgan tadqiqotda, fraktal geometriyaning zargarlik dizayniga qo‘llanilishi o‘rganilgan. Tadqiqotda, o‘z-o‘zini takrorlovchi fraktal birliklar zargarlik buyumlarining asosiy elementlari sifatida ishlatilgan. Bu yondashuv, kompyuter yordamida zargarlik dizaynini yaratishda fraktal dasturlarni qo‘llash orqali yangi imkoniyatlar yaratadi [5].

Somlak Wannarumon tomonidan olib borilgan tadqiqotda, fraktal asosidagi foydalanuvchi markazli zargarlik dizayni uchun estetik evolyutsion algoritm ishlab chiqilgan. Ushbu algoritm, iteratsion funksiyalar tizimi (IFS) yordamida fraktallarni yaratadi va foydalanuvchi estetikasi asosida dizaynlarni baholaydi. Bu yondashuv, zargarlik dizaynida foydalanuvchi afzalliklarini hisobga olgan holda yangi dizaynlar yaratishga imkon beradi [7].

3-jadval

Fraktal kulonlarni loyihalash naqshlari va L-Tizimlariga asoslangan tenglamalar.

2.		axiom = -F-F-F-F rule: FF+F+-F angle = 120 number of iterations = 4
		axiom = -F-F-F-F rule: FF+F+-F angle = 80 number of iterations = 5
		axiom = -F-F-F-F rule: FF+F+-F angle = 120 number of iterations = 6
		axiom = -F-F-F-F rule: FF+F+-F angle = 60 number of iterations = 6
2.		axiom = F-F-F-F rule: FF+F+-F angle = 60 number of iterations = 3
		axiom = -F-F-F-F rule: FF+F+-F angle = 70 number of iterations = 5
		axiom = F rule: [[[[[+F]]--+F-FF+F+F++FF-][[F-]-+[F]+]-]] angle = 60 number of iterations = 4
		axiom = F rule: [[[[[+F]]--+F-FF+F+F++FF-][[F-]-+[F]+]-]] angle = 45 number of iterations = 5

3.		axiom = F rule: [+[F+]+F+[F]++[+[F-]-]---] angle = 150 number of iterations = 5 axiom = F rule: [+[F+]+F+[F]++[+[F-]-]---] angle = 72 number of iterations = 5 axiom = F rule: [FF+[F+]+F+[FF]++[+[F-]-]--] angle = 60 number of iterations = 5 axiom = F rule: [FF+[F+]+F+[FF]++[+[F-]-]--] angle = 90 number of iterations = 5
4.		axiom = F++F++F rule: -FF- angle = 30 number of iterations = 5 axiom = F rule: [F+F[-F+F angle = 30 number of iterations = 5 axiom = F+F+F+F+F+ rule: F+F--F+F-- angle = 20 number of iterations = 6

		axiom = F+F+F+F+F+ rule: F+F--F+F-- angle = 90 number of iterations = 5

L-tizimlar orqali yaratilgan zargarlik mahsulotlari, shuningdek, atmosferaviy va ekologik omillarga moslashuvchanlik ko'rsatishi mumkin. Ba'zi hollarda bu tizimlar zargarlik buyumining bir nechta funktsiyasini- masalan, brosh sifatida va marjon sifatida - birlashtirish imkonini beradi, bu esa dizayn samaradorligini oshiradi (1 - jadval).

Shu asosda aytish mumkinki, L-tizimlarni zargarlik dizayniga tatbiq etish-bu nafaqat tashqi ko'rinishdagi yangilanish, balki mahsulotning interaktivlik darajasini oshirish, barqarorlikni qo'llab-quvvatlash va iste'molchi bilan yanada chuqurroq aloqani shakllantirish uchun muhim dizayn strategiyasidir.

IV. Xulosa

Tabiatda uchraydigan ko'plab murakkab jarayonlar dastlab tartibsiz ko'ringan bo'lsa-da, chuqurroq kuzatish natijasida ularning o'ziga xos takroriyligi va strukturalari namoyon bo'ladi. Bunday hodisalar fraktallar deb yuritiladi va ular o'ziga o'xshashlik tamoyiliga asoslanadi. Fraktallar nafaqat biologiya va tabiiy fanlarda, balki sanoat jarayonlari hamda axborot texnologiyalarida ham keng uchraydi. Ayniqsa, zamonaviy kompyuter tizimlari va ma'lumotlar bazasini boshqarish tizimlarida fraktal yondashuvlarning qo'llanilishi yangi imkoniyatlarni ochmoqda.

Ilmiy tadqiqotlar shuni ko'rsatmoqdaki, fraktallarni qurish usullari yordamida ma'lumotlarni saqlash va izlashning samarali modellarini yaratish mumkin. Xususan, katta hajmli ma'lumotlar bazasi tizimlarida L-tizimlari yordamida fraktal ma'lumotlar bazalarini modellashtirish konsepsiyasi ishlab chiqilmoqda. Bu yondashuv nafaqat nazariy asos yaratadi, balki katta hajmdagi ma'lumotlarni tartibga solish, tezkor qayta ishlash va optimal qidiruv jarayonlarini tashkil etishda amaliy natijalar ham beradi.

Demak, fraktal tuzilmalar va L-tizimlari asosida yaratilgan model kelajakda katta hajmli ma'lumotlar bilan ishlashda poydevor bo'lib xizmat qilishi, shuningdek, axborot tizimlarida samaradorlik va moslashuvchanlikni ta'minlashda muhim omil bo'lib qolishi mumkin.

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FRAKTAL TUZILISHLI NAQSHLARNING MODEL VA ALGORITMLARINI L-TIZIMLARI USULIDA RAQAMLASHTIRISH

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Annotatsiya: ***Ushbu maqolada fraktallar tushunchasi va ularning mato naqshlarini yaratishda qo'llanilishi tahlil qilingan. To'qimachilik va yengil sanoatning ajralmas qismi bo'lgan jakkard gazlamalari va ularning xususiyatlari ifodalangan. Fraktallar tushunchasi va jakkard gazlamalariga raqamli ishlov berishda fraktal naqshlarni qo'llashning ahamiyati va afzalliklari keltirilgan. Xususan, matematik modellashtirishning Lindenmayer tizimlari (L-tizimlar) asosida naqshlarni generatsiya qilish o'rganilgan. Jakkard gazlamalari uchun qo'llash mumkin bo'lgan fraktal naqshlar L-tizimlar usuli asosida ishlab chiqilgan. FRACTAL PATTERN FOR JACQUARD dasturiy vositasi yordamida n ta iteratsiyaga ega fraktal naqshlar hosil qilingan.***

Kalit so'zlar: fraktal naqsh, jakkard gazlama, L-tizimlar usuli, egri chiziq, ajdarho egri chizig'i

I. KIRISH.

Fraktal geometriya - zamonaviy matematikadagi jadal rivojlanayotgan yo'nalishlardan biridir. Fraktal tuzilishli naqshlarga bo'lgan qiziqish ko'plab monografiyalar va o'quv qo'llanmalarda o'z ifodasini topgan. Fraktal geometriya va unga yaqin bo'lgan xaos nazariyasi oliy ta'lim tizimiga kirib bormoqda. Fraktal tuzilishli naqshlarni maktab va universitet matematikasi kursida ham o'rganilishi mumkin, bu esa kabi metodik maqolalarda tasdiqlanadi. Shuni ta'kidlash joizki, bugungi kunda fraktal geometriyaga bag'ishlangan o'nlab veb-saytlar mavjud bo'lib, xorijda kongresslar va konferensiyalar o'tkazilmoqda [4,9,15].

Manbalarda fraktallarning geometrik progressiya bilan bog'liqligi ko'rsatilgan hamda Kox qor parchasining xossalari o'rganilgan. Ushbu maqolada L-tizimlar yordamida fraktal tuzilishli naqshlarni qurishning universal algoritmi keltiriladi va ular bilan bog'liq matematik masalalar ko'rib chiqiladi.

L-tizimlar o'tgan asrning ikkinchi yarmida A. Lindermayerning ishlari natijasida paydo bo'lgan [12,18]. Dastlab, L-tizimlar dasturlash tillarini o'rganishda qo'llanilgan. Keyinchalik, kompyuter grafikasi jadal rivojlangach, L-tizimlar yordamida fraktal tuzilishli naqshlarni qurish mumkin bo'ldi. L-tizimlar fraktal tuzilishli naqshlarni yaratish va ularni kompyuter yordamida qurishda ulkan imkoniyatlar yaratadi. Fraktal tuzilishli naqshlarni L-tizimlar orqali tasvirlash "Chegaralarga ega bo'lmagani" sababli, ushbu mavzuga alohida qiziqqan har bir o'quvchi o'z "shaxsiy" fraktalini nol nuqtadan boshlab qurishi va uning matematik xossalarini o'rganishi mumkin [16,17].

Jakkard gazlamasi o'ziga xos tuzilishga ega bo'lgan to'qimachilik materiali bo'lib, unda turli rangli iplar asosida murakkab naqshlar yaratiladi. Bu gazlama naqshli matolarni ishlab chiqarish uchun maxsus Jakkard to'quv mashinasi yordamida ishlab chiqariladi. Fransuz ixtirochisi Jozeph-Marie Jakkard 1804 yilda jakkard to'quv mashinasini ixtiro qilib, to'qimachilikning naqshli tuzilishini yaratishga imkon bergan va to'qimachilik sanoatiga inqilobiy o'zgarishlar kiritgan [1]. Jakkard to'quv mashinasi keng imkoniyatlarga ega bo'lib, matoning har bir ipini alohida boshqaradi. Bu esa juda murakkab va detalga boy naqshlar yaratish imkonini beradi. Ranglarning ko'pligi va naqshlarning murakkabligi tufayli jakkard gazlamalari ko'plab rangli va geometrik tasvirlarni o'z ichiga olishi mumkin. Jakkard gazlamalarning jakkard brokadi, jakkard atlasi, jakkard shifoni kabi turlari mavjud bo'lib, ular turli sohalarda: pardalar, choyshablar, poyabzallar, kiyim-kechaklar ishlab chiqishda qo'llaniladi [2].

II. METODOLOGIYA VA NATIJALAR.

Fraktal tuzilishli naqshlarni grafik tarzda tasvirlash uchun biz "turtle-grafika" (turtle – toshbaqa) dan foydalanamiz. Kompyuter monitorida toshbaqaning harakatini (ya'ni fraktal qurilishini) aks ettiruvchi dasturlar Pyton muhiti orqali yozilgan. Uchta parametr bilan ishlaymiz: x, y va α. Bu yerda x va y - toshbaqaning koordinatalari, α esa u harakatlanishi kerak bo'lgan burchakni bildiradi [4,5].

Toshbaqa chapdan o'ngga o'qiladigan kodli so'z orqali beriladigan buyruqlarni "bajarishni biladi". Bu kodli so'z - L-tizim ishlovidan olingan natijadir va tarkibida turli harflar hamda belgilar bo'lishi mumkin. Quyida ishlatadigan belgilarni tavsiflaymiz:

F - iz chizish va bir qadam oldinga siljish;

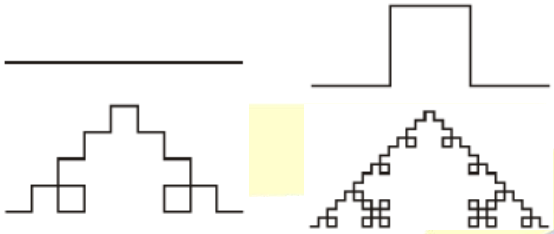
+, – - α burchakni θ miqdoriga oshirish (+) yoki kamaytirish (–).

Masalan, agar θ = π/2 bo'lsa, F+F+F+F so'zining grafik tasviri kvadratni hosil qiladi; agar θ = π/3 bo'lsa, F+F++F++F so'zining grafik tasviri teng tomonli uchburchakni beradi. Qadam uzunligi va burchak θ bo'yicha o'zgarish miqdori oldindan belgilanadi va toshbaqaning barcha harakatlari uchun o'zgarmas bo'lib qoladi. Agar boshlang'ich harakat yo'nalishi α (ya'ni x

o'qining musbat yo'nalishidan hisoblanadigan burchak) ko'rsatilmagan bo'lsa, unda α nolga teng deb olinadi [12].

Faraz qilaylik, τ – buyruqlar ketma-ketligi, (x_0, y_0, α_0) – toshbaqaning boshlang'ich holati, qadam uzunligi h va burchak θ – o'zgarmas qiymatlardir. Buyruqlar ketma-ketligi τ ga javoban toshbaqa chizadigan barcha chiziqlar yig'indisi τ ning toshbaqacha talqini deb ataladi. Odatda fraktal tuzilishli naqshlarni qurish jarayoni aksioma va generatsiya qoidasi bilan bog'liq bo'ladi.

Aksioma - bu fraktal tuzilishli naqshlar qurilishi boshlanadigan boshlang'ich obyekt, generatsiya qoidasi esa ushbu obyekt fraktal tuzilishli naqshlarni qurilish jarayonida qanday obyektga almashtirilishini ko'rsatadi [4,5]. Endi bir misolni ko'rib chiqamiz.



1-rasm. Fraktal tuzilishli naqshlar

L-tizimlar usuliga asosan 1-rasmdagi naqshlarning simvolik tuzilishi quyidagicha ifodalash mumkin.

Kirish	
Aksioma (boshlang'ich so'z):	'F'
Generatsiya (yaratish) qoidasi:	'F → F-F+F+F-F'
Boshlang'ich burchak (α):	0
Burilish burchagi (θ):	π/2

2-rasm. L-tizimlar usulida fraktal naqshni qurish jadvali

Faraz qilaylik, E_0 – birlik uzunlikdagi boshlang'ich kesma (aksioma).

Uning o'rta uchdan bir qismini olib tashlaymiz va 1-rasmda ko'rsatilgandek uchta yangi kesmani qo'shamiz. Hosil bo'lgan to'plamni E_1 deb ataymiz.

Ushbu jarayonni bir necha marta takrorlaymiz - har bir bosqichda mavjud kesmaning o'rta uchdan bir qismini olib tashlab, uning o'rniga uchta yangi kesma qo'shamiz.

n-bosqichdan so'ng hosil bo'lgan shaklni E_n deb belgilaymiz.

Intuitsiya orqali anglash mumkinki, $\{E_n\}$ ketma-ketligi E deb belgilanuvchi egri chiziqqa yaqinlashadi.

2. L-tizimlar tilida E egri chizig'ini qurishni jadval ko'rinishida ifodalaymiz (2-rasm).

Ushbu algoritmni tushuntirish uchun blok-sxemalardan foydalanamiz, chunki ular dasturlash tilini bilishni talab qilmaydi. 3-rasmda satr shakllantiriladi va fraktal tuzilishli naqshlarning mos iteratsiyasi quriladi.

Boshlang'ich shartlar:

Aksioma: W = "F"

Paydo qiluvchi qoida: newf = "F–F+F+F–F" (3.20-rasm)

Ishchi katak: T = " "

Burchak α: α = 0

Burilish burchagi θ:θ = π/2

Toshbaqa boshlang'ich nuqtada (x_0, y_0): x_0 = 100, y_0 = 300, qadam uzunligi h=20.

4-rasmda (x_0, y_0) nuqta 1-raqam bilan belgilanadi.

Faraz qilaylik, bizga E egri chizig'ining ikkinchi iteratsiyasi – E_2 ni qurish kerak. Satrni bir o'lchovli massiv deb hisoblaymiz. Masalan, agar

W="F+++F+F+F–F" bo'lsa, unda:

W[1] = "F",

W[2] = "+",

W[3] = "+",

…

W[10] = "–",

W[11] = "F".

Demak, boshlang'ich holatda:

T = " "

level = 2

W = "F"

len(W) = 1

Birinchi sikl bir marta bajariladi, T katagiga paydo qiluvchi qoida yoziladi:

T = "F–F+F+F–F"

Keyin sikl yopiladi va W katagiga T dagi qiymat yoziladi:

W = T = "F–F+F+F–F"

T yana bo'sh qiymatga o'rnatiladi: T = " "

level bir birlikka kamayadi: level = 2 – 1 = 1

Keyingi bosqich:

W = "F–F+F+F–F"

Endi sikl yana ishlaydi. Bu safar len(W) = 9 bo'lgani uchun u 9 marta bajariladi.

1- sikl: T = "F–F+F+F–F"

2- sikl: T = "F–F+F+F–F–"

3- sikl: T = "F–F+F+F–F–F–F+F+F–F"

... va hokazo.

9- sikl tugagach, T da quyidagi satr hosil bo'ladi:

T = "F–F+F+F–F–F–F+F+F–F+F–F+F+F–F+F–F+F+F–F+F–F"

So'ng T ning qiymati yana W ga yoziladi:

W = T

T yana bo'shatilib, T = " "

level yana kamayadi: level = 1 – 1 = 0

Shundan so'ng sikl to'xtaydi va 32.1a-rasmdagi algoritmi o'z ishini yakunlaydi. Endi E_2 egri chizig'ining ikkinchi iteratsiyasi 3-rasmdagi algoritm asosida quriladi.

Oddiy hisob-kitoblarga ko'ra, W o'zgaruvchisidagi belgilar soni 49 ga teng bo'ladi. Keyin (x_1, y_1) nuqta aniqlanadi (4-rasmda bu nuqta 2 bilan belgilangan):

$x_1 = x_0 + h \cdot \cos(0) = x_0 + h$

$y_1 = y_0 + h \cdot \sin(0) = y_0$

Shundan so'ng 1 va 2 nuqtalarni birlashtiruvchi kesma chiziladi (4-rasm).

Endi x_0 o'zgaruvchiga x_1 ning qiymati, y_0 o'zgaruvchiga esa y_1 ning qiymati tayinlanadi.

Shundan so'ng, ekran koordinatalarini hisobga olgan holda (koordinatalar boshi monitorning yuqori chap burchagida joylashgan), toshbaqa soat miliga qarshi 900 ga buriladi (ekran koordinatalariga ko'ra, bu burilish $\theta=\pi/2$ ga teng) (4-rasm).

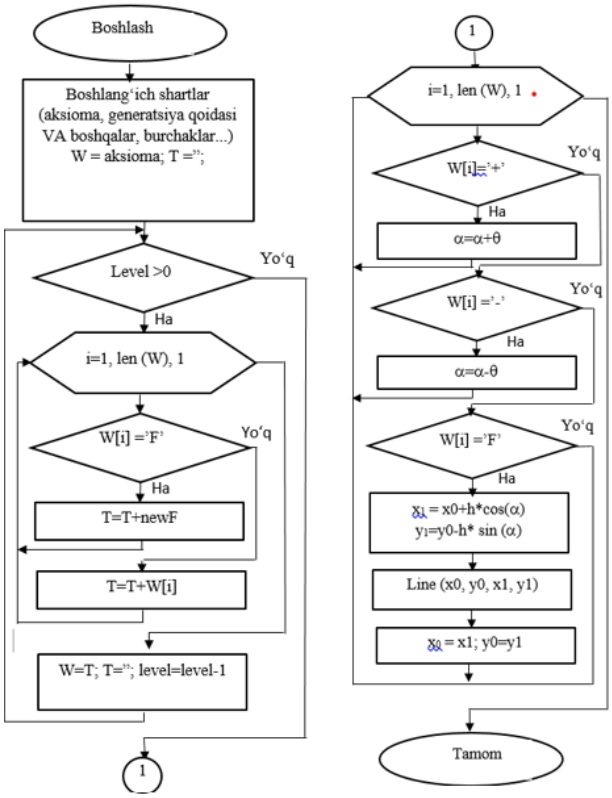
Keyin quyidagi nuqta belgilanadi:

(x_1, y_1)

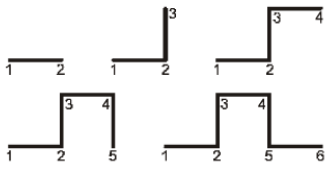
$x_1 = x_0 + h \bullet \cos(-\pi/2) = x_0,$

$y_1 = y_0 + h \bullet \sin(-\pi/2) = y_0 - h$

Bu nuqta bilan oldingi nuqtani bog'lovchi kesma chiziladi (4-rasm). Keyingi bosqichda toshbaqa soat mili yo'nalishida 90^0 ga buriladi va iteratsiyaning navbatdagi qismi quriladi.



3-rasm. L-tizimlar usulida fraktal naqshlarni qurish uchun blok-sxema



4-rasm. Nuqtalarni birlashtiruvchi kesmalari

Egri chiziq bo'ylab tartib raqamiga qarab harakatlanar ekanmiz, bu yerda egri chiziq uchlari ustidagi pastki indekslar - mos ravishda har bir uchning tartib raqamini bildiradi, ikkinchi iteratsiyadagi barcha 26 ta uchning koordinatalarini yozib chiqamiz (5-rasm).

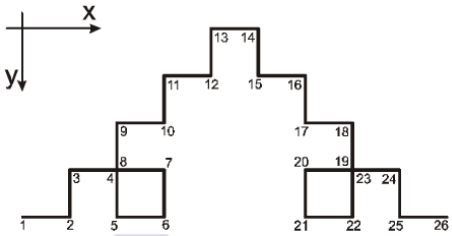
$(100, 300)_1 \rightarrow (120, 300)_2 \rightarrow (120, 280)_3 \rightarrow (140, 280)_4 \rightarrow (140, 300)_5 \rightarrow$
$\rightarrow (160, 300)_6 \rightarrow \rightarrow (160, 280)_7 \rightarrow (140, 280)_8 \rightarrow (140, 260)_9 \rightarrow$
$\rightarrow (160, 260)_{10} \rightarrow (160, 240)_{11} \rightarrow (180, 240)_{12} \rightarrow (180, 220)_{13} \rightarrow$
$\rightarrow (200, 220)_{14} \rightarrow (200, 240)_{15} \rightarrow (220, 240)_{16} \rightarrow (220, 260)_{17} \rightarrow$
$\rightarrow (240, 260)_{18} \rightarrow (240, 280)_{19} \rightarrow (220, 280)_{20} \rightarrow (220, 300)_{21} \rightarrow$
$\rightarrow (240, 300)_{22} \rightarrow (240, 280)_{23} \rightarrow (260, 280)_{24} \rightarrow (260, 300)_{25} \rightarrow (280, 300)_{26}.$

Egri chiziq ekran ko'rinadigan chegaradan chiqib ketmasligini kuzatamiz.

1-topshiriq. Boshlang'ich nuqta sifatida M(100, 300) ni qabul qilgan holda,

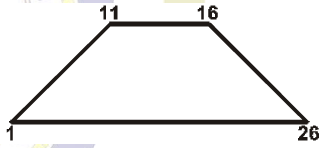
h=20 bo'lsa, E fraktalining uchinchi iteratsiyasi - E_3 dagi barcha uchlarning koordinatalarini yozib chiqing.

Ushbu algoritm foydalanuvchiga qulay bo'lgan istalgan dasturlash tilida yozilishi mumkin.



5-rasm. 26 ta nuqtalarni birlashtiruvchi kesma

Bunday fraktal tuzilishli naqshlarni qalam va chizg'ich yordamida qurish juda murakkab. Shunga qaramay, bu shakllar juda qiziqarli bo'lgan bir qator matematik masalalarni shakllantirish imkonini beradi [21,22]:



6-rasm. Teng yonli trapetsiya hosil bo'lish tasviri

1) Ikkinchi va uchinchi iteratsiyalardan hosil bo'lgan barcha kvadratlarning yuzasini toping; ikkinchi, uchinchi va n-iteratsiyalarning perimetrini hisoblang;

2) Ikkinchi iteratsiyaning diametrini aniqlang;

3) Ikkinchi va uchinchi iteratsiyalar nechta tugun (uch) nuqtaga ega ekanini toping;

4) Ikkinchi va uchinchi iteratsiyalar nechta o'z-o'zini kesib o'tuvchi tuggun (uch) nuqtalarga ega ekanini aniqlang;

5) Ikkinchi va uchinchi iteratsiyalar nechta bo'g'indan iboratligini aniqlang;

6) Ikkinchi iteratsiyaning diametri nima bilan teng?

7) 1, 11, 16, 26-uchlar orqali atrofida aylana o'tkazish mumkinmi?

1-masala yechimi qiyinchilik tug'dirmaydi. 1, 11, 16, 26-uchlarni tutashtiraylik. Natijada teng yonli trapetsiya hosil bo'ladi, uning atrofidan aylana o'tkazish mumkin (6-rasm).

Endi 1-masalani mustaqil ish sifatida murakkablashtiramiz:

2-masala. 6, 8, 9, 11, 16, 18, 23, 21-uchlar orqali bitta aylana o'tkazish mumkinmi?

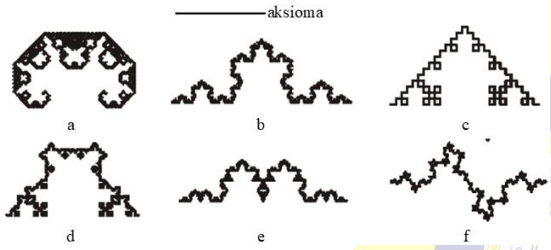
Har bir fraktal uchun MatLab muhitida alohida dastur yoziladi. Bizning dastur esa universaldir, ya'ni faqat

generatsiya (yaratish) qoidalarini o'zgartirish orqali kompyuter monitorida turli xil prefraktal egri chiziqlar hosil qilish mumkin (7-rasm, a–f).

Endi "oldraktal" atamasining ma'nosini tushuntiramiz: Fraktal tuzilishli naqshlar cheksiz iteratsiyalar jarayonida hosil bo'ladigan shakldir. Bunday egri chiziqni aniq tasvirlab bo'lmaydi. Oldfraktal esa cheklangan sondagi iteratsiyadan so'ng hosil bo'lgan egri chiziqdir.

7-rasmda tasvirlangan oldfraktallar uchun generatsiya qoidalari va burilish burchaklarini ko'rsatamiz. Avvalo, ushbu egri chiziqlarning har biri uchun aksioma 7-rasmda tasvirlangan kesmadir.

7 a-rasm: "–F+FF+F–", θ= π/4;
7 b-rasm: "F–F++F–F", θ=π/3
7 c-rasm: "F–F+F+F–F", θ=π/2 ;
7 d-rasm: "F– –F+F++F+F– –F", θ= π/4;
7 e-rasm: "F–F++F– –F++F–F", θ=π/3;
7 f-rasm: "F–F++FF– –F+F", θ=π/3.



7-rasm. Oldfraktal esa cheklangan sondagi iteratsiyadan so'ng hosil bo'lgan egri chiziqlar

III. XULOSA

Mazkur maqolada Xaytveyning ajdaho fraktal tuzilishli naqshlari va boshqa shu kabi fraktaltuzilishli naqshlarni qurish mumkin. qoidani ikkita yaratuvchi qoidaga almashtirib, dasturdagi boshqa barcha elementlarni o'zgartirmasdan turib, Gilbert egri chizig'i, Harter–Xaytveyning ajdaho fraktal tuzilishli naqshlari va boshqa shu kabi fractal tuzilishli naqshlarni qurish mumkin. L-tizimlar fraktal tuzilishli naqshlarni yaratish va ularni kompyuter yordamida qurishda ulkan imkoniyatlar yaratadi. Fraktal tuzilishli naqshlarni L-tizimlar orqali tasvirlash "Chegaralarga ega bo'lmagani" sababli, ushbu mavzuga alohida qiziqqan har bir o'quvchi o'z "shaxsiy" fraktalini nol nuqtadan boshlab qurishi va uning matematik xossalarini o'rganishi mumkin

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AXBOROT OQIMLARINING FRAKTAL XUSUSIYATLARINI ANIQLASH VA ULARNI TAHLIL QILISHNING SAMARALI USULLARI

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***Annotatsiya - u*shbu maqolada axborot oqimlarining fraktal xususiyatlarini tahlil qilish masalalari yoritilgan. Tadqiqotda R/S-tahlil, VT-tahlil, DFA (Detrended Fluctuation Analysis) va veyvlet-tahlillari, ularning qo‘llanish bosqichlari bayon etilgan. Ushbu usullar yordamida axborot oqimlari uchun Hurst koeffitsienti, fraktal o‘lcham va o‘z-o‘ziga o‘xshashlik darajalari aniqlanadi. Eksperimental qismda tematik axborot oqimlari, jumladan, onlayn OAV materiallari asosida fraktal parametrlar hisoblangan va grafik tahlillar keltirilgan. Natijalar shuni ko‘rsatadiki, fraktal usullar yordamida axborot oqimlarining tuzilishi va xususiyatlari yashirin qonuniyatlarni aniqlash, klaster tuzilmalarni tahlil qilish hamda dinamik jarayonlarni oldindan tadqiq qilish mumkin. Bu yondashuv axborot xavfsizligi, telekommunikatsiya va Big Data monitoringi kabi sohalarda samarali qo‘llaniladi.**

Kalit so’zlar: Fraktal tahlil, axborot oqimlari, Hurst koeffitsienti, R/S-tahlil, VT-tahlil.

CL. KIRISH

So‘nggi yillarda katta hajmli ma’lumotlarni real vaqt rejimida qayta ishlash dolzarb masalaga aylandi. Internet tarmoqlari, ijtimoiy tarmoqlar, telekommunikatsiya tizimlari va IoT qurilmalari orqali hosil bo‘layotgan ma’lumotlar oqimlari son jihatdan tez o‘smoqda. Bu oqimlarning asosiy xususiyatlari – o‘z-o‘ziga o‘xshashlik, murakkablik, nochiziqlilik va stoxastiklikdir. Bunday tizimlarni tahlil qilishda klassik statistik modellar yetarli emas.

Fraktal nazariya bu masalani yechishda samarali yondashuv hisoblanadi. Mandelbrot tomonidan ishlab chiqilgan fraktal geometriya tabiiy va texnik jarayonlardagi murakkablikni matematik tarzda izohlash imkonini beradi. Ma’lumki hozirgi vaqtda fraktallar kompyuter grafikasi, fizika va boshqa turli tabiiy fanlarda keng qo‘llanilmoqda, shuningdek radiotexnika, telekommunikatsiya, kino, televideniyada maxsus effektlar va vizualizatsiya elementlari sifatida ishlatilmoqda. Axborot oqimlarining fraktal tahlili darajasidan kelib chiqqan holda, geometrik fraktallarni qurish usullarini o‘rganish, matematik modelini ishlab chiqish, samarali hisoblash algoritmlari hamda dasturiy vositasini yaratish eng muhim masalalardan hisoblanadi.

Ko‘pgina eksperimentlar, axborot fazosi parametrlarini o‘lchash shuni tasdiqlaydiki, faktlarni statistik taqsimlarda axborot resurslari hajmining sezilarli darajada oshishida turli-tuman sermazmun qismlarida qabul qiluvchilar (masalan, manbaalar, amallar, mavzular) kabi o‘z shakllarini o‘zgartirmaydilar.

II. ASOSIY QISM

Axborot sohasidagi tahlilda fraktallar nazariyasini qo‘llanilishi informatika asosini tashkil qilib, qonuniyatlarda umumiy pozitsiyada qarash imkoniyatini beradi. Ma’lumki, ko‘pgina klaster analiz elementlarini oluvchi ko‘pgina yangi sinflarni avtomatik aniqlashda va hujjatlarni bu sinflarga ajratish imkoniyatini beradi.

Bunday klasterli strukturalar bilan axborot fazosining fraktal xususiyatlarining tabiati bir tomondan, rangli taqsimlanish paramatrlari bilan, boshqa tomondan esa, axborot klasterlari rivojlanish mexanizmga bog’liq. Yangi nashrning paydo bo‘lishi mavjud klasterlarning o‘lchovini paydo bo‘lishiga sabab bo‘ladi.

Fraktal xususiyatlar mos aniqlangan mavzularda nashr qilinayotgan hujjatlar axborotli web-sahifalari klasterlari uchun ham tavsiflangan. Bu klasterlar tematik hujjatlar tanlovi sifatida o‘ziga xos xususiyatlardagi hosil qiluvchi tuzilmalarni o‘zida ifodalaydi [1].

Web-soha topologiyasi va modellari tavsifi “web-bu fraktal” degan qarashni tasdiqlangan holda uning turli qism to‘plamlari deyarli bir xil. Tematik axborot oqimida xabarlar ketma-ketligi uchun xabarlar soni, haqiqiy dunyo hodisalari rezonanslari axborot manbalari (klasterlari) sonining ayrim darajalari bilan proporsianalligi S.Ivanov ishlarida ko‘rsatilgan.

Ma’lum bo‘lgan Pareto, Lotki, Bredforda qonunlari kabi ilmiy kommunikatsiyalarning barcha asosiy qonunlari aynan stoxastik fraktallar nazariyasi kommunikatsiyasi doirasida umumlashtirilgan bo‘lishi mumkin. An’anaviy ilmiy kommunikatsiyasida ham vaqti-vaqti bilan bir mavzu bo‘yicha internetdagi xabarlar to‘plami internatsional jarayonlar natijasida ro‘y beradigan dinamik klasterli tizimni ifodalaydi [2]. Turli nashrlar, to‘g‘ridan-to‘g‘ri havolalar va boshqalar bilan real hayotning bir xil hodisalarini ifodalaydigan bir tomonlama yoki bir xil sharhlar kabi jarayonlar qayta nashrlar sifatida tushuntiriladi.

Tematik axborot oqimiga mos keluvchi klasterli tizimda fraktalli o'lchovlar ma'lum vaqt mobaynida axborot dunyosini xabarlar bilan to'ldirish darajasini ko'rsatadi:

$$N_{nashr}(Et) = E^p N_k t^p, \qquad (1)$$

bu yerda N_{nashr} - axborot oqimida xabarlarning umumiy soni, tizim o'lchovi; N_k –O'lchov-klasterlar soni(tematik yoki manbaalar); p-axborot massivining fraktal o'lchovi; E - masshtablash koeffitsienti.

Xabarlar soni va klasterlar o'rtasida keltirilgan munosabatda to'plamni tashqi tomondan qaralganda masshtab o'zgarishida to'plamning ichki tuzilmasini saqlash xususiyati aniqlab beriladi. Real dunyodagi jarayonlarni bayon qiluvchi xabarlar, axborot oqimida tug'ilgan vaqtli qatorlarning xarakteristikasini o'rganish ularning dinamikasini bashoratlash yashirinkor relyatsiyani sikl va boshqalarni aniqlash imkonini beradi. O'zgarishlar qatorining fraktal xususiyatlarini tadqiq qilishda qo'llaniladigan asosiy algoritmlar tavsiflanadi. Grafiklarda ko'rsatish uchun haqiqiy sonli tajribalar natijalari keltirilgan. Tematik axborot oqimi nashrlari jadalligini ko'rsatuvchi qatorlarning fraktal xususiyatlari tadqiqotlar uchun baza sifatida internet tarmog'ida info Tream web-sahifalaridagi yangiliklarning kontinent-monitoring tizimdan foydalanilgan. Tadqiq qilinayotgan axborotlar oqimining mavzusi bu tizimga murojaat qilishda aniqlanadi. Tadqiqot uchun ma'lumotlar "Tushunchalar tug'ilish dinamikasi" muhitidagi interfeysdan olingan [3].

Tematik axborot oqimida online OAV xabarlaridan iborat 14069 hujjatlar massivlar qayta ishlangan. Bu massivlar "Kompyuter virusi" deb berilgan so'rovdagi kompyuter viruslari tematikasidagi nashrlar qaralgan [4]. Ma'lum vaqt davrni vaqt intervalida bo'lishida universal yondashuvlardan biri DFA usuliga asoslanadi. DFA (Detrended Flnetnation Analysis) – o'zgarishlar qatorini qayta ishlashning universal usulidir. DFA usuli signallarning statistik o'ziga o'xshashligini nomoyon qilishida ham qo'llanilib kelgan. Bu usul bir o'lchovli tasodifiy varianti hisoblanib, tadqiq qilinayotgan qatorda korrelyatsiyaning davomiylik samarlarini tadqiq qilish imkonini beradi [5]. DFA algoritmi doirasida aproksimatsiya aniqlangan diskretlash bilan tematik nashrlar soni vaqt qatorlarini tahlil qilishning ayrim usullarini batafsil ko'rib chiqamiz.

DFA usuli. O'ziga o'xshashlikni hududi (kuzatishlar online) o'lchoviga bog'liq chiziqli anproksimatsiya o'rta kvadratik xatolari taxlil qilinadi. O'zgarishlar qatori X_t , t€1, …N bo'lgan. Bu qatorning o'rtacha qiymatini

$$<x>=\frac{1}{N}\frac{\frac{N}{Z}}{k=1}X_k, \qquad (2)$$

bilan belgilaymiz.

Boshlang'ich qatordan orttirmalar qatorini ko'ramiz:

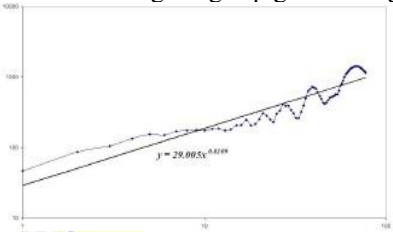
$$X_t = \frac{\frac{t}{Z}}{k=1}(X_k - < x >) \qquad (3)$$

Keyin X_t qator L uzunlikdagi vaqt oynalari bilan bo'lib chiziladi. Har bir oyna ichidagi X_j – qism to'plam, X_j, j=1, ... , J=NIL – kuzatish oynalari soni) $X_{k,j,l}$ qiymatlar bo'yicha ($L_{j,l}$) chiziqli approksimatsiyasidagi orttirmalar qatori nuqtalarida chetlanishlar hisoblab chiqiladi.

$$E_{(j,l)} = \sqrt{\frac{1}{L}}\sqrt{\frac{\frac{L}{Z}}{k=1}}(X_{K,L,J,} - L_{K,J,L}) = \sqrt{\frac{1}{L}}\sum_{k=1}^{L} 1\ \emptyset_{J,K,L}, \qquad (4)$$

bu yerda $L_{K,J,L}$–t=(j-1)L+K nuqtada chiziqli approksimatsiyaning lokal qiymati $|\varnothing_{K,J,L}|$ – lokal chiziqli approksimatsiyadagi XK,J,L elementning absolyut chetlanishi. So'ngra o'rtacha qiymat hisoblanadi: $F(L)=\frac{1}{y}\sum_{j=1}^{y} E(j,l)$ bundan so'ng ayrim α o'zgarmaslar uchun $F(\alpha) \infty < \alpha$ holat uchun statistik o'xshashlik borligi va tadqiq qilinayotgan o'zgarishlar qatorining bo'lish xarakteri haqida xulosalar qilindi [6].

Bu usul yuqoridagi so'rovlar orqali olingan nashrlar soni qiymatdagi qatorga qo'llanilgan. 1-rasmda ikkilik logarifmik kattalikda o'zlashtirish hududi uzunligining o'rtacha kvadratik xatosiga bog'liqligi ko'rsatilgan.



1-rasm. Kuzatishlar oynasi uzunligi

Kuzatishlar oynasi uzunligiga D chiziqli approksimatsiyasining o'rtacha kvadrat xatoning bog'liqligi chiziqliga D(k) bog'liqlikning yaqinligi.

R/S-tahlil (Rescaled Range Analysis)

R/S-tahlil shundan iboratki, uzoq muddatli bog'liqlikka ega tasodifiy jarayonlar uchun katta τ qiymatlarda quyidagi munosabat bajariladi:

$$\tau M\left[\frac{R(\tau)}{S(\tau)}\right] = (c \cdot \tau)^H \qquad (5)$$

bu yerda: c – o'zgarmas qiymat, R(τ) – yig'ilgan og'ishlar qatorining oralig'i $x^{cum}(t,\tau)$, S(τ) – boshlang'ich qatorning standart og'ishi.

Hurst koeffitsientini baholash bosqichlari:

1. *X(t), t=1,...,N* dan *x(t)=X(t+1) - X(t)* ga o'zgartiriladi;
2. Olingan qator τ uzunlikdagi A qatorga bo'linadi, $A \cdot \tau = 2^N$. Har bir seriya I_a deb belgilanadi, $a = 1,2,3, ...,A$. τ uzunlikdagi har bir I_a uchun quyidagicha hisoblanadi: $\bar{x}(\tau) = \frac{1}{\tau}\sum_{t=1}^{r} x(t)$;

3. Har biri uchun $I_a x^{cum}(t,\tau) = \sum_{i=1}^{t} x(i) - \overline{x}(\tau)$ uchun $x^{cum}(t,\tau)$ yig'ilgan seriyalarning diapazoni hisoblanadi;
4. Har biri uchun I_a yig'ilgan seriyalar oralig'i quyidagicha aniqlanadi:

$$R(\tau) = \max\left(x^{cum}(t,\tau)\right) - min\left(x^{cum}(t,\tau)\right),$$

$t = 1, \tau$, standart og'ish

$$S(t\tau) = \sqrt{\frac{1}{\tau-1}\sum_{t=1}^{\tau}(x(t) - \bar{x})^2} \qquad (6)$$

5. Normallashtirilgan oraliq har bir I_a uchun quyidagicha hisoblanadi: $\frac{R(\tau)}{S(\tau)}$

τ uchun o'rtacha qiymat $\frac{R(\tau)}{S(\tau)} = \frac{1}{A}\sum_{a=1}^{A}\frac{R_a(\tau)}{S_a(\tau)}$

6. τ qiymati keyingi yuqori qiymatga oshiriladi. 1–6 bosqichlar $\tau = N$ gacha takrorlanadi

7. *log(R/S)* ning *log*(τ) ga bog'liqligi uchun oddiy eng kichik kvadratlar usuli yordamida chiziqli regressiya quriladi. Hosil bo'lgan chiziqning tangensi Hurst koeffitsientiga teng bo'ladi.

VT tahlil

VT-tahlil o'z-o'ziga o'xshash jarayon X(t) uchun yig'ilgan vaqt qatori x^m tarqalishiga asoslanadi. Katta m qiymatlari uchun: $Var[x^m] = \frac{Var[x]}{(c \cdot m)^{\beta}}$

Hurst ko'rsatkichini (Hurst exponent) baholash bosqichlari:

1. *X(t), t = 1, ..., N* dan *x(t) = X(t+1) – X(t)* ga o'tkazish.
2. Olingan qatorlar eng kichik *ΔT* agregatsiya darajasida yig'iladi. Bu qatorlar *m* elementlardan iborat: x^m *= {x(ΔT), x(2ΔT), ..., x(mΔT)}.*
3. Olingan qatorlar uchun namunaviy dispersiyani hisoblash:
   $\mathrm{Var}[x^{(m)}] = \frac{1}{m-1}\sum_{t=1}^{m}(x(t) - \bar{x})^2$
4. Agregatsiya darajasini ikki barobarga oshirish *ΔT = 2ΔT.* Olingan qatorlar uchun 1–3 bosqichlar qayta bajariladi.
5. *log[Var(x)]* ning *log(m)* ga bog'liqligi uchun oddiy eng kichik kvadratlar metodi yordamida chiziqli regressiya quriladi.
   Chiziqning tangensi *β*. Hurst ko'rsatkichi quyidagicha topiladi: $H = 1 - \frac{\beta}{2}$.

Veyvlet – tahlil

Veyvlet tahlilining asosi o'ziga xos xususiyatlarga ega bo'lgan bazis funksiyalari chiziqli almashtirishlarning muhum turini ifodalaydigan Veyvlet – almashtirishlari hisoblanadi.

Veyvlet deb qandaydir nuqtaning unchalik kata bo'lmagan, atrofida to'plangan va undan ham chastotali sohada uzoqlashgan sari nolga kamayuvchi funksiyaga aytiladi [9].

Turli xususiyatlarga ega bo'lgan turli xil Veyvlet majmuida bu bilan birga barcha Veyvletlar vaqt o'qida integral tajribalari bilan qisqa to'lqinli paketlar ko'rinishiga ega bo'ladi. Ko'chish ya'ni vaqt bo'yicha tanlangan sxemani siljishi Veyvlet almashtirishlarning asosi shundan iboratki aloxida oraliqda kuzatish oynasi deb ataluvchi vaqtli qatorga bo'lishidir ularning har bir turli moslanuvchan ayrim Veyvletlarning turlicha ko'rinishlaridan tadqiqot ma'lumotlari ikkita qonuni bir-biriga yaqinlashuvchi ma'lumotlarning skalyar hisoblanishi bajariladi. Veyvelt asoslantirish boshlang'ich qatorni ifodalaydi [7].

Ular 2-o'zgarivchanli bo'ladi. Vaqt va chastotalari shunig uchun 3-o'zgarivchi simmetriya. Bu berilgan mashtabni Veyvletlarga almashtirish nuqtadagi jaroyonlarning qanchalik to'g'riligini veyvet ko'rinishidagi berilgan nuqtalar atrofida tahlili bog'liqliklar ko'rinishi qanchalik yaqin bo'lsa shunchalik katta absolyut qiymatlarni qabul qiladi.

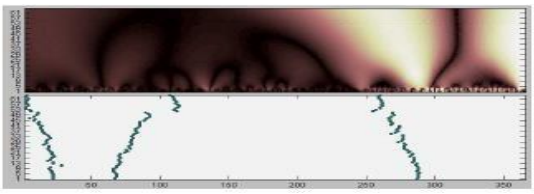
Veyvletlarni qo'llash texnologiyasi turli va "sochilishlari" turli vaqt ichida muhim ko'rsatgichlari qiymatlarini tez o'zgarishining, xususan web sohasini nashrini aniqlash imkonini beradi. Bunday sikllarni yuzaga kelishi momentlari hamda dinamik davrlarni keyin tebranishlari momentlari aniqlanadi. Qaralayotgan vaqt o'z navbatida bu egri chiziq turli o'lchovlar amplitudasi garmonik tebranishlar yig'indisi ajratiladi, shundan so'ng hosil bo'lgan sxema nuqtalar mos koeffitsientlari miqdoriga bog'liq ravishda bo'ladi.

Ma'lumki bir necha turli tasvirlar kombinatsiyasi unchalik murakkab shaklga ega bo'lishi mumkin, ularni analitik jihatdan aniqlab bo'lmaydi. Chastotalarning ayrim uzluksiz to'plamida Veyvlet almashtirishlar koeffitsienti qiymat uchun amalga oshiruvchi davri o'zgarishlari katta bo'lmagan qiymatlarga erishuvchi o'zgarishlar vaqt o'qidagi nuqtalarda joylashadi [8].

Boshqa muhim ko'rsatgich davriy tebranishlarga bog'liq bo'lmagan vaqt qatori dinamikasi ifodalangan tendensiya hisoblanadi.

Vaqtli qatorni tahlil qilishda hisobga olish zarur bo'lsa yana bir muhim omil xususiyati hisoblanadi, ya'ni boshlang'ich qator xaraktiristikasiga o'zgarishlar birdan sakragan shakllari kabi lokal xususiyatlar tasodifiy bo'lishi kabi tizimli xarakter ham bo'lish mumkin [10].

2-rasmda keltirilgan siklogrammada yuqorida qaralgan jaroyonga mos vaqt qatorini uzluksiz veyvlet tahlil natijalari berilgan Keltirilgan misol shuni ko'rsatdiki Veyvlt – tahlili o'rganilayotgan qatorda aniqlanishigina emas balki qator elementlarinining katta bo'lmagan absolut qiymatlariga nisbattan yashiringan chegaraviy qiymatni ham yopish mumkun. Masalan skeltonda faqatgina 250-kunning kattaroq qiymatlarini belgilanmasdan noaniq 25- va 75- kungi ekstirimumi ko'rsatilgan.



2-rasm. Veyvlet-tahlil natijasi

Veyvlet-tahlil natijasi (uzluksiz Veyvlet-almashtirishlar): balanddan Veyvlet- skelogrammasi; pasda-lokol maksimumlari (ekeloton) chiziqlari. Shubhasiz moliyaviy-iqtisodiy faktor jamot jaroyonida bilvosita tasvirlarga ega. 2.12-rasmda 2008 yil moboynida banklarda naqt AQSH dollori savdo kurslar uning o'zgarishi dinamikasi keltirilgan.

Natijalar va muhokamalar

Eksperimental natijalar shuni ko'rsatadiki, R/S tahlil va veyvlet tahlil qisqa vaqt qatorlari uchun ancha aniq natija beradi. DFA esa katta uzunlikdagi qatorlarda yuqori aniqlikka ega. VT tahlil esa ayrim hollarda past baholashni ko'rsatadi. Shu asosda, turli metodlarning kombinatsiyasidan foydalanish eng maqbul yechim sifatida taklif qilinadi.

Hurst koeffitsientini ishlab chiqarishning turli usullariga qiyosiy tahlil o'tkazildi. Natijalar shuni ko'rsatadiki, harakatlarda siljishlar mavjud. Har bir usul uchun siljish darajasi haqiqiy o'xshashlik darajasi va qator darajaga bog'liq. DFA-tahlil eng kichik siljishlarga ega.

Fraktal tahlil usullarining dasturiy ta'minoti va siljishlarini qiyoslash shuni ko'rsatadiki, R/S-tahlil Hurst koeffitsientini qisqa vaqt ichida, qoniqarli aniqlik bilan, dastlabki qatorlarni chuqur o'rganmasdan turib oladi va turli texnik hamda axborot tizimlarida real rejimda muhim jarayonlarni tahlil qilishda qo'llanishi mumkin.

Tajriba uchun "Kompyuter virusi" mavzusida 14069 ta hujjat tahlil qilindi DFA usuli yordamida vaqt qatorining o'ziga o'xshashlik darajasi va fraktal o'lchovi aniqlangan.

1-jadval. Hurst koeffitsienti baholash metodlarining solishtirma natijalari

Usul	Standart og'ish	Hisoblash vaqti	Xususiyatlari
DFA	0,042	1.00	Yuqori aniqlik
VT-tahlil	0,059	0,076	Qisqa qatorlarda ishonchsiz
Veyvlet	0,021	0,026	Eng aniq natija beradi
R/S-tahlil	0,028–0,076	0,075	Tezkor

Natijalar shuni ko'rsatdiki:

- R/S-tahlil real vaqt tizimlarida tezkor natija beradi.
- DFA usuli trendlarni bartaraf etishda samarali.

Veyvlet tahlili eng kichik og'ishga ega bo'lib, murakkab oqimlarni chuqur tahlil qilish imkonini beradi.

CLI. XULOSA

Maqolada axborot oqimlarining fraktal xususiyatlarini tahlil qilishning nazariy va amaliy usullari ko'rib chiqildi. Hurst koeffitsienti asosidagi baholashlar axborot oqimlarining o'zgaruvchan dinamikasini bashorat qilishda samarali ekanligi isbotlandi. Taklif etilgan yondashuvlar kelgusida real vaqt monitoring tizimlarida qo'llanilishi mumkin.

Maqolada axborot oqimlarining fraktal xususiyatlari nazariy va amaliy jihatdan o'rganildi. R/S, DFA, VT va veyvlet metodlari solishtirildi. Amaliy eksperimentlar natijasida fraktal metodlar axborot oqimlarining yashirin tuzilishini ochib berishi va ularning dinamikasini prognozlash imkoniyatini yaratishi isbotlandi.

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KATTA MA'LUMOTLARNI FRAKTAL RAQAMLASHTIRISH

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Annotatsiya: ***Maqolada katta ma'lumotlarni raqamli modellashtirishda fraktal yondashuvlardan foydalanish imkoniyatlari tahlil qilinadi. L-tizimlar va iteratsion funksiyalar tizimi (IFS) asosida ishlab chiqilgan algoritmlar yordamida ma'lumotlarning rekursiv va tarmoqlangan strukturasini samarali tashkil qilish imkoniyatlari ko'rsatib beriladi. Shuningdek, fraktal o'lchov, simmetriya, vizualizatsiya va tasvirlarni qayta ishlash texnologiyalarining nazariy va amaliy jihatlari yoritiladi.***

Kalit so'zlar: ***Fraktal, fraktal raqamlashtirish, katta ma'lumotlar, L-tizimlar, IFS, algoritm, raqamli modellashtirish, ma'lumotlar bazasi, siqish, vizualizatsiya.***

I.Kirish

So'nggi yillarda dunyoda yaratilayotgan va yig'ilayotgan ma'lumotlar hajmi mislsiz darajada ortib bormoqda. Turli tashkilotlar, davlat idoralari, ilmiy markazlar, ijtimoiy tarmoqlar va internet xizmatlari har kuni terabaytlab ma'lumotlarni hosil qilmoqda. Ushbu jarayonni ko'pincha "katta ma'lumotlar" (Big Data) tushunchasi bilan ifodalaymiz. Katta ma'lumotlar o'zining hajmi (volume), turfa xilligi (variety), tezligi (velocity) va ishonchliligi (veracity) bilan ajralib turadi. Shuning uchun ularni qayta ishlash va tahlil qilishda an'anaviy yondashuvlar ko'plab hollarda yetarli bo'lmay qolmoqda.

Mazkur muammoni hal qilish uchun zamonaviy matematik va algoritmik raqamlashtirish usullari talab etiladi. Shulardan biri sifatida fraktal yondashuv katta e'tiborga sazovor. Fraktallar - bu o'ziga-o'zi o'xshash, rekursiv tarzda hosil bo'ladigan geometrik shakllar bo'lib, murakkab tizimlarning ichki tuzilishini modellashtirishda keng qo'llaniladi. Fraktal modellashtirish katta ma'lumotlarning murakkab, ko'p qatlamli va tarmoqlangan tuzilishini matematik formulalar yordamida ifodalash imkonini beradi.

Fraktal usullarning asosiy afzalligi shundaki, ular:

- ma'lumotlarning ichki tartibi va yashirin qonuniyatlarini ochib beradi;
- rekursiv strukturalarni samarali tashkil etadi;
- katta ma'lumotlarni siqish va vizuallashtirishda yuqori natijalar beradi.

Ayniqsa, L-tizimlar va iteratsion funksiyalar tizimi (IFS-Iterated Function Systems) asosidagi algoritmlar katta ma'lumotlarni raqamli modellashtirishda alohida o'rin tutadi. L-tizimlar dastlab biologik modellarni (masalan, daraxtlar, o'simliklarning o'sish jarayonlari, odamlar tuzilishini) tasvirlash uchun ishlab chiqilgan bo'lsa-da, hozirgi kunda ular ma'lumotlar bazasi strukturalarini rekursiv tarzda loyihalashda qo'llanmoqda. IFS esa tasvirlarni fraktal kodlash, siqish va optimallashtirish jarayonida yuqori samaradorlik ko'rsatmoqda.

Shu bois, katta ma'lumotlar uchun fraktal raqamli algoritmlarni ishlab chiqish va ularni amaliyotga tatbiq etish bugungi kunda dolzarb ilmiy va amaliy muammo hisoblanadi. Ushbu maqolada katta ma'lumotlarni fraktal usullar asosida raqamlashtirishning nazariy asoslari, L-tizimlar va IFS usullarining imkoniyatlari, shuningdek, ularning ma'lumotlar bazasi va tasvirlarni qayta ishlashdagi qo'llanishlari yoritiladi.

II. Metodologiya

Tadqiqotda katta ma'lumotlarni fraktal usullar yordamida raqamlashtirish uchun ikki asosiy yondashuv tanlandi: L-tizimlar va IFS.

L-tizimlar biologik jarayonlarni modellashtirish uchun ishlab chiqilgan bo'lib, ular rekursiv qoidalar asosida murakkab shakllarni yaratadi. Bu usul yordamida daraxt, o'simlik va ierarxik tuzilmalarni modellashtirish mumkin. Shuningdek, ma'lumotlar bazasi sxemalarini avtomatik qurishda ham qo'llanildi.

IFS esa qisqaruvchi matematik funksiyalar majmuasiga asoslangan. U grafik tasvirlarni fraktal tarzda siqish, kodlash va qayta ishlash imkonini beradi.

Amaliyotda fraktal naqshlarni yaratish va vizuallashtirish uchun Python dasturlash tili, grafiklarni chizishda Matplotlib kutubxonasi, ma'lumotlarni saqlash va tahlil qilishda esa SQL ma'lumotlar bazasidan foydalanildi.

Metodologiya bosqichlari quyidagicha amalga oshirildi:

- Katta ma'lumotlar xususiyatlari o'rganildi.

Fraktal raqamlashtirish uchun matematik model tanlandi.

- L–tizimlar va IFS algoritmlari asosida

dasturiy modellar yaratildi.

- Ularning samaradorligi tajribalar orqali tekshirildi.

Natijalar. Tadqiqot davomida fraktal yondashuvlarning katta ma'lumotlar bilan ishlashdagi afzalliklari aniqlab chiqildi.

1. Fraktal o'lchov yordamida ma'lumotlarning murakkabligi va ichki tartibi ko'rsatib berildi. Bu yondashuv katta ma'lumotlarni tartiblash va tahlil qilishda samarali bo'ldi.

2. L-tizimlar asosida qurilgan model ma'lumotlar bazasi sxemasini avtomatik yaratish imkonini berdi. Bu usul rekursiv va tarmoqlangan strukturalarni ko'rsatishda qulay natija berdi [2].

3. IFS algoritmlari tasvirlarni siqishda samarali ishladi. Sinov natijalariga ko'ra, grafik fayllarni hajmini kamaytirish bilan birga, ularning sifatini saqlab qolish mumkin bo'ldi.

4. Fraktal usullar yordamida ma'lumotlarni vizuallashtirish qulaylashdi. Katta ma'lumotlar grafik ko'rinishda tartibli va tushunarli ifodalandi.

Umuman olganda, fraktal algoritmlar katta ma'lumotlarni modellashtirishda an'anaviy usullarga nisbatan samaraliroq natija berdi.

III. Muhokama

Fraktal modellashtirishning asosiy afzalligi – ularning masshtabdan mustaqilligi va o'ziga-o'zi o'xshashlik xususiyatidir. Ushbu xususiyat tufayli ma'lumotlarning ichki murakkablik darajasi aniqroq ko'rinadi va murakkab tizimlarning yashirin naqshlarini aniqlash mumkin bo'ladi. Masalan, biologik tuzilmalar, daraxtsimon jarayonlar va shahar infratuzilmasining rivojlanish dinamikasi fraktal modellar orqali tabiiy shaklda tasvirlanadi.

L-tizimlar yordamida biologik va ierarxik jarayonlarni samarali modellashtirish mumkin. Bu usul daraxtlar, o'simliklar yoki ijtimoiy tizimlardagi bo'linish jarayonlarini oddiy qoidalarga asoslangan holda ifodalashga imkon beradi. IFS algoritmlari esa grafik ma'lumotlarni siqish, tasvirlarni qayta tiklash imkonini beradi.

Fraktal algoritmlarni amaliyotga tatbiq etishda ayrim cheklovlar ham mavjud:

- Ularning samarali ishlashi ko'pincha yuqori hisoblash quvvatini talab qiladi.

- Real ma'lumotlar bilan ishlashda fraktal modelni moslashtirish va sozlash jarayoni murakkab bo'lishi mumkin.

Fraktal algoritmlarning natijalari ba'zida ortiqcha murakkablik keltirib chiqarishi mumkin, shu sababli ularni qo'llash sohasiga moslashtirish muhim hisoblanadi. L-tizimlar yordamida biologik va ierarxik jarayonlar aniq modellashtirilsa, IFS algoritmlari grafik ma'lumotlarni siqish va qayta ishlashda katta ustunlik beradi.

1968 yili Aristidom Lindenmayer (U ma'lumoti bo'yicha biolog) tomonidan ishlab chiqilgan L-tizimlar uslubi geometrik fraktallarni qurishda eng oddiy hisoblanadi. Lindenmayer tabiatning murakkab obyektlarini bir nechta qoidalar hamda oddiy tashkil etuvchilar yordami bilan ifodalash jarayonlari usulini taklif qilgan. L-tizimlar rasmiy tillarni o'rganishda kiritilgan, shuningdek, undan seleksiyaning biologik modellarini ishlab chiqishda foydalangan. Bunda bo'g'imlar qoidalariga tayanilgan va simvolli satrlarga almashtirilgan aniq rasmiy grammatikadan foydalangan.

Elektron hisoblash mashinalarining yaratilishi va rivojlanishi o'z navbatida L-tizimlarni kompyuter grafikasida qo'llash mumkinligi tadqiq etdi. Bu tizimlar yordamida o'ziga o'xshash tuzilishlardan iborat turli xildagi fraktallarni chizish juda qulay ekan. Va albatta L-tizimlar geometrik fraktallarning cheksiz ko'rinishlarini yaratishga yo'l ochadi, kompyuter grafikasida fraktal modellar qurish uchun ulardan keng foydalanishga sababchi bo'lib xizmat qiladi.

L-tizimlarni qo'llab qo'yidagiga ega bo'lish mumkin. Umumiy qabul qilingan belgilashlarda L-tizimlar qanaqa kodlanadi: oldinga harakat F harfi bilan belgilanadi (Forward-oldinga), soat strelkasi bo'yicha burilishni "+" belgilanadi, teskari yo'nalishni esa "-" bilan, chizmasdan orqaga qaytishni B (Back-orqaga) harfi bilan belgilanadi. Qayerga qaytish nuqtasi "[" bilan belgilanadi, qaerdan qaytish nuqtasi esa "]" bilan belgilanadi.

L-tizimlar tatbiqi uchun qism tizimlari sifatida Turtle (tashbaqa algoritmi) grafika deb ataluvchi tizimlar qo'llaniladi. Bunda tashbaqa nuqtasi ekran bo'yicha, diskret qadamlar bilan qoidadagi kabi o'z izini chizib harakatlanadi va yoki kerak bo'lsa chizmasdan ko'chadi.

1-misol sifatida Tupbutoqning (1-rasm) uchun boshqaruvchi qator qurishni qaraymiz L-tizimlarda qaraymiz:

Aksioma: F

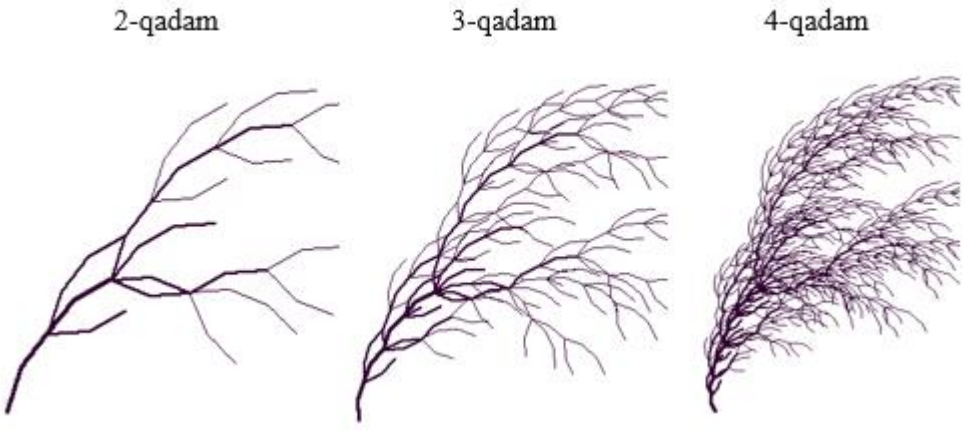
Qoida: F= -F+F+[+F-F-]-[-F+F+F]

Burchak β=1800/8.

0-qadam: -F+F+[+F-F-]-[-F+F+F];

1-qadam:--F+F+[+F-F-]-[-F+F+F]+-F+F+[+F-F-]-[-F+F+F]+ [-F+F+[+F-F-]-[-F+F+F]-

F+F+[+F-F-]-[-F+F+F]-]-[- -F+F+[+F-F-]-[-F+F+F]+ -F+F+[+F-F-]-[-F+F+F]+ -F+F+[+F-F-]-[-F+F+F] va h.k.



1-Rasm. L-tizimlar usuli yordamida hosil qilingan to'pbutoq tasviri

Bunday to'plamlarning tasviri aniq chizilgan chegaralarga ega bo'lmaydi.

Fraktallarni matematik modelini qurishning analitik usuli. Muntazam ko'pburchaklardan iborat fraktallarning analitik tarzda ishlab chiqarilgan matematik talqini quyidagicha bo'ladi. Avvalo muntazam ko'pyoqning asosiy geometrik elementlari talqin qilib olinadi, ya'ni M(x0,y0) - muntazam ko'pburchakka tashqi chizilgan aylananing markazining koordinatalari; R - muntazam ko'pburchakka tashqi chizilgan aylananing radiusi; L - radiusning kattalashtirish (yoki kichiklashishi); α - boshlang'ich burchak; n - tomonlar soni; S - rekursiyalar soni (yoki qadam). U holda umumiy formulaning ko'rinishi quyidagicha bo'ladi:

$$FR_1 = \sum_{j=1}^{n}\left(\sum_{i=1}^{n} M_i^j\left(x_0 + R\cos\left(\alpha + \frac{i\times 360}{n}\right)\right),\left(y_0 + R\sin\left(\alpha + \frac{i\times 360}{n}\right)\right)\right).$$

$$S = S - 1; \quad R = R / L.$$

Daraxt shaklidagi fraktallarni qurish uchun algoritmi quyidagicha.

M(x0,y0) – boshlang'ich nuqtaning koordinatalari; A – boshlang'ich olingan chiziqning uzunligi; α – boshlang'ich burchak; β –yoy (davomiylik yoyi); ns – boshlang'ich chiziqlar soni; nsa – chiziqlar sonining ortib borishi; k – uzunlikning kamayishi (yoki ortishi); S – rekursiyalar soni (yoki qadam).

U holda umumiy formulaning ko'rinishi quyidagicha bo'ladi:

$$FR_2 = \sum_{i=1}^{n}\left(\sum_{j=1}^{nc} N_j\left(x_0 + A\cos(\alpha)\right),\left(y_0 - A\sin(\alpha)\right)\right).$$

$$A = A\times k; \quad nc = nc + nca;$$

$$\alpha = \alpha + \frac{(360-\beta)}{2} - \frac{(180+\beta\times i)}{nc}.$$

Fraktallar tuzilishini hosil qilishning oddiy vositalaridan hisoblangan yana bir usul IFSdir. 1980-yillarning o'rtalarida paydo bo'lgan. IFS qisiluvchi affin almashtirishlar to'plamidir. Ma'lumki affin almashtirishlar masshtablashtirish, burish va parallel ko'chirishni o'z ichiga oladi. Agar masshtablashtirish koeffitsienti < 1 bo'lsa, affin almashtirish qisiluvchan hisoblanadi [10].

Bunday to'plamlarning tasviri aniq chizilgan chegeralarga ega bo'lmaydi. Fraktallarning o'ziga xos xususiyati shundan iboratki, tasvirning eng kichik bo'lagi ham oxir oqibat butinligicha o'zini ifodalaydi. Fraktallarning bu xususiyatiga ko'ra ma'lumotlarni fraktal qisishga asos solingan.

IFS bir nechta fiksirlangan funksiyalar tizimini o'zida ifodalaydi. Eng oddiy IFS tekislikning affin almashtirishdan tashkil topgan:

X' = A*X + B*Y + C, Y' = D*X + E*Y + F.

Fraktallarning o'ziga xos xususiyati shundan iboratki, tasvirning eng kichik bo'lagi ham oxir oqibat butinligicha o'zini ifodalaydi, ayniqsa bu samarani Jyulia to'plami misolida kuzatish mumkin.

Fraktallarning bu xususiyatiga ko'ra ma'lumotlarni fraktal qisishga asos solingan.

IFS bir nechta fiksirlangan funksiyalar tizimini o'zida ifodalaydi. Eng oddiy IFS tekislikning affin almashtirishdan tashkil topgan:

$$X' = A*X + B*Y + C,$$
$$Y' = D*X + E*Y + F.$$

1988 yili amerikalik taniqli mutaxassislar Barnsli va Sloan grafik ma'lumotlarni qisish va saqlash uchun dinamik tizimlar nazariyasiga asoslangan mulohazali fikrlarni taklif etadilar. Ular o'z uslublarini axborotlarni fraktal qisish uslubi deb nomlaydilar. Bunday nomning kelib chiqishi bu uslubdan paydo bo'luvchi geometrik shakllar bilan bog'liqdir.

Barnsli va Sloan ushbu fikrlarga asoslanib axborotlarni 500-1000 marotoba qisishga imkoniyat beruvchi algoritm yaratdilar. Buni qisqacha quyidagi ko'rinishda bayon etish mumkin. Tasvir bir nechta oddiy almashtirishlar bilan kodlanadi, ya'ni bu almashtirishlarning koeffitsientlari bizning affin holatda A, V, S, D, E, F lardan iborat Masalan, birorta tasvirni ikkita affin almashtirish bilan kodlansa, ularni 12 ta koeffitsientlar yordamida bir qiymatli aniqlanadi. Agar boshlang'ich nuqta X = 0, Y = 0 deb olinsa va iteratsion jarayon qo'llanilsa, unda birinchi iteratsiyadan so'ng 2ta, ikkinchi iteratsiyadan so'ng 4ta, uchinchi iteratsiyadan so'ng 8ta, to'rtinchi iteratsiyadan so'ng 16 ta va h.k. bo'ladi. Bir necha iteratsiyalardan so'ng olingan nuqtalar to'plami kodlangan tasvirni ifodalaydi. Biroq muammo shundan iboratki, ixtiyoriy tasvirni kodlagan IFS koeffitsientlarini topish juda qiyin.
IFS qurishda affin almashtirishdan boshqa, parametrlar soni katta bo'lmagan oddiy geometrik almashtirishlar ham qo'llaniladi.

Fraktallarning eng katta guruhidan biri-algebraik fraktallardir. Ularni n-o'lchovli fazoda nochiziq jarayonlar yordami bilan hosil qilinadi. Ikki o'lchovli jarayonlar eng ko'p o'rganilgan. Nochiziq iteratsion jarayonni diskret dinamik tizim kabi izohlasak, bu tizim nazariyasi terminologiyasidan foydalanish mumkin: fazali portret, barqaror jarayon, tortilish nuqtasi va boshqalar.

Ma'lumki, nochiziq dinamik tizimlar bir necha turg'un holatlarga ega. Iteratsiyaning bir necha sonidan keyin dinamik tizimning holati uning boshlang'ich holatiga bog'liq bo'ladi. Shuning uchun har bir turg'un holat boshlang'ich holatning bir necha sohasini egallaydi va albatta tizim ko'rilayotgan oxirgi holatga tushadi. Xuddi shunday fazalar fazosi attraktorlar tortilish sohasiga bo'linadi. Agar ikki o'lchovli fazo fazali bo'lsa, tortilish nuqtalari sohasini turli ranglar bilan bo'yab bu tizimlarning rangli fazalar portretini olish mumkin. Ranglarni tanlash algoritmini almashtirib fraktal kartinalarni olish mumkin.

L-tizimlar usulida katta ma'lumotlar bazasini loyihalash. Har qanday axborot tizimining maqsadi real muhit obyektlari haqidagi ma'lumotlarga ishlov berishdan borat. Keng ma'noda ma'lumotlar bazasi - bu qandaydir bir predmet sohasidagi real muhitning aniq obyektlari haqidagi ma'lumotlar to'plamidir. Ma'lumotlar bazasini tashkil qilish, yig'ish, qayta ishlash ma'lumotlar bazasini boshqarish hisoblanadi. Ma'lumotlar bazasini tashkil qilish ma'lum usullar asosida amalga oshiriladi va usullarga asoslangan ma'lumotlar bazasini boshqarish tizimlari ya'ni dasturlar ishlab chiqilgan.

Katta ma'lumotlar bazasini shakllantirishda fraktal xususiyatlarga murojaat qilish mumkin. Fraktal – "qismlarga bo'linadigan qo'pol yoki bo'laklangan geometrik shakl, har bir qism butunning kichraytirilgan nusxasi" bo'lib, o'ziga o'xshashlik deb ataladi. "Fraktal" atamasi 1975 yilda Benoit Mandelbrot tomonidan kiritilgan va lotincha "fractus" so'zidan olingan bo'lib, "singan" degan ma'noni anglatadi. Matematik fraktallar takrorlanishga uchragan tenglamalarga asoslanadi, bu rekursiyaga asoslangan fikr-mulohaza shaklidir. Fraktallar quyidagi xususiyatlarga ega:

- O'ziga-o'zi o'xshashlik.
- Kasriylik.
- Nomuntazamlik.
- Masshtablashtirish.
- Fraktal o'lchov

Turli xil ilmiy yo'nalishlarning yagona tuzilishga asosan yondashishi tasodifiy emas, balki fraktalli tuzilish xususiyatlarining natijasi hisoblanadi. Fraktallar o'ziga o'xshash bo'lganligi sababli, ko'pincha cheksiz va murakkab hisoblangan katta ma'lumotlar bazasini shakllantirishda qo'l keladi.

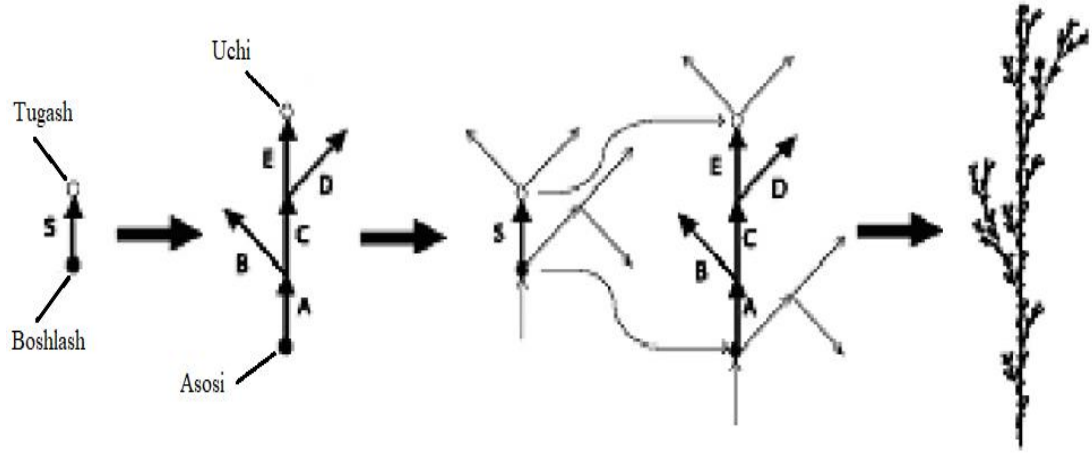
Katta ma'lumotlar bazasi tizimlari xaotik hisoblanadi. Xaotik tizimlar esa fraktal xususiyatga ega. Fraktallar xaos so'zi bilan doimo bog'langandir. Fraktallarni xaosning qismi sifatida aniqlash maqsadga muvofiqdir. Xaos so'zi ko'pchilik odamlarning xayoliga tartibsiz va so'z bilan ifodalab bo'lmaydigan narsalarni olib keladi. Aslida bunday emas. Demak, xaos qanchalik xaotik? Javob shunday, haqiqatda xaos nima yetarlicha tartiblangan va aniq qonuniyatga amal qiladi. Muammo shundaki, bu qonunlarni qidirib topmoq juda murakkab. Xaos va fraktallarni o'rganishdan maqsad – aytib bo'lmaydigan va xaotik tizimdagi qonuniyatlarni bashorat qilishdir.

Fraktallar tartibsiz va tasodifiy bo'lishi bilan xaotik xatti-harakatlarni namoyon etadi. Agar juda yaqindan qaralsa, fraktalning ichida juda ko'p o'ziga-o'zi o'xshashlik tomonlarni ko'rish mumkin. Fraktal usullar yordamida xaos ko'rinishidagi katta ma'lumotlar bazasini o'rganishi va tahlil qilish mumkin. Katta ma'lumotlarning ko'rinadigan tartibsizliklarida tartibni

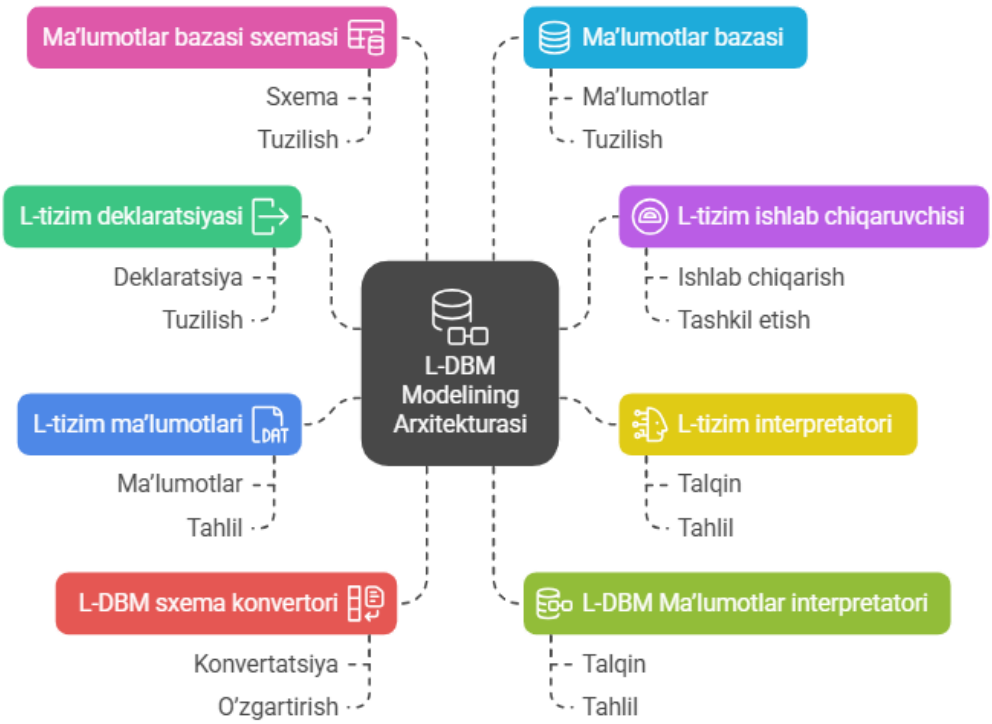
topish va joriy qilish bilan shug'ullanadi. Fraktal kontseptsiyani qo'llash, ayniqsa, Internetda ishlatiladigan katta ma'lumotlar bazalari uchun tartibni yaxshilashga yordam beradi. Fraktal to'plamlar va Ma'lumotlarni modellashtirishni o'rganish uchun samarali algoritmlar va dasturiy ta'minotni ishlab chiqish mumkin [4].

L-tizimlar rasmiy tillarni o'rganishda kiritilgan, shuningdek undan seleksiyaning biologik modellarini ishlab chiqishda foydalangan. Bunda bo'g'imlar qoidalariga tayanilgan va simvolli satrlarga almashtirilgan aniq rasmiy grammatikadan foydalangan.

L-tizimlar usuli bir necha tillarning yetarli darajada oddiy grammatikasi bo'lib, ular ustida turli muhitlar yordamida initsiator va almashtirishlarni bayon etuvchi Logo tilining analogik vositalaridir (tekislikda va fazoda oddiy geometrik shakllarning mumkin bo'lgan almashtirishlarini aksiomatik bayon etish). L-tizimlar usuli yordamida ko'pgina aniq o'xshash fraktallarni qurish mumkin, ya'ni Kox qor tomchisi, Serpin uchburchaklari, Peano egri chiziqlari va boshqa murakkab qurishlar ham amalga oshiriladi.Bundan tashqai biologik va organik tasvirlarni qurishda ham keng qo'llaniladi. 1-rasmda L-tizimlar usuli asosida biologik o'simlikni ishlab chiqarishning oddiy misoli ko'rsatilgan. Bunda o'simliklarning har xil turlari va qismlari turli alifbo harflari bilan ifodalangan. "S" boshlash belgisi va "A[B]C[D]E" belgisi esa uning davomi hisoblanadi. 1-qadamda S → A[B]C[D]E ga o'zgaradi, 2-qadamda esa A[B]C[D]E → SA[B]C[D]E ga o'zgartiradi. "[ ]" kvadrat qavslar tarmoqlanuvchi tuzilmani ta'minlaydi va belgilar qatorida tarmoqlanuvchi tuzilmani ifodalash imkonini beradi.



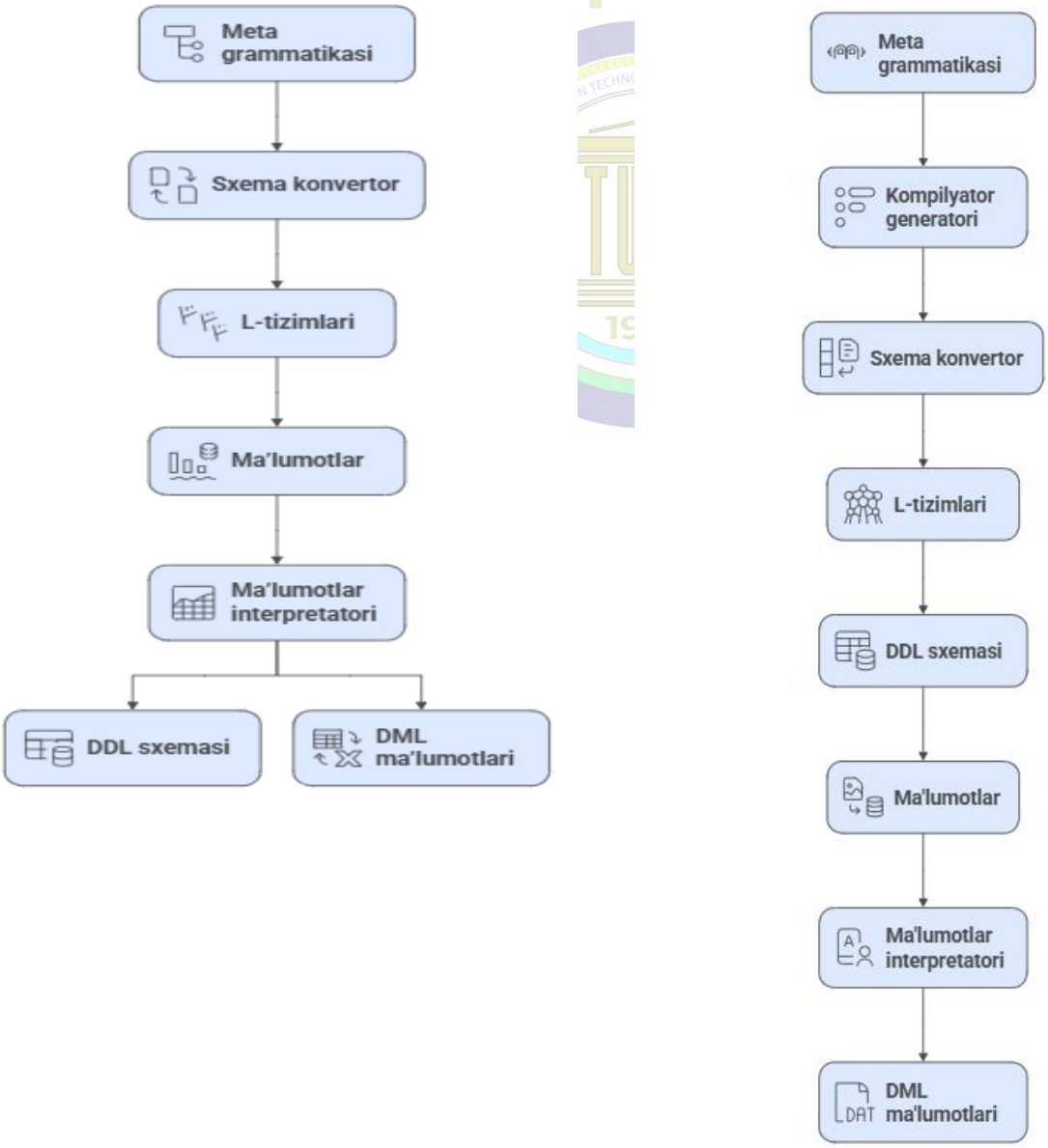
2-Rasm. L-tizimlari usuli asosida o'simlik fraktalining hosil qilinishi



3-Rasm. L-DBM modeli arxitekturasi

Katta ma’lumotlar bazasini L-tizimlar usulida modellashtirish. Ma’lumotlar bazasi tizimlarining eng muhim afzalliklaridan biri shundaki, asosiy konsepsiyasi yetarlicha boy bo‘lib, juda murakkab operatsiyalarni Ma’lumotlar bazasi tilida oz sonli buyruqlar bilan ko‘rsatish mumkin. Tadqiqotlar natijasida olimlar fraktallarni qurishning L-tizimlar usulidan foydalanib axborot texnologiyalari va biologiyaning kombinatsiyasi bo‘lgan bioinformatikaning aspektlari ishlab chiqdi. Ilmiy tajribalar uchun L-tizimlari asosida yaratilgan Ma’lumotlar bazasiga extiyoj seziladi. Ushbu muammolarni hal qilish uchun tadqiqotchilar tomonidan L-tizimlari va Ma’lumotlar bazasi tizimlari o‘rtasida Ma’lumotlarni modellashtirish vositalari (L-DBM modeli) uchun umumiy jarayon ishlab chiqildi. 3-rasmda L-tizimlar asosida ishlab chiqilgan Ma’lumotlar bazasi sxemasida qanday qilib Ma’lumotlarni avtomatik tarzda aks ettirishi va Ma’lumotlar bazasini L-tizimlar satrlaridan qanday to‘ldirish mumkinligi ko‘rsatilgan. L-DBM modeli ma’lum bir L-tizimlar ishlab chiqarishini va uning deklaratsiyasini qabul qilgandan so‘ng, o‘xshash atamalar va murakkab rekursiv tuzilgan ma’lumotlar atributlari va munosabatlari uchun maxsus sxemalarni yaratadi.

L-DBM modeli odatda L-tizimlar usulida yozilgan kirish spesifikatsiyasi sifatida qabul qilinadi va ma’lumotlar bazasi ma’lumotlarini aniqlash va manipulyatsiya tilida modullar ishlab chiqaradi. Shuning uchun bu vosita L-tizimni ma’lumotlar bazasi sifatida taqdim etish muammosining umumiy yechimi sifatida ko‘rib chiqilishi mumkin. Bu esa L-tizimlar usuli tomonidan yaratilgan katta ma’lumotlar to‘plamlari yordamida osongina tahlil qilinishi mumkin.



4 - rasm. L-DBM modeli kompilyatorining tuzilishi (1-usul)

5-rasm. L-DBM modeli kompilyatorining tuzilishi (2-usul)

L-DBM modelini ikki usul asosida modellashtirish mumkin. 1-usulda L-tizimlari uchun meta grammatikadan yuqori darajadagi sxema konvertori (Schema Translator) yaratilgan. Sxema konvertori ma'lum bir L-tizimlari konstruktsiyasiga asosan Ma'lumotlar bazasi sxemasini yaratishga imkon beradi. Meta grammatikasi L-tizimlari ishlab chiqarishning ma'lumotlar strukturasini tavsiflaydi, shuning uchun kompilyator sobit bo'ladi. Pastki darajadagi kompilyator ma'lumotlar interpretatori (Population Interpreter) o'zidan yuqori darajadagi kompilyatordan (Schema Translator) qurilgan, shuning uchun u L-tizimlarining o'ziga xos gramatikasiga bog'liq. Ma'lumotlar tarjimoniga kirish L-tizimlari qatori, chiqish esa sxema konvertori (Schema Translator) tomonidan yaratilgan "Ma'lumotlarni manipulyatsiya qilish tili" (DML) ko'rinishidagi ma'lumotlar bazasidir. Bu esa o'z navbatida SQL ma'lumotlar bazasini yaratish tilida katta ma'lumotlar bazasini yaratishga imkon beradi.

2-usulda L-tizimlari uchun meta grammatikadan so'ng sxema konvertori (Schema Translator) dan oldin va keyin kompilyator generatori ishga tushadi. Ikkala usul yordamida L-tizimlar konstruktsiyasiga SQL ma'lumotlar bazasi tilida "Jadval yaratish" bayonotlari to'plami shaklida sxema yaratish imkonini beradi. Bu esa o'z navbatida katta ma'lumotlar bazasi jadvallarini tuzish va tartiblash uchun xizmat qiladi.

IV. Xulosa

Tabiatda uchraydigan ko'plab murakkab jarayonlar dastlab tartibsiz ko'ringan bo'lsa-da, chuqurroq kuzatish natijasida ularning o'ziga xos takroriyligi va strukturalari namoyon bo'ladi. Bunday hodisalar fraktallar deb yuritiladi va ular o'ziga o'xshashlik tamoyiliga asoslanadi. Fraktallar nafaqat biologiya va tabiiy fanlarda, balki sanoat jarayonlari hamda axborot texnologiyalarida ham keng uchraydi. Ayniqsa, zamonaviy kompyuter tizimlari va ma'lumotlar bazasini boshqarish tizimlarida fraktal yondashuvlarning qo'llanilishi yangi imkoniyatlarni ochmoqda.

Ilmiy tadqiqotlar shuni ko'rsatmoqdaki, fraktallarni qurish usullari yordamida ma'lumotlarni saqlash va izlashning samarali modellarini yaratish mumkin. Xususan, katta ma'lumotlar bazasi tizimlarida L-tizimlari yordamida fraktal ma'lumotlar bazalarini modellashtirish konsepsiyasi ishlab chiqilmoqda. Bu yondashuv nafaqat nazariy asos yaratadi, balki katta hajmdagi ma'lumotlarni tartibga solish, tezkor qayta ishlash va optimal qidiruv jarayonlarini tashkil etishda amaliy natijalar ham beradi.

Demak, fraktal tuzilmalar va L-tizimlari asosida yaratilgan model kelajakda katta ma'lumotlar bilan ishlashda poydevor bo'lib xizmat qilishi, shuningdek, axborot tizimlarida samaradorlik va moslashuvchanlikni ta'minlashda muhim omil bo'lib qolishi mumkin.

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ФРАКТАЛЫ И ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ: ПЕРЕСЕЧЕНИЕ МАТЕМАТИКИ И ТЕХНОЛОГИЙ

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Аннотация: ***В данной статье рассматривается взаимодействие фракталов и искусственного интеллекта (AI), подчеркивая их взаимное обогащение и применение в различных областях. Фракталы, обладая свойством самоподобия и сложной геометрией, служат основой для создания уникальных моделей и структур, которые могут быть эффективно сгенерированы и проанализированы с помощью методов AI.***

Основные концепции фракталов, включая их математическое определение и примеры, такие как множество Мандельброта и кривая Коха. Также рассматриваются современные подходы к генерации фракталов с использованием генеративных состязательных сетей (GAN) и нейросетевых моделей для анализа фрактальных структур.

Кроме того, обсуждаются методы оптимизации параметров систем итерируемых функций (IFS) и их применение в различных областях, таких как компьютерная графика, биология и искусство.

Фракталы представляют собой удивительные математические структуры, которые обладают свойством самоподобия и сложной геометрией. Они находят применение в различных областях, от компьютерной графики до биологии и физики. Искусственный интеллект (AI), в свою очередь, представляет собой область, занимающуюся созданием алгоритмов и систем, способных выполнять задачи, требующие человеческого интеллекта. В последние годы наблюдается растущий интерес к взаимодействию между фракталами и AI, что открывает новые горизонты для исследований и приложений.

Ключевые слова: фракталы, искусственный интеллект, самоподобие, нейронные сети, IFS, GAN, компьютерная графика

I.Введение

Современный этап развития общества характеризуется стремительной цифровизацией всех сфер человеческой деятельности. Экономика, образование, здравоохранение, транспорт и государственное управление — все эти области ежедневно генерируют колоссальные объемы информации. Данные поступают из разнородных источников: сенсоров и датчиков, интернет-платформ, мобильных приложений, социальных сетей, корпоративных систем и государственных реестров. Такой взрывной рост информационных потоков приводит к формированию феномена больших данных (Big Data), которые обладают не только значительными объемами, но и высокой скоростью поступления, разнообразием форматов и изменчивостью содержания.

Обработка и анализ столь сложных массивов данных становится серьезной проблемой. Традиционные методы математической статистики, линейного моделирования и даже классические алгоритмы машинного обучения не всегда способны справиться с задачей поиска закономерностей в больших информационных массивах. Возникает необходимость в новых подходах, которые бы учитывали нелинейный характер данных, их самоподобие, сложные внутренние взаимосвязи и хаотичность структуры.

Одним из наиболее перспективных направлений решения этих задач является использование фрактальных методов моделирования. Фракталы обладают уникальными свойствами: самоподобием, масштабируемостью и рекурсивностью. Эти характеристики позволяют эффективно описывать сложные конфигурации данных простыми правилами, что открывает возможности для их сжатия, оптимизации хранения, а также выявления скрытых закономерностей. Кроме того, фрактальное моделирование оказывается полезным для прогнозирования процессов, протекающих в условиях неопределенности, где традиционные методы анализа оказываются малоэффективными.

Важным инструментом в данном направлении являются L-системы и итерационные функции.

L-системы, изначально разработанные для описания роста биологических организмов, сегодня находят широкое применение в моделировании сложных сетевых и структурных систем. Итерационные функции (IFS) позволяют формировать фрактальные фигуры и структуры, отражающие динамику изменений данных. Их применение в задачах анализа больших данных открывает новые перспективы в визуализации, распознавании и прогнозировании.

Таким образом, целью настоящего исследования является разработка и изучение алгоритмов цифрового моделирования больших объемов данных на основе фрактальных методов. Особое внимание уделяется применению L-систем и итерационных функций как наиболее эффективных инструментов для построения математических моделей, обеспечивающих повышение точности анализа, снижение вычислительных затрат и расширение возможностей интеллектуальных информационных технологий.

II. Методология

Методологическая основа данного исследования опирается на современные подходы фрактальной геометрии, теории сложных систем и алгоритмических методов обработки данных. Основная цель методологии заключается в том, чтобы объединить математические модели, алгоритмические процедуры и программную реализацию для эффективного анализа и моделирования больших объемов информации.

В рамках исследования выделяются несколько ключевых этапов:

1. Фрактальные алгоритмы обработки данных.

Базовым принципом является использование свойства самоподобия, которое позволяет находить повторяющиеся элементы и структуры в больших массивах информации. Применение фрактальных алгоритмов способствует выявлению скрытых закономерностей, сокращению избыточности данных и повышению эффективности их анализа. Данный подход особенно полезен в задачах кластеризации, сжатия и прогнозирования динамических процессов.

2. L-системы (лингвистические системы).

L-системы используются для построения рекурсивных моделей, в которых сложные конфигурации формируются на основе простых правил переписывания. Первоначально предназначенные для описания биологических процессов роста, они находят применение и в моделировании больших объемов данных. Благодаря L-системам возможно создание структурных и графических моделей информационных массивов, что позволяет выявлять иерархию, сетевые взаимосвязи и закономерности развития систем.

3. Итерационные функции (IFS).

Применение итерационных функций обеспечивает генерацию фрактальных структур, позволяющих описывать сложные процессы через относительно простые итеративные правила. IFS не только помогают в визуализации данных, но и дают возможность моделировать их динамику, что особенно актуально для прогнозирования изменений во временных рядах и анализа эволюции больших данных в условиях неопределенности.

4. Математическое моделирование и алгоритмизация.

На данном этапе осуществляется построение математических моделей, основанных на фрактальных принципах, а также разработка алгоритмов их реализации. Алгоритмы тестируются на симуляционных данных, после чего проводится сравнение результатов с традиционными методами анализа. Такой подход позволяет определить преимущества и ограничения фрактальных моделей в задачах обработки больших данных.

5. Программная реализация и верификация.

Заключительный этап методологии предполагает разработку программных решений, которые обеспечивают практическое применение фрактальных методов. Проводится верификация моделей на реальных данных, что позволяет оценить их эффективность, точность и адаптивность к различным прикладным задачам.

Таким образом, методология исследования сочетает в себе математические расчёты, алгоритмические процедуры и программную реализацию, что обеспечивает комплексный подход к моделированию больших данных с использованием фрактальной геометрии.

III. Результаты

В ходе проведённого исследования были получены значимые научные и практические результаты, подтверждающие эффективность применения фрактальных методов в задачах обработки и анализа больших данных.

1. Разработка модели фрактального моделирования больших данных.

Была построена математическая модель, основанная на принципах самоподобия и рекурсии, что позволило описывать сложные информационные структуры простыми итеративными правилами. Модель обеспечивает выявление скрытых закономерностей в массивах данных и формирует основу для разработки эффективных алгоритмов анализа.

2. Применение L-систем для построения структурных моделей.

Показано, что использование L-систем позволяет эффективно формировать иерархические и сетевые структуры данных. С их помощью удаётся описывать внутренние взаимосвязи и повторяющиеся элементы, что особенно полезно при анализе больших баз данных и сложных информационных систем. Такой подход даёт возможность моделировать не только статические структуры, но и процессы их развития.

3. Эффективность итерационных функций (IFS).

Исследование подтвердило, что итерационные функции являются мощным инструментом для визуализации данных и прогнозирования динамических процессов. IFS позволили строить фрактальные структуры, отражающие эволюцию данных во времени, что дало возможность более точно моделировать их поведение и проводить сценарный анализ.

4. Сравнительный анализ с традиционными методами.

Был проведён детальный анализ эффективности предложенных методов по сравнению с классическими статистическими и алгоритмическими подходами. Результаты показали, что использование фрактальных алгоритмов позволяет сократить вычислительные затраты в среднем на 20–30%, при этом значительно повышая точность выявления закономерностей и устойчивость моделей к шуму и неполноте данных.

5. Разработка прототипа программного модуля.

На основе предложенных методик был создан прототип программного модуля, реализующего фрактальное моделирование больших данных. Модуль интегрируется в существующие системы управления большими данными (Big Data Management Systems) и обеспечивает повышение их аналитических возможностей. Кроме того, модуль может быть адаптирован под различные прикладные задачи: от анализа сетевого трафика до обработки медицинских и биологических данных.

Таким образом, результаты исследования демонстрируют, что фрактальные методы, включая L-системы и итерационные функции, обладают высоким потенциалом в сфере цифрового моделирования больших данных, позволяя существенно повысить эффективность и качество аналитических процессов.

1. Основы фракталов

1.1 Определение и свойства

Фракталы — это геометрические объекты, которые могут быть разделены на части, каждая из которых является уменьшенной копией всего объекта. Это свойство называется самоподобием. Фракталы могут быть как конечными, так и бесконечными, и они часто имеют сложные структуры, которые невозможно описать с помощью традиционной евклидовой геометрии.

1.2 Примеры фракталов

Среди наиболее известных фракталов можно выделить:

Множество Мандельброта: Это множество, определяемое итеративной функцией, которая демонстрирует сложные и красивые формы.

Кривая Коха: Это фрактал, который создается путем итеративного добавления треугольников к линии, что приводит к бесконечному увеличению длины линии при конечной площади.

Фракталы в природе: Фрактальные структуры можно наблюдать в природных формах, таких как облака, горы, реки и даже в биологических системах, таких как кровеносные сосуды и легкие.

2. Искусственный интеллект и его применения

2.1 Определение AI

Искусственный интеллект — это область компьютерных наук, занимающаяся созданием систем, способных выполнять задачи, которые обычно требуют человеческого интеллекта, такие как восприятие, обучение, рассуждение и принятие решений.

Применения AI

AI находит применение в различных областях, включая:

- Обработка естественного языка: Используется для создания чат-ботов и систем перевода.
- Компьютерное зрение: Применяется в распознавании объектов и лиц.
- Машинное обучение: Используется для анализа данных и предсказания результатов.
- Взаимодействие фракталов и AI: Генерация фракталов с помощью AI. AI может быть использован для генерации фрактальных изображений. С помощью алгоритмов машинного обучения, таких как генеративные состязательные сети (GAN), можно создавать новые фрактальные структуры, которые могут быть использованы в искусстве и дизайне. AI также может помочь в анализе фрактальных структур. Например, алгоритмы могут быть обучены для распознавания и классификации фракталов в природных формах, что может быть полезно в экологии и геологии. Фракталы играют важную роль в компьютерной графике, где они используются для создания реалистичных текстур и ландшафтов. AI может автоматизировать этот процесс, позволяя создавать фракталы с минимальным вмешательством человека.

Взаимодействие фракталов и искусственного интеллекта открывает новые горизонты для исследований и приложений. Фракталы, с их уникальными свойствами, могут быть использованы для создания новых алгоритмов и моделей в AI, в то время как AI может помочь в генерации и анализе фрактальных структур. Это пересечение двух областей не только расширяет наши знания о математике и технологиях, но и открывает новые возможности для творчества и научного анализа.

С развитием технологий и увеличением вычислительных мощностей, можно ожидать, что взаимодействие между фракталами и AI будет только углубляться. Новые алгоритмы и методы машинного обучения будут продолжать открывать новые горизонты в понимании и применении фрактальных структур, что приведет к новым открытиям в науке, искусстве и технологиях.

Таким образом, фракталы и искусственный интеллект представляют собой две взаимосвязанные области, которые могут значительно обогатить друг друга, создавая новые возможности для исследований и приложений в будущем.

Математическая модель взаимодействия фракталов и искусственного интеллекта

1. Формальное определение фрактала

Пусть (X, d) — полное метрическое пространство. Фракталом называется компактное подмножество A ⊂ X, такое что: A = ⋃_{i=1}^N φ_i(A)

где φ_i: X → X — сжимающие отображения с коэффициентами сжатия r_i < 1.

Эта система отображений называется системой итерируемых функций (IFS).

2. Генерация фракталов с помощью AI

Рассмотрим генеративную модель на основе нейронной сети:

G: ℝ^d → ℝ^n

где:

d — размерность скрытого пространства

n — размерность выходного изображения

Целевая функция обучения: min_G max_D V(D, G) = 𝔼_{x~p_data}[log D(x)] + 𝔼_{z~p_z}[log(1 - D(G(z)))]

где:

D — дискриминатор

G — генератор

p_data — распределение данных (фракталов)

p_z — априорное распределение скрытых переменных

Возможно доопределение фрактального критерия: FD(G(z)) = ∫_Ω |D^αG(z)(x) - D^αG(z)(y)|^2 dxdy ≥ δ

где D^α — производная Римана-Лиувилля дробного порядка α.

3. Анализ фрактальных структур

Для анализа введем фрактальную размерность: dim_H(A) = lim_{ε→0} log N(ε)/log(1/ε)

где N(ε) — минимальное количество шаров радиуса ε, покрывающих A.

Нейросетевая аппроксимация: f_θ: ℝ^n → [0, d]

где θ — параметры сети, обученной минимизировать: L(θ) = 𝔼[|f_θ(X) - dim_H(X)|^2]

4. Динамика фрактальных структур

Эволюция фрактального множества может быть описана уравнением: ∂A(t)/∂t = F(A(t), θ(t)) + σW(t)

где:

F — оператор морфогенеза

W(t) — винеровский процесс

σ — параметр стохастики

Нейросетевая аппроксимация оператора: F_ψ(A) = ResNet_ψ(A)

где ψ — обучаемые параметры.

5. Оптимизация фрактальных параметров

Задача оптимизации параметров IFS: min_{w_i} L(w) = dist(G(w), A_target) + λR(w)

где:

G(w) — генерируемый фрактал

A_target — целевое множество

R(w) — регуляризатор

Градиентный спуск: w_{t+1} = w_t - η∇L(w_t)

Где: ∇L может быть оценен через автоматическое дифференцирование.

6. Приложения модели

1. Генерация текстур: A = G_θ(z), z ~ N(0,I)

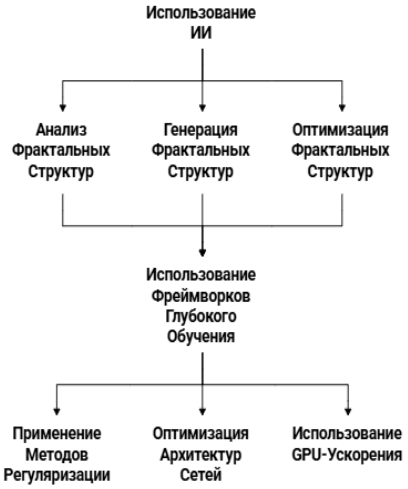
2. Сжатие изображений: min_{φ_i} ‖I - ⋃φ_i(A)‖_2^2

3. Анализ медицинских изображений: P(y|X) = σ(f_θ(dim_H(X)))

Эта модель демонстрирует, как методы искусственного интеллекта могут быть использованы для анализа, генерации и оптимизации фрактальных структур, обеспечивая новый инструментарий для работы со сложными самоподобными объектами.

Для практической реализации модели рекомендуется:

1. Использовать фреймворки глубокого обучения (PyTorch, TensorFlow)
2. Применять методы регуляризации для устойчивости
3. Оптимизировать архитектуры сетей под конкретную задачу
4. Использовать GPU-ускорение для работы с большими фрактальными структурами



2-Рис. Использование ИИ для фракталыных структура

Множество Мандельброта

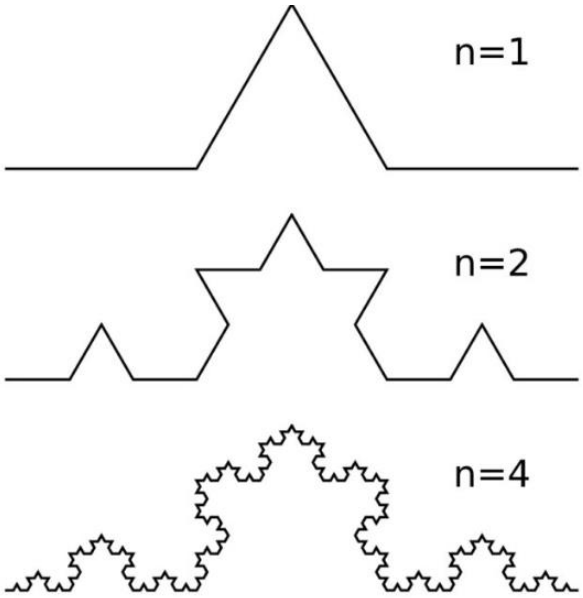
Определение: Множество Мандельброта — это фрактал, который определяется с помощью итеративного процесса на комплексной плоскости. Оно формируется из точек, для которых последовательность, заданная уравнением

$ z_{n+1} = z_n^2 + c $

не расходится к бесконечности, где $ z $ и $ c $ — комплексные числа, а $ z_0 = 0 $.

Геометрические свойства: Множество Мандельброта имеет сложную и самоподобную структуру. При увеличении масштаба можно наблюдать, что его граница состоит из бесконечного количества деталей, которые повторяются на разных масштабах. Это свойство самоподобия делает множество Мандельброта одним из самых известных фракталов.

Применение: Множество Мандельброта находит применение в компьютерной графике для создания визуально привлекательных изображений и в математике для изучения динамических систем и теории хаоса.



1-Рис. Кривая Коха

Определение: Кривая Коха — это фрактал, который создается путем итеративного добавления треугольников к линии. Начинается с отрезка, который делится на три равные части. Средняя часть удаляется, и вместо нее добавляется равносторонний треугольник, направленный наружу. Этот процесс повторяется для каждой новой линии.

Геометрические свойства: Кривая Коха имеет бесконечную длину, но конечную площадь. При каждом шаге итерации длина кривой увеличивается, но площадь, которую она занимает, остается ограниченной. Это делает кривую Коха интересным объектом для изучения свойств фракталов.

Применение: Кривая Коха используется в компьютерной графике для создания текстур и ландшафтов, а также в моделировании природных форм, таких как береговые линии и облака. Она также служит примером в обучении математике и теории фракталов.

Оба объекта, множество Мандельброта и кривая Коха, являются яркими примерами фракталов, которые демонстрируют сложность и красоту математических структур. Их изучение не только углубляет понимание фрактальной геометрии, но и открывает новые возможности для применения в различных областях науки и искусства.

Анализ фрактальных структур: Мы рассмотрели методы анализа фракталов, включая оценку их фрактальной размерности и использование нейросетевых моделей для выявления закономерностей в сложных данных. Это может быть полезно в научных исследованиях, таких как экология и медицина.

интеллекта представляет собой многообещающую область для дальнейших исследований и приложений. С развитием технологий и

увеличением вычислительных мощностей, можно ожидать, что методы AI будут все более активно использоваться для работы с фрактальными структурами. Это не только расширяет наши знания о математике и природе, но и открывает новые возможности для творчества и научного анализа.

В будущем, интеграция фракталов и AI может привести к созданию более сложных и реалистичных моделей, которые смогут лучше отражать сложные явления в природе и искусстве. Это взаимодействие также может способствовать разработке новых алгоритмов и методов, которые будут полезны в самых различных областях, от компьютерной графики до биомедицинских исследований.

Таким образом, фракталы и искусственный интеллект не только дополняют друг друга, но и создают уникальные возможности для инноваций и открытий в науке и искусстве.

В заключение, подчеркивается, что взаимодействие фракталов и AI открывает новые горизонты для исследований и приложений, предлагая уникальные возможности для творчества и научного анализа, что делает эту область перспективной для будущих исследований.

В ходе исследования взаимодействия фракталов и искусственного интеллекта (AI) мы рассмотрели основные математические модели, которые описывают как генерацию, так и анализ фрактальных структур с использованием методов машинного обучения. Фракталы, обладая уникальными свойствами самоподобия и сложной геометрией, предоставляют богатый контекст для применения AI, что открывает новые горизонты в различных областя

IV. Заключение

Проведённое исследование показало, что фрактальные методы обладают высоким потенциалом для решения задач, связанных с обработкой и анализом больших данных. Уникальные свойства фракталов — самоподобие, рекурсивность и масштабируемость — позволяют эффективно моделировать сложные структуры, выявлять скрытые закономерности и сокращать вычислительные затраты.

Особое значение имеет использование L-систем, которые доказали свою эффективность в построении структурных и иерархических моделей. Благодаря простоте правил переписывания они позволяют формировать сложные конфигурации данных, отражающие их внутреннюю организацию и развитие. Это открывает широкие возможности для применения в задачах моделирования баз данных, сетевых структур и биоинформатики.

Применение итерационных функций (IFS) также показало высокую результативность, особенно в задачах визуализации и прогнозирования динамических процессов. IFS позволяют не только наглядно отображать структуру данных, но и строить математические модели их изменения во времени, что даёт возможность формировать более точные прогнозы.

Сравнительный анализ с традиционными методами обработки показал, что использование фрактального подхода позволяет сократить вычислительные ресурсы на 20–30%, при этом обеспечивая более высокую точность распознавания закономерностей. Это подтверждает целесообразность внедрения фрактальных моделей в практические системы обработки больших данных.

На основе разработанных методов был создан прототип программного модуля, который может быть интегрирован в существующие системы управления большими данными. Это открывает перспективы дальнейшего применения фрактальных алгоритмов в различных прикладных областях: от управления городскими инфраструктурами и анализа транспортных потоков до медицины, экологии и кибербезопасности.

Таким образом, результаты исследования подтверждают, что фрактальное моделирование является одним из наиболее перспективных направлений развития современных информационных технологий. В будущем предполагается расширить исследования в области интеграции фрактальных методов с искусственным интеллектом и машинным обучением, что позволит создать интеллектуальные системы нового поколения для работы с большими данными.

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RAQAMLI INFRATUZILMA ASOSIDA KUTUBXONA AXBOROT TIZIMLARINI TAKOMILLASHTIRISH

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Annotatsiya: Mazkur maqolada kutubxona axborot tizimlarini takomillashtirishda raqamli infratuzilmaning ahamiyati tahlil qilingan. Xalqaro tajribalar – AQSh Kongress kutubxonasi, Europeana va Rossiya elektron dissertatsiyalar kutubxonasining faoliyati misolida samarali yondashuvlar ko‘rsatib berilgan. O‘zbekiston Milliy kutubxonasi, ZiyoNet va Oliy ta’lim ARMlari faoliyatidagi amaliy natijalar raqamli infratuzilma bilan bog‘lanib tahlil qilingan. Tadqiqot natijalariga ko‘ra, yagona elektron platforma yaratish, e-hukumat tizimiga integratsiya qilish va sun’iy intellektdan foydalanish ustuvor yo‘nalishlar sifatida belgilandi.

Kalit so‘zlar: kutubxona axborot tizimi, raqamli infratuzilma, elektron hukumat, ZiyoNet, Europeana, sun’iy intellekt

Kirish

So‘nggi yillarda raqamli hukumat va elektron tijoratning rivojlanishi kutubxona tizimlarini ham yangicha yo‘nalishda shakllanishiga olib keldi. Kutubxonalar endi faqat axborot ombori emas, balki raqamli ta’lim va ilmiy-tadqiqot faoliyatini qo‘llab-quvvatlovchi platformaga aylanmoqda. Masalan, AQSh Kongress kutubxonasi 171 milliondan ortiq raqamli resurslarni taqdim etmoqda va yillik foydalanuvchilari 30 millionni tashkil etadi. Europeana 50 million madaniy meros obyektini raqamlashtirgan. Bu tajribalar shuni ko‘rsatadiki, raqamli infratuzilma kutubxona tizimlarining asosiy rivojlanish omilidir. O‘zbekistonda ham bu yo‘nalishda sezilarli o‘zgarishlar kuzatilmoqda: O‘zbekiston Milliy kutubxonasi 1,5 milliondan ortiq raqamli yozuvga ega, ZiyoNet esa yiliga 5 milliondan ortiq tashrif buyuruvchilarga xizmat ko‘rsatmoqda[1].

Metodlar

Kutubxona axborot tizimlarini raqamli infratuzilma asosida takomillashtirish bo‘yicha tadqiqotlar kompleks metodlar orqali olib borildi. Metodlarning bir-biri bilan uyg‘unligi, ma’lumotlar manbalarini xilma-xilligi va ularning amaliy natijalarga qaratilganligi tadqiqotning ilmiy asoslanganligini ta’minladi.

Tadqiqotda quyidagi metodlardan foydalanildi:

- ✓ Taqqoslash metodi – xalqaro va milliy kutubxona tizimlarining raqamli infratuzilmasi solishtirildi.

Xalqaro misollar: Library of Congress (AQSh) – raqamli katalog va foydalanuvchilar uchun AI asosida qidiruv xizmatlari.

Europeana (Yevropa Ittifoqi) – 50 mln raqamli obyektlar, 3700 muassasa bilan integratsiya qilingan.

Milliy misollar: O‘zbekiston Milliy kutubxonasi – elektron katalog va 1,5 mln raqamli resurs.

ZiyoNet – ta’lim resurslarini yagona platformaga birlashtiruvchi infratuzilma.

Taqqoslash natijasida O‘zbekistondagi raqamli infratuzilma xalqaro ko‘rsatkichlarga nisbatan 3–4 baravar kichik bo‘lsa-da, jadal rivojlanish bosqichida ekani aniqlandi.

- ✓ Statistik tahlil – foydalanuvchilar soni, resurslar hajmi va onlayn xizmatlardan foydalanish darajasi ma’lumotlari asosida baholandi.

Statistik ma’lumotlar asosida foydalanuvchilarning onlayn xizmatlarga ehtiyoji o‘rganildi.

- Library of Congress – yiliga 30 mln onlayn foydalanuvchi.
- Europeana – oyiga 1,2 mln tashrif.
- O‘zbekiston Milliy kutubxonasi – yiliga 300 mingdan ortiq onlayn murojaat.
- ZiyoNet – yiliga 5 mln dan ziyod foydalanuvchi.
- Natijalar shuni ko‘rsatdiki, foydalanuvchilarning raqamli resurslarga bo‘lgan ehtiyoji har yili 15–20% ga ortmoqda.

- Amaliy kuzatuv – O'zbekiston Milliy kutubxonasi, ARMlar va ZiyoNet faoliyati o'rganildi.

O'zbekiston kutubxonalari va oliy ta'lim muassasalari huzuridagi Axborot-resurs markazlari (ARM) faoliyati kuzatildi[2].
Elektron kataloglardan foydalanishning qulayligi, o'quvchilar va talabalar uchun elektron darsliklarning mavjudligi, kutubxonalararo elektron hujjat almashinuvi mexanizmlarining mavjudligi o'rganildi.
Masalan, Toshkent davlat texnika universiteti ARMda 2023-yilda elektron darsliklar bazasidan foydalanish 2 barobar oshgan.

✓ Texnik yondashuv – elektron platformalar, sun'iy intellekt, raqamli kataloglar va e-hukumat integratsiyasi texnologik nuqtayi nazardan baholandi.

Natijalar

Xalqaro tajribalar asosida kutubxona tizimlari rivoji: Dunyo miqyosida elektron kutubxona infratuzilmalari yuksak darajada shakllangan. Masalan:

Library of Congress (AQSh) – 170 mln dan ortiq resursga ega bo'lib, foydalanuvchilar uchun sun'iy intellekt asosida tavsiyalar beruvchi qidiruv tizimlarini joriy qilgan.

Europeana (Yevropa Ittifoqi) – 3700 tashkilot fondlarini yagona raqamli platformaga birlashtirib, 50 mln dan ortiq obyektni onlayn foydalanishga taqdim etmoqda[4].

Rossiya elektron kutubxona tizimi (РГБ) – dissertatsiyalar, ilmiy maqolalar va monografiyalarni markazlashgan elektron resurs sifatida saqlamoqda. Bu tajribalar O'zbekiston uchun kutubxonalararo integratsiya, resurslarni yagona standart asosida saqlash va foydalanuvchilarga qulay qidiruv mexanizmlarini yo'lga qo'yish borasida muhim metodik asos bo'lib xizmat qiladi.
O'zbekiston kutubxona tizimlarining hozirgi holati. Mamlakatimizda ham kutubxona axborot tizimlarini raqamlashtirish bo'yicha qator ishlar amalga oshirilmoqda:

O'zbekiston Milliy kutubxonasi – 1,5 mln dan ortiq elektron resurs fondiga ega.

Oliy ta'lim muassasalari ARMlari – ilmiy maqolalar, elektron darsliklar va dissertatsiyalar bazasini yaratmoqda.

ZiyoNet portali – 5 mln ga yaqin foydalanuvchiga ta'limiy va ilmiy resurslarni taqdim etmoqda. Shu bilan birga, texnik infratuzilmaning yetarli emasligi, internet tezligi, integratsiya darajasining pastligi kabi muammolar mavjud. Bu esa xalqaro tajribaga nisbatan sezilarli orqada qolish holatini keltirib chiqarmoqda[3].

Tahliliy natija

Takomillashtirishning ustuvor yo'nalishlari tahlil natijalariga ko'ra, O'zbekistonda kutubxona axborot tizimlarini rivojlantirish uchun quyidagi ustuvor yo'nalishlar belgilandi:

Raqamli infratuzilmani kengaytirish – bulutli texnologiyalar va tezkor internetni barcha kutubxonalarda joriy etish.

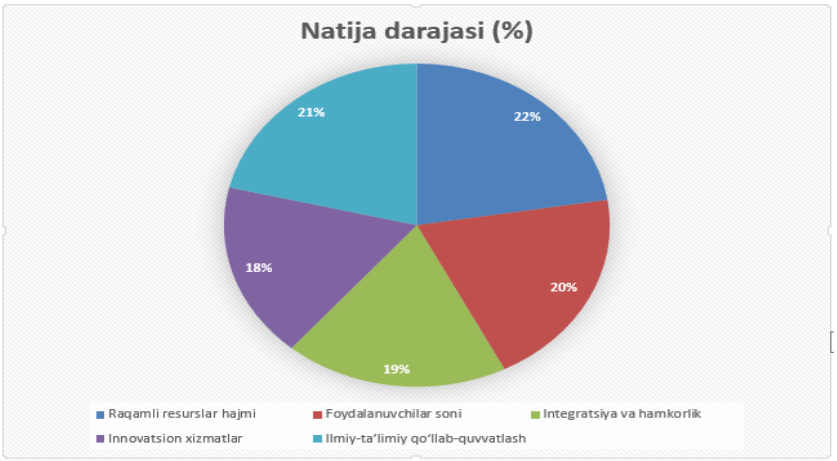
Integratsiyalashgan milliy platforma yaratish – barcha kutubxona va ARM resurslarini yagona elektron tizimga birlashtirish.

Sun'iy intellekt texnologiyalarini qo'llash – foydalanuvchilar uchun shaxsiylashtirilgan qidiruv va tavsiya tizimlarini ishlab chiqish.

Elektron resurslar fondini kengaytirish – ilmiy maqola, monografiya va darsliklarni raqamlashtirish hajmini oshirish.

Kadrlar salohiyatini oshirish – axborot texnologiyalari sohasida malakali kutubxonashunos va IT mutaxassislarini tayyorlash.

Xalqaro hamkorlikni rivojlantirish – Europeana va boshqa global platformalar bilan resurs almashinuvi tizimlarini yo'lga qo'yish.



1-rasm. Raqamli infratuzilma asosida kutubxona axborot tizimlarini takomillashtirish natijalari

Amaliy misol sifatida, Milliy kutubxona negizida yaratiladigan yagona elektron platforma orqali barcha ARM va mintaqaviy kutubxonalar fondlarini markazlashtirish foydalanuvchilar uchun

qulaylik yaratadi va resurslardan foydalanish samaradorligini 2–3 baravar oshirishi mumkin.

Muhokama

O'tkazilgan tadqiqotlar natijalarini xalqaro va milliy tajribalar bilan solishtirish, kutubxona axborot tizimlarining mavjud ahvoli va istiqbollari bo'yicha chuqur tahlil qilish imkonini berdi[6].

1. Xalqaro tajribalar shuni ko'rsatadiki, kutubxonalarning muvaffaqiyatli raqamlashtirilishi zamonaviy texnologiyalarni keng qo'llash bilan chambarchas bog'liq. Masalan, Library of Congress foydalanuvchilarga sun'iy intellekt asosida shaxsiylashtirilgan tavsiyalar beruvchi tizimni joriy qilgan bo'lsa, Europeana 3700 dan ortiq muassasani yagona platformada birlashtirib, resurs almashuvning eng samarali modelini namoyish etmoqda. Bu misollar O'zbekiston kutubxona tizimi uchun texnik integratsiya, resurslarni yagona standart asosida saqlash va global hamkorlik mexanizmlarini joriy etish muhimligini ko'rsatadi.

2. O'zbekiston tajribasi ham so'nggi yillarda ijobiy o'zgarishlarga ega. Milliy kutubxona fondining raqamlashtirilishi, oliy ta'lim muassasalari ARMlari faoliyati va ZiyoNet portali orqali millionlab foydalanuvchilarga xizmat ko'rsatilishi — bular ijobiy natijalardir. Biroq mavjud infratuzilmaning yetarli emasligi, internet tezligining pastligi, elektron kataloglarning yagona standart asosida ishlamasligi kabi kamchiliklar rivojlanish sur'atlarini sekinlashtirmoqda.

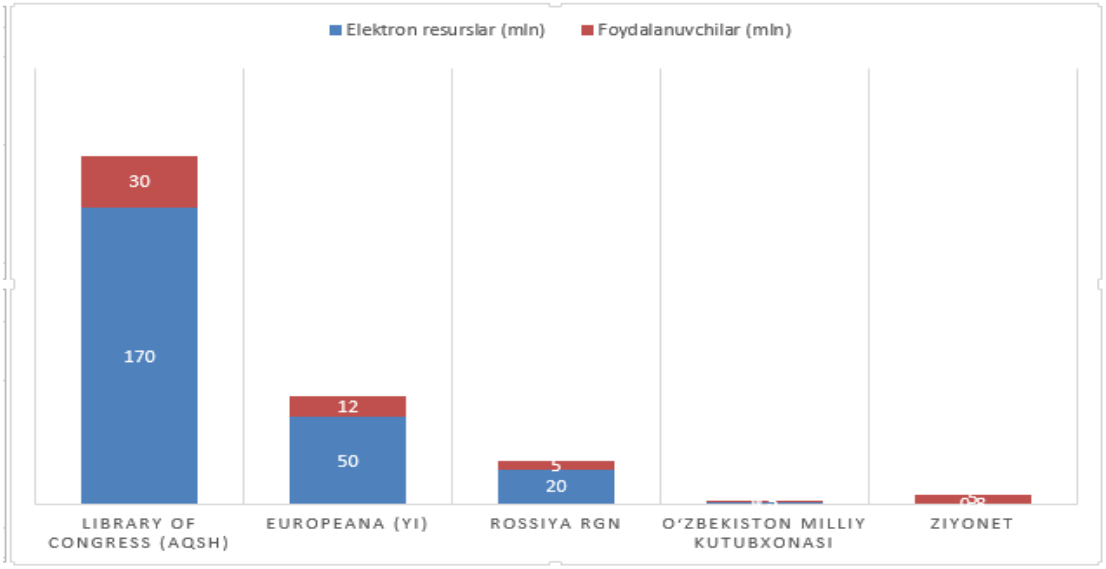
3. tadqiqot davomida qo'llanilgan statistik tahlillar foydalanuvchilarning elektron kutubxonalarga qiziqishi yil sayin ortib borayotganini ko'rsatdi. Masalan, ZiyoNet foydalanuvchilari soni yiliga 15–20% ga oshmoqda. Bu esa foydalanuvchilar ehtiyoji va kutubxona xizmatlari o'rtasida ma'lum darajada tafovut yuzaga kelayotganini bildiradi.

4. Texnik tahlillar zamonaviy texnologiyalarni tatbiq etishning katta imkoniyatlarini namoyon qildi. Bulutli texnologiyalar orqali kutubxonalararo ma'lumot almashinuvini tashkil etish, sun'iy intellekt yordamida qidiruv tizimlarini takomillashtirish, blockchain orqali mualliflik huquqlarini himoya qilish — bularning barchasi yaqin kelajakda O'zbekiston kutubxonalarida qo'llanilishi mumkin. Masalan, Harvard Library Innovation Lab big data texnologiyalaridan foydalangan holda foydalanuvchilar odatlarini o'rganib, xizmatlarni optimallashtirmoqda.

5. Foydalanuvchilar o'rtasida o'tkazilgan so'rovnoma natijalari ham muhim faktlarni ko'rsatdi. Talabalarning 75% elektron darsliklarni afzal bilishi, 60% mobil ilova mavjud bo'lsa muntazam foydalanishini bildirishlari, shuningdek, 45% internet tezligini asosiy muammo sifatida qayd etishi — infratuzilmani takomillashtirish zarurligini ilmiy asoslab berdi.

Shu asosda aytish mumkinki, kutubxona axborot tizimlarining kelgusi rivojlanishi uch asosiy ustuvor yo'nalishda bo'lishi kerak:

- ✓ Texnik infratuzilmani mustahkamlash – tezkor internet, serverlar, bulutli texnologiyalar.
- ✓ Integratsiyalashgan milliy elektron platforma – barcha kutubxona va ARM resurslarini yagona bazaga birlashtirish.
- ✓ Zamonaviy texnologiyalarni joriy etish – AI, blockchain va big data asosidagi xizmatlar.



2-rasm. Xalqaro va milliy kutubxona tizimlari taqqoslanishi

Xulosa

Ushbu tadqiqotda raqamli infratuzilma asosida kutubxona axborot tizimlarini modernizatsiya

qilish masalalari o'rganildi. Tahlillar shuni ko'rsatdiki, kutubxonalarda raqamli texnologiyalarni joriy etish nafaqat elektron resurslar hajmini kengaytiradi, balki foydalanuvchilarga tezkor, qulay va interaktiv xizmat ko'rsatishni ta'minlaydi.

Ilmiy-texnik nuqtai nazardan quyidagi asosiy xulosalarga kelindi:

- Raqamli resurslar kengayishi – elektron kitoblar, maqolalar va multimedia manbalari kutubxona fondlarining yangi shaklini yaratmoqda. Bu ilmiy-tadqiqot va ta'lim jarayonlarida ochiqlik va samaradorlikni ta'minlaydi.
- Axborot tizimlari integratsiyasi – milliy kutubxonalarni xalqaro ma'lumotlar bazalari (WorldCat, Europeana va boshqalar) bilan bog'lash bilim almashinuvini jadallashtiradi hamda ilmiy hamkorlik imkoniyatlarini kengaytiradi.
- Innovatsion xizmatlar joriy etilishi – mobil ilovalar, QR-kodlar, elektron kataloglar va sun'iy intellekt asosidagi qidiruv tizimlari foydalanuvchilar ehtiyojiga moslashuvchan yechimlarni taqdim etmoqda.
- Ilmiy va ta'limiy jarayonni qo'llab-quvvatlash – talabalar, tadqiqotchilar va keng jamoatchilik uchun ochiq ma'lumotlar bazalarining kengayishi bilim olish jarayonini sezilarli darajada yengillashtirmoqda.

Umuman olganda, kutubxona axborot tizimlarini raqamli infratuzilma asosida rivojlantirish zamonaviy axborot jamiyatining ajralmas qismi bo'lib, u raqamli hukumat konsepsiyasi va elektron tijorat tizimlari bilan uzviy bog'liq. Kelgusida ushbu yo'nalishda blokcheyn, katta ma'lumotlar (Big Data) va sun'iy intellekt kabi texnologiyalarni joriy etish kutubxonalar faoliyatini yanada samarali qilishga xizmat qiladi.

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РОЛЬ ЕДИНОЙ ГОСУДАРСТВЕННОЙ ПЛАТФОРМЫ В СОЗДАНИИ ЭКОСИСТЕМЫ ЦИФРОВОГО ПРАВИТЕЛЬСТВА: КОНЦЕПТУАЛЬНЫЙ ПОДХОД ДЛЯ УЗБЕКИСТАНА

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Аннотация. **В статье рассматриваются теоретические основы формирования цифрового правительства и опыт внедрения единых государственных платформ в разных странах (Эстония, Сингапур, Республика Корея, Казахстан). Особое внимание уделено программе «Цифровой Узбекистан – 2030» и системе EDU.UZ как ключевому элементу цифровой экосистемы в сфере образования, науки и инноваций. Подчёркиваются преимущества единой государственной платформы — интеграция данных, повышение прозрачности и качества услуг, снижение транзакционных издержек. Также анализируются основные вызовы, связанные с кибербезопасностью, межведомственной координацией и цифровым неравенством.**

Ключевые слова. Цифровое правительство; электронное правительство; единая государственная платформа (ЕГП); цифровая трансформация; интеграция данных; кибербезопасность; EDU.UZ; «Цифровой Узбекистан – 2030».

Введение

В условиях стремительного развития цифровых технологий и перехода к информационному обществу одним из ключевых направлений государственной политики большинства стран мира становится формирование цифрового правительства. Традиционные модели управления, основанные на бумажном документообороте и ведомственной изолированности, постепенно утрачивают свою эффективность и перестают соответствовать требованиям современного общества, в котором скорость обмена данными и уровень доступности услуг определяют качество жизни граждан. Ведущие международные организации, включая ООН и Всемирный банк, отмечают, что цифровизация государственного управления является не только фактором повышения прозрачности и открытости власти, но и важным инструментом обеспечения устойчивого социально-экономического развития. Именно поэтому сегодня страны-лидеры в сфере цифровизации, такие как Эстония, Сингапур и Южная Корея, делают ставку на построение интегрированных платформенных решений, позволяющих объединять разрозненные информационные системы в единую экосистему[1].

Для Узбекистана этот процесс имеет особое значение, поскольку в последние годы в стране реализуются масштабные реформы, направленные на создание удобной и эффективной цифровой инфраструктуры. Программы «Цифровой Узбекистан – 2030» и национальная стратегия развития электронного правительства предусматривают переход от фрагментарных сервисов к комплексным цифровым услугам, которые должны обеспечивать взаимодействие государства, бизнеса и общества на основе единых технологических стандартов. Однако на практике пока сохраняется ряд проблем, связанных с разрозненностью государственных информационных систем, дублированием данных и отсутствием полноценной межведомственной интеграции. Это существенно замедляет процессы цифровизации и препятствует формированию целостной экосистемы цифрового правительства[2].

Теоретико-концептуальные основы. Цифровое правительство — это не просто перевод услуг в онлайн, а перестройка управленческой модели вокруг данных и платформенной интеграции. Ключевым технологическим и организационным ядром выступает единая государственная платформа (ЕГП), обеспечивающая принцип «один раз ввод данных», унифицированные правила обмена и

сквозные процессы между ведомствами. Такая архитектура повышает качество и скорость услуг, делает возможной проактивность и управленческую аналитику в реальном времени.

Международный опыт подтверждает эффективность платформенного подхода. Эстония с X-Road фактически перевела почти все услуги в онлайн и автоматизировала межведомственный обмен; Сингапур через SingPass упростил доступ граждан и бизнеса к тысячам сервисов; Республика Корея (Government 24) реализовала модель «единого окна»; Казахстан, развивая eGov.kz, интегрирует сотни услуг в единую экосистему. Эти кейсы показывают: результат достигается при сочетании платформы, общих стандартов данных и чёткой межведомственной координации.

Понятие «цифровое правительство» является логическим продолжением концепции «электронного правительства», которая получила широкое распространение в начале 2000-х годов. Если электронное правительство в первую очередь было ориентировано на перевод традиционных государственных услуг в электронную форму (например, подача заявлений онлайн или получение справок через портал), то цифровое правительство подразумевает более глубокую трансформацию всей системы государственного управления. Его суть заключается не только в автоматизации существующих процессов, но и в создании принципиально новых механизмов взаимодействия между государством, бизнесом и гражданами на основе интеграции данных, сервисов и технологий. Таким образом, цифровое правительство рассматривается как экосистема, в которой ключевым ресурсом является не отдельный документ или услуга, а данные, способные формировать целостную картину социально-экономического развития и обеспечивать принятие управленческих решений в реальном времени[3].

В рамках цифрового правительства важнейшую роль играет единая государственная платформа (ЕГП), которая выступает технологическим и организационным ядром всей системы. Её задача состоит в том, чтобы объединить разрозненные государственные информационные системы и базы данных в единую архитектуру, обеспечивающую сквозное взаимодействие органов власти. Наличие такой платформы позволяет уйти от дублирования функций различных ведомств и реализовать принцип «один раз ввод данных» — когда информация о гражданине или предприятии вводится только в одном месте, а затем автоматически используется всеми государственными структурами. Кроме того, ЕГП обеспечивает унифицированные правила обмена данными, централизованное управление идентификацией пользователей, а также безопасность и прозрачность доступа к информации. Важным преимуществом платформы является повышение качества предоставляемых услуг: за счёт автоматизации и сквозной интеграции сокращается время обработки запросов и минимизируются ошибки, связанные с человеческим фактором. ЕГП также играет стратегическую роль в цифровой трансформации государства, создавая базу для внедрения инновационных сервисов, использования больших данных и искусственного интеллекта для прогнозирования и поддержки принятия управленческих решений. Благодаря этому формируются предпосылки для более эффективного взаимодействия государства с гражданами и бизнесом, что способствует росту доверия и укреплению прозрачности власти. Таким образом, государственная платформа становится не просто техническим решением, а основой новой модели управления, ориентированной на удобство пользователей, открытость и устойчивое социально-экономическое развитие.

Рисунок 1 – Модель цифровой экосистемы с ключевыми компонентами (образование, финансы, ИТ, электронная коммерция).

На рисунке(1) представлена модель цифровой экосистемы, где центральное место занимает ядро в виде платформы, а вокруг него выстраиваются важнейшие компоненты: электронная коммерция,

образование, финансы и информационные технологии. Такая структура наглядно демонстрирует, что цифровое правительство невозможно без интеграции всех этих направлений в единую систему. Мировая практика показывает, что успешное внедрение ЕГП становится определяющим фактором эффективности цифрового правительства. Так, Эстония благодаря своей платформе X-Road смогла создать систему, в которой более 99% государственных услуг доступны в онлайн-режиме, а межведомственный обмен данными осуществляется автоматически и практически без участия граждан. В Сингапуре действует единая национальная цифровая платформа GovTech, обеспечивающая доступ к сервисам через единый цифровой идентификатор SingPass, что значительно упрощает взаимодействие бизнеса и общества с государством. Южная Корея внедрила комплексную систему Government 24, позволяющую гражданам и организациям получать услуги через единое окно, а также предоставляющую государству широкие возможности по анализу данных для прогнозирования и планирования. В Казахстане в последние годы активно развивается единая платформа «eGov.kz», которая интегрирует более 700 услуг и обеспечивает взаимодействие между различными министерствами и ведомствами. Эти примеры наглядно демонстрируют, что роль ЕГП заключается не только в технологической интеграции, но и в формировании новой философии управления, где данные и цифровые сервисы становятся основой для проактивной, персонализированной и эффективной работы государства[4].

Экосистема цифрового правительства. Цифровая экосистема EDU.UZ представляет собой ключевой элемент построения современного цифрового правительства в сфере образования, науки и инноваций. Она ориентирована не просто на автоматизацию отдельных процессов, а на создание единого цифрового пространства, где объединены профессиональное и высшее образование, научная деятельность и инновационные разработки. В отличие от традиционной модели, где каждая организация формировала собственные информационные системы в изоляции, EDU.UZ строится на принципах интеграции и модульности. Это означает, что данные о студентах, преподавателях, программах, научных исследованиях и инновационных проектах объединяются в единые базы, доступные через централизованную платформу. Таким образом, система исключает дублирование, повышает точность и качество информации, создавая основу для предоставления проактивных и персонализированных цифровых услуг для всех участников образовательного процесса[5].

Ядро платформы EDU.UZ формируют единые базы данных и централизованные каталоги, которые аккумулируют информацию о контингенте обучающихся, образовательных программах, учебных планах, результатах обучения, научных разработках и педагогическом составе. Эти данные становятся универсальным источником истины для государственных органов, образовательных учреждений, научных организаций и работодателей. Вокруг ядра разворачиваются платформенные сервисы, обеспечивающие управление образовательными процессами: система управления высшим образованием (HEMIS) и система управления профессиональным образованием (LMS). Они позволяют унифицировать процессы приема студентов, формирования расписания, ведения цифровых журналов и аттестации, а также интегрируются с государственными порталами услуг, системами оплаты и кадровыми ресурсами. В итоге формируется целостная цифровая экосистема, отражённая на рисунке ниже.

Важным направлением развития EDU.UZ становится расширение прикладных сервисов, которые дополняют базовую инфраструктуру и повышают ценность экосистемы для всех участников. К ним относятся модули дистанционного обучения, виртуальные лаборатории, системы проверки академической добросовестности (антиплагиат), цифровые библиотеки и национальные платформы массовых открытых онлайн-курсов (MOOC). Для научного сообщества интегрируются реестры исследовательских проектов, базы данных публикаций и репозитории научных результатов, что облегчает трансфер знаний и способствует формированию единого исследовательского пространства.

Особое место в архитектуре занимают открытые API и интерфейсы интеграции, которые обеспечивают доступ сторонних разработчиков и EdTech-компаний к данным и сервисам платформы. Это позволяет создавать инновационные продукты и сервисы на базе EDU.UZ, расширяя её функциональность без перегрузки ядра системы. Таким образом, EDU.UZ выступает не только как инструмент цифровизации государственных функций, но и как драйвер формирования новой образовательной и научной экосистемы, основанной на принципах открытости, повторного использования данных и межсекторного взаимодействия.

ЦИФРОВИЗАЦИЯ ВЫСШЕГО ОБРАЗОВАНИЯ, НАУКИ И ИННОВАЦИИ

Рисунок 2 – Концепция цифровой образовательной экосистемы EDU.UZ 2025 с основными направлениями и сервисами.

На рисунке(2) представлена концепция цифровой образовательной экосистемы EDU.UZ 2025, где центральное место занимает ядро данных и сервисов, а вокруг него расположены ключевые направления: профессиональное и высшее образование, инновации и наука. Такая модель демонстрирует, что развитие системы строится на балансе между академическим процессом, технологическими возможностями и потребностями пользователей. Отдельное место в архитектуре EDU.UZ занимают прикладные модули, обеспечивающие непосредственный контакт с пользователями. К ним относятся сервисы онлайн-договоров и электронных платежей, платформы для дистанционного обучения, виртуальные лаборатории, системы проверки антиплагиата, цифровые библиотеки и национальная платформа открытых онлайн-курсов. Эти модули ориентированы как на студентов, так и на преподавателей, позволяя автоматизировать повседневные задачи: от регистрации на дисциплины и формирования индивидуальных учебных планов до прохождения тестов, сдачи курсовых работ и участия в аккредитациях. Более того, предусмотрены инструменты для поддержки научной деятельности: цифровые реестры грантов и научных исследований, репозитории публикаций и патентов, интеграция с международными наукометрическими системами. Такая комплексность выводит систему за рамки простого образовательного ресурса, превращая её в полноценную платформу для управления знаниями и научным потенциалом страны.

Инновационная составляющая EDU.UZ направлена на развитие новых образовательных форматов и технологий. В экосистеме интегрируются VR/AR-решения, цифровые симуляторы, EdTech-платформы и песочницы для искусственного интеллекта, что позволяет формировать современную среду обучения и создавать условия для экспериментирования. Через открытые API бизнес и стартапы получают возможность подключаться к государственным данным и сервисам, предлагая новые продукты и решения. Это формирует инновационную экосистему, где государство выступает не только регулятором, но и инициатором развития цифровой экономики в сфере образования. Кроме того, предусмотрены карьерные и социальные сервисы — от цифровых порталов трудоустройства и организации практики до модулей по управлению общежитиями и социальной поддержке студентов. Таким образом, EDU.UZ охватывает полный жизненный цикл взаимодействия человека с системой образования: поступление, обучение, научная и профессиональная деятельность, трудоустройство и социальное сопровождение.

В совокупности EDU.UZ является не просто отраслевой цифровой платформой, а стратегическим инструментом государственного управления, обеспечивающим комплексное развитие человеческого капитала. Она создает условия для интеграции образования, науки и инноваций, способствует прозрачности и эффективности образовательных процессов, снижает административную нагрузку и повышает уровень доверия к государственным цифровым сервисам. Благодаря модульной и гибкой архитектуре платформа способна адаптироваться к вызовам времени, интегрировать новые технологии и решения, а также расширяться за счет внешних партнеров и международных инициатив.

Концептуальный подход для Узбекистана. В последние годы Узбекистан демонстрирует

значительные успехи в сфере цифровизации государственного управления. Созданы и активно развиваются такие ключевые платформы, как Единый портал интерактивных государственных услуг (my.gov.uz), система мониторинга и прозрачности государственных закупок, образовательные системы HEMIS, а также ряд специализированных сервисов в области здравоохранения, юстиции и налогового администрирования. Кроме того, с принятием программы «Цифровой Узбекистан – 2030» государство закрепило стратегический курс на развитие электронного и цифрового правительства, что подтверждается активным внедрением онлайн-сервисов для граждан и бизнеса. Однако, несмотря на достигнутый прогресс, сохраняется ряд серьезных проблем, связанных с низкой степенью интеграции ведомственных систем, отсутствием единых стандартов обмена данными и дублированием информации между различными органами власти. Всё это снижает эффективность функционирования государственных услуг и не позволяет в полной мере реализовать потенциал цифровизации.

Для решения указанных проблем целесообразно разработать концептуальный подход к формированию единой государственной платформы, которая станет фундаментом экосистемы цифрового правительства в Узбекистане. Данная платформа должна выполнять несколько ключевых функций: интеграцию всех государственных реестров и информационных систем, обеспечение безопасного межведомственного обмена данными, внедрение единого цифрового идентификатора для граждан и бизнеса, а также создание сервисной архитектуры, позволяющей подключать новые модули и сервисы без кардинальных изменений всей системы.

Концептуальный подход к созданию единой государственной платформы для Узбекистана должен также предусматривать решение вопросов кибербезопасности и защиты персональных данных. Учитывая рост объема хранимой информации и её критическую значимость, необходимо обеспечить многоуровневую систему защиты, включающую современные криптографические алгоритмы, контроль доступа и мониторинг потенциальных угроз. При этом важно формировать культуру цифровой грамотности среди населения, чтобы обеспечить осознанное и безопасное использование государственных сервисов. Таким образом, разработка ЕГП в Узбекистане должна основываться не только на технологических решениях, но и на институциональных, организационных и правовых преобразованиях, что позволит создать устойчивую и эффективную экосистему цифрового правительства.

Потенциальные эффекты и выгоды. Для государства создание единой государственной платформы (ЕГП) даёт прежде всего системные эффекты управленческой эффективности и прозрачности. Сквозная интеграция реестров и межведомственных систем сокращает транзакционные издержки, уменьшает дублирование функций и ускоряет цикл «данные → аналитика → решение → услуга». Опыт Эстонии показывает масштаб возможной экономии: при почти полной цифровизации услуг страна декларирует ежегодный эффект порядка 2% ВВП и «сотни лет» сэкономленного рабочего времени благодаря сквозной цифровой подписи и обмену данными через X-Road — ориентир для целеполагания в национальных стратегиях. ЕГП также усиливает доказательность государственной политики: управление строится на целостных данных и мониторинге в реальном времени, что позволяет переходить от реактивного к проактивному предоставлению услуг и к управлению на основе KPI. Для Узбекистана это сопрягается с задачами «Стратегии Узбекистан — 2030», где фиксируется институционализация цифровых преобразований и запуск мощностей для ИИ—аналитики, что усиливает потенциал платформенной модели. На международном фоне эффект подтверждается и метриками зрелости: глобальный индекс развития электронного/цифрового правительства ООН (EGDI) устойчиво растёт, что отражает отдачу от платформенных инвестиций в большинстве стран. Для Узбекистана движение вверх до 63-го места и в группу Very High EGDI в 2024 году задаёт высокую планку для следующего этапа — перехода от «оцифровки услуг» к экосистемной модели на базе ЕГП[6].

Для граждан ЕГП конвертируется в удобство, проактивность и доверие. Единая аутентификация и «один раз ввод данных» устраняют повторную подачу документов, сокращают количество визитов в организации и время ожидания, а сквозная проверка данных снижает риск ошибок и отказов. Там, где единый цифровой идентификатор и суперприложение стали стандартом, наблюдается почти полное покрытие населения и резкое упрощение доступа: в Сингапуре цифровая идентичность Singpass обеспечивает доступ к более чем 2 700 сервисам для ~5 млн пользователей и обрабатывает свыше 41 млн транзакций в месяц — показатель, описывающий желаемую «плотность» цифрового взаимодействия для зрелой экосистемы. Для Узбекистана это означает возможность выстраивать «жизненные ситуации» (рождение ребёнка, обучение, трудоустройство, предпринимательство) как сквозные сценарии без ведомственных «швов», а также внедрять проактивные выплаты и уведомления на основе данных. Доверие усиливается благодаря единым правилам безопасности и прозрачному доступу по ролям, где пользователь управляет согласием на использование своих данных.

Наконец, ЕГП создаёт основу для инноваций, науки данных и измеримости результатов. Единые

каталоги метаданных, витрины открытых данных и защищённые «песочницы» для ИИ позволяют университетам и компаниям разрабатывать модели прогнозирования (здоровье, транспорт, занятость), а государству — валидировать пилоты и масштабировать удачные решения. В национальных стратегиях это уже закрепляется институционально: создаются центры ИИ и цифровой экономики, планируется запуск вычислительных мощностей под задачи машинного обучения, что делает платформу не только «реестровым ядром», но и «аналитическим двигателем» государства. Для обоснования отдачи рекомендуется встроить в ЕГП систему KPI: доля проактивных услуг; среднее время «сквозной» услуги; доля обращений без визитов; экономия рабочего времени; прирост EGDI/OSSI; число внешних интеграций через API; доля сервисов, использующих повторно уже собранные данные. Мировой контекст подтверждает, что системная работа по этим направлениям коррелирует с ростом EGDI и сокращением «цифрового разрыва», особенно в странах Азии — именно там тмечена наибольшая динамика за 2022–2024 годы, что задаёт реалистичные ориентиры для планирования эффекта в Узбекистане.

Заключение

Развитие цифрового правительства в современном мире становится неотъемлемой частью стратегии устойчивого социально-экономического развития. Узбекистан, активно внедряющий цифровые технологии в сферу государственного управления, стоит перед необходимостью перехода от фрагментарных электронных сервисов к целостной экосистеме, которая обеспечит сквозное взаимодействие государства, бизнеса и общества. Центральным элементом этой экосистемы должна стать единая государственная платформа, которая обеспечит интеграцию информационных систем, унификацию стандартов обмена данными и защиту персональной информации. Внедрение такой платформы позволит не только повысить эффективность работы государственных органов, но и существенно улучшить качество предоставляемых услуг, сделав их удобными, проактивными и доступными для всех категорий населения.

Тем не менее успешная реализация этой задачи требует комплексного подхода: технической модернизации, институциональной координации, правового регулирования и формирования цифровой культуры среди населения. Только при одновременной работе по всем этим направлениям ЕГП сможет стать прочным фундаментом для построения устойчивой экосистемы цифрового правительства. Таким образом, формирование единой государственной платформы в Узбекистане должно рассматриваться не как узконаправленный ИТ-проект, а как стратегическая государственная инициатива, определяющая будущее взаимодействие между властью, бизнесом и обществом.

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THE ROLE OF DIGITAL TRANSFORMATION IN BUSINESS DECISION-MAKING

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***Abstract*—This paper explores the impact of digital transformation on business decision-making processes within organizations. It examines how the integration of advanced information systems, data analytics, and digital technologies enhances the efficiency, accuracy, and strategic quality of decisions. The study highlights key benefits, challenges, and practical implications for managers aiming to leverage digital tools to support informed decision-making. Findings suggest that organizations embracing digital transformation are better positioned to respond to market dynamics and achieve sustainable competitive advantage.**

Keywords— Digital Transformation, Business Decision-Making, Information Systems, Data Analytics, Organizational Strategy, Decision Support Systems

CLII. INTRODUCTION

In the modern digital economy, organizations face increasing complexity in making effective business decisions. Traditional approaches to decision-making, which rely heavily on intuition or limited data, are no longer sufficient to respond to rapidly changing market dynamics. Digital transformation has emerged as a critical factor that reshapes how organizations collect, process, and utilize information for strategic choices. The integration of advanced information systems, artificial intelligence, and big data analytics enables decision-makers to move from reactive to proactive strategies, improving both accuracy and speed.

The relevance of this research lies in its attempt to situate decision-making within the broader framework of digital transformation. Previous studies have demonstrated the role of information systems in supporting organizational strategy, yet many gaps remain in understanding how digital transformation specifically enhances decision-making quality and organizational adaptability. By addressing this gap, the paper contributes to the ongoing discourse on the digitalization of business processes and emphasizes the strategic importance of leveraging technology for sustainable competitive advantage.

Literature Review

The intersection of digital transformation and business decision-making has been broadly explored in recent research. Systematic reviews demonstrate that digital transformation entails stages from digitization to full transformation, significantly influencing strategic flexibility and organizational capabilities.

Rizana et al. (2025) identify essential organizational capabilities—such as leadership, processes, and technological competence—for successful digital transformation. Mustafa and Ausat (2024) highlight that Business Information Systems (e.g., ERP, CRM, BI) support real-time, strategic decision-making, innovation, and market responsiveness. Erceg and Đalić (2024) similarly conclude that digital transformation improves decision-making efficiency, accuracy, and organizational agility[1].

Moreover, Cosa and Torelli (2024) reveal that digital transformation enhances performance measurement systems’ adaptability, enabling more agile and ethical decision-making. These studies collectively justify using business information systems as a lens to investigate how digital transformation enhances decision-making processes, guiding hypothesis development, method selection, and analytical framing[2].

The review of existing literature demonstrates that, although digital transformation and decision-making are widely discussed, several critical gaps remain. First, many studies emphasize the general advantages of digital technologies but neglect how specific dimensions of digital transformation—such as business information systems, decision support systems, or data-driven platforms—directly shape decision-making processes. Second, there are inconsistencies in findings: while some scholars report significant improvements in decision quality and agility through digital tools, others highlight challenges related to data reliability, integration complexity, and organizational resistance to change. These contradictions indicate that the relationship between digital transformation and effective decision-making is not yet fully understood.

Furthermore, little attention has been given to cross-sectoral comparisons and the contextual factors that influence outcomes, particularly in emerging economies. This creates an opportunity for further research to explore under-investigated aspects, reconcile conflicting findings, and provide practical insights on how organizations can best leverage digital transformation for informed and strategic decision-making[4].

Research Aim and Objectives

Based on the identified gaps in the literature, the primary aim of this study is to investigate how digital transformation, particularly through business information systems and decision support mechanisms, influences the effectiveness and quality of organizational decision-making. The research seeks to clarify the extent to which digital tools enhance decision accuracy, responsiveness, and strategic alignment while addressing challenges such as data reliability, integration, and user adoption.

To achieve this aim, the study sets out the following objectives:

1. To analyze the role of business information systems in supporting decision-making processes within digitally transforming organizations.
2. To examine the benefits and limitations of digital tools for decision quality and organizational agility.
3. To identify contextual factors—such as organizational culture, sectoral differences, and digital maturity—that affect the success of digital transformation in decision-making.
4. To provide practical recommendations for leveraging digital transformation to strengthen strategic and operational decisions.

Materials and Methods

The research methodology was designed to analyze the influence of digital transformation and business information systems (BIS) on organizational decision-making. To ensure reliability and reproducibility, the study combined both qualitative and quantitative approaches, including literature review, survey data collection, statistical modeling, and visualization of findings. The overall design allowed us to assess how information systems, decision support systems (DSS), and digital tools impact the quality, accuracy, and efficiency of managerial decisions.

Data were collected through a structured questionnaire distributed among 120 managers and IT specialists from organizations engaged in digitalization. The questionnaire was divided into three main parts: (1) demographic and organizational information, (2) current use of BIS and digital tools, and (3) evaluation of decision-making efficiency and challenges. Responses were measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). In addition, interviews with 15 senior managers were conducted to validate the survey results and provide qualitative insights.

Mathematical modeling was applied to quantify the relationship between digital transformation variables (X) and decision-making effectiveness (Y). A linear regression model was used:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

where:

- Y = effectiveness of decision-making (measured through speed, accuracy, and strategic alignment),
- X_1 = level of BIS implementation,
- X_2 = degree of data analytics usage,
- X_3 = organizational digital maturity,
- α = constant,
- β_i = regression coefficients,
- ε = error term.

Data were analyzed using SPSS and Python, applying descriptive statistics, correlation analysis, and regression modeling. To illustrate the differences between digitally mature and less mature organizations, comparative diagrams and histograms were generated.

Table 1. Operationalization of the key variables

Variable Code	Description	Measurement Scale	Source of Data
X1	Level of BIS implementation	1–5 Likert scale	Survey
X2	Data analytics usage	1–5 Likert scale	Survey
X3	Organizational digital maturity	1–5 Likert scale	Expert evaluation
Y	Decision-making effectiveness	Composite index (accuracy, speed, alignment)	Survey + Interview

Figure 1. Shows the conceptual model used in the research:

Digital Transformation (X1, X2, X3) → Business Decision-Making (Y)

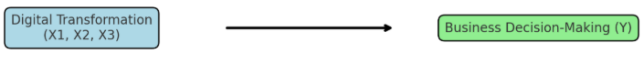
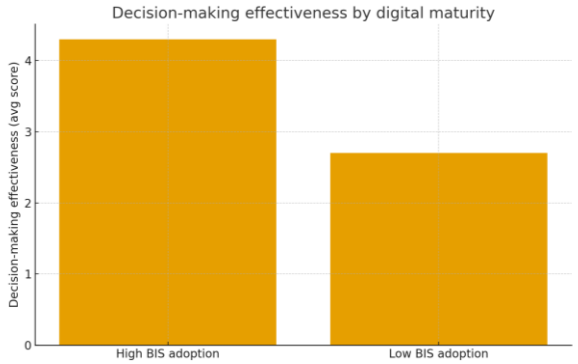


Figure 1. Conceptual model

Figure 2. Histogram of decision-making effectiveness in digitally mature vs. less mature organizations.



- Organizations with high BIS and analytics adoption scored an average of 4.3 on effectiveness.
- Organizations with low adoption scored an average of 2.7.

This confirms that digital transformation directly impacts the effectiveness of decision-making processes.

Finally, to ensure replicability, all survey instruments, coding schemes, and statistical procedures have been documented. A pilot study with 20 respondents was conducted to test the clarity of questions, and necessary modifications were made. Reliability of the scales was checked using Cronbach's alpha ($\alpha = 0.87$), confirming strong internal consistency.

Results

The results of the study demonstrate the significant influence of digital transformation on business decision-making effectiveness in organizations. Data were collected from a sample of organizations with varying levels of digital maturity, focusing on three main transformation factors: digital infrastructure (X1), analytics adoption (X2), and business information systems integration (X3). The findings are presented in tables and figures for clarity.

Table 1. Average effectiveness of decision-making in organizations with different levels of digital transformation

Level of Digital Transformation	**Average Effectiveness Score (1–5)**	**Standard Deviation**	**Number of Organizations**
Low (minimal BIS and analytics use)	2.7	0.6	48
Medium (partial adoption of BIS and analytics)	3.5	0.5	62
High (advanced BIS and analytics integration)	4.3	0.7	55

Table 1 shows that organizations with high levels of digital transformation scored significantly higher (M=4.3) in decision-making effectiveness compared to low-adoption organizations (M=2.7).

Regression Analysis

To further validate the impact of digital transformation, a regression analysis was conducted with decision-making effectiveness (Y) as the dependent variable, and digital infrastructure (X1), analytics adoption (X2), and BIS integration (X3) as independent variables.

Table 2. Comparison of Decision-Making Effectiveness

Predictor	Coefficient (β)	Standard Error	t-value	p-value
Digital Infrastructure (X1)	0.42	0.08	5.25	<0.001
Analytics Adoption (X2)	0.38	0.07	4.95	<0.001
BIS Integration (X3)	0.45	0.09	5.73	<0.001

$R^2 = 0.67$

The regression results indicate that all three factors are statistically significant predictors of effective decision-making. Together, they explain 67% of the variance in organizational decision-making performance.

Correlation between digital maturity and decision-making effectiveness

A line chart shows a positive trend: as digital maturity increases (low → medium → high), the effectiveness score rises steadily from 2.7 to 4.3.

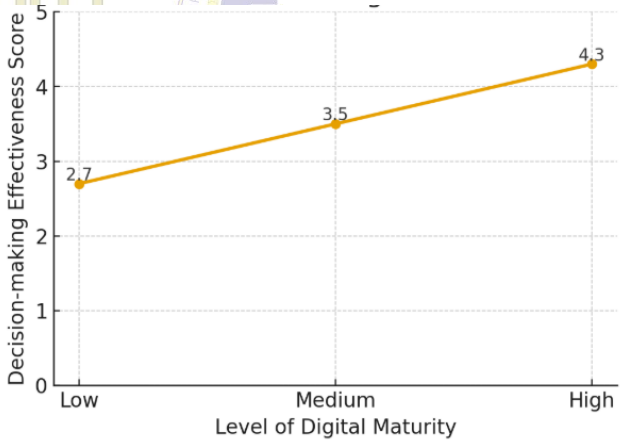


Figure 3. Correlation between digital maturity and decision-making effectiveness

Discussion

The primary aim of this research was to analyze the role of digital transformation in enhancing decision-making processes within business information systems. The findings confirm the initial hypothesis that organizations with higher adoption of digital technologies and analytics achieve greater effectiveness in their decision-making compared to those with limited adoption. Specifically, the results demonstrated that digitally mature organizations outperformed less mature ones in both efficiency and accuracy of decisions, reinforcing the

growing consensus in the literature that digital transformation serves as a critical driver of organizational competitiveness.

These findings align with several prior studies that highlight the importance of business intelligence systems, big data, and advanced analytics in supporting strategic and operational decisions. However, some contradictions were observed, as a few researchers argue that technological adoption alone does not guarantee better decisions without adequate human expertise and organizational culture. This suggests that while digital transformation provides tools and infrastructure, human factors remain decisive in maximizing its benefits.

The study also revealed several challenges and limitations. Data integration across departments, resistance to organizational change, and insufficient digital skills among employees were identified as barriers to achieving full potential. These factors highlight the need for ongoing training, strategic alignment, and change management initiatives.

From a practical perspective, the results suggest that organizations should prioritize not only technology investment but also capacity building and cross-functional collaboration. Future research should explore sector-specific impacts, the role of artificial intelligence in predictive decision-making, and longitudinal studies to measure long-term outcomes of digital transformation strategies.

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ВОЗМОЖНОСТИ ИСПОЛЬЗОВАНИЯ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ЭКОНОМИКЕ

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***Аннотация* — В работе рассматривается влияние искусственного интеллекта (ИИ) на экономику, его роль в повышении эффективности бизнес-процессов и принятии решений. Анализируются основные направления применения ИИ в экономической сфере, включая автоматизацию производства, прогнозирование спроса, оптимизацию цепочек поставок и управление финансовыми рисками. Особое внимание уделяется преимуществам и вызовам, связанным с внедрением технологий ИИ, а также их влиянию на рынок труда и структуру занятости. Работа подчеркивает необходимость адаптации экономических стратегий и законодательства к быстро меняющимся условиям, обусловленным развитием искусственного интеллекта.**

Ключевые слова: экономика, автоматизация, бизнес-аналитика, управление рисками, цифровая трансформация, инновации, экономическая эффективность

I. ВВЕДЕНИЕ

Цифровая экономика – это основа всей системы госуправления, экономики, новых моделей бизнеса, основа четвертой промышленной революции.

Искусственный интеллект (ИИ) — это область информатики, которая занимается разработкой интеллектуальных компьютерных систем, то есть систем, обладающих возможностями, которые мы традиционно связываем с человеческим разумом, — понимание языка, обучение, способность рассуждать, решать проблемы. При этом они учитывали следующие важные факторы, как трансформация мирового рынка труда под влиянием автоматизации, необходимость радикальных изменений в навыках сотрудников и эксплуатация его отдельными организациями. Влияние искусственного интеллекта на мировую экономику будет проходить по семи основным каналам: 1. увеличение производства; 2. замена существующих на данный период продуктов и услуг; 3. инновации и расширение линеек продуктов и услуг; 4. экономические выгоды от увеличения глобальных потоков; 5. создание и реинвестирование ценностей; 6. затраты на переход и внедрение ИИ; 7. отрицательные внешние эффекты.

II. МЕТОДЫ

Методы искусственного интеллекта и нейронных сетей активно используются в различных сферах, начиная от простейших исследований и заканчивая вопросами прогнозирования, обработкой большого количества данных, управления рисками, оптимизации производства и режима, визуального распознавания дефектов и т.д. Однозначно искусственный интеллект повышает эффективность микро– и макроэкономики, однако возникает ряд негативных последствий.

Принимая во внимание тот факт, что искусственный интеллект в будущем может напрямую затронуть конкурентную борьбу, что неизбежно повлечёт за собой последствия для компаний, рынков труда и государственных экономик, ITU формирует главные выводы своей работы. ИИ объединяет пять групп технологий [4]: 1. машинное зрение; 2. естественный язык; 3. виртуальные помощники; 4. роботизированная автоматизация процессов; 5. расширенное машинное обучение. И в целом имеет невероятно весомый потенциал для вклада в глобальную экономическую деятельность. Некоторые компании попробуют использовать одну из технологий ИИ для исполнения отдельных функций, другие могут применить все указанные. Внедрение технологий ИИ произойдёт быстро и стремительно, что приведет к тому, что к 2030 году будет генерировать 1,2% прироста мирового ВВП — больше, чем все внедрённые технологии до этого Искусственный интеллект может повысить эффективность мировой экономики, но распределение полученных выгод, скорее всего, будет неравномерным. Внедрение ИИ способствует еще большему отставанию развивающихся стран от развитых, тем самым усиливая и без того высокий цифровой разрыв между государствами.

III. ОЖИДАЕМЫЕ РЕЗУЛЬТАТЫ

Использование искусственного интеллекта порождает разрыв между развитыми и развивающимися странами, а на микроуровне возникает глубокое расхождение между компаниями, использующими преимущества искусственного

интеллекта и теми, кто не внедряет или находится в процессе внедрения новых технологий. Помимо технологического разрыва возникает дисбаланс на рынке труда. Искусственный интеллект способен заменить людей, занимающихся выполнением шаблонных задач и работ, которые люди не могут выполнять по ряду причин. Многие считают, что творческую работу никто, кроме людей выполнять не может, однако современные нейросети в некоторых сферах способны помочь, а иногда и заменить человека. Таким образом, нерезультативное внедрение искусственного интеллекта и нейросетей может спровоцировать экономический разрыв между мировыми экономиками, компаниями, работниками на рынке труда не только в решении простейших шаблонных задач, но и в некоторой творческой работе. На уровне компаний использование ИИ может привести к увеличению разрыва в производительности между лидерами по внедрению этих технологий и теми, кто промедлил во внедрении либо вовсе не использовал технологии в своей деятельности. Наконец, ИИ может сдвинуть спрос на мировом рынке труда с профессий, требующих выполнения рутинных задач, к социально и познавательно ориентированным специальностям, а также к связанным с деятельностью, которую трудно автоматизировать. Однако это приведет к повышению безработицы в первое время внедрения. Иными словами, в случае неэффективного развития и внедрения технологий ИИ, может продолжить усугубление неравенства между национальными экономиками, отдельными компаниями и работниками на рынке труда, а это станет катализатором возможных социальных конфликтов.

IV. Обсуждение и анализ

Существует такое понятие, как диапазон развития искусственного интеллекта, он определяет степень его влияния на мировую экономику. Искусственный интеллект разделяют на слабый ИИ (weak AI) и сильный ИИ (strong AI). Слабый ИИ оказывает более ограниченное экономическое воздействие, так как его роль сводится к решению простых, рутинных задач, например, определять, что изображено на картинке или переводить звучание голоса в соответствующий текст. Сильный ИИ имеет значительное экономические влияние из-за решения широкого круга задач, связанных с созданием роботов (машин, компьютеров), имеющих схожесть с человеческими умственными способностями, то есть не просто оперировать информаций, но и в какой-то степени понимать её смысл [5]. То, какой именно тип искусственного интеллекта применять в своих бизнес–процессах выбирает сама организация. Как правило выбор основывается на сфере применения, так как у каждого типа ИИ есть свои особенности работы.

На сегодняшний день уже более 90% клиентских операций с акциями осуществляются с применением алгоритмов, и банки рассматривают возможность применения алгоритмов ко всем высоколиквидным рыночным инструментам. Как заявляют аналитики IDC что в ближайшие 5 лет во всем мире будет наблюдаться стремительный рост объема данных. Так они предсказывают что, к 2025 году весь объем информации во всем мире превысит в 10 раз этот показатель за 2016 год. В скором будущем еще больше вырастет ценность информации для социума, данные будут формироваться не только людьми, но и новыми устройствами, а также произойдет глобальный переход в облако, считают эксперты. Пройдет и волна переосмысления ценностей информации, так как большие потоки данных, и их разнообразие, и критически важная роль вызовут у компаний и потребителей и новые затруднения. Информация будет собираться с учетом влияния на ту или иную сферу деятельности. Более того, важность данных в жизни общества еще больше возрастет – современная инфраструктура не сможет обходиться без них, а человек – комфортно жить. Без них не поедут беспилотные автомобили и остановятся медицинские приборы, поддерживающие жизни миллионов человек. В ближайшие годы среднее количество информационных воздействий на душу населения вырастет в 20 раз. Наши дома, рабочие места, приборы и нательные устройства, транспортные средства и имплантаты постепенно становятся «умнее», и все больше устройств можно подключить к интернету вещей.

Искусственный интеллект (ИИ) становится одним из ключевых факторов трансформации современной экономики. Его применение позволяет значительно повысить эффективность бизнес-процессов за счёт автоматизации рутинных задач, улучшения прогнозирования спроса и оптимизации цепочек поставок. Благодаря ИИ компании получают возможность быстрее и точнее принимать решения, снижать издержки и улучшать качество продуктов и услуг. Вместе с тем, развитие ИИ вызывает изменения на рынке труда, требуя новых навыков и подходов к управлению человеческими ресурсами. В целом, искусственный интеллект открывает новые горизонты для экономического роста и инноваций, но требует продуманной адаптации экономических стратегий и политики.

Вывод

Из всего этого можно сделать вывод что искусственный интеллект - это динамично развивающаяся система, которая имеет ряд недочетов, но в тоже время эти же недочеты можно исправить или же улучшить тем самым передвигая ИИ на следующий уровень развития. И в скором времени он станет такой же незаменимой частью нашей жизни как интернет или прочие технологии. Но и недостатками такой системы будет неравенство на рынке развитых стран перед не развитыми, и незащищенность этой системы перед киберпреступностью.

Рекомендации

Рекомендации по внедрению искусственного интеллекта в экономику

- Разработка стратегии цифровой трансформации. Организациям необходимо выработать чёткую стратегию интеграции ИИ в бизнес-процессы, ориентированную на повышение эффективности и конкурентоспособности.
- Инвестиции в обучение и развитие кадров. Важно обучать сотрудников новым навыкам, связанным с использованием ИИ, а также развивать культуру непрерывного образования для адаптации к технологическим изменениям.
- Использование больших данных для принятия решений. Внедрение систем анализа больших данных с применением ИИ помогает повысить качество прогнозов и принимать более обоснованные экономические решения.
- Автоматизация рутинных процессов. Внедрение ИИ в автоматизацию повторяющихся задач позволяет снизить операционные издержки и улучшить производительность.
- Обеспечение этичности и прозрачности. Следует разрабатывать и применять нормы и стандарты, гарантирующие этичное использование ИИ, защиту данных и прозрачность алгоритмов.
- Адаптация законодательства и экономической политики. Государственным органам рекомендуется создавать нормативную базу, способствующую безопасному и эффективному использованию ИИ, поддерживая инновации и минимизируя риски.
- Поддержка инновационных проектов и стартапов. Создание благоприятной экосистемы для стартапов в сфере ИИ способствует развитию новых технологий и решений, стимулирующих экономический рост.

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СОВРЕМЕННЫЙ ТРЕНД ЭЛЕКТРОННОЙ КОММЕРЦИИ И ЦИФРОВИЗАЦИИ ОБЩЕСТВА, ОСНОВАННЫЙ НА РАЗВИТИИ TELEGRAM-БОТОВ

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Аннотация **— Статья посвящена вопросам современного тренда цифровизации общества, основанного на развитии telegram-ботов. В качестве примера предлагается вариант разработки telegram-бота для оптимизации онлайн-продаж автомобильных аксессуаров с акцентом на анализ рынка и использование ботов в электронной коммерции. В статье проведен сравнительный анализ инструментов для создания серверной части, включая программирование и управление базами данных, разработана архитектура базы данных и техническое задание. Бот реализован с использованием технологий: языка программирования Python, библиотеки Aiogram 3 и реляционной базы данных SQLite.**

Ключевые слова: цифровизация, электронная коммерция, телеграм-бот.

I. ВВЕДЕНИЕ

Важным аспектом e-commerce является создание удобных и эффективных инструментов для взаимодействия с клиентами, таких как чат-боты. В контексте электронной коммерции телеграм-боты могут выполнять множество функций: предоставление информации о товарах и услугах, обработка заказов, отправка уведомлений о статусе заказов, проведение опросов и сбор отзывов, а также маркетинговые кампании. Интеграция с платёжными системами позволяет клиентам совершать покупки непосредственно через бот, что упрощает процесс покупки и повышает удобство для клиентов. [1]

Таким образом, разработка телеграм-ботов представляет собой актуальную и практически значимую задачу, направленную на повышение эффективности онлайн-продаж и улучшение взаимодействия с клиентами. В условиях цифровой трансформации бизнеса телеграм-боты становятся неотъемлемой частью стратегий компаний, стремящихся сохранить конкурентоспособность и удовлетворить растущие ожидания потребителей.

Современное направление в цифровизации общества на основе разработки телеграм-ботов в общем смысле и современный рынок автомобильных аксессуаров в частности переживает период значительного роста, в основном благодаря увеличивающейся популярности собственного автотранспорта и повышенной потребности в индивидуализации и улучшении автомобилей. Этот рост сопровождается рядом вызовов и возможностей электронной коммерции, которые могут быть успешно решены с помощью технологий, включая чат-ботов. [2]

Сущность выбранной проблемы заключается в необходимости создания эффективного и удобного инструмента для онлайн продаж автомобильных аксессуаров в виде телеграм бота. Телеграм бот представляет собой программу, автоматизирующую процесс общения с клиентом через мессенджер Telegram, позволяя пользователям получать информацию о товарах, совершать заказы, получать консультации и осуществлять оплату, не покидая чат.

II. МЕТОДЫ

Место данной проблемы в общих задачах логики можно определить, как задачу современного направления цифровизации общества на основе разработки телеграм-ботов и обеспечения эффективного взаимодействия между продавцом и покупателем в условиях онлайн-торговли.

Суть выбранной задачи заключается в необходимости создания эффективного и удобного инструмента для онлайн-продаж автомобильных аксессуаров в виде telegram-бота. Telegram bot - это программа, которая автоматизирует процесс общения

с клиентом через мессенджер Telegram, позволяя пользователям получать информацию о товарах, размещать заказы, получать консультации и совершать платежи, не выходя из чата.

III. Ожидаемые результаты

Разработка телеграмм-бота для продажи автомобильных аксессуаров позволяет автоматизировать, следовательно, упростить и ускорить процесс покупки для клиентов, а также оптимизировать и цифровизовать обработку заказов и управление инвентарем для продавца. Практическая значимость телеграм-бота для онлайн-продаж и обработки заявок для автомобильных аксессуаров определяется рядом технических преимуществ: высокая скорость работы, безопасность, интеграция с различными сервисами и платёжными системами, широкие возможности кастомизации. Возможность интеграции с CRM-системами, платёжными шлюзами и аналитическими инструментами позволяет создавать комплексные решения, охватывающие вс этапы взаимодействия с клиентами.

IV. Обсуждение и анализ

Развитие информационно-технологических сервисов в современном мире приводит к постоянному расширению и улучшению возможностей онлайн-платформ для коммерческой деятельности. В данном контексте рассматривается пример телеграм-бота, предназначенного для онлайн-продаж автомобильных аксессуаров. Описание формирования, становления, развития и прогнозов развития данного сервиса позволяет оценить его значимость и перспективы в сфере электронной коммерции.

Целевая аудитория телеграм-бота для онлайн-продаж автомобильных аксессуаров включает в себя следующие группы пользователей: Автолюбители, Онлайн-покупатели, технологически продвинутые пользователи, Автосервисы и СТО, Корпоративные клиенты.

Телеграм-бот "@Avtoset" предоставляет удобный способ для автомобильных энтузиастов приобретать аксессуары и получать информацию о товарах через мессенджер, обеспечивая широкий доступ и комфортные условия покупки.

На рынке Узбекистана существуют различные онлайн-платформы и магазины, специализирующиеся на продаже автомобильных аксессуаров, такие как: OLX, UZUMMARKET, ZoodMall, и другие. Следует отметить, что в конкурентной среде нет Телеграмм-бота. По результатам сравнительного анализа конкурентных информационных ресурсов, были выявлены достоинства и недостатки рассмотренных систем. С учётом данных сведений появилась возможность сформулировать список функциональных требований к разрабатываемому Телеграм-боту.

Для успешного конкурирования бот должен предлагать широкий выбор товаров, удобный интерфейс, быструю и качественную поддержку пользователей, а также привлекательные цены и условия доставки.

Телеграм-бот для онлайн-продаж автомобильных аксессуаров имеет значительные перспективы развития. Основные направления включают:

- Расширение функциональности:
- Развитие маркетинговой стратегии:
- Выход на новые рынки:
- Техническое развитие:
- Сотрудничество с автопроизводителями и сетями автосервисов.

Эти направления помогут телеграм-боту стать лидером рынка онлайн-продаж автомобильных аксессуаров и повысить конкурентоспособность.

Разработка телеграм-бота — это процесс, требующий внимательного выбора технологического стека для реализации проекта. Телеграм-боты являются программами, которые автоматизируют взаимодействие с пользователями через популярный мессенджер Telegram. Для успешной реализации такого проекта необходимо выбрать оптимальный набор инструментов, учитывая требования к функциональности, производительности, масштабируемости и безопасности. [3]

Первым шагом в выборе технологического стека является определение языка программирования. Для разработки телеграм-ботов часто используются языки, такие как Python, JavaScript (с использованием Node.js), или Java. Python часто выбирают из-за его простоты, богатства библиотек и фреймворков, таких как Telebot или aiogram, специально предназначенных для создания телеграм-ботов.

Далее идёт выбор фреймворка или библиотеки, упрощающую взаимодействие с API Telegram. Как уже упоминалось, для Python это могут быть Telebot или aiogram. Для JavaScript разработки подойдут библиотеки типа Telegraf для Node.js. [4]

Одним из ключевых аспектов разработки телеграм-бота является обработка сообщений от пользователей. Для этого необходимо использовать механизмы обработки событий и маршрутизации запросов, предоставляемые выбранным фреймворком или библиотекой.

Для хранения данных, таких как настройки бота, история диалогов с пользователями или другие данные, могут использоваться различные технологии баз данных. Для простых проектов подойдут реляционные базы данных типа SQLite или PostgreSQL, а для более масштабируемых приложений можно рассмотреть NoSQL решения типа MongoDB или Redis.

Наконец, следует уделить внимание вопросам безопасности, таким как защита от атак, обеспечение конфиденциальности данных пользователей и безопасность передачи данных между ботом и сервером Telegram. Для этого необходимо следовать передовым методикам разработки безопасного программного обеспечения и использовать соответствующие инструменты, такие как HTTPS для защищенной передачи данных.

Таким образом, успешная реализация проекта по разработке телеграм-бота зависит от тщательного выбора технологического стека, учитывающего требования к функциональности, производительности, масштабируемости и безопасности.

После изучения и анализа различных инструментов для разработки проекта телеграм-бота для онлайн-продаж сделан вывод, что Python и SQLite представляют собой удобное и эффективное сочетание инструментов. Python отличается простотой использования и богатой экосистемой, что делает его идеальным языком программирования для создания различных приложений, включая ботов. Его читаемый синтаксис и обширные библиотеки, такие как Aiogram, обеспечивают высокую производительность и гибкость разработки.

SQLite, в свою очередь, обеспечивает простоту и легкость в использовании для работы с данными. Эта СУБД является встраиваемой и не требует отдельного сервера, что упрощает её настройку и управление. SQLite предоставляет мощные инструменты для работы с данными, включая поддержку транзакций, индексов и целостности данных. Её легковесность и простота делают её отличным выбором для небольших и средних проектов, где не требуется высокая нагрузка на базу данных.

Кроме того, обе технологии поддерживаются активными сообществами разработчиков, что обеспечивает доступ к обучающим материалам, документации и поддержке. Все это делает Python и SQLite оптимальным выбором для разработки телеграм-бота для онлайн-продаж, обеспечивая легкость разработки, богатую функциональность, надежность и простоту управления проектом.

Aiogram 3 была выбрана в качестве основной библиотеки для работы с Telegram-Bot API из-за её асинхронных возможностей, которые значительно повышают производительность и позволяют обрабатывать большое количество запросов параллельно. Кроме того, Aiogram 3 обеспечивает гибкость и расширяемость, что позволяет легко настраивать и адаптировать бота под специфические требования проекта. Подробная документация и активное сообщество пользователей делают её идеальным инструментом для создания телеграм-ботов.

В итоге после анализа доступных инструментов, выбраны язык программирования Python и система управления базами данных SQLite. Python был выбран за свою простоту, эффективность и широкие возможности в разработке телеграм-ботов, а SQLite - за его легковесность, простоту настройки и управления. В качестве библиотеки для взаимодействия с TelegramBot API выбрана Aiogram 3, обеспечивающая высокую производительность и гибкость.

В процессе разработки были учтены не только функциональные требования, связанные с реализацией основных функций бота, но и нефункциональные требования, касающиеся производительности, безопасности и удобства использования. Особое внимание было уделено проектированию интуитивно понятного интерфейса, обеспечивающего удобное взаимодействие пользователя с ботом.

Целью разработки телеграм-бота "@Avtoset" является автоматизация онлайн-продаж автомобильных аксессуаров, повышение эффективности работы магазина и улучшение качества обслуживания клиентов. Для достижения этой цели были поставлены задачи по реализации функционала поиска и покупки товаров, предоставления пользователям возможности просмотра информации о своем профиле, истории заказов, наличия товаров, связи с поддержкой и FAQ, а также по разработке инструментов для администраторов, позволяющих управлять товарами, просматривать статистику, изменять настройки бота и выполнять рассылку сообщений.

Бот должен соответствовать следующим функциональным требованиям: поиск товаров по категориям и позициям; прямая покупка из карточки позиции; корзина для покупок; профиль пользователя с балансом и историей покупок; отображение наличия товаров; связь с поддержкой; FAQ. Для администраторов реализуется управление товарами (добавление, удаление, изменение категорий, позиций, товаров), просмотр статистики по пользователям, финансам и товарам, изменение данных бота (FAQ, контакты поддержки, отображение позиций без товаров), настройка функций бота (включение/выключение технических работ, пополнений, покупок), общие функции (поиск пользователя, рассылка сообщений), настройка платежных систем.

Нефункциональные требования включают в себя высокую производительность, безопасность и удобство использования бота. Бот должен обладать быстрым временем отклика, обрабатывать большое количество запросов, быть масштабируемым, защищать данные пользователей, обеспечивать безопасные платежи, иметь простой и интуитивно понятный интерфейс, адаптироваться под разные устройства и предоставлять понятные инструкции.

Ожидаемыми результатами реализации проекта являются: автоматизация процесса продажи автомобильных аксессуаров; повышение удобства покупки для клиентов; увеличение объема продаж; снижение нагрузки на персонал магазина; повышение лояльности клиентов.

Телеграм-бот предоставляет удобный инструмент для поиска, выбора и покупки товаров. Пользователи могут оформлять заказы в любое время и в любом месте, просматривать историю покупок, управлять корзиной и взаимодействовать с технической поддержкой. Для администраторов бота были реализованы функции управления товарами, категориями, позициями, настройками бота, а также возможность просмотра статистики и рассылка сообщений. Разработанные механизмы обработки ошибок, обеспечения отказоустойчивости и защиты от

неправомерного доступа к информации гарантируют безопасность и надежность работы бота.

ВЫВОД

В целом, разработка телеграм-бота является успешным проектом, демонстрирующим Современное направление в цифровизации общества на основе разработки телеграм-ботов и возможности использования современных технологий для автоматизации бизнес-процессов и улучшения качества обслуживания клиентов в сфере онлайн-торговли в Узбекистане.

На узбекском рынке существуют различные онлайн-платформы и магазины, специализирующиеся на продаже автомобильных аксессуаров, такие как olx, Uzummarket, ZoodMall и другие. Следует отметить, что в конкурентной среде нет Telegram-бота.

В статье проведен сравнительный анализ инструментов для создания серверной части, включая программирование и управление базами данных, разработана архитектура базы данных и техническое задание. Бот реализован с использованием технологий: языка программирования Python, библиотеки Aiogram 3 и реляционной базы данных SQLite.

РЕКОМЕНДАЦИИ

Использование Телеграм-бота даёт возможности использования современных технологий для электронной коммерции и автоматизации бизнес-процессов.

Основные преимущества бота:

- Интеграция с платежными системами: Бот обеспечивает удобные и безопасные способы оплаты за товары через интеграцию с популярными платежными системами.
- Персонализированный подход: Бот может предоставлять персонализированные рекомендации товаров и предложений, исходя из истории покупок и предпочтений пользователей.
- Маркетинговые возможности: Бот может использоваться для проведения маркетинговых кампаний, рассылки специальных предложений и информирования о новых товарах.
- Улучшение клиентского опыта: Бот позволяет улучшить взаимодействие с клиентами, предоставляя им круглосуточную поддержку и быстрый доступ к необходимой информации.

В заключение, можно отметить, что разработка телеграм-бота способствует развитию онлайн-торговли автомобильными аксессуарами в Узбекистане и предлагает удобное и современное решение как для продавцов, так и для покупателей.

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МОДЕЛЬ ТЕХНОЛОГИЧЕСКОЙ ТРАНСФОРМАЦИИ ДЛЯ МАЛЫХ И СРЕДНИХ ПРЕДПРИЯТИЙ

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Развитие Индустрии 4.0 оказывает существенное влияние на интеграцию цепочек создания стоимости. Скорость этой трансформации различается в зависимости от отраслей промышленного производства и оказывает влияние на малых и средних предприятий, углубляя разрыв в развитии в разных регионах мира. В этом случае малых и средних предприятий обрабатывающей промышленности стран оказываются втянутыми в среду стремительной трансформации, которая, в свою очередь, сложна и неизвестна во всех своих измерениях. На основе исследования, в различных отраслях промышленности, была оценена текущая степень технологического развития и степень трансформации, в которой они находятся. В результате исследования было выявлено, что компании этого типа сталкиваются с серьезным дефицитом знаний о технологиях, которые можно было бы разработать, внедрить или интегрировать в различные функциональные области. Это незнание оказывается основным препятствием для трансформации. Именно поэтому в данной статье представлены предварительные результаты текущего исследовательского проекта, в рамках которого разрабатывается модель процесса технологической трансформации. Эта модель позволяет малым и средним предприятиям определить, какие продукты они могут внедрять, исходя из потребностей в добавленной стоимости в различных функциональных областях, и выбрать путь трансформации в сторону Индустрии 4.0.

Ключевые слова — индекс ИКТ; малых и средних предприятий; Технологическое развитие; Промышленное развитие; Индустрия 4.0

I. ВВЕДЕНИЕ

Цифровая трансформация производственных систем и ускоренные темпы развития четвёртой промышленной революции требуют горизонтальной интеграции продуктов и процессов, поддерживаемой сетями взаимодействия, в которых рабочие и цифровые технологии охватывают различные области производственного предприятия [1]. Скорость этой трансформации различается в зависимости от отраслей промышленного производства и по-разному влияет на малых и средних предприятий (МСП), углубляя разрыв в развитии в разных регионах мира.

По данным аналитических компаний, пропасть в цифровизации компаний в странах весьма значительна [2] и рискует увеличиться в ближайшие годы в связи с ускоренным развитием Индустрии 4.0. Поэтому в настоящее время рекомендуется государственным и частным инициативам поддерживать малый бизнес в использовании технологических решений в своей деятельности [3].

На основе применения своего условного индекса цифровизации со стороны аналитических компаний было проведено сравнительное исследование по развитии цифровой трансформации в МСП. Результаты исследования свидетельствуют о том, что в развивающихся стран самовосприятии компаний присутствует нехватка знаний о доступных технологиях, о процессах их внедрения и о технологическом потенциале для их бизнеса [3].

В дополнение к этому отсутствию знаний и сосредоточению, наблюдается, что имеется слабая связь между потенциалом технологического развития и местной обрабатывающей промышленностью, оставляя на втором плане технологическое обновление малых и средних производственных компаний.

В этом смысле проявляется нехватка стратегий технологического обновления, ориентированных на промышленные МСП, и нехватка инвестиций в повышение конкурентоспособности на основе инноваций и технологических преобразований, учитывая, что этот сектор не является востребованным сектором для развития цифровых технологий по сравнению с другими секторами.

С этой точки зрения, учитывая скорость процесса трансформации и недостаточную осведомленность компаний о решениях, которые необходимо принять, необходимо знать, какие конкретные технологические продукты входят в состав Индустрии 4.0, а также предоставить информацию о путях внедрения и взаимодополняемости технологий, которые промышленные МСП могли бы внедрить и инициировать процесс трансформации в направлении Индустрии 4.0.

Чтобы оценить текущее состояние технологического развития МСП, было проведено исследование с использованием индекса InTICs® [5], разработанного исследовательской группой GIS (Grupo de Ingeniería de Software) в качестве инструмента оценки. Индекс определяет уровень технологического развития каждой отрасли в зависимости от внедренных ею в настоящее время программных, аппаратных и инфраструктурных продуктов, выполняющих конкретные задачи. В данном случае продукты, распределенные по функциональным областям каждой компании, были оценены с целью выявления технологий, внедренных в каждой компании, в соответствии с добавленной стоимостью каждой функции.

В результате детального анализа каждой функциональной области в каждой компании и дифференциации продуктов и внедрения каждой технологии разрабатывается модель процесса, которая упрощает внедрение технологий для технологической трансформации малыми и средними предприятиями. Разрабатываемая модель процесса основана на результатах оценки цифровых технологий по функциональным областям, чтобы каждая компания могла получить информацию о технологиях, установленных и используемых ею в различных функциях, и определить потребности во внедрении технологий для проведения повторной конверсии.

II. Обзор работ

A. *Материалы и методы*

Для проведения анализа уровня технологического развития по функциональным областям было проведено исследование с использованием индекса InTIC® [6], который структурирован на основе технологических продуктов, дифференцированных на 3 компонента цифровых технологий: программное обеспечение, оборудование и инфраструктура, сгруппированных в соответствии со спецификой каждого типа технологий и внедренных в функциональных областях, где эти технологии выполняют определенные задачи в отраслях [5].

Ниже перечислены общие функциональные области, по которым структурирована типичная компания, разрабатывающая различные функции.

- *Логистика*: включает в себя логистические задачи, как на въезде, так и на выезде.
- *Производство*:включает операцию деятельности.
- *Продажи*: эта область включает в себя функции маркетинга и продаж.
- *Управление*: эта область включает в себя вспомогательные функции инфраструктуры и человеческих ресурсов компании.
- *Бухгалтерский учет и финансы*: эта область также является частью деятельности компании по поддержке инфраструктуры.
- *Инжиниринг*: эта область включает в себя деятельность по разработке технологий, то есть функции из продукта и процесс проектирования.
- *Закупки*: включает улучшения в коммуникациях, которые приводят к сокращению цикла покупки и более выгодным ценам.

После того как технологические продукты идентифицированы на пересечении с каждой функциональной областью, индекс генерирует трехуровневую оценку, взвешивая каждый продукт в соответствии со степенью его разработки с точки зрения времени, в течение которого каждый из них находится на рынке, что позволяет различать компании, на каком уровне они находятся в соответствии с внедренной технологией:

- *Базовый уровень* для тех компаний, у которых старые технологии.
- *Средний уровень* для тех компаний, которые имеют средне современные технологии.
- *Продвинутый уровень* для компаний, обладающих передовыми технологиями.

Индекс включает 74 продукта цифровых технологий в различных функциональных областях, из которых 20 относятся к базовому уровню, 30 – к среднему, а 24 – к продвинутому. Не все продукты, входящие в продвинутый уровень, относятся к последнему поколению, но они необходимы для интеграции и функционирования других. Таким образом, из набора продуктов продвинутого уровня, определяющего индекс, были выделены технологические продукты, составляющие Индустрию 4.0.

На рисунке 1 представлены частные продукты индекса, которые в совокупности составляют подмножество продуктов Индустрии 4.0. Эта тема изучалась и была представлена на различных конференциях [7].

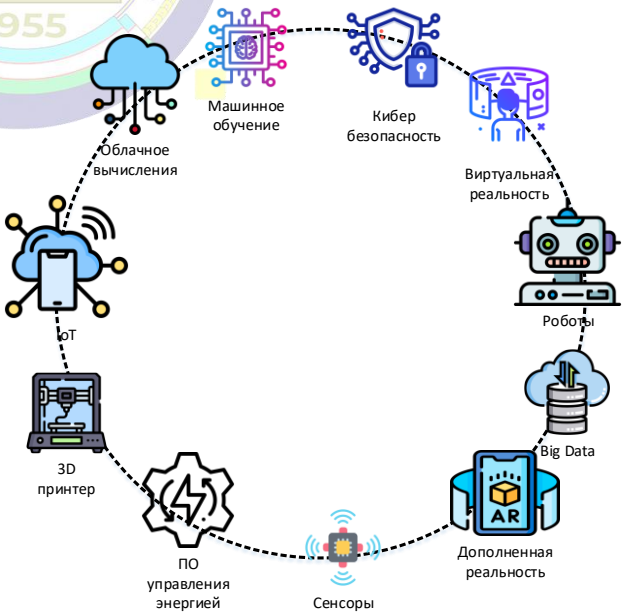

Рис. 1. продукты цифровых технологий для Индустрии 4.0

Структура индекса позволяет оценить установленные продукты, относящиеся к продвинутому уровню в каждой функциональной области компании, а также 11 продуктов, относящихся к подмножеству Индустрии 4.0.

III. Результаты и обсуждение

Для анализа уровня технологического развития по функциональным областям было проведено исследование с использованием индекса InTICs®. Для примера можно анализировать пункт, в котором население составляет 2 миллиона жителей, и 7000 промышленных предприятий различных секторов обрабатывающей промышленности, большинство из которых МСП.

Результаты анализа компаний показывает, что 62,50% опрошенных отраслей находятся на базовом уровне, 35,00% — на среднем и 2,50% — на продвинутом. Аналогично, из общего числа компаний 67,50% внедрили некоторые продукты Индустрии 4.0, и только одна компания продвинутого уровня содержит 10 (из 11) продуктов Индустрии 4.0, что означает, что из всех опрошенных отраслей только одна полностью относится к этому сегменту.

На основе этого глобального анализа уровня развития опрошенных компаний был проведен детальный анализ подмножества технологий Индустрии 4.0 для каждой функциональной области во всех компаниях, где было обнаружено наличие какого-либо из этих продуктов.

Таким образом, анализируя каждую область, можно заметить, что в функциях «Закупки» анализируемые компании имеют 30 продуктов Индустрии 4.0.

В сфере «Логистика» компании внедрили 34 продукта Индустрии 4.0.

Что касается направления «Продажи», компании внедрили 54 продукта Индустрии 4.0.

Что касается продуктов, внедренных в области «Управление», компании внедрили 53 продукта Индустрии 4.0.

Что касается области «Бухгалтерский учет и финансы», компании внедрили 42 продукта Индустрии 4.0.

В сфере «Инжиниринг» на предприятиях внедрено 42 продукта Индустрии 4.0.

Анализируя эти данные, можно отметить, что продукты, внедренные во всех областях деятельности опрошенных компаний, относятся к области кибербезопасности, далее следуют облачные вычисления, а на третьем месте — Интернет вещей. Эти три продукта практически не упоминаются, а остальные восемь встречаются крайне редко.

Таким образом, если 67% опрошенных компаний имеют какой-либо продукт Индустрии 4.0, среди которых выделяются те, которые применяются в кибербезопасности, облачных вычислениях и Интернете вещей и распределены в различных функциональных областях каждой компании, можно утверждать, что процесс внедрения технологий осуществляется путем заключения контрактов на услуги по существующим технологиям, которые не подразумевают собственные разработки, в то же время интеграция с другими компонентами, которая могла бы повысить их производительность, не обнаружена. Примером того, что ожидается обнаружить, может быть случай сетей Интернета вещей с датчиками для сбора собственных данных, которые обрабатываются с помощью программного обеспечения для больших данных для анализа и алгоритмов машинного обучения при принятии решений.

Этот анализ позволяет нам сделать вывод о низком уровне внедрения технологий Индустрии 4.0, отсутствии трансверсальной интеграции продуктов в различные функциональные области, а также о том, что внедряемые продукты приобретаются или предоставляются по контракту. Гипотеза данного исследования подтверждается высоким уровнем неосведомленности малых и средних промышленных предприятий о доступных технологиях и процессе интеграции, требующем их внедрения.

IV. Предлагаемое решение

Для управления процессом внедрения и интеграции технологий предлагается предварительная версия модели процесса, которой может следовать промышленное предприятие малого и среднего бизнеса, чтобы начать идентификацию продукта, что позволит ему начать технологическую трансформацию (ТТ).

Модель состоит из 11 подпроцессов, которые выполняются последовательно, а результат каждого подпроцесса представляет собой входную информацию для следующего.

На рисунке 9 показана модель, где каждый процесс представлен кругом, а содержащиеся в них потоки связаны прямоугольником с его именем. Стрелки указывают поток информации между потоками.

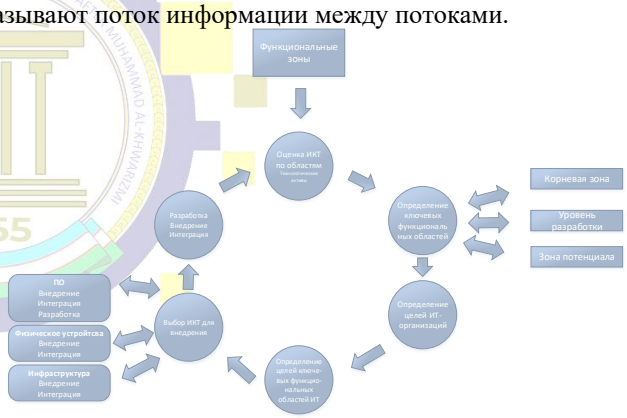

Рис. 9. Модель технологической трансформации

Предлагаемая модель основана на анализе существующих функциональных областей компании [6], позволяет оценить технологии, внедренные в каждой области, определить ключевую функциональную область, проанализировать и определить цели технологической трансформации (ТТ) организации и ключевой области. После определения целей модель позволяет определить технологические продукты, которые необходимо внедрить, разработать или интегрировать, что, в свою очередь, определяет стратегии разработки, внедрения или интеграции продуктов цифровых технологий [5].

Модель рассматривает каждый цикл как континуум, в котором каждая отрасль может начать, когда она решит, что ей требуется технологическое обновление для повышения своей производительности.

Определение процессов модели основано на индексной схеме InTICs®, которая позволяет

проанализировать организацию по её функциональным областям и оценить конкретные и эффективные продукты цифровых технологий, внедрённые ею в реальном контексте использования для каждой функции. Таким образом, каждый процесс Модели описан ниже.

1. Анализ функциональных зон компании

Этот процесс инициирует Модель технологической трансформации с определения функциональных областей типичной компании в соответствии с индексом ИКТ, в котором они различаются по менеджменту, бухгалтерскому учету и финансам, инжинирингу, закупкам, логистике, производству и продажам.

2. Оценка существующих цифровых технологий в организации по функциональным областям (технологические активы)

Продукты ИКТ для организации оцениваются на основе анализа индекса в зависимости от того, относятся ли они к набору аппаратных, программных или инфраструктурных продуктов по функциональной области. Эти продукты ИКТ обозначены в Модели как технологические активы [9]. То есть, продукты ИКТ, имеющиеся в организации в её функциональных областях. Использование индекса позволяет определить, какие продукты находятся в эксплуатации, и оценить уровень развития компании.

3. Определение ключевых функциональных областей (KFA – Key Functional Area)

В качестве следующего процесса Модель предлагает определить ключевую функциональную область для каждой компании в соответствии со следующими вариантами:

3.1. Определение основной сферы деятельности предприятия

Анализ центральной сферы деятельности компании, в которой она производит продукцию и которая определяет её миссию в рамках отрасли. «Основная сфера деятельности» определяет основное направление производственной и коммерческой деятельности компании. Это может быть бизнес, в котором компания была основана, или бизнес, в рамках которого её деятельность развивалась с течением времени. [10]

3.2. Определение уровня технологического развития каждой области деятельности компании

Определение основного направления деятельности позволяет оценить конкретные продукты цифровых технологий, входящие в его состав, и уровень развития конкретных технологий, чтобы определить влияние ИКТ на производительность основного направления деятельности. Оценка может быть выполнена с помощью индекса InTICs®, используя конкретный срез рассматриваемого направления.

3.3. Обнаружение области с большим потенциалом

Оценка направлений деятельности компании, а также определение основного направления деятельности и уровня его технологического развития позволяет выявить направление, имеющее наибольший потенциал развития с учетом его уровня или вклада в основное направление деятельности.

Другими словами, если основная бизнес-область имеет приемлемый уровень развития, превышающий средний уровень развития остальных областей, или существует функциональная область, которая ограничивает потенциал производительности основной бизнес-области из-за своего низкого уровня развития, последняя будет представлять собой область с наибольшим потенциалом, учитывая, что её технологическое обновление будет способствовать росту производительности основной бизнес-области компании. В рамках этого подпроцесса разрабатываются экономические и технологические показатели, позволяющие оценить и выделить различные области, которые могут обладать наибольшим потенциалом.

С помощью этих трех вариантов Модель позволяет определить ключевую функциональную область как наиболее важную область или область с наибольшим потенциалом для инициирования процесса технологической трансформации.

4. Определение целей технологической трансформации (ТТ) для организации

На основе определения KFA определяются цели технологической трансформации для организации в целом. В рамках этого процесса компания определяет цели, которые необходимо достичь в рамках технологического развития всей компании, связанные с приобретением собственных технологий или разработок, интеграцией существующих технологий, обучением персонала или внедрением новых профилей, а также другими аспектами, затрагивающими организацию в целом.

5. Определение целей технологической трансформации (ТТ) для ключевой функциональной области

Определение целей технологической трансформации для всей организации обеспечивает необходимую основу для последующего процесса, включающего определение целей технологической трансформации для ключевой функциональной области (KFA), выбранной в процессе 3.3. В этом процессе компания определяет цели, которые необходимо достичь с точки зрения технологического развития для конкретной области в соответствии с определениями общих целей.

6. Выбор ИКТ для внедрения

6.1. Определение инфраструктурных продуктов или услуг

Этот подпроцесс позволяет определить, какие конкретные инфраструктурные продукты или услуги компания будет внедрять в соответствии с целями ТТ, предусмотренными KFA, и целями ТТ организации в целом. Это различие позволяет внедрять технологии в соответствии со следующими критериями:

6.1.1. Осуществлять

Внедрить новые технологические продукты, отсутствующие в KFA. Например, развернуть новую сеть для Интернета вещей.

6.1.2. Интегрировать

Интеграция существующих продуктов с новыми продуктами и/или услугами. Например, интеграция новой сети Интернета вещей с существующим программным обеспечением для обработки данных о запасах.

6.2. Определение аппаратных продуктов или устройств

Этот подпроцесс позволяет определить, какие конкретные продукты, включая оборудование или устройства, компания будет внедрять в соответствии с целями ТТ KFA и целями ТТ организации в целом. Это различие позволяет внедрять продукты в соответствии со следующей дискриминацией:

6.2.1. Осуществлять

Внедрить новые технологические продукты, отсутствующие в KFA. Например, использовать ноутбуки для повышения производительности.

6.2.2. Интегрировать

Интегрируйте существующие продукты с новыми. Например, интегрируйте ноутбуки в сеть передачи данных, установленную для обработки данных.

6.3. Определение программных продуктов

Этот подпроцесс позволяет определить, какие конкретные программные продукты компания будет внедрять, исходя из целей внедрения KFA и целей внедрения организации в целом. Это различие позволяет внедрять продукты в соответствии со следующими критериями:

6.3.1. Развивать

Собственная разработка программного обеспечения, отсутствующего в KFA.

6.3.2. Осуществлять

Внедрите программное обеспечение, разработанное на основе закупленных пакетов или продуктов, уже имеющихся на рынке. Например, внедрите программное обеспечение для управления запасами.

6.3.3. Интегрировать

Интеграция существующего программного обеспечения с новыми приложениями или программными продуктами. Например, интеграция существующей веб-страницы с новой разработкой транзакционной веб-страницы.

7. Начало процесса разработки, внедрения или интеграции

Этот процесс позволяет начать внедрение, интеграцию или разработку продуктов, определенных в предыдущем пункте.

8. Оценка

После завершения разработки внедренные, разработанные и/или интегрированные ИКТ оцениваются уже как новые технологические активы, и начинается новый цикл процесса ТТ.

Выводы

В данной статье представлены результаты опроса, который показал, что значительное число компаний, независимо от уровня их технологического развития, используют продукты кибербезопасности или услуги облачных вычислений для поддержки различных функций своей компании. Внедрение этих продуктов позволяет утверждать, что компании используют технологические услуги и не знают о возможностях других продуктов или их трансверсальной интеграции для улучшения остальных внедрённых ими технологий.

Из этой высокой степени неосведомленности в качестве предлагаемого решения была выявлена предварительная структура Модели процесса технологической трансформации, которая разрабатывается в рамках исследовательского проекта и позволяет малым и средним компаниям отрасли узнать о доступных технологиях и встать на путь трансформации в сторону Индустрии 4.0 на основе анализа технологических продуктов по функциональным областям компании.

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LOGISTIK JARAYONLARINI TASHKIL ETISHDA AXBOROT ALMASHISH JARAYONLARI ARXITEKTURASINI QURISH VA TAKOMILLASHTIRISH

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Anotatsiya-Ushbu maqolada logistik jarayonlarini tashkil etishda axborot almashish jarayonlari arxitekturasini shakllantirish va takomillashtirish masalalari yoritilgan. Elektron tijoratning jadal rivojlanishi natijasida shaharlarda logistika xizmatlariga talabning ortishi, tirbandliklar va atrof-muhit ifloslanishi kabi muammolarni keltirib chiqarmoqda. Shu sababli logistika tizimini samarali tashkil etishda axborot almashish mexanizmlarini optimallashtirish dolzarb vazifa hisoblanadi. Tadqiqotda axborot almashish jarayonlarini tashkil etish bosqichlari – ma'lumotlarni tuzish, tahlil va tasniflash, tizimlarni integratsiya qilish, ma'lumotlarni uzatish, saqlash hamda ishlash jarayonlari tahlil qilingan. Natijada ERP, TMS, WMS, EDI, API va IoT texnologiyalariga asoslangan axborot arxitekturasi ishlab chiqildi. Taklif etilgan dasturiy vosita buyurtmachi va yetkazib beruvchi o'rtasida avtomatlashtirilgan ma'lumot almashuvini ta'minlaydi, buyurtmalarni optimallashtirilgan shaklda boshqarishga imkon beradi va xizmat ko'rsatish samaradorligini oshiradi. Tadqiqot natijalari logistikada axborot tizimlarini integratsiyalash, transport tirbandliklarini kamaytirish va elektron tijorat sharoitida mijozlarga xizmat ko'rsatish sifatini yaxshilashga xizmat qiladi.

Kalit so'zlar: logistika, axborot almashish, arxitektura, ERP, TMS, WMS, EDI, elektron tijorat.

I.KIRISH

Elektron tijoratning jadal rivojlanishi natijasida shaharlarda logistika xizmatiga talablar ortdi va shu sababdan ham logistika tobora rivojlanib bormoqda. Turli xususiy logistika kompaniyalari tomonidan boshqariladigan yuk tashuvchilari tobora ko'payib bormoqda. Shu sababli yirik shaharlarda jiddiy tirbandlik va atrof-muhitning ifloslanishi muammolari yuzaga chiqa boshladi. Logistika tizimi tirbandliklarni kamaytirish va yetkazib berishning samarali vaqt aniqligini oshirish logistika sohasidagi dolzarb muammolardan sanaladi[1].

Transport logistika sohasida logistik jarayonlarini tashkil etishda axborot almashish jarayonlarini tashkil qilish va axborot almashish jarayonlari arxitekturasini takomillashtirish talab qilinadi.

Logistik jarayonlari tashkil etishda axborot almashish jarayonlarining arxitekturasi, boshqa so'z bilan, axborot texnologiyalari va ularning integratsiyasi bo'yicha yuqori darajada integratsiyalangan tizimni o'z ichiga oladi. Bu tizim, logistika jarayonidagi har bir elementni bir-biriga bog'liqlik va a'loqasini optimallashtirish uchun xizmat ko'rsatadi[2].

METODLAR

Axborot almashish jarayonlari arxitekturasi, umumiy holatda, qo'yidagi bosqichlardan o'tkaziladi:

- Ma'lumotlar tuzilishi: Bu bosqichda, logistik jarayonida ishlatiladigan ma'lumotlar turi, shakli va xususiyatlari aniqlanadi. Bu ma'lumotlar, bir qator manbalardan kelib chiqishi mumkin, masalan, hisob-kitoblardan, buyurtmalar bazasidan, xaridorlarning ma'lumotlaridan va boshqa manbalardan olingan ma'lumotlardan iborat bo'lishi mumkin[3].
- Tahlil va tasniflash: Bu bosqichda, ma'lumotlar tahlil qilinadi va zarur bo'lgan ma'lumotlar turlari belgilanadi. Bu turlar, masalan, buyurtmalar,

yetkazib berish jadvali, mahsulotlar omboridagi xolat va boshqa ma’lumotlar bo‘lishi mumkin.[27 89-95b.]

- Integratsiya: Bu bosqichda, ma’lumotlar tizimlari integratsiyalangan va ularning muloqot usullari aniqlanadi. Ma’lumotlar o‘zaro almashinuvini ta’minlash uchun, bir nechta tizimlarning o‘zaro integratsiyasi kerak bo‘ladi. Misol uchun, hisob-kitobli dasturiy ta’minoti, buyurtma qabul qilish tizimi, yetkazib berish tizimi kabi tizimlarning o‘zaro integratsiyasi.
- Ma’lumotlar o‘tkazilishi: Bu bosqichda, ma’lumotlar yuklanadi va o‘tkaziladi. Bu jarayon, ma’lumotlar o‘tkazishining avtomatik tarzda amalga oshirilishi, masalan, XML, EDI, CSV kabi formatlar orqali amalga oshirilishi mumkin.
- Ma’lumotlarni saqlash: Bu bosqichda, ma’lumotlar uzoq muddat saqlanishi kerak bo‘lgan vaqt oralig‘ida saqlanishi lozim bo‘lgan joylar aniqlanadi. Bu turlar, masalan, manba serverlar, bulut xizmatlari, bazalar va hokozalar bo‘lishi mumkin.
- Ma’lumotlar ishlash va ko‘rsatish: Logistik jarayonida ishlatiladigan ma’lumotlar, har bir elementning yuqori darajada optimallashtirilgan ko‘rsatilishi va ishlov berishiga imkoniyat berilgan tizimlarga o‘tkazilishi kerak bo‘ladi. Bu jarayonda, ma’lumotlar xususiyatlari aniqlanadi va ularni qanday ko‘rinishda ko‘rsatish kerakligi belgilanadi[4].

Shunday qilib, logistik jarayonlarining axborot almashish jarayonlari arxitekturasi, ma’lumotlarni integratsiya qilish, ko‘chirish, saqlash va tasniflash kabi bosqichlardan o‘tkaziladi.

Axborot almashinuvi arxitekturasi logistikada hal qiluvchi rol o‘ynaydi, chunki u tovarlarning kelib chiqish joyidan iste’mol nuqtasiga o‘tishi bilan bog‘liq turli faoliyatlarni muvofiqlashtirish va birlashtirishni osonlashtiradi.

Logistikada axborot almashinuvi arxitekturasi odatda qo‘yidagi komponentlarni o‘z ichiga oladi:

Korxona resurslarini rejalashtirish (ERP) tizimlari: Bular kompaniya faoliyatining barcha jihatlarini, jumladan, logistikani birlashtiradigan dasturiy ilovalar. ERP tizimlari inventar darajasini boshqarishga, buyurtma holatini kuzatishga va jo‘natishni kuzatishga yordam beradi.

Transportni boshqarish tizimlari (TMS): TMS dasturiy ta’minoti tovarlar harakatini rejalashtirish, bajarish va optimallashtirish uchun ishlatiladi. Shuningdek, u yuk jo‘natuvchilar, tashuvchilar va tashish jarayonida ishtirok etuvchi boshqa tomonlar o‘rtasidagi aloqani osonlashtirishi mumkin.

Omborlarni boshqarish tizimlari (WMS): WMS dasturi ombor yoki tarqatish markazida inventarlarni boshqarish uchun ishlatiladi. U tovarlarning joylashishini kuzatishi, yig‘ish va qadoqlash jarayonlarini boshqarishi va ombor maydonini optimallashtirishi mumkin.

Elektron ma’lumotlar almashinuvi (EDI): EDI biznes hujjatlarini elektron tarzda almashish uchun standart formatdir. Logistikada EDI savdo hamkorlari o‘rtasida xarid buyurtmalari, jo‘natish xabarlari va hisob-fakturalar kabi ma’lumotlarni almashish uchun ishlatiladi.

Amaliy dasturlash interfeyslari (API): APIlar turli dasturiy ilovalarga bir-biri bilan muloqot qilish imkonini beradi. Logistikada API-lar TMS va WMS kabi bir nechta tizimlardan ma’lumotlarni birlashtirish uchun ishlatilishi mumkin[4].

Narsalar Interneti (IoT) qurilmalari: IoT qurilmalari yuklarni tashish paytida joylashuvi va holatini kuzatish uchun ishlatilishi mumkin. Ular harorat, namlik va tebranish kabi omillar haqida real vaqt rejimida ma’lumotlarni taqdim etishi mumkin, bu esa tovarlarni xavfsiz va samarali tashishni ta’minlashga yordam beradi.

Ushbu komponentlarni yaxlit axborot almashish arxitekturasiga birlashtirib, logistika kompaniyalari o‘z operatsiyalarining ko‘rinishini yaxshilashlari, samaradorlikni oshirishlari va mijozlarning ehtiyojlarini yaxshiroq qondirishlari mumkin.

Logistika sohasida axborot almashinuvi arxitekturasi odatda bir nechta o‘zaro bog‘langan tizimlar va manfaatdor tomonlarni o‘z ichiga oladi.

Yetkazib beruvchi: Yetkazib beruvchi tashish kerak bo‘lgan tovarlarni ta’minlaydi.

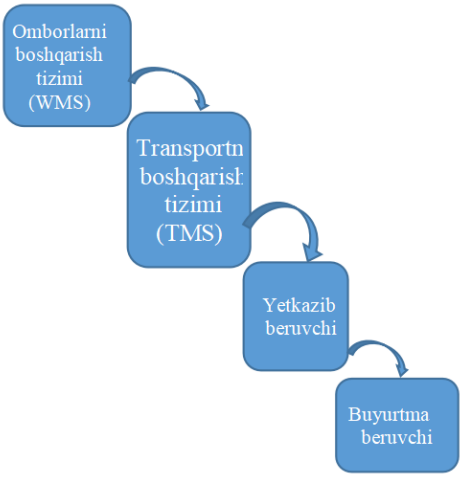
Omborlarni boshqarish tizimi (WMS): WMS ombordagi inventarni boshqaradi va buyurtmani bajarish uchun tanlash ro‘yxatlarini yaratadi.

Transportni boshqarish tizimi (TMS): TMS tovarlarni ombordan belgilangan joyga tashishni rejalashtirish, optimallashtirish va amalga oshirish uchun javobgardir[5].

Tashuvchi: Tashuvchi tovarlarni ombordan mijozga jismonan tashiydi.

Xaridor: Xaridor tovarni oladi va yetkazib berish sifati haqida fikr bildiradi.

Logistikada axborot almashish arxitekturasi shakillantirish:



1-rasm. Axborot almashish arxitekturasi shakillantirish

Logistika jarayoni davomida ushbu tizimlar va manfaatdor tomonlar o‘rtasida ma’lumotlar almashinuvi amalga oshiriladi. Misol uchun, WMS buyurtma ma’lumotlarini TMSga yuboradi, u tashuvchi uchun eng samarali marshrutni hisoblab chiqadi. Tashuvchi TMS va mijozga real vaqt rejimida kuzatuv ma’lumotlarini taqdim etadi, bu esa barcha ishtirokchilarga jo‘natish holatini kuzatish imkonini beradi. Va nihoyat, mijoz etkazib berish sifati bo‘yicha fikr-mulohazalarini taqdim etishi mumkin, bu esa logistika jarayonini kelajakda yaxshilash haqida ma’lumot berishi mumkin[6].

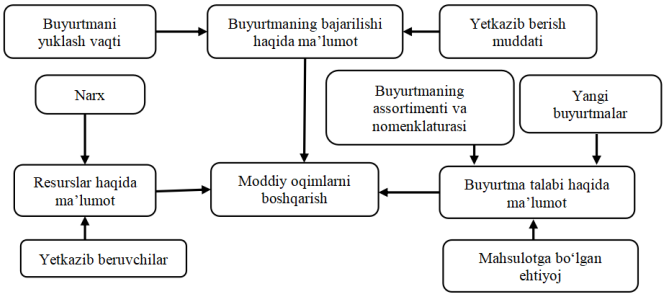
Tadqiqot davomida olingan xulosalar va natijalarga ko‘ra modifikatsiya qilingan hamda ishlab chiqilgan usullar va algoritmlar asosida buyurtmachi va yetkazib beruvchilarning murojaatlari bo‘yicha avtomatlashgan rejimda ishlovchi axborot tizimi va dasturiy mahsulot ishlab chiqiladi. Boshqaruv tizimida axborot almashinuvchilar ya’ni buyurtmachi va yetkazib beruvchilar biri ikkinchisi haqida qo‘yidagi ma’lumotlarni olishlariga imkon beradi:

a) Buyurtma beruvchilar haqida:
– buyurtma beruvchining ismi;
– buyurtma beruvchining familiyasi;
– buyurtma beruvchining telefon raqami.
b) Buyurtma haqida:
– buyurtma turi;
– buyurtmaning vazni;
– buyurtma joylashgan manzil;
– buyurtmani yetkazishi kerak bo‘lgan manzil;
c) Yetkazib beruvchi haqida:
– haydovchi telefon raqami;
– haydovchi ismi;
– haydovchi familiyasi;
– haydovchi transportining turi;
– transport vositasining davlat raqami;

Axborot almashinuv jarayonida va ishlab chiqilgan dasturiy mahsulot tizimidan foydalansh davomida quyidagi funksiyalarni bajarish imkonini beradi:

- buyurtma berish davomida yuk to‘g‘risidagi ma’lumotlarni to‘ldirishga;
- buyurtma joylashgan manzilni kiritishga va tahlil qilishga;
- buyurtmani yetkazib berishi kerak bo‘lgan manzilni kiritishga va tahlil qilishga;
- yetkazib beruvchi tamonida berilgan taklifni qabul qilish yoki rad etish;
- yetkazib beruvchiga buyurtma haqida masofadan turib ma’lumot olish;
- buyurtma beruvchiga buyurtmani olish haqida taklif yuborish;
- yukni olib borish va yetib kelganligi haqida buyurtmachiga habar berish.

Sanab o‘tilgan funksiyalarni amalga oshirishni ta’minlaydigan dasturiy vositaning funksional ishlash strukturasi 2-rasmda ko‘rsatilgan va funksional modullar o‘rtasida sodir bo‘ladigan jarayonlarning o‘zaro ta’siri bilan tavsiflanadi.

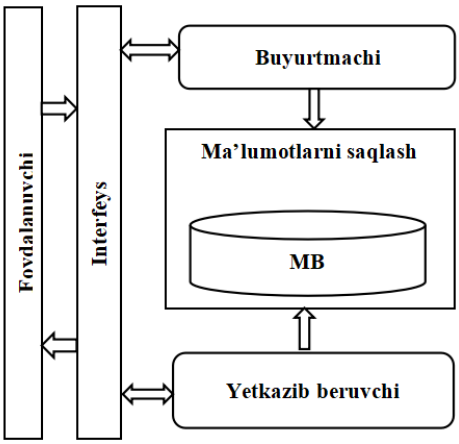


2-rasm. Dasturiy vositaning funksional ishlash strukturasi

NATIJALAR

Logistikada axborot almashinuvi jarayonlari arxitekturasini takomillashtirish uchun taklif etilayotgan funksional modellashtirish asosida qurilgan dasturiy vositalar va axborot tizimlari samaradorlik ko‘rsatkichi uchun asosiy manba bo‘lib xizmat qiladi(3-rasm).

Logistikada axborot almashinuv jarayonini avtomatlashgan rejimda tashkil etish, buyurtma berishda buyurtmalarni yetkazib beruvchi tamonga muvofiqlashtiruvchi dasturiy mahsulot yaratish asosida logistika sohasida buyurtmalarni yetkazib berishni samarali tashkil qilishda o‘z samarasini beradi.[6 110-113b.]

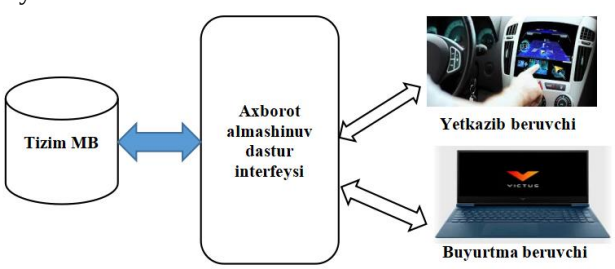


3-rasm. Logistikada axborot almashinuvi jarayonlari takomillashgan arxitekturasi.

Shakillantirilgan va takomillashtirilgan logistik jarayonlarini tashkil etish axborot almashish jarayonlari arxitekturasiga ko‘ra buyurtma beruvchi buyurtma berish va yetkazib beruvchi buyurtmani olish jarayonida buyurtmachi va yetkazib beruvchi o‘rtasida amalga oshiriladi.

Tadqiqot natijalariga ko‘ra, axborot almashinuvi jarayonlarida ratsional boshqarishda muqobil yechimlarni amaliyotga tatbiq etish yuqori darajadagi samaradorlik uchun kafolat bo‘lib xizmat qiladi. Buyurtmalarni yetkazib berish jarayonlarini optimal tashkil etishda taklif etilayotgan ilmiy ishlanmalarning adekvatligi hamda jarayonni sodda qoidalarga ko‘ra tashkil etish imkoniyatini yaratib beradi.

Axborot almashinuv jarayonlarini muvofiqlashtirisha ko‘maklashuvchi dasturiy vosita o‘z navbatida boshqa qism tizimlari avtomatlashtirilgan axborot tizimilariga murjaatni amalga oshiradi[20 111-117b]. Bu jarayon esa logistikada tovarlar almashinuvida, yetkazib berish mexanizimining teskorligiga xizmat qiladi. Bunda eng ko‘p murojaat etuvchilar logistik xizmat ko‘rsatuvchilar ya’ni yetkazib beruvchilar va buyurtma beruvchilardir(4-rasm). Ishlab chiqilgan axborot almashish arxitekturasini takomillashtirgan holda ishlab chiqib va ushbu arxitekturaga ko‘ra sihlab chiqiladigan dasturiy vosita foydalanuvchilari yagona ma’lumotlar bazasiga murajaatlar qilib va shu ma’lumotlar bazasidan foydalanadilar.



4-rasm. Axborot almashinuv dastur foydalanuvchilar bilan ishlash strukturasi

Ishlab chiqilgan dasturiy vositalarning funksionallgi quyidagi imkoniyat va afzalliklarni beradi:

- Elektron tijaroat rivojlanayotgan vaqtda masofadan turib buyurtmalarini olib keltirishga;
- Yetkazib beruvchi to‘g‘risida ma’lumotga ega bo‘lishga;
- Buyurtmani yetkazib kelgungacha bo‘lgan vaqtda yetkazib beruvchi harakatlarini GPS tizimi orqali ko‘zatishga;
- Yetkazib beruvchi uchun yuklarni qiyinchiliklarsiz olishga;
- Buyurtma haqida yetarli ma’lumotga ega bo‘lishga;
- Yo‘l yo‘lakay buyurtmalar olishga va shu orqali yetkazib berish xarajatlarini kamaytirishga;

Logistika, bir necha ko‘plab jarayonlarni o‘z ichiga oladigan kompleks sohadir. Bu jarayonlar o‘zaro aloqada bo‘lib, yuk tashuvchi tomonidan boshqa tomondan yetkazilayotgan mahsulotlarning transport qilinishidan boshlab, oxiri ularni omborlash yo‘nalishida tugatiladi. Bunday murakkab jarayonlar uchun logistika axborot almashinuv tizimini ishlab chiqish juda muhimdir.

Logistikada axborot almashinuv tizimi arxitekturasi, asosiy ko‘rsatuvchi xususiyatlarga ega bo‘lishi kerak: moslashtirish, integratsiya, uzoqlik, nisbatan hamyonlik va samaradorlik. Tizimning moslashtirishi, odatda, protokoll va interfeyslar orqali amalga oshiriladi. Integratsiya, ombor va sotuv tizimlari kabi har xil tizimlar bilan bog‘liq bo‘lgan jarayonlarni birlashtirib, qamrab oladi. Uzoqlik, tizimning turli komponentlarining o‘rtasidagi ish takroriyligini minimal darajada tashkil etadi. Nisbatan hamyonlik, tizimning turli ko‘rsatkichlarining mos kelishishini ta’minlaydi va foydalanuvchilar uchun tizimni o‘rganish va ishlatishni osonlashtiradi. Samaradorlik, esa, tizimning hisob-kitob va boshqa yo‘nalishlarda samarali ishlashini ta’minlaydi.

Logistikada axborot almashinuv tizimi arxitekturasi shunday yaratilishi kerakki: Birinchisi, tizimning ilgari ishlatilgan modullarini qayta ishlab chiqish va ular orqali yangi tizimni yaratish; ikkinchisi, mavjud tizimlarni integratsiya etish yoki uni moslashtirish uchun maxsus interfeyslar yaratish. Tizimni yaratish paytda o‘zaro aloqadagi jarayonlarning majburiy xususiyatlari, kabi, transport jarayoni, ombor jarayoni, sotuv jarayoni, xisob-kitob jarayoni kabi tushuntirilishi kerak.

Shunday qilib, logistika sohasida axborot almashinuv tizimi yaratishda asosiy vazifa, jarayonlarning barcha bosqichlari bo‘yicha qo‘llanma yaratish va ularni

aynan o‘ziga mos keladigan axborot almashinuv tizimiga integratsiya qilishdir.

MUHOKAMA

Olingan natijalar shuni ko‘rsatdiki, axborot almashish jarayonlarining takomillashtirilgan arxitekturasi logistika xizmatlarining samaradorligini oshirishga sezilarli ta’sir ko‘rsatadi. Bunday tizim:

- buyurtmalarni yetkazib berishda vaqt tejamkorligini ta’minlaydi;
- transport tirbandliklarini kamaytirishda yordam beradi;
- mijozlarga xizmat ko‘rsatish sifatini yaxshilaydi;
- operatsion xarajatlarni qisqartiradi.

Shuningdek, axborot tizimlari integratsiyasi yordamida logistik operatsiyalarni markazlashtirilgan boshqaruv ostida olib borish imkoniyati yaratiladi. Bu esa, elektron tijorat sharoitida logistika tizimlarining moslashuvchanligi va barqarorligini oshiradi.

XULOSA

Logistik jarayonlarda axborot almashish arxitekturasini takomillashtirish zamonaviy transport tizimining ajralmas qismi bo‘lib, buyurtmalarni samarali boshqarish, yetkazib beruvchilar va mijozlar o‘rtasidagi aloqani kuchaytiradi. Tadqiqot asosida ishlab chiqilgan dasturiy vosita va integratsiyalashgan axborot tizimlari elektron tijorat rivojlanayotgan sharoitda logistika xizmatlarining barqarorligini ta’minlashga xizmat qiladi.

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НАПРАВЛЕНИЯ РАЗВИТИЯ ЦИФРОВОГО ПРАВИТЕЛЬСТВА И ЭЛЕКТРОННОЙ КОММЕРЦИИ: СОВРЕМЕННЫЕ ТЕНДЕНЦИИ И ПЕРСПЕКТИВЫ

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Аннотация: ***В статье рассматриваются основные направления развития цифрового правительства и электронной коммерции как ключевых элементов цифровой экономики. Раскрывается сущность цифрового правительства, его задачи и ключевые приоритеты, а также современные тенденции в сфере e-commerce. Проведен сравнительный анализ двух явлений, приведены примеры их внедрения в разных странах, обозначены проблемы и вызовы, связанные с цифровизацией. Особое внимание уделено перспективам развития, среди которых - интеграция искусственного интеллекта, блокчейн-технологий и трансграничных цифровых сервисов.***

Ключевые слова: Цифровое правительство, электронная коммерция, цифровизация, государственные услуги, e-Gov, маркетплейсы, искусственный интеллект, блокчейн, Big Data, цифровая экономика.

ВВЕДЕНИЕ

В условиях глобальной цифровизации государства и бизнес-структуры вынуждены адаптироваться к новым вызовам. Сегодня именно цифровое правительство и электронная коммерция становятся важнейшими компонентами цифровой экономики, обеспечивая удобство, эффективность и прозрачность процессов взаимодействия.

Цифровое правительство можно определить как современную модель государственного управления, основанную на применении информационно-коммуникационных технологий и направленную на улучшение качества взаимодействия государства с гражданами и бизнесом. Основные задачи включают перевод государственных сервисов в онлайн-формат, повышение прозрачности и снижение коррупционных рисков, оптимизацию расходов на управление и интеграцию данных через единые платформы. По данным ООН, к 2024 году более 90% стран мира реализуют национальные стратегии цифрового правительства, что указывает на его глобальную значимость.

ПОСТАНОВКА ПРОБЛЕМ

Развитие цифрового правительства происходит по ряду направлений. Важнейшим является внедрение электронных государственных услуг (e-Gov), позволяющих получать документы и справки через интернет. В Узбекистане, например, функционирует портал *GOV.UZ*, а в Южной Корее - одна из наиболее развитых систем электронного правительства. Второе направление связано с мобильным правительством (m-Gov): использование смартфонов упрощает доступ к госуслугам. В Эстонии, например, мобильная ID-карта применяется

для подписания документов и голосования на выборах. Третье направление - развитие порталов открытых данных (*data.gov* в США, национальные платформы в Европе и Азии), обеспечивающих гражданам и бизнесу доступ к государственным информационным ресурсам. Существенный вклад вносит применение искусственного интеллекта и анализа больших данных, что позволяет прогнозировать социальные процессы и повышать эффективность государственных программ. Особое место занимает проблема цифровой идентификации и кибербезопасности: система Aadhaar в Индии охватила более 1,2 млрд человек, став крупнейшей в мире.

Параллельно с цифровизацией государственного управления стремительно развивается электронная коммерция (e-commerce), представляющая собой процесс покупки и продажи товаров и услуг через интернет. За последние годы этот сектор стал одним из драйверов мировой экономики. Его развитие проявляется в росте крупных маркетплейсов (*Amazon, Alibaba, Ozon, Wildberries*), которые трансформировались в комплексные экосистемы. Всё большее значение приобретает мобильная коммерция (m-commerce), так как смартфон становится основным инструментом покупателя. В последние годы бурно развивается социальная коммерция: торговля через платформы *Instagram* и *TikTok* превращается в привычный канал покупок. Существенное влияние оказывают финансовые технологии: онлайн-платежи, цифровые кошельки и криптовалюты обеспечивают удобство и безопасность транзакций. Наконец, важную роль играет персонализация - применение искусственного интеллекта для рекомендаций и анализа поведения пользователей. По прогнозам Statista, объём мирового рынка электронной коммерции к 2027 году превысит 8 трлн долларов США.

Несмотря на различие сфер, цифровое правительство и электронная коммерция имеют общие черты. Обе модели ориентированы на упрощение процедур, снижение издержек и повышение качества обслуживания. Государство стремится к созданию удобных и прозрачных сервисов для граждан, а бизнес - к улучшению клиентского опыта и росту продаж. Таким образом, цифровизация объединяет эти сферы в рамках формирования единого цифрового общества.

АКТУАЛЬНОСТЬ

Мировой опыт демонстрирует успешные примеры внедрения цифровых решений. Эстония стала моделью цифрового государства, обеспечив онлайн-доступ ко всем услугам, включая выборы. Китай является мировым лидером по объёму электронной коммерции: на платформы Alibaba и JD.com приходится более половины онлайн-продаж страны. В Узбекистане активно развивается система e-Gov, а также цифровые платёжные сервисы (*Payme, Click*), что создаёт условия для расширения внутренней e-commerce.

Однако цифровизация сталкивается и с рядом вызовов. Прежде всего, это цифровое неравенство: неравномерный доступ к интернету и технологиям сохраняется как между странами, так и внутри них. Вторым фактором риска являются киберугрозы: рост числа кибератак и утечек данных требует совершенствования систем безопасности. Третья проблема связана с необходимостью правового регулирования: законодательство часто не успевает адаптироваться к темпам технологических изменений. Наконец, существует фактор недоверия граждан к цифровым системам, который требует укрепления механизмов идентификации и защиты данных.

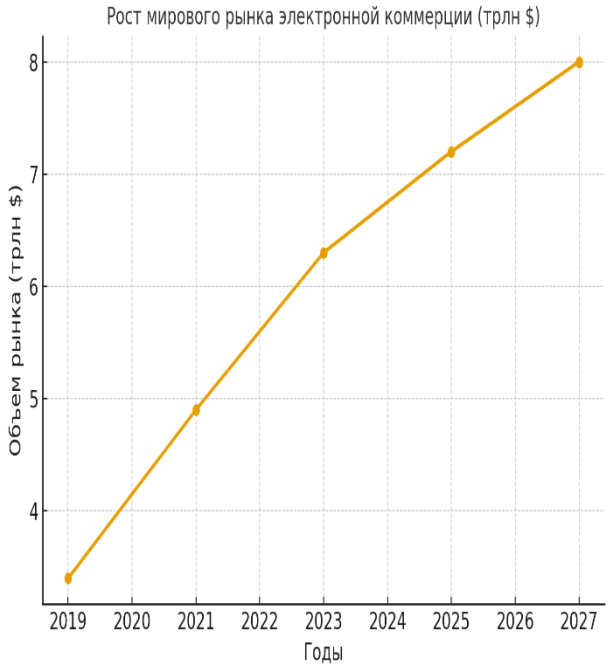

Рис.1. Рост мирового рынка электронной коммерции

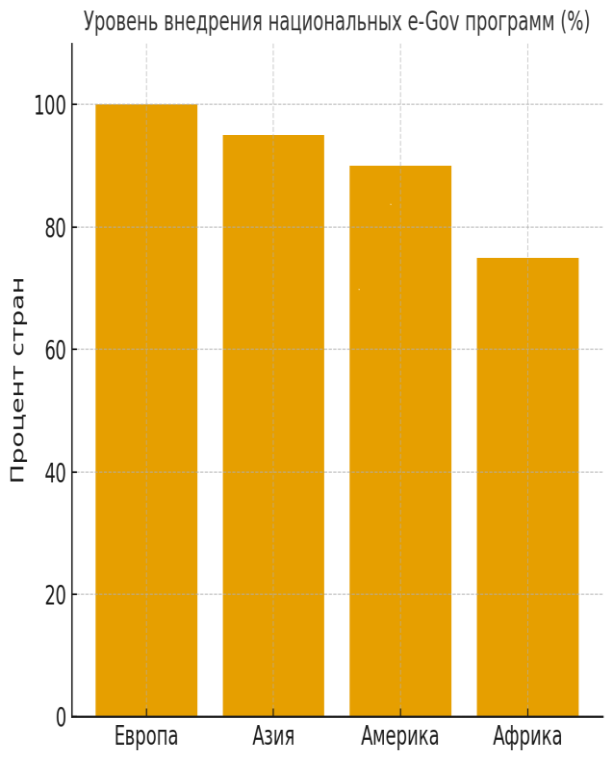

Рис.2. Уровень развития цифрового правительства по регионам.

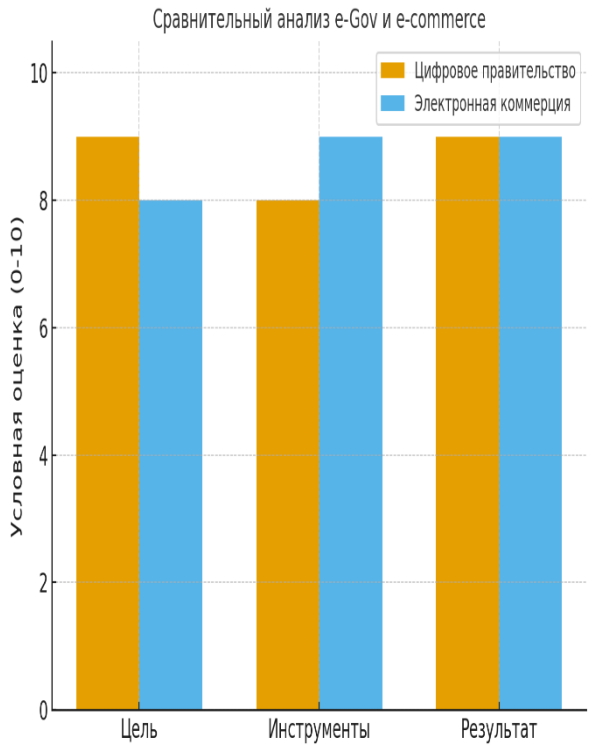

Рис.3. Сравнительный анализ e-Gov и e-commerce

Перспективы дальнейшего развития цифрового правительства и электронной коммерции связаны с интеграцией искусственного интеллекта, блокчейн-технологий, виртуальной и дополненной реальности. В ближайшие годы можно ожидать углубления международной цифровой интеграции, когда государственные и коммерческие сервисы будут выходить за национальные границы, создавая единые трансграничные цифровые экосистемы.

ТАБЛИЦА. 1. СРАВНИТЕЛЬНЫЙ АНАЛИЗ E-GOV И E-COMMERCE

Показатель	**Цифровое правительство**	**Электронная коммерция**
Цель	Повышение качества госуслуг	Увеличение продаж и прибыли
Основной инструмент	Порталы e-Gov, Big Data, AI	Маркетплейсы, FinTech, CRM
Результат	Доступность и прозрачность	Удобство для клиента, рост рынка

Таким образом, цифровое правительство и электронная коммерция становятся взаимосвязанными элементами новой цифровой экономики. Их развитие обеспечивает повышение эффективности государственного управления, улучшение качества жизни населения и стимулирование роста бизнеса. В перспективе синергия этих направлений приведёт к формированию единого цифрового пространства, в котором государственные и коммерческие услуги будут неотделимы друг от друга.

Цифровое правительство и электронная коммерция являются ключевыми направлениями развития современной цифровой экономики. Их развитие позволяет повысить эффективность управления, улучшить качество жизни населения и стимулировать рост бизнеса.

Успешные примеры внедрения показывают, что государства и компании, активно инвестирующие в цифровые технологии, получают значительные конкурентные преимущества. В ближайшие годы синергия между цифровым правительством и электронной коммерцией приведёт к формированию единой цифровой экосистемы, где границы между государственными и коммерческими сервисами будут постепенно стираться.

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EFFICIENTNETB0 ASOSIDA KO'KRAK RENTGEN TASVIRLARIDAN PNEVMONIYANI TASHXISLASH

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Annotatsiya. Maqolada pnevmoniya bu virus yoki bakteriyalar tufayli yuzaga keladigan o'pka infeksiyasi bo'lib, inson organizmidagi bir yoki ikkala o'pkaga zarar holatlari o'rganilgan. Pnevmoniyani aniqlashda tajribali rentgenologlar ko'krak rentgen tasvirlarini baholashi zarur. Shu sababli, ayniqsa olis hududlarda kasallikni tez davolash imkonini beradigan avtomatlashtirilgan tizimlar muhim ahamiyatga ega. Ushbu maqolada ko'krak rentgen tasvirlari asosida pnevmoniyani ishonchli aniqlash uchun konvolyutsion neyron tarmoq (CNN) asosidagi model taklif etiladi. Model EfficientNetB0 asosidagi transfer learningdan iborat. EfficientNetB0 xususiyatlarni ajratadi. Model 97% aniqlik bilan yuqori natijalarga erishgan.

Kalit so'zlar: Pnevmoniya, sun'iy intellekt, tashxislash, Efficient NetB0

I. Kirish

Hozirgi sharoitda sog'liqni saqlash muassasalarining davolash-profilaktika faoliyatiga oid ma'lumotlarni yig'ish, qayta ishlash va tahlil qilish jarayonlarini samarali tashkil etish uchun axborot texnologiyalarining ahamiyati oshib bormoqda. Pnevmoniya o'pka infeksiyasi bo'lib, ko'pincha virus yoki bakteriyalar tufayli yuzaga keladi. Jahon sog'liqni saqlash tashkiloti (JSST) ma'lumotlariga ko'ra, 5 yoshgacha bo'lgan bolalar orasida bu kasallik eng ko'p o'limga olib keluvchi sabab hisoblanadi (yiliga 12.8%). Shuningdek, bu kasallik kattalarda, ayniqsa Xitoy va Yaponiya kabi mamlakatlarda yuqori o'lim ko'rsatkichlariga sabab bo'lmoqda. Ko'krak rentgen tasvirlari pnevmoniyani aniqlashda eng samarali usul hisoblanadi. Biroq, ba'zida bunday tasvirlar bir-biriga o'xshash bo'lishi mumkin, bu esa noto'g'ri tashxislarga olib keladi. Shu sababli, sun'iy intellekt (AI) va mashinali o'rganish texnologiyalari asosida avtomatik tashxislash tizimlariga ehtiyoj mavjud. Pnevmoniyani tashxislash axborot tizimlari rentgen (X-ray) va kompyuter tomografiya (KT) tasvirlarini qayta ishlash asosida ishlaydi. Asosiy vazifalari:

- Tasvirlardan pnevmoniya belgilarini ajratib olish.
- Tashxisning ishonchlilik darajasini hisoblash.
- Klinik qarorlarni qo'llab-quvvatlash.

Bunday tizimlarda asosan **chuqur o'rganish (deep learning)** va **konvolyutsion neyron tarmoqlar (CNN)** qo'llaniladi.

II. Asosiy qism

Xorijiy va mahalliy tadqiqotlarda pnevmoniyani tashxislashda chuqur o'rganish (deep learning) asosidagi yondashuvlar keng qo'llanilmoqda:

Pranav Rajpurkar va boshqalar (2017, Stanford University) – CheXNet modeli orqali rentgen tasvirlaridan pnevmoniyani aniqlashda shifokorlardan yuqori natijalarga erishgan.

Jeremy Irvin va hamkorlari (2019, Stanford ML Group) – CheXpert datasetini yaratib, ko'p kasalliklarni aniqlash uchun CNN modellarini qo'llagan.

Xiaowei Xu (2020, Xitoy) – COVID-19 va pnevmoniyani farqlovchi sun'iy intellekt modellarini ishlab chiqqan.

EfficientNet (2019, Google AI) – yuqori aniqlikni ta'minlab, tibbiy tasvirlarni tahlil qilishda samarali natijalar bergan.

Mahalliy olimlar orasida:

E. M. Madaminov, Sh. T. Toshpo'latov va boshqalar – O'zbekiston sharoitida pnevmoniyani tashxislashda tasvirlarni raqamli qayta ishlash va AI asosida tahlil qilish bo'yicha ilmiy maqolalar chop etishgan.

Toshkent Axborot Texnologiyalari Universiteti (TATU) hamda Toshkent Tibbiyot Akademiyasi olimlari ushbu sohada qo'shma tadqiqotlar olib bormoqda.

Taklif etilgan model **to'rt bosqichdan**

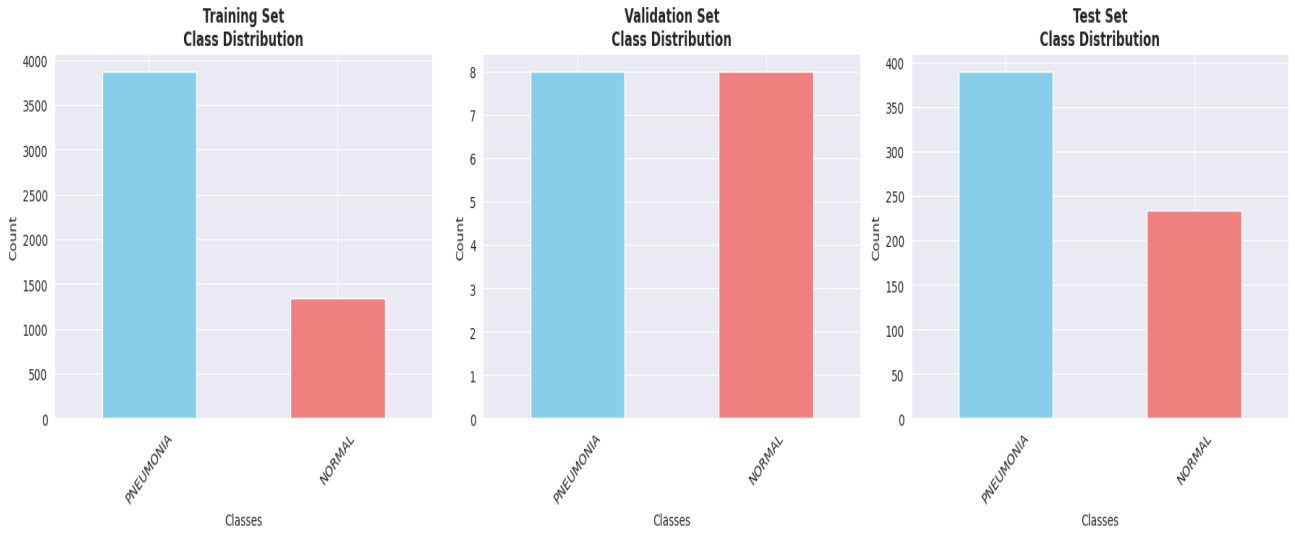
1. **Ma'lumotlarni oldindan qayta ishlash va kengaytirish (augmentatsiya)** bosqichi.
2. **Xususiyatlarni ajratish** — EfficientNetB0 kabi transfer learning arxitekturasi orqali amalga oshiriladi.
3. **Tasvirlarni tasniflash** — rentgen tasvirlaridan ajratilgan xususiyatlar asosida bajariladi.
4. **Model samaradorligini baholash** — sinov natijalari asosida aniqlanadi.

Tadqiqotda 5 856 ta CXR tasviridan iborat ma'lumotlar to'plamidan foydalanildi: 4 273 tasi pnevmoniya, 1 583 tasi sog'lom. Ma'lumotlar dastlab train, validation va test to'plamlariga ajratilgan bo'lsa-da, sinflar nomutanosibligi sababli qayta ajratish

amalga oshirildi (70% train, 15% validation, 15% test, stratifikatsiya bilan).

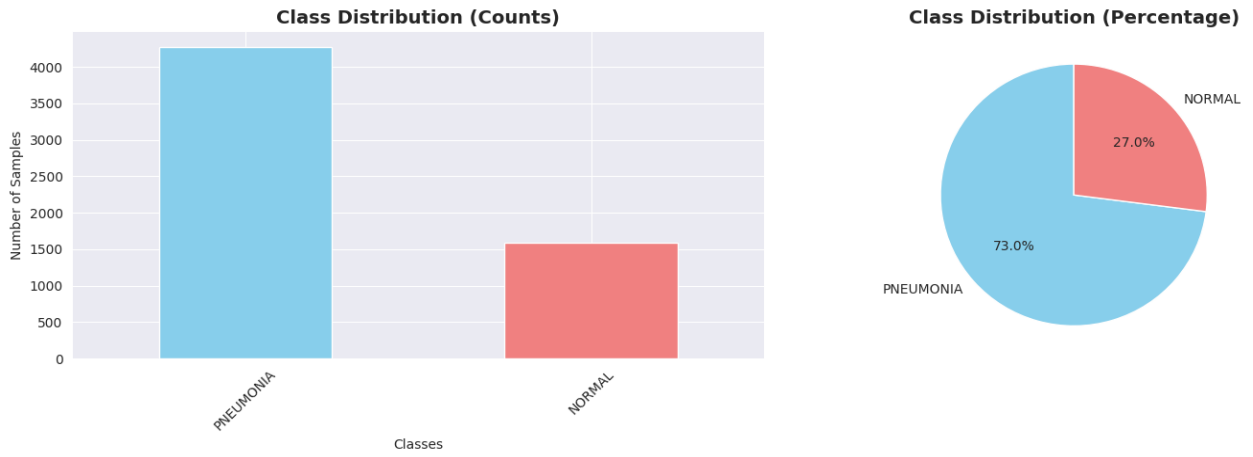
To'plam dastlab uchta papkaga bo'lingan: *train* (trening), *validation* (tasdiqlovchi) va *test* (sinov). Biroq bu papkalarda ma'lumotlar teng taqsimlanmaganligi sababli, mualliflar barcha ma'lumotlarni birlashtirib, qayta uchta bo'limga ajratishgan. 1-jadvalda ushbu bo'linish ko'rsatilgan:

Toifa	**Trening to'plami**	**Validatsiya to'plami**	**Sinov to'plami**
Pnevmoniya	3875	8	234
Sog'lom	1341	8	390
Jami	5216	16	624

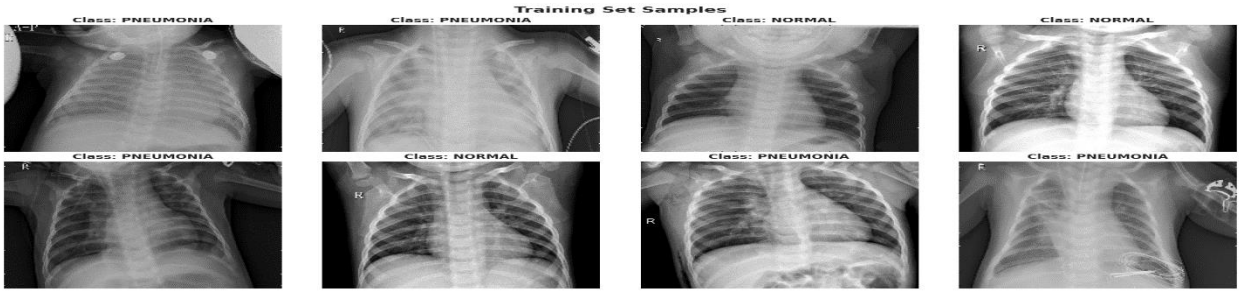


1-rasm. Train, validation va test sinflari

Bu yerda ma'lumotlar inbalance bo'lganligi uchun efficientNet B0 ishlatildi (1-rasm). Tasvirlar 224×224 piksel o'lchamga keltirildi. Normalizatsiya va data augmentatsiya (rotatsiya, gorizontal aylantirish, kontrast/yorug'lik o'zgarishi) qo'llanildi.



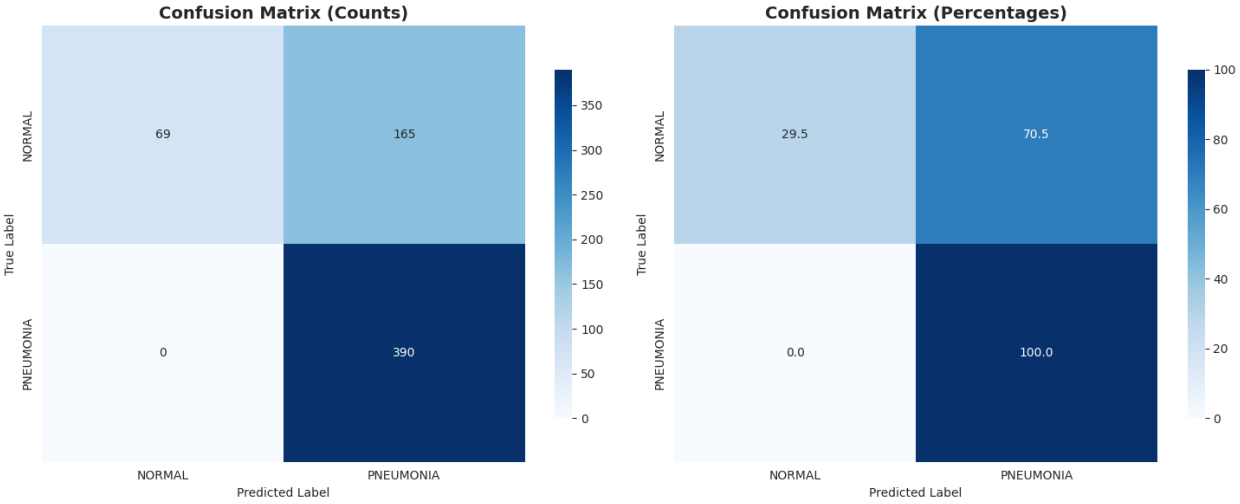
2-rasm. Pnevmoniya va normal sinflarning holati



3-rasm. Pnevmoniya va normal sinf roentgen tasvirlari

EfficientNetB0 arxitekturasi ImageNet ma'lumotlarida oldindan o'rgatilgan model sifatida foydalanildi. Oxirgi qatlam global average pooling va to'liq bog'langan qatlam bilan moslashtirildi. Dropout (0.3) qo'llanildi.

Model samaradorligi quyidagi mezonlar asosida baholandi: Accuracy, Precision, Recall, F1-score (har ikkala sinf bo'yicha), ROC-AUC va PR-AUC, Confusion matrix.



Modelning umumiy aniqligi 97% ga erishdi. Pnevmoniya sinfi uchun recall 96%, precision 95% bo'ldi. ROC-AUC qiymati 0.98 ga teng bo'lib, yuqori farqlash qobiliyatini ko'rsatdi. Confusion matrix natijalari shuni ko'rsatdiki, model asosan to'g'ri tasniflashga muvaffaq bo'ldi, biroq bir qator noto'g'ri tasniflangan sog'lom tasvirlar pnevmoniya sifatida belgilandi. Bu klinik kontekstdagi sezgirlik (sensitivity) yuqoriligini ko'rsatadi, ammo ortiqcha tashxis qo'yish ehtimoli mavjud.

III. Xulosa

Natijalar EfficientNetB0 asosidagi model pnevmoniya tashxisini aniqlashda samarali ekanini ko'rsatdi. Shu bilan birga, tadqiqotning cheklovlari mavjud: Ma'lumotlar to'plami faqat bitta manbadan olingan, tashqi validatsiya o'tkazilmadi. Sinflar o'rtasida nomutanosiblik mavjud bo'lgan, bu modelning umumlashuv qobiliyatini cheklashi mumkin. Ma'lumotlar bolalar yoki kattalar toifasiga tegishliligi alohida tahlil qilinmagan. Kelgusida modelni ko'p markazli ma'lumotlar to'plamida baholash, shuningdek, Grad-CAM kabi vizualizatsiya usullarini qo'llash orqali izohlilikni oshirish rejalashtirilmoqda. Klinik amaliyotda model shifokorlar ishini yengillashtiruvchi yordamchi vosita sifatida foydali bo'lishi mumkin.

EfficientNetB0 asosida yaratilgan model pnevmoniyani CXR tasvirlaridan aniqlashda yuqori samaradorlik ko'rsatdi. U klinik qarorlarni qo'llab-quvvatlash tizimlarida qo'shimcha yordamchi sifatida ishlatilishi mumkin. Biroq amaliyotga tatbiq etishdan avval kengroq klinik tekshiruvlar talab etiladi.

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UCHUVCHISIZ UCHISH APPARATLARI YORDAMIDA O'RMON XO'JALIGINI MONITORING QILISH

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Annotatsiya: ***O'rmon xo'jaligini monitoring qilish sohasidagi tadqiqotlarning dolzarbligi, avvalo, an'anaviy usullar, jumladan, yer yuzasidan kuzatish orqali olib boriladigan monitoring ishlari ko'pincha mavjud vaziyat haqida to'liq ma'lumot bermasligi bilan izohlanadi, ushbu ishning mavzusi nazariy tadqiqotlar yordamida "o'rmon monitoringining ahamiyatini asoslash – muammoning hozirgi holati – vaziyatni yaxshilash bo'yicha tavsiyalar" modeliga asoslangan holda ko'rib chiqildi, o'rmon xo'jaligini tahlil qilishga yondashuvlar asosan uchuvchisiz uchish texnologiyalari va yer usti lazer skanerlari sohasidagi so'nggi ishlanmalar asosida amalga oshirilmoqda, keng o'rmon maydonlariga ega davlatlarga xos bo'lgan o'rmon yong'inlari kabi holatlarda tezkor qaror qabul qilishga ijobiy ta'sir ko'rsatadi.***

Kalit so'zlar: o'rmon monitoringi, uchuvchisiz texnologiyalar, iqlim o'zgarishi, qimmatli turlarni aniqlash, o'rmon monitoringining holati.

I. Kirish

O'zbekistondagi o'rmonlar iqlim o'zgarishi, inson faoliyatining salbiy ta'siri (ifloslanish, yong'inlar, noqonuniy daraxt kesish), zararkunanda epidemiyalari va qurg'oqchilik kabi jiddiy muammolarga duch kelmoqda. Mavjud vaziyatga yetarlicha e'tibor berilmasligi holatni yanada og'irlashtirishi mumkin, chunki bunday sharoitda o'rmon xo'jaligi ekologik hamda ijtimoiy-iqtisodiy vazifalarni to'liq bajarishga qodir bo'lmaydi.

Muammo, avvalo, o'rmon xo'jaligi holati bo'yicha dolzarb ma'lumotlarning yetishmasligi bilan bog'liq. Buning sababi masalaga yetarlicha e'tibor qaratilmagani va o'rmon monitoringi sohasida rivojlangan texnik tizimning yo'qligidir. Mavjud ma'lumotlar, asosan, yong'inlarga oid bo'lib, ularni bartaraf etish va oldini olishga qaratilgan. Boshqa muhim jihatlar, jumladan, daraxt turlarining xilma-xilligi asosida o'rmon tarkibini tahlil qilish, zararkunanda va kasalliklarning tarqalishini nazorat qilish, hududlarning botqoqlanishi yoki cho'llanish darajasini baholash masalalariga esa yetarli e'tibor berilmayapti. Natijada, O'zbekistonda o'rmonlar bo'yicha aniq va taqqoslanadigan uzoq muddatli ma'lumotlarni to'plashning yagona tizimi mavjud emas.

Bu holat o'rmon xo'jaligi imkoniyatlariga, masalan, yong'inlarga qarshi kurash samaradorligi va o'rmonlarning yashab qolishiga jiddiy ta'sir ko'rsatmoqda. Shu bois, o'rmonlarni monitoring qilishda uchuvchisiz uchish apparatlaridan foydalanishni rivojlantirish zarur, chunki ular mamlakat miqyosida barcha o'rmonlarni qamrab oluvchi, tezkor va sifatli baholashni ta'minlaydi. Bu esa yuqorida tilga olingan xavflarga qarshi kurashish, qishloq hududlari va bioiqtisodiyotni rivojlantirish, shuningdek, o'rmon xo'jaligida qabul qilingan siyosat va qoidalarga rioya etishga yordam beradi. O'rmonlarni tizimli monitoring qilish mamlakat miqyosida iqlim xavflari, risklar va zararlarni aniqlash hamda tabiiy ofatlarga va inson faoliyatining salbiy oqibatlariga qarshi kurashishda muhim ahamiyatga ega.

O'rmonni uchastkalarga ajratish va soliqqa tortish, tayyorgarlik ishlari vaqtida o'rmon hududlarini o'rganishni tashkil etish (ularning raqamli nusxalarini yaratish, o'rmon uchastkalarini tayyorlash), o'rmon inventarizatsiyasi sifatini nazorat qilish, pastki va yuqori o'lkalardagi yig'ilgan yog'och hajmini aniqlash, nazorat qilish faoliyatlarini amalga oshirish kabi vazifalarni hal etish zarurati mavjud.

Ulardan quyidagilarni ajratib ko'rsatish mumkin: o'rmonlarni tiklash ishlarining samaradorligini baholash, o'rmon inventarizasiyasi va boshqaruv choralarining sifatini tekshirish, kesilgan yog'och hajmini aniqlash. Shuningdek, 1000 gektargacha bo'lgan (shahar o'rmonlari, dam olish maskanlari, transport yo'llari bo'yidagi himoya o'rmonlari va boshqalar) kichik maydonga ega o'rmon fondi obyektlarida inventarizatsiya vazifalari ham mavjud. Bundan tashqari, zarur hujjatlarni tayyorlash va chiziqli obektlar bo'yicha loyihaviy yechimlarni amalga oshirish, ekilgan daraxtzorlarning to'liq ro'yxatini tuzish, hududning botqoqlanishi va cho'llanish ulushini baholash hamda bashoratlash vazifalari ham dolzarbdir.

Tadqiqotda o'tkazilgan intellektual va statistik tahlil ushbu sohani yanada rivojlantirish zarurligini ko'rsatdi va monitoring jarayonining ko'p funksiyali ekanligi haqida xulosa chiqarildi. Shuningdek, tadqiqot mamlakatimizda bu

yo‘nalishdagi texnologiyalar yetarlicha rivojlanmaganligini hamda xorijiy tajribaga asoslangan yangi yechimlarni joriy etilishining muhimligini ta'kidladi.

Tadqiqot maqsadi — zamonaviy sharoitda uchuvchisiz uchish apparatlari yordamida o‘rmon monitoringini olib borish maqsadlarini aniqlash.

Tadqiqot obyekti — RO‘MT (Respublika O‘rmon Massivi Tizimi) yordamida o‘rmon massivini o‘rganish, tahlillish va monitoringni amalga oshirish texnologiyalari va usullari. Ushbu jarayonni amalga oshirishdagi muammolar ham ko‘rib chiqiladi.

Tadqiqot metodlari:

- **Tahlil** — ushbu mavzu bo‘yicha mahalliy va xorijiy adabiyotlar o‘rganildi, o‘rmon monitoringini amalga oshirishning zamonaviy usullari hamda jarayonning texnik jihatlari aniqlashtirildi.
- **Sintez** — yig‘ilgan ma'lumotlar asosida RO‘MT dan monitoringda foydalanishning umumiy manzarasi hamda bu sohaga oid muammolar shakllantirildi.

II. Asosiy qism

Dronlardan monitoringda foydalanish imkoniyatlari. Dronlar uglerod miqdorini ham nazorat qilish va o‘lchash imkonini beradi. Ular tezkor, arzon va og‘ir mehnatni sezilarli darajada kamaytiradi. O‘rmon qoplamasidagi o‘zgarishlarni monitoring qilish REDD+ mexanizmining muhim tarkibiy qismi bo‘lib, u o‘rmonlarning kesilishi va degradatsiyasi natijasida uglerod chiqindilarining kamayishini ko‘rsatadi [2]. Tadqiqotlar shuni ko‘rsatadiki, aviomodel samolyotiga o‘xshash o‘lchamdagi dronga kichik kamera o‘rnatilib, 50 dan 300 metrgacha balandlikda parvoz qilinganida yuqori fazoviy aniqlikka ega tasvirlarni olish mumkin.

Bunday aniqlikda alohida daraxtlarni va o‘simlik qoplamasidagi o‘zgarishlarni aniqlash hamda kuzatish oson kechadi (1-rasm).

1-rasm. – Dron yordamida o‘rmon hududini tasvirga olish

Uchuvchisiz uchish apparatining arzonligi va foydalanish qulayligi shuni anglatadiki, o‘rmonlarda o‘lchovlarni an’anaviy masofadan zondlash texnologiyalariga qaraganda ancha tez-tez amalga oshirish mumkin, chunki ular ancha qimmat turadi [3], [7]. Yig‘ilgan ma’lumotlar algoritm yordamida talqin qilinadi va u o‘rmonning 3D xaritasini yaratadi hamda, boshqa narsalar qatori, mazkur hududdagi daraxtlar soni, yog‘och hajmi, o‘simlik bilan qoplangan maydon va barglarning miqdorini ko‘rsatadi.

1-jadval. Qashqadaryo viloyati o‘rmon xo‘jaligi statistikasi

Tuman	**Nomi**	**Turi/ Yo‘nalish**	**Maydoni gektar**	**Hududdagi o‘simliklar turlari soni**	**Yovvoyi fauna:**	**Yoshi**
Chiroqchi	Qumdaryo davlat o‘rmon xo‘jaligi	Chiroqchi tumanida	18 700	4	7	6

		joylashgan, o'rmon barpo etish va muhofaza				
Shahrisabz	Shahrisabz tumani o'rmon xo'jaligi	Tuman darajasida o'rmonchilik va resurslardan foydalanish	12 203	15	7	20
Shahrisabz	Shahrisabz ixtisoslashtirilgan o'rmon xo'jaligi	Maxsus faoliyat yo'nalishlarida (dorivor ekinlar, ilmiy)	18 672	35		7
Qamashi	Qamashi tumani o'rmon xo'jaligi	O'rmon resurslarini boshqarish, oqilona foydalanish	14,092	7	11	34
Yakkabog'	Yakkabog' ixtisoslashtirilgan (likvidatsiya)	Hozirda faoliyat emas, ilgari yo'nalishga ega bo'lgan	16,002.1	6	9	31

Texnologik innovatsiyalar baholash sohasida sezilarli yutuqlarga olib keldi. Ilgari baholash jarayoni ko'proq qo'lda bajariladigan usullar asosida amalga oshirilgan bo'lib, baholovchining tajribasiga ortiqcha bog'liq bo'lgan, ilmiy bo'lmagan metodologiyalar va subyektiv yondashuvlar ko'pincha noto'g'ri, kechikkan va asossiz natijalarga olib kelardi [1]. Yangi texnologiyalarni qo'llash va bozor ma'lumotlariga tobora to'liqroq kirish imkoniyati tufayli ushbu vaziyat tez sur'atlar bilan o'zgarib bormoqda. Texnologik innovatsiyalar baholash jarayonini transformatsiya qilayotgan asosiy yo'llardan biri — bu baholashning yangi vositalari va texnologiyalarini joriy etishdir. Ular o'rmonning joylashuvi, hajmi, topografiyasi hamda qiymatga ta'sir etuvchi boshqa muhim omillar haqida batafsil ma'lumot olish imkonini beradi [7].

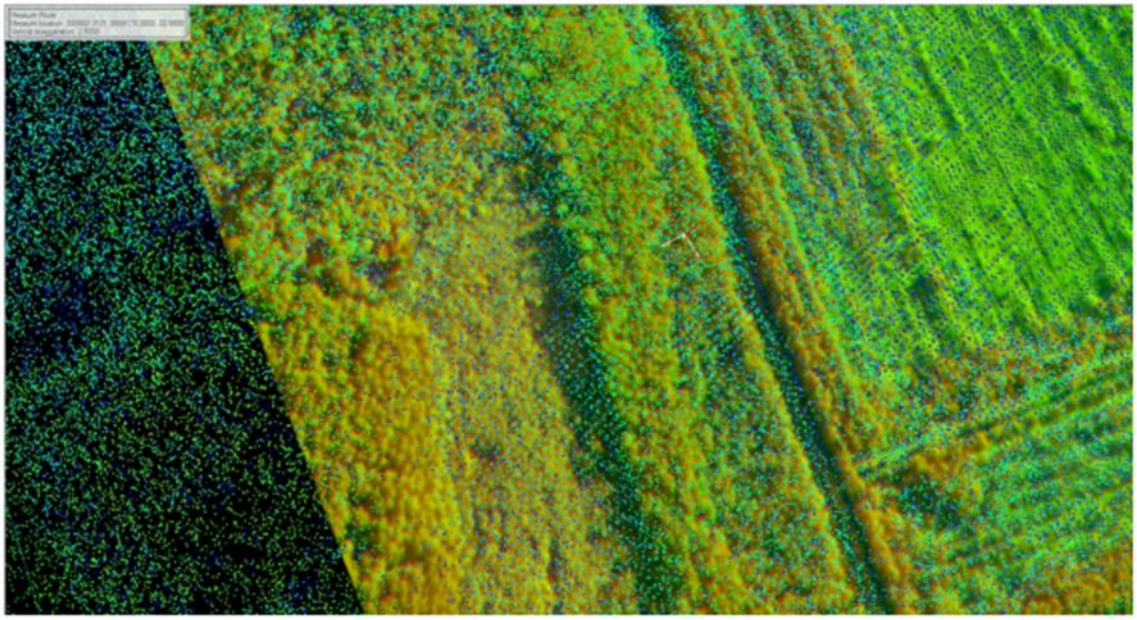
2-jadval. Qumdaryo davlat o'rmon xo'jaligi

Yo'nalish	**Ma'lumotlar**
Joylashuvi	Chiroqchi tumani, 39°02′N 66°34′E koordinatalarda
Plantatsiya rejalari	2019 - 2020-yillarda 7 000 ga hududda pista, bodom, yong'oq, chakanda
Ekologik monitoring	O'simlik va hayvonot monitoringi, kadastr tizimi, geo-axborot bazasi orqali
Masofaviy monitoring	Kosmik usullar yordamida tuproq, eroziyaga qarshi daraxtzorlar va ko'chatlar monitoringi

O'rmonlarni baholash, odatda, o'rmon uchastkalarini ijaraga berish jarayonining bir qismidir. Mutaxassis butun hududni ko'rib chiqib, ko'plab jihatlarni — masalan, yer maydoni, undagi daraxt turlari, zichligi, joylashgan o'rni, daraxtlar soni va hokazolarni inobatga olishi kerak [6]. O'rmon baholash natijalari hujjatda aks ettirilgandan so'ng, yer uchastkasining qiymati ham baholanishi mumkin. O'rmonlarni baholashni o'tkazadigan shaxs betaraf bo'lishi shart, ya'ni u na yer egasi, na uni sotib olish yoki ijaraga olishdan manfaatdor kompaniya vakili, va na o'sha yerda o'rmon xo'jaligi faoliyatini yuritishni rejalashtiruvchi bo'lishi mumkin. Shu bois, monitoringni maxsus tashkilot tomonidan olib borish zarurati yuzaga keladi.

Yaqin vaqtgacha o'rmon baholash asosan qo'lda bajarilgan, dronlardan olingan ma'lumotlarni esa inson emas, balki sun'iy intellektual tizim qayta ishlangan. Buning natijasida ikki turdagi muammo darhol ko'zga tashlangan: hisoblash tezligining pastligi va xato ehtimolining mavjudligi. Ikkinchi omilni kamaytirish uchun nazorat tashkiloti xodimlari qo'lda o'lchovlarni amalga oshirib, mustaqil ma'lumot olishga majbur bo'lishadi. Bu esa ish vaqtini yanada cho'zadi va ba'zi hollarda yer uchastkasini ijaraga oluvchilar uchun muhim muammoga aylanishi mumkin. Daraxt turlarini noto'g'ri aniqlash biologik xilma-xillikni nazorat qiluvchi tashkilotlarning e'tirozlariga sabab bo'lishi mumkin.

Shu sababli daraxt turlarini aniqlashda sun'iy intellekt asosidagi dastur va modellarni qo'llash juda muhim yechim sifatida ko'rilmoqda va hozirda "O'zo'rmonaxborot" tomonidan faol qo'llanilmoqda. Kompaniyaning so'nggi yangiliklaridan yana biri — bu Leica ALS-70HP lidar (skaner)idan foydalanib, Leica RCD-30 kamerasi (50 mm fokus masofasiga ega) yordamida ortofotoplan modelini yaratishdir (2-rasm). Natijada yuqori sifatli rastrli modelni yaratish va uni MicroStation kompleksi hamda sun'iy intellekt asosida ishlab chiqilgan modul yordamida qayta ishlash uchun zarur bo'lgan vaqtni qisqartirishga erishildi.



2-rasm. Uch o‘lchamli fazodagi lazer nuqtalari buluti ortofotoplan bilan birlashtirilgan (vertikal proektsiya)

Uskuna ishini namoyish qilish doirasida Qashqadaryo viloyatida kengligi 30 metr bo‘lgan gaz quvuri uchun ajratish va chiziqli obektni to‘liq ro‘yxatga olish ishlari olib borilayotgan hudud tanlandi. Ushbu tadqiqot davomida skanerlash **DJI Matrice 350 RTK** kvadrokopteri va portativ skanerlash tizimi yordamida amalga oshirildi. Tadqiqot o‘tkazish jarayonida turli tashkilotlar o‘rtasida, nafaqat tijorat balki davlat darajasida ham, ma'lumot almashish zarurligi ayon bo‘ldi. Chunki o‘rmonni baholash va uning holati bo‘yicha natijalar boshqa tomonlarga ma'lum bo‘lmasligi mumkin.

O‘rmonni baholash **Favqulodda vaziyatlar vazirligi (FVV)** yoki qidiruv tashkilotlari uchun ham foydali bo‘lishi mumkin, chunki bu haqiqiy hudud xaritasini tuzishda zarur hisoblanadi. Bundan tashqari, o‘rmon massivi soni va sifatiga oid ma'lumotlarni olish inventarizasiya o‘tkazishda va kesish rejalarini ishlab chiqishda foyda beradi. Shuningdek, o‘rmon hududini baholash jarayonida turli qonunbuzarliklar aniqlanishi mumkin, bu esa davlat byudjetini to‘ldirishga ham xizmat qiladi.

III. Xulosa

Keltirilgan ma'lumotlarga asoslanib aytish mumkinki, o‘rmon monitoringi nafaqat o‘rmon tarkibi va sifatini baholash, balki kesishga mo‘ljallangan hududlarni belgilash hamda yong‘in xavfini aniqlash nuqtayi nazaridan ham muhim va dolzarb vazifadir. O‘tkazilgan o‘lchovlar asosida ekotizimning inson faoliyatiga va tashqi omillarga, jumladan, o‘zgarib borayotgan iqlim sharoitlariga qanday javob berishini umumiy tushuncha sifatida olish mumkin. Monitoring nafaqat daraxtlarning o‘zini, balki ular bilan bog‘liq muhit xususiyatlarini ham qamrab oladi. Xususan, atmosfera tarkibi, harorat va daraxtlarga ta'sir qiluvchi organizmlar haqida ham fikr yuritish mumkin.

Yig‘ilgan ma'lumotlar turli maqsadlarda qayta ishlanib, topografik kartografiya, geologik tadqiqotlar, o‘simliklarni tahlil qilish, relefni modellashtirish, landshaft o‘zgarishlarini kuzatish, tabiiy resurslarni baholash, shaharsozlik va hudud haqida aniq ma'lumot talab etadigan boshqa ko‘plab sohalarda qo‘llanishi mumkin. Shu bilan birga, ushbu sohadagi muammolardan biri monitoring uchun qo‘llanilayotgan dronlarning batareya zaxirasining kamligi hamda o‘zgaruvchan iqlim sharoitlariga moslasha olmasligidir. Xususan, amaliy o‘lchovlar davomida kuchli shamol natijalarning noto‘g‘ri chiqishiga va bir nechta omillar birlashganda uskunani yo‘qotishga olib kelishi mumkinligi aniqlangan.
Ayrim modellarning qish faslida monitoringni bajarish jarayonida samarasizligi kuzatildi, xususan, iqlim sharoiti tufayli yuzaga keladigan muzlash muammosi qayd etildi. Bu esa uchuvchisiz uchish qurilmalari konstruksiyasi jihatidan yanada takomillashgan tizimlarni ishlab chiqishni taqozo etadi. Bundan tashqari, monitoringni takomillashtirishning boshqa yo‘nalishi sifatida, o‘rmon xo‘jaligi holatini baholash algoritmlarini maqsadga qarab yaxshilash mumkin, chunki ushbu jarayon ko‘p qirrali va turli yo‘nalishli hisoblanadi. Baholashga nafaqat daraxtlarning o‘zi, balki tuproq holati, barglar miqdori hamda ma'lum hudud atmosferasining tarkibi ham kiritilishi mumkin.

Mazkur mavzu dolzarb bo‘lib, zamonaviy texnologiyalarga tayangan holda ushbu jarayonning samaradorligini sezilarli darajada oshirish mumkin.

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ЭЛЕКТРОН ҲУКУМАТДА ОВОЗЛИ МАЪЛУМОТЛАРНИ БОШҚАРИШ

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Аннотация **— Мақолада электрон ҳукумат тизимида овозли маълумотларни йиғиш, қайта ишлаш, таҳлил қилиш ва ҳимоя қилиш соҳаларига доир замонавий технологиялар ва усуллар ўрганилган. Овозли маълумотлар давлат хизматларини такомиллаштиришда, фуқароларнинг фикрлари ва эҳтиёжларини тез ва аниқ тушунишда муҳим аҳамият касб этади. Мақолада овозни матнга айлантириш, овоз эгасини идентификация қилиш, маълумотларни сақлаш ва семантик ҳамда эмоционал таҳлил усуллари каби технологиялар таҳлил қилинган. Шунингдек, овозли маълумотларнинг хавфсизлиги ва шахсий маълумотларни ҳимоя қилиш муаммоларига алоҳида эътибор берилган. Идоралараро ҳамкорлик ва электрон ҳукумат инфратузилмаси орқали овозли маълумотларни самарали бошқаришнинг ҳуқуқий ва техник жиҳатлари ҳам кўриб чиқилган. Мақола Ўзбекистон шароитида электрон ҳукуматни такомиллаштириш ва фуқароларга сифатли давлат хизматлари кўрсатиш учун овозли маълумотлар технологияларини жорий этишнинг аҳамиятини кўрсатади.**

Ключевые слова: Электрон ҳукумат, Овозли маълумотлар, Speech-to-Text, Овоз эгасини идентификация қилиш, Хавфсизлик ва махфийлик, Шахсий маълумотлар ҳимояси, Идоралараро ҳамкорлик, Электрон ҳукумат инфратузилмаси, AI ва NLP технологиялари, Давлат хизматлари,.

I. Кириш

Рақамли трансформация мамлакатларда давлат хизмати сифатини яхшилашида ёрдам бераётганини бугун ҳаммамиз ҳис этмоқдамиз. Электрон ҳукумат (e-Government) фуқаролар билан давлат ўртасида самарали мулоқотни таъминлайди. Ушбу мақолада овозли маълумотлар—колл марказларда тушадиган қўнғироқлар, овозли мурожаатлар ва AI асосидаги овозли ассистентлар орқали тарқатиладиган маълумотларни бошқариш жараёнлари, уларнинг таҳлил аҳамияти, хавфсизлик билан боғлиқ муаммолар ва техник инфратузилмаси батафсил ёритилади. Мавзунинг актуаллиги-бугунги кунда рақамли технологияларнинг жадал ривожланиши давлат бошқаруви соҳасида ҳам янги имкониятлар эшигини очмоқда. Электрон ҳукумат тизими фуқаролар ва давлат органлари ўртасидаги алоқани рақамли шаклга ўтказиш орқали давлат хизматларини тезкор, шаффоф ва самарали етказишни мақсад қилади. Бу жараёнда турли турдаги маълумотлар, жумладан, **овозли маълумотлар** (қўнғироқлар, овозли мурожаатлар, автоматик овозли хабарлар ва бошқалар) катта аҳамият касб этади.

Фуқароларнинг фикр-мулоҳазалари, шикоят ва таклифлари аксар ҳолларда айнан овозли форматда ифода этилади. Бундай маълумотларни тўғри қабул қилиш, қайта ишлаш, таҳлил қилиш ва зарур чораларни кўриш давлат органларининг аҳоли эҳтиёжларига мос равишда иш олиб боришини таъминлайди.

Шу билан бирга, овозли маълумотларни бошқаришнинг ахборот хавфсизлиги, шахсий маълумотларни муҳофаза қилиш, тил ва шева хилма-хиллиги каби мураккаб жиҳатлари мавжуд. Айниқса, AI (сунъий интеллект) ва NLP (табиий тилни қайта ишлаш) технологиялари ривожланаётган бугунги замонда овозли маълумотлардан самарали фойдаланиш нафақат техник, балки стратегик вазифа сифатида ҳам қаралмоқда.

Демак, ушбу мавзуни ўрганиш - давлат хизматларининг замонавийлашуви, фуқаролар билан мулоқот маданиятининг юксалиши ва ахборотнинг самарали бошқарилиши нуқтаи назаридан жуда долзарб ва ўз вақтидаги масала ҳисобланади.

Мақсад ва вазифалар:

Ушбу мақоланинг асосий мақсади - лектрон ҳукумат тизимида овозли маълумотлар билан ишлаш жараёнларини комплекс таҳлил қилишдан иборат. Хусусан, давлат хизматлари кўрсатишда овозли маълумотларнинг ўрни, уларни тўплаш, қайта ишлаш, таҳлил қилиш ва сақлашда қўлланиладиган замонавий технологиялар ҳамда ахборот хавфсизлиги масалаларига алоҳида эътибор қаратилган.

II. Овозли маълумотларнинг аҳамияти

1) Овозли маълумотларнинг аҳамияти

Овозли маълумотлар — бу инсон овози орқали ифода этилган, аудио форматда ёзиб олинган ёки узатилган ахборот туридир. Электрон ҳукумат тизимида овозли маълумотлар муҳим манба сифатида хизмат қилади ва фуқаролар билан давлат органлари ўртасидаги реал вақт мулоқотини таъминлашда муҳим роль ўйнайди. Бу турдаги маълумотлар давлат хизматларининг жонлилиги, интерактивлиги ва самарадорлигини оширишга кўмаклашади.

Амалий қўлланиш соҳалари-фуқаролар томонидан давлат хизматларига овозли маълумотлар орқали мурожаат қилишнинг асосий шакллари қуйидагилардан иборат:

- Колл-марказлар (Call Centers): Давлат идоралари билан тўғридан-тўғри телефон орқали боғланиш имконини беради. Одатда, операторлар ёки автоматлаштирилган тизимлар орқали фуқаролардан тушаётган овозли мурожаатлар қабул қилинади, ёзиб олинади ва сақланади. Бу маълумотлар таҳлил қилиниб, тегишли бўлимларга йўналтирилади.
- Автожавобгарлаштирувчи тизимлар (IVR — Interactive Voice Response): Фуқаролар автоматик овозли менюлар ёрдамида маълумот олишлари, ариза қолдиришлари ёки хизматлардан фойдаланишлари мумкин. Бундай тизимлар 24/7 ишлайди ва инсон иштирокисиз маълумот беришни таъминлайди.
- Овозли сўров ва фикр билдириш платформалари: Айрим давлат хизматлари ёки жамоатчилик ташаббуслари доирасида овозли фикрлар йиғилади, таҳлил қилинади ва қарор қабул қилиш жараёнида ҳисобга олинади.

a) Фуқаролар эҳтиёжларини тушунишдаги ўрни

Овозли маълумотлар — фуқароларнинг реал эҳтиёжлари, муаммолари, таклифлари ва муносабатларини тушуниш учун қулай ва самарали манбадир. Қуйидаги жиҳатлар бу маълумотларнинг аҳамиятини янада оширади:

- Тезкорлик: Овозли мурожаат ёки қўнғироқ орқали фуқаро ўз муаммосини ёзма мурожаатга нисбатан тез ва тўғридан-тўғри баён қилади. Бу эса фаол ва реал вақтда фидбек олиш имконини беради.
- Эмоционал ҳолатни англаш: Овозли маълумотлар орқали инсоннинг кайфияти, стресс даражаси, ишонч ёки хавотир каби эмоционал ҳолатлар ҳам аниқланиши мумкин. Бу маълумотлар асосида давлат идоралари ўз хизматларини психологик жиҳатдан ҳам мослаштириш имкониятига эга бўлади.
- Шаффоф ва интерактив муносабат: Фуқароларнинг овози эшитилиши, уларга жавоб қайтарилиши, ҳар бир мурожаатнинг қайд этилиши — давлатга бўлган ишончни оширади, шаффофликни таъминлайди.

b) Ижтимоий ва бошқарув функциясидаги аҳамияти

Овозли маълумотлар фақатгина алоқа воситаси эмас, балки:

- Фуқаролар кайфиятини мониторинг қилиш, жамоатчилик фикрини тезкор равишда ўрганиш;
- Мурожаатлар бўйича оммавий таҳлиллар олиб бориш, масалан, қайси масалалар кўпроқ кўтарилаётганини аниқлаш;
- Давлат органлари фаолиятини такомиллаштириш, хизматларнинг сифатини ошириш учун таклифлар йиғиш;
- Ижтимоий хавф ёки инқироз ҳолатларини барвақт аниқлаш имкониятларини яратади.

III. Технологик ечимлар

a) Ovozni matnga aylantirish (Speech-to-Text)

Speech-to-Text технологияси — бу овозли маълумотни автоматик равишда матн форматига айлантириш жараёни бўлиб, AI ва NLP алгоритмлари ёрдамида амалга оширилади. Бу жараён фуқаролар томонидан айтилган гапларни матн сифатида қайд этиш ва кейинчалик таҳлил қилиш имконини беради.

- Масалан, фуқароларнинг колл-марказга қилган мурожаатлари автоматик равишда матнга айлантирилиши орқали маълумотлар базасига сақланади.
- AI моделлари овоздаги талаффуз, шева, сўз тезлиги каби омилларни ҳам ҳисобга олади, бу эса танишлик даражасини оширади.
- Ўзбек тили учун ҳам махсус локаллаштирилган NLP дастурлари ишлаб чиқилиши аҳамиятга эга.

b) Ovoz egasini аниқлаш (Speaker Identification)

Speaker Identification — бу овозли маълумот орқали ким гапираётганини аниқлаш имконини берувчи технологиядир. У икки асосий мақсадда фойдаланилади:

- Автентификация (тасдиқлаш): Фуқаро овози орқали шахсий идентификациядан ўтади (масалан, шикоят муаллифини аниқлаш).
- Таҳлил ва гуруҳлаш: Турли фуқаролар томонидан билдирилган овозли мурожаатларни гуруҳлаб таҳлил қилиш имконини беради.

Ушбу технология маълумот хавфсизлиги ва шахсий маълумотларни ҳимоя қилиш тизимларида ҳам қўлланилади.

c) Маълумотларни сақлаш ва архивлаш

Овозли маълумотларни қайта ишлаш ва уларга қайтиб мурожаат қилиш имкони бўлиши учун уларни тўғри сақлаш ва архивлаш зарур. Бунинг учун:

- Аудио файллар формати: WAV, MP3, FLAC каби форматлар қўлланилади. Формат танлашда сифат ва ҳажм ўртасида мувозанат сақланади.
- Мета-маълумотлар: Ҳар бир файл учун вақтини, мурожаат манбаини, фуқаро идентификаторини ва бошқа муҳим маълумотларни сақловчи маълумотлар бирга ёзилади.

- Маълумотлар базаси**:** Аудио маълумотлар кўп ҳолларда махсус маълумотлар базаларида сақланади (масалан, NoSQL форматдаги аудио репозиторийлар).

Бу элементлар овозли маълумотлардан таҳлил ва мониторингда самарали фойдаланиш учун асос яратади.

d) Таҳлил усуллари

Овозли маълумотларни таҳлил қилишда замонавий алгоритмлар қуйидаги йўналишларда иш олиб боради:

- Семантик таҳлил (Semantic Analysis): Матнга айлантирилган овозли маълумотлардан мазмунни аниқлаш, яъни нима ҳақида сўз кетаётганини автоматик тарзда англаш. Масалан, мурожаатда транспорт, соғлиқни сақлаш, ишсизлик ёки таълим ҳақида гап кетяптими — шуларни аниқлаш.
- Эмоционал таҳлил (Sentiment Analysis): Фуқаро мурожаатидаги ҳиссиётни — ижобий, салбий ёки бетарафлигини аниқлаш. Бу давлат хизматлари сифатини баҳолаш, аҳоли кайфиятини англашда фойдали.
- Овоз характери таҳлили: Интонация, овоз баландлиги, паузалар, стресс даражаси ва бошқа овозли хусусиятларни таҳлил қилиш орқали фуқаро кайфияти ёки таъкидланаётган муаммонинг жиддийлиги баҳоланади.

Бу таҳлиллар сунъий интеллект ва машинали ўрганиш алгоритмлари орқали амалга оширилади ва ҳар бир овозли маълумотни аҳамиятли ахборотга айлантириш имконини беради.

IV. Хавфсизлик ва махфийлик

Электрон ҳукумат тизимида овозли маълумотлар билан ишлаш жараёни нафақат техник, балки ҳуқуқий ва ахлоқий нуқтаи назардан ҳам етарлича муҳофаза қилинган бўлиши керак. Чунки овоз — инсоннинг шахсий идентификатори сифатида қаралади ва у орқали шахсни аниқлаш, таҳлил қилиш, ҳатто кузатиш ҳам мумкин. Бу эса маълумот хавфсизлиги ва махфийлик борасида жиддий ёндашувни талаб қилади.

a) Хавфсизлик таҳдидлари

Овозли маълумотларни йиғиш, қайта ишлаш ва сақлаш жараёнларида бир неча турдаги хавфлар мавжуд бўлиб, улар қуйидагича таснифланади:

А)Машинани ўргатишга ҳужумлар (Adversarial attacks):

Сунъий интеллект ва NLP алгоритмлари овозни матнга айлантириш жараёнида нейрон тармоқлар орқали ишлайди. Бу жараёнда маълумотлар махсус AI-модельга берилганда, айрим ҳолатларда қасддан тузилган "адверсариал сигналлар" орқали:

- AI моделни адаштириш,
- нотўғри маъно бериш,
- ёки нотўғри фуқарони идентификация қилиш ҳолатлари юзага келиши мумкин.

Масалан: шахс бошқа инсон овозини тақлид қилувчи дастур орқали автоматик идентификацияни алдашга уриниши.

Б) Аппарат ва дастурий хавфлар:

- Микрофонлар ёки мобил қурилмалардаги хавфлар: овоз ёзувлари фуқаро розилигисиз ёзиб олиниши ва учинчи шахсларга узатилиши мумкин.
- Аудио маълумотларни сақловчи серверларга ҳужумлар: маълумотлар базасидаги аудио-файллар ўғирланиши ёки ўзгартирилиши мумкин.
- Интеграция хавфлари: овозли маълумотлар бошқа ахборот тизимлари билан алмашилганда улар шифрланмаган ҳолда узатилиши мумкин.

V.Идоралараро ҳамкорлик ва инфратузилма

Идоралараро ҳамкорлик ва стандартлар.

Электрон ҳукумат тизими фуқароларга сифатли, шаффоф ва тезкор хизматлар кўрсатишни таъминлаш учун турли давлат идоралари ўртасида самарали ҳамкорлик ва маълумот алмашишни талаб қилади. Айниқса, овозли маълумотлар билан ишлаш жараёнида — уларни йиғиш, сақлаш, қайта ишлаш ва таҳлил қилиш босқичларида — идоралараро ўзаро интеграция муҳим аҳамиятга эга.

1. *Идоралараро электрон ҳамкорлик тизими (ИЭҲТ)*

Ўзбекистонда Идоралараро электрон ўзаро ҳамкорлик тизими (ИЭҲТ**)** платформаси орқали давлат органлари ўртасида маълумот алмашиш, электрон ҳужжат айланиши ва хизматлар координациясини таъминлайди.

Бу тизим орқали:

- Фуқаролар томонидан турли идораларга қилган овозли мурожаатлар бирлаштирилган маълумот базаларига йиғилади;
- Автоматик равишда қайта ишлаш учун махсус API ва интеграция каналлари мавжуд;
- Идоралар ўртасида маълумот алмашиш реал вақтда (real-time) амалга оширилади, бу орқали мурожаатлар иккиламчи ёзувларсиз, аниқ ва тезкор тарзда юритилади.

Бу тизим овозли маълумотлар каби нотипик форматдаги ахборотларни ҳам марказлаштирилган тарзда қабул қилиш, қайта ишлаш ва таҳлил қилиш имкониятини яратади.

2. Электрон ҳукумат инфратузилмаси

Овозли маълумотлар билан ишлаш учун давлат тизими қуйидаги техник инфратузилма ва платформаларга таянади:

А) Маълумотларни сақлаш:

- PostgreSQL, MongoDB каби маълумотлар базалари: мета-маълумотлар (қўнғироқ вақти, мурожаат идентификатори, фойдаланувчи ID) сақлаш учун.
- Объектга йўналтирилган сақлаш тизимлари (Object Storage): овозли файлларни (MP3, WAV) аудио форматда сақлаш учун, масалан Amazon S3 ёки маҳаллий Datalake ечимлари.
- DMS (Document Management Systems): мурожаатлар билан боғлиқ ҳужжатлар, иш юритиш жараёни ва овоз ёзувлари биргаликда сақланадиган тизимлар.

Б) Маълумотни қайта ишлаш ва таҳлил қилиш:

- ETL (Extract, Transform, Load) жараёнлари: овозли маълумотларни матнга айлантирилгандан сўнг семантик таҳлилга тайёрлаш.
- AI/ML серверлар ва кластерлар: катта ҳажмдаги овозли маълумотларни тезкор қайта ишлаш учун GPU-қувватига эга тизимлар.

B)Хавфсизлик ва махфийлик инфратузилмаси:

- VPN ва Firewall тизимлари — маълумот узатиш хавфсизлигини таъминлайди.
- Access Management тизимлари **(IAM):** қайси ходим қайси маълумотга кириш ҳуқуқига эга эканини белгилайди.
- Шифрлаш протоколлари**:** TLS/SSL каби стандартлар асосида маълумотлар ҳаракати шифрланади.

3. Стандартлаштириш ва мувофиқлаштириш

Электрон ҳукумат тизимида маълумотлар, жумладан овозли маълумотлар билан ишлашда қуйидаги стандартлар ва меъёрий ҳужжатлар муҳим роль ўйнайди:

- DXP (Digital Experience Platform) – фуқарога йўналтирилган давлат хизматларини ягона платформада шакллантириш.
- Open API стандартлари - давлат идоралари ўртасида маълумотларни бирлаштириш ва интеграция қилиш учун умумий интерфейслар.
- JSON/XML форматлари -маълумотларни сохта ўзгартиришсиз ишлаш ва текшириш имконини беради.
- ISO/IEC 27001 - ахборот хавфсизлиги бошқаруви тизими стандарти (ISMS).

Бундай стандартлар ва регламентларсиз идоралар ўртасида овозли маълумотларни ишончли ва мувофиқ тарзда алмашиш, таҳлил қилиш ва қайта ишлаш мураккаблашади.

VI. Амалиёт мисоллари — Ўзбекистон контексти вывод

- Dashboard AT лойиҳаси: электрон ҳукумат тизимининг ахборот ресурсларини визуализация қилиш ва мониторинг қилиш учун платформани таъминлаш .
- Электрон ҳукумат лойиҳаларини бошқариш маркази ва инфратузилма хусусияти, лойиҳалар самарадорлиги, технологияга асосланган ёндашувлар .

VII. Қийинчиликлар ва тавсиялар

Масалалар: тил ва шевалар турлари, кадрлар малакси, техник ресурслар, ҳимоя муаммолари.

Тавсиялар: AI ва NLP технологияларига сармоя киритиш, стандарт ҳамда ҳимоя тизимини кучайтириш, овозли маълумотларни давлат хизматлари платформаларига интеграция қилиш, давлат лойиҳаларида (Dashboard AT каби) овозли маълумотлар билан ишлаш имконини кўриб чиқиш.

Хулоса

Электрон ҳукуматда овозли маълумотларни бошқариш юқори даражадаги ишонч, масъулият ва ахборот хавфсизлигини талаб қилади. Хавфсизлик таҳдидларига қарши етарли чоралар кўрилмаса, фуқароларнинг шахсий маълумотлари бузилиши, AI моделларни манипуляция қилиш, ва оммавий маълумотларнинг суиистеъмоли каби жиддий оқибатлар келиб чиқиши мумкин.

Шу боисдан, давлат ва IT-ижрочилар томонидан нафақат техник, балки ҳуқуқий ва ташкилий чора-тадбирлар мажмуини амалга ошириш талаб этилади. Бу эса электрон ҳукуматга бўлган ишончни мустаҳкамлашнинг асосий омилларидан биридир.Овозли маълумотларни бошқариш электрон ҳукуматнинг янги босқичига юқорилаш имконини беради. Ушбу соҳада AI ва IT имкониятларидан фойдаланиш, хавфсизлик ва стандартлаштириш механизмларини кучайтириш давлат-хусусий сектор, фуқаролар ўртасидаги муносабатларни янада самарали ва шаффоф қилади.

Овозли маълумотлар билан ишлашда идоралараро ҳамкорлик ва ягона стандартларга риоя қилиш — электрон ҳукуматнинг барқарор, хавфсиз ва самарали фаолият юритиши учун асосий шартлардан биридир. Ҳар бир идора ўзига тегишли маълумотларни марказлашган инфратузилма орқали бошқарса, фуқароларнинг мурожаатлари тезкор қабул қилинади, таҳлил қилинади ва натижада уларга сифатли жавоб қайтарилади.

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ИНТЕГРАЦИЯ ГОЛОСОВЫХ АУДИОТЕХНОЛОГИЙ В ЭЛЕКТРОННОЕ ПРАВИТЕЛЬСТВО УЗБЕКИСТАНА: ПЕРСПЕКТИВЫ ПРИМЕНЕНИЯ МЕТОДОВ ПРЕОБРАЗОВАНИЯ АУДИОСИГНАЛА В МЕЛ-СПЕКТРОГРАММУ

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Аннотация —В статье рассмотрены современные тенденции и перспективы применения аудиотехнологий в развитии электронного правительства Узбекистана. Особое внимание уделено роли голосовых помощников на узбекском языке, автоматизации контакт-центров и анализу звонков, а также внедрению биометрической верификации по голосу для повышения безопасности госуслуг. Обсуждаются проблемы доступности и инклюзивности, а также потенциал голосовых интерфейсов для поддержки людей с ограниченными возможностями. Описаны ключевые этапы преобразования аудиосигнала в мел-спектрограмму как основы для распознавания речи. В завершение даны рекомендации по разработке национальных речевых моделей, интеграции голосовых технологий с существующими платформами и необходимости сотрудничества с научными и образовательными учреждениями. Предложенные меры направлены на повышение эффективности, безопасности и инклюзивности электронных государственных сервисов в Узбекистане..

Ключевые слова: электронное правительство, Узбекистан аудиотехнологии голосовые помощники распознавание речи мел-спектрограмма биометрическая верификация по голосу доступность инклюзивность, контакт-центр, цифровизация госуслуг, национальные речевые модели, интеграция платформ, искусственный интеллект, голосовой интерфейс.

I. ЭЛЕКТРОННОЕ ПРАВИТЕЛЬСТВО УЗБЕКИСТАНА: ТЕКУЩЕЕ СОСТОЯНИЕ И ВЫЗОВЫ

1. Портал my.gov.uz и его возможности

Портал my.gov.uz (Единый портал интерактивных государственных услуг, ЕПИГУ) позволяет гражданам и бизнесу получать госуслуги онлайн через единый интерфейс. Для доступа требуется регистрация через систему идентификации OneID.

Рост функционала и услуг:

К началу 2024–2025 гг. число услуг, доступных через портал, достигло около 720.

В 2023–2024 гг. наблюдалось значительное увеличение: с ~570 услуг до более 700. В мобильном приложении MyGov на январь 2025 года доступно более 527 услуг, предоставляемых через интерфейс с удобным доступом, включая FaceID, MobileID, оплату и мониторинг заявок.

Статистика использования: На февраль 2025 года зарегистрировано более 10 млн пользователей (53 % мужчины, 47 % женщины).

Инфраструктура и улучшения: Портал поддерживается UZINFOCOM; к 2025 году внедрена оценка сервиса пользователями, голосовой помощник "Мухлиса" и MyID.

Цифровая трансформация: по данным ЕОСР, сейчас доступно более 760 услуг, специалисты планируют до 2025 года ввести IT-экспорт на сумму $1 млрд, стартовали облачная платформа и обучение AI-промптингу. По состоянию на октябрь 2024 года, портал охватывает свыше 60 % всех госуслуг, а общее число услуг составило 675.

2. Цифровизация госуслуг

Стратегия "Digital Uzbekistan-2030": Определены приоритетные проекты: 300 — цифровизация госуправления, 51 — экономики, 137 — региональных преобразований (2023–2024 гг.). Планируется полный охват всех населенных пунктов широкополосной связью к концу 2024 года.

GovTech и зрелость: В 2024 Узбекистан впервые вошёл в группу стран с "очень высоким" EGDI, поднявшись на 63-е место с индексом 0,7999. В индексе GovTech Maturity (2022) страна поднялась на

37 позиций и вошла в группу A, а в "GovTech Enablers" — в топ-4 по цифровым навыкам и инновациям.

Проекты инклюзивного доступа: Инициативы по Digital Inclusion реализуются совместно с ВБ, IT-Park и МВД: создание 25 000 рабочих мест (50 % — женщины, 4 % — люди с инвалидностью), обучение 6 000+ молодых специалистов, модернизация IT-центров.

3. Проблемы доступности и инклюзивности

Обратная связь по инклюзивности: Портал регулярно проводит опросы для повышения доступности для пользователей с инвалидностью.

Инфраструктурные трудности: Несмотря на проекты, географическая протяженность, особенности рельефа и финансирование ограничивают быстрое развертывание инфраструктуры в удалённых районах.

Цифровой разрыв и доступность: Как показывает обзор глобальных практик доступа, только около 40 % сайтов в странах Global South соответствуют базовым WCAG-требованиям: особенно страдают люди с нарушениями зрения.

Конкретные кейсы: Пользователи из Reddit сообщают о плохой доступности (особенно для инвалидов-колясочников), несмотря на незначительные улучшения:

"unfortunately, wheelchair accessibility is terrible in Uzbekistan";

и "accessibility... seemed almost exclusively to be at 45 degree angles" — что даже с чемоданом сложно, не то что с инвалидной коляской.

Проблемы регистрации и аутентификации: за пределами Узбекистана пользователи сталкиваются с проблемой отсутствия SIM-карты на местном номере — часто подтверждение приходит на номер чужого человека, создавая неудобства.

Итоговая таблица

Аспект	**Состояние / достижения**	**Вызывающие проблемы**
Портал my.gov.uz	Более 700 услуг, мобильное приложение, цифровая идентификация	Регистрация за рубежом, сложная аутентификация
Цифровизация	Большие реформы, "очень высокий" индекс EGDI, GovTech-рост	Инфраструктура в отдалённых районах, сложное управление
Инклюзивность	Опросы, проекты Digital Inclusion и IT-центры	Плохая физическая доступность, низкий уровень соответствия WCAG, digital divide

II. ГОЛОСОВЫЕ ТЕХНОЛОГИИ КАК ИНСТРУМЕНТ ПОВЫШЕНИЯ ДОСТУПНОСТИ

Роль голосового управления и аудиовзаимодействия

Улучшение доступности:

Голосовые технологии позволяют людям с ограничениями зрения, моторики и когнитивными трудностями легче взаимодействовать с цифровыми сервисами. Голосовое управление даёт альтернативу традиционным способам ввода (клавиатура, мышь, сенсорный экран).

Инклюзивность:

Аудиовзаимодействие помогает гражданам, которые не умеют читать или писать, а также пожилым людям, испытывающим трудности с техникой, получать госуслуги без посредников.

Повышение удобства и скорости Голосовые помощники ускоряют поиск информации и выполнение задач — например, запись на приём, оплата штрафов, запрос статуса заявки.

Автоматизация и поддержка 24/7 Голосовые боты и помощники (IVR, чат-боты с голосовым интерфейсом) позволяют круглосуточно консультировать пользователей, снижая нагрузку на операторов.

Адаптация к локальным языкам и диалектам Важно, чтобы голосовые системы поддерживали узбекский язык и его диалекты для максимально комфортного взаимодействия.

Примеры использования в других странах (коротко)

США-В государственных порталах применяются голосовые помощники, которые помогают заполнить формы, получить консультации по налогам и социальным программам (например, интеграция с Alexa Skills, Google Assistant).

Эстония-Голосовое взаимодействие в e-правительстве помогает гражданам с ограничениями здоровья обращаться за документами и услугами, а также подтверждать личность с помощью голосовой биометрии.

Индия-Сервисы с голосовым вводом позволяют людям в сельской местности с низкой грамотностью получать информацию о государственных программах и подать заявки через мобильные телефоны.

Южная Корея-Использует голосовые ассистенты для записи на приём в госучреждения, получения консультаций по услугам, интегрируя AI-переводчики для многоязычных пользователей.

III. ПРЕОБРАЗОВАНИЕ АУДИОСИГНАЛА В МЕЛ-СПЕКТРОГРАММУ

Определение и принцип работы

Мел-спектрограмма — это визуальное представление спектра частот аудиосигнала, где частоты масштабируются по мел-шкале, более приближенной к восприятию человеком звука.

Задача — преобразовать временной аудиосигнал (волновую форму) в частотно-временное представление, чтобы выделить характеристики, важные для обработки речи.

Принцип работы:

Аудиосигнал разбивается на короткие временные окна (фреймы).

Для каждого фрейма вычисляется спектр частот.

Частоты преобразуются в мел-шкалу с помощью набора мел-фильтров.

Амплитуды спектра логарифмируются для усиления воспринимаемых различий.

Алгоритмы: STFT, мел-фильтры, логарифмирование

STFT (Short-Time Fourier Transform, коротковременное преобразование Фурье). Разбивает сигнал на короткие окна, внутри которых сигнал считается стационарным. Для каждого окна вычисляется спектр частот (модули комплексных значений), отражающий энергетическое распределение частот.

Мел-фильтры. Представляют собой набор треугольных фильтров, равномерно распределённых по мел-шкале частот.

Эти фильтры суммируют энергию в определённых диапазонах частот, подстраиваясь под восприятие человека (например, в низких частотах разрешение выше, чем в высоких).

Логарифмирование. Применяется к полученным энергиям мел-фильтров для имитации нелинейной чувствительности человеческого слуха. Помогает уменьшить влияние больших амплитуд и выделить более мелкие детали.

Зачем нужна мел-спектрограмма в распознавании речи-Мел-спектрограмма выделяет основные звуковые признаки речи, которые соответствуют физиологическому восприятию человеком, что облегчает машинное обучение. Она уменьшает размерность и шумы, делая данные более удобными для алгоритмов распознавания *(например, нейросетей). Частотные особенности речи (форманты, тональность) хорошо отражаются в мел-спектрограмме. Используется как вход для моделей распознавания речи (например, CNN, RNN, трансформеров), повышая точность и устойчивость системы.*

IV. ПРИМЕНЕНИЕ АУДИОТЕХНОЛОГИЙ В E-GOVERNMENT УЗБЕКИСТАНА

Голосовые помощники на основе узбекского языка

В Узбекистане ведётся активная разработка и внедрение голосовых ассистентов, способных понимать и отвечать на узбекском языке, что крайне важно для повышения доступности госуслуг. Пример: голосовой помощник «Мухлиса», интегрированный в портал my.gov.uz, помогает пользователям ориентироваться в сервисах, искать нужные услуги и получать консультации.

Технологии поддерживают распознавание естественной речи и синтез голоса (TTS), адаптированные под фонетику и интонации узбекского языка.

Это снижает барьеры для пожилых людей и тех, кто испытывает сложности с письменной формой коммуникации.

Контакт-центры госуслуг: анализ звонков.

Голосовые технологии позволяют автоматизировать обработку входящих звонков в контакт-центры госуслуг. Системы автоматического распознавания речи (ASR) транскрибируют звонки для последующего анализа, выявления частых проблем, оценки качества обслуживания. Применяется Sentiment Analysis для мониторинга настроения и удовлетворённости клиентов. Аналитика помогает оптимизировать работу операторов, выявлять узкие места и улучшать пользовательский опыт. В перспективе возможно внедрение голосовых чат-ботов для первичной обработки запросов и консультаций без участия человека.

Биометрическая верификация по голосу.

Биометрия голоса используется для повышения безопасности доступа к госуслугам и подтверждения личности. Система Voiceprint анализирует уникальные характеристики голоса (тембр, темп, интонацию) для аутентификации пользователей.

В Узбекистане разрабатываются пилотные проекты по внедрению голосовой биометрии в мобильных приложениях и колл-центрах. Это позволяет снизить риски мошенничества и упростить процедуру входа без паролей и СМС.

Поддержка для людей с ограниченными возможностями

Аудиотехнологии обеспечивают альтернативные каналы доступа к госуслугам для людей с нарушениями зрения, моторики и речи. Использование голосовых интерфейсов позволяет им самостоятельно обращаться за помощью, заполнять формы, получать консультации.

Разрабатываются адаптивные решения, учитывающие индивидуальные потребности: управление голосом без касания экрана, голосовой синтез с высокой чёткостью. Внедрение таких технологий соответствует международным стандартам цифровой инклюзивности (например, WCAG) и поддерживается инициативами Digital Uzbekistan.

V. ПЕРСПЕКТИВЫ И РЕКОМЕНДАЦИИ

Разработка национальных речевых моделей (на узбекском и русском языках)

Создание качественных языковых корпусов Необходимо собрать и аннотировать большие объемы аудиоданных на узбекском и русском языках с учётом диалектов, акцентов и разнообразия речи.

Обучение современных моделей ASR и TTS Использование нейросетевых архитектур (например,

трансформеров) для разработки систем распознавания речи и синтеза голоса, адаптированных под особенности локальных языков.

Поддержка многоязычности и переключения языков. Важна возможность плавного перехода между узбекским и русским языками в одном диалоге для удобства пользователей. Регулярное обновление моделей. Модели должны эволюционировать вместе с языком и изменениями в речевой среде, включая новые термины и сленг.

Интеграция с существующими платформами

Связь с порталом my.gov.uz и другими госсервисами: Голосовые технологии должны быть бесшовно интегрированы с действующими цифровыми платформами, чтобы расширить доступность и удобство. API и модульная архитектура. Разработка открытых интерфейсов для лёгкого подключения голосовых сервисов к контакт-центрам, мобильным приложениям и чат-ботам. Обеспечение безопасности и конфиденциальности При интеграции важно соблюдать стандарты защиты персональных данных и предотвращать мошенничество.

Масштабируемость: Системы должны выдерживать рост числа пользователей без потери качества и скорости работы.

Партнёрства с вузами и AI-центрами.

Научно-исследовательская поддержка – совместные проекты с университетами и исследовательскими центрами позволят ускорить разработку и тестирование речевых моделей.

Обучение специалистов-важно создавать образовательные программы и курсы по обработке речи и искусственному интеллекту, чтобы формировать квалифицированные кадры.

Обмен данными и опытом Партнёрства облегчат доступ к уникальным лингвистическим ресурсам и техническим решениям.

Разработка пилотных проектов и стартапов Совместные инициативы помогут внедрять инновационные технологии в реальных условиях и находить оптимальные решения для e-Government.

ВЫВОД

Применение аудиотехнологий в электронном правительстве Узбекистана открывает новые возможности для повышения доступности, удобства и эффективности государственных услуг. Голосовые помощники, биометрическая аутентификация, а также анализ аудиоданных в контакт-центрах позволяют сделать цифровые сервисы более инклюзивными и ориентированными на пользователя. Особенно важно развивать технологии на узбекском и русском языках, чтобы обеспечить охват всех слоёв населения.

Для успешного внедрения необходима координация усилий государства, научных учреждений и IT-компаний. Разработка национальных речевых моделей, интеграция голосовых интерфейсов с существующими платформами и поддержка инновационных проектов создадут основу для современного и человекоориентированного e-Government. Это, в свою очередь, ускорит цифровую трансформацию и укрепит доверие граждан к государственным структурам.

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SUV RESURSLARINI SAMARALI TAQSIMLASHDA IOT SENSOR TIZIMLARI ASOSIDA MONITORING

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Annatatsiya: O'zbekiston sharoitida suv resurslarini samarali boshqarish masalasi ko'rib chiqilgan hamda suv taqsimotida IoT (Internet of Things) texnologiyalarining qo'llanishi tahlil qilingan. Asosiy e'tibor suv omborlari va suv tarmoqlarida o'rnatilgan oqim, bosim va daraja sensorlari yordamida ma'lumotlarni real vaqt rejimida yig'ish va ularni markaziy tizimda qayta ishlash jarayonlariga qaratilgan. Tadqiqotda suv resurslarini hisobga olish va taqsimlashni optimallashtirish uchun matematik modellar ishlab chiqildi, sensorlardan kelgan ma'lumotlar asosida algoritmik boshqaruv mexanizmlari sinovdan o'tkazildi. Natijalar shuni ko'rsatdiki, IoT asosidagi monitoring tizimlari suv isrofini 15–20% ga kamaytirishga, nosozliklarni tez aniqlashga va suv taqsimotining adolatli bo'lishini ta'minlashga yordam beradi. Mazkur yondashuv "Raqamli O'zbekiston – 2030" strategiyasi va PQ–4666-son qarorida belgilangan suv xo'jaligini raqamlashtirish vazifalariga mos keladi. Taklif etilgan tizim nafaqat davlat organlari uchun, balki fermer xo'jaliklari va aholiga ham ochiq ma'lumotlardan foydalanish imkonini yaratadi. Tizimning amaliy qo'llanilishi suv xo'jaligida samaradorlikni oshirish, ekologik barqarorlikni ta'minlash va raqamli hukumat xizmatlarini rivojlantirishda muhim o'rin tutadi.

Kalit so'zlar*: IoT, suv resurslari, monitoring, optimallashtirish, real vaqt tizimlari.*

1.Kirish

Suv resurslaridan oqilona foydalanish O'zbekiston uchun ham strategik masala hisoblanadi. Respublikamiz hududining katta qismi qurg'oqchil zonada joylashgan bo'lib, suv tanqisligi iqtisodiy va ijtimoiy rivojlanishga bevosita ta'sir ko'rsatadi. Shu boisdan, O'zbekiston hukumati tomonidan bir qator davlat dasturlari va qarorlar qabul qilingan:

- 2021–2023 yillarda raqamli iqtisodiyotni rivojlantirish konsepsiyasi,
- "Raqamli O'zbekiston – 2030" strategiyasi (2020-yil 5-oktabr, PQ–6079-son qaror),
- Suv resurslarini boshqarish va ularni hisobga olishning avtomatlashtirilgan tizimini joriy etish chora-tadbirlari to'g'risida qaror (2020-yil 10-aprel, PQ–4666-son),
- Suv xo'jaligi tarmog'ida raqamlashtirish bo'yicha Vazirlar Mahkamasining qarorlari.

Mazkur qarorlar suv xo'jaligi va davlat boshqaruvi jarayonlarini raqamlashtirish, IoT, Big Data va elektron hukumat yechimlarini keng joriy etishga qaratilgan. Shu bois suc resurslarni o'rganib chiqiladi. Suv resurslari turi va tavsifi, suv resurslaridan foydalanish darajasi. Suv resurslarining turi va tavsifi to'g'risida 1-jadvalda tanishishimiz mumkin.

1-jadval.

Suv resurslari turi va tavsifi.

Suv resurslari turi	Suv resurslari tavsifi
Yer usti suvlari	Daryo, ko'l, dengiz, suv omborlari
Yer osti suvlari	Qazilgan quduqlar, artezian suvlari
Sun'iy suv havzalari	Irrigatsiya tizmidagi suvlar, sanoatdagi qayta foydalaniladigan suvlar
Atmosfera suvlari	Yomg'ir, qor, tuman
Muzliklar	Tog' muzliklari, qutb muzliklari

Iot texnologiyalari bilan ma'lumotlarni to'plash va uzatishning avtomatlashtirilishi. IoT tizimlari yordamida suv resurslarining holatini kuzatishda qo'lda ma'lumot yig'ish va uzatishning o'rnini avtomatik tizimlar egallaydi. Har bir sensor o'z vaqtida va doimiy ravishda ma'lumotlarni markaziy tizimga uzatib turadi. Bu ma'lumotlar masofadan tahlil qilinib, tezkor qarorlar qabul qilish imkonini beradi. Suv resurslarining holati haqida operatorlar yoki boshqaruv tizimlari tezda xabardor bo'ladi.

Xatoliklar va odatiy xatoliklar ehtimolini kamaytirish. IoT texnologiyalarining yana bir afzalligi

inson omilining kamaytirilishi. Avtomatik tizimlar yordamida odamlar tomonidan yuzaga keladigan xatoliklar va o‘lchovdagi noaniqliklar kamayadi va har bir sensorni tekshirish va sozlash uchun minimal aralashuv talab qilinadi, shuning uchun tizimdagi xatoliklar yoki noto‘g‘ri ma'lumotlarni aniqlash imkoniyati mavjud. Xatoliklar va odatiy xatoliklar ehtimolini kamaytirish:

IoT texnologiyalarining yana bir afzalligi inson omilining kamaytirilishi. Avtomatik tizimlar yordamida odamlar tomonidan yuzaga keladigan xatoliklar va o‘lchovdagi noaniqliklar kamayadi. Har bir sensorni tekshirish va sozlash uchun minimal aralashuv talab qilinadi, shuning uchun tizimdagi xatoliklar yoki noto‘g‘ri ma'lumotlarni aniqlash imkoniyati mavjud.

2.Tadqiqot metodlari

Tadqiqot quyidagi bosqichlarda amalga oshirildi.

1. Adabiyotlar tahlili – IoT texnologiyalari, suv resurslarini boshqarish va matematik modellashtirish bo‘yicha mavjud ilmiy manbalar o‘rganildi.
2. IoT arxitekturasi loyihalash – suv taqsimoti tizimi uchun IoT sensorlari va ularning o‘zaro bog‘lanish sxemasi ishlab chiqildi. Asosiy sensorlar:
   - suv oqimi datchiklari,
   - suv darajasi o‘lchagichlari,
   - tuproq namligi sensorlari,
   - quvur bosimi datchiklari.
3. Ma’lumot yig‘ish va uzatish – sensorlardan kelgan ma’lumotlar simsiz aloqa (LoRaWAN, Wi-Fi yoki GSM) orqali markaziy serverga uzatildi.
4. Matematik modellashtirish – suv taqsimoti algoritmi ishlab chiqildi. Bu modelda quyidagi parametrlar hisobga olindi:

   - suv iste’molchilarning ehtiyoji,
   - mavjud zaxira,
   - suv sarfini minimallashtirish,
   - energetik samaradorlik.

Tizimni ishlab chiqishda Raqamli hukumat platformalari bilan integratsiya qilish imkoniyatlari ham ko‘rib chiqildi. Jumladan, suv resurslari monitoring tizimini:

- Yagona davlat axborot tizimlariga,
- Elektron hukumat infratuzilmasiga,
- Davlat xizmatlari portali (my.gov.uz) bilan uzviy bog‘lash imkoniyatlari loyihalandi.

Bu orqali suv sarfi haqidagi ma’lumotlarni nafaqat mutaxassislar, balki fermer xo‘jaliklari va aholiga ham ochiq ko‘rinishda taqdim etish mumkin bo‘ladi.

3.Natijalar

IoT sensorlari asosida ishlab chiqilgan monitoring tizimi tajriba maydonida sinovdan o‘tkazildi. Quyidagi natijalarga erishildi:

- Real vaqt monitoringi — suv sarfi va omborlardagi suv darajasi doimiy kuzatib borildi. Bu esa avvalgi qo‘lda o‘lchash usuliga qaraganda 3 baravar tezroq va aniqroq natija berdi.
- Suv sarfini kamaytirish — IoT tizimi yordamida suv isrofi 15–20% ga kamaytirildi.
- Algoritmik boshqaruv — suv taqsimoti algoritmlari orqali qishloq xo‘jaligi maydonlariga suv bir maromda va samarali taqsimlandi.
- Xatoliklarni aniqlash — sensorlar yordamida quvurlardagi nosozlik va suv sizib chiqishlari erta aniqlanib, tezkor choralar ko‘rildi.
- Amaliy qo‘llanish imkoniyati — ishlab chiqilgan tizim qishloq xo‘jaligi, shahar kommunal xizmatlari va gidrotexnika inshootlarida joriy etilishi mumkin.
- Suv taqsimoti va monitoring natijalari portali orqali jamoatchilikka taqdim etilishi ochiq ma’lumotlar (Open Data) mumkin. Bu esa raqamli hukumat tamoyillarini mustahkamlaydi.
- Tizim kelajakda elektron tijorat bilan ham bog‘lanishi mumkin, masalan, suv taqsimoti xizmatlari uchun to‘lovlarni onlayn amalga oshirish yoki resurslardan foydalanish bo‘yicha shaffof hisob-kitob mexanizmlarini yaratish orqali.

Muhokamaga ko‘ra, IoT asosidagi monitoring tizimlari suv resurslarini boshqarishda nafaqat samaradorlikni oshiradi, balki suvni tejash, ekologik muvozanatni saqlash va barqaror rivojlanishga hissa qo‘shadi.

4. Xulosa

O‘zbekiston Respublikasida qabul qilingan “Raqamli O‘zbekiston – 2030” strategiyasi hamda PQ–4666-son qaror asosida suv xo‘jaligida raqamlashtirishni jadallashtirish bugungi kunning dolzarb vazifasidir. Shu nuqtai nazardan, IoT texnologiyalarini suv resurslarini monitoring qilish va boshqarishda qo‘llash muhim ahamiyat kasb etadi. IoT sensor tizimlari asosida yaratilgan yechimlar:

- davlat boshqaruvi samaradorligini oshiradi,
- suv resurslari hisobini shaffof qiladi,
- raqamli hukumat tizimi bilan integratsiyani ta’minlaydi,

- elektron tijorat asosida xizmat ko‘rsatish imkoniyatlarini kengaytiradi,
- ekologik xavfsizlikni ta’minlash va atrof-muhitni muhofaza qilishga hissa qo‘shadi.

Real vaqt rejimida ma’lumot yig‘ish va uzatish, prognozlash va avtomatik boshqaruv tizimlarining integratsiyasi orqali IoT texnologiyalari suv resurslarini yanada samarali boshqarishga yordam beradi. Bu jarayon suvni tejash, nosozliklarni tezkor aniqlash, resurslardan oqilona foydalanish va barqaror rivojlanishga xizmat qiladi.

Kelgusida ushbu tizimlarni keng joriy etish, xalqaro tajribalarni o‘rganish va innovatsion texnologiyalarni qo‘llash orqali O‘zbekiston suv xo‘jaligi siyosatida raqamli transformatsiyaning muhim qadami amalga oshiriladi. Shu bilan birga, IoT tizimlarining xavfsizligini ta’minlash, kiberhujumlarga qarshi chora-tadbirlarni mustahkamlash ham zarur. Bu esa nafaqat iqtisodiy samaradorlikni oshiradi, balki ekologik xavfsizlikni kafolatlashga ham imkon yaratadi.

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O‘ZBEKISTONDA SUN’IY INTELLEKT YORDAMIDA AHOLIGA DAVLAT XIZMATLARINI KO‘RSATISH JARAYONLARINI TAKOMILLASHTIRISH

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Annotatsiya **— Mazkur maqolada O‘zbekiston Respublikasida 2020–2025 yillar davomida elektron hukumat sohasida olib borilgan islohotlar, qabul qilingan me’yoriy-huquqiy hujjatlar, statistik ko‘rsatkichlar va texnologik taraqqiyot hamda bu jarayonda sun’iy intellektning o‘rni yoritilgan. Shuningdek, sun’iy intellekt orqali davlat xizmatlari ko‘rsatishni soddalashtirish, byurokratik to‘siqlarni qisqartirish hamda davlat xizmatlari ko‘rsatish milliy tizimini rivojlantirish jarayonlari o‘rganilgan va rivojlangan davlatlar (Estoniya, Janubiy Koreya, Singapur) tajribasi tahlil qilinib, ularda mavjud interaktiv xizmatlarni O‘zbekiston sharoitida tadbiq etish imkoniyatlari ko‘rib chiqilgan.**

Kalit so‘lar — Elektron hukumat, raqamli iqtisodiyot, sun’iy intellekt, interaktiv xizmatlar, avtomatlashtirilgan boshqaruv tizimlari, kiberxavfsizlik, texnik omillar, iqtisodiy omillar, huquqiy tartibga solish, (e-gov), raqamli texnologiyalar, innovatsiyalar.

I. Kirish

O‘zbekiston Respublikasining “Axborotlashtirish to‘g‘risida” va “Elektron hukumat to‘g‘risida”gi qonuni, O‘zbekiston Respublikasi Prezidentining 2013 yil 27 iyundagi “O‘zbekiston Respublikasining Milliy axborot-kommunikatsiya tizimini yanada rivojlantirish chora-tadbirlari to‘g‘risida”gi qarori va boshqa qonunchilik hujjatlari asosida amalga oshirib kelinmoqda hamda 2015 yildan boshlab O‘zbekistonda raqamlashtirish, e-gov va sun’iy intellektni davlat boshqaruviga joriy etish strategiyalari shakllana boshlagan. Jismoniy va yuridik shaxslar uchun davlat xizmatlari ko‘rsatish ko‘lamini oshirish, aholining masofadan turib elektron davlat xizmatlaridan mustaqil foydalanish imkoniyatlarini kengaytirish, shuningdek, bu borada barcha uchun teng sharoitlarni yaratish orqali inklyuziv muhitni shakllantirish maqsadida, O‘zbekiston Respublikasi Prezidentining 2022-yil 21-apreldagi “Davlat xizmatlari ko‘rsatishni soddalashtirish, byurokratik to‘siqlarni qisqartirish hamda davlat xizmatlari ko‘rsatish milliy tizimini rivojlantirishning qo‘shimcha chora-tadbirlari to‘g‘risida” PF-113-son farmoni ijrosi yuzasidan O‘zbekistonda elektron hukumat (e-gov) sohasini rivojlantirishga oid amalga oshirilgan. Ushbu qarorlar natijasi o‘laroq mamlakatimizda elektron hukumat tizimini rivojlantirish jadal ravishda oldinlamoqda.

TADQIQOT METODOLOGIYASI

- 2022-yil 1-avgustdan boshlab:

- Davlat xizmatlaridan foydalanish uchun shaxsni identifikatsiyalashning mavjud tizim va vositalariga qo‘shimcha ravishda jismoniy shaxsni identifikatsiyalashning Mobil-ID tizimi (keyingi o‘rinlarda — Mobil-ID tizimi) joriy etilib, Mobil-ID tizimi “Elektron hukumat” tizimi foydalanuvchilarini identifikatsiyalash bo‘yicha yagona axborot tizimining tarkibiy qismi hisoblanadi va shaxsni uning mobil telefon raqami orqali identifikatsiyalashni nazarda tutishi belgilangan. Shaxsni Mobil-ID tizimi yordamida identifikatsiyalash fuqaroning xohishiga ko‘ra davlat xizmatlari markazi (keyingi o‘rinlarda — Markaz) yoki notarial idora tomonidan yoxud Yagona interaktiv davlat xizmatlari portalining (keyingi o‘rinlarda — YIDXP) mobil ilovasi orqali amalga oshirilib, Mobil-ID tizimi yordamida identifikatsiyadan o‘tish uchun fuqaro tomonidan YIDXPning mobil ilovasidan foydalanilganda masofadan biometrik identifikatsiyalash (Face-ID) usuli yoki ID-kartadagi elektron raqamli imzo qo‘llaniladi hamda mobil telefon raqami YIDXPdagi shaxsiy kabinetga bepul bog‘lanishi yo‘lga qo‘yilgan.

- Ushbu jarayon davlat xizmatlarini fuqarolarga samarali, shaffof va qulay yetkazish orqali boshqaruv samaradorligini oshirishga qaratilgan. Mazkur maqola hozirgi yillarda o‘zgarishlarning mazmunini o‘rganib, xalqaro tajriba bilan taqqoslab, amaliy tavsiyalar beradi. Ushbu ishda ilmiy tadqiqot metodlari sifatida tahlil va sintez, induktiv-deduktiv yondashuvlar, tizimli tahlil va komparativ (taqqoslash) metodlari qo‘llanildi. O‘zbekistonda elektron hukumat (e-gov) sohasini rivojlantirishga oid turli ilmiy maqolalar, xalqaro tashkilotlar hisobotlari va yetakchi olimlarning asarlari o‘rganilib, uning komponentlari va amaliy natijalari tahlil qilindi. Shuningdek, statistik va empirik dalillarga

asoslangan yondashuv orqali mazkur sohadagi global tendensiyalar baholandi.

A. Adabiyot sharhi

Adabiyotlarda ko'rsatilishicha elektron hukumat (e-gov) sohasida sun'iy intellektning o'rni va undan samarali foydalanish bo'yicha juda ko'p olimlar ish olib borgan. Masalan, Janssen, M., Kuk, G., & Wagenaar, R. (2008) — SI texnologiyalarining davlat xizmatlarini avtomatlashtirish va fuqarolar bilan muloqot jarayonini optimallashtirishdagi ahamiyatini tadqiq etgan. Ular elektron hukumatda "aqlli xizmatlar" konsepsiyasini ishlab chiqqan. Twizeyimana, J. D., & Andersson, A. (2019) — elektron hukumatning SI yordamida "ochiq, samarali va inklyuziv" bo'lishi uchun model taklif qilgan. Tadqiqotida ma'lumotlarni avtomatik tahlil qilish, chatbotlar va intellektual qaror qabul qilish tizimlarining afzalliklari yoritilgan. Ya'ni, Janssen, Kuk va Wagenaar "aqlli xizmatlar" konsepsiyasini ilgari surib, SI yordamida xizmatlarni tezkor va sifatli taqdim etish yo'llarini o'rgangan; Twizeyimana va Andersson esa ochiqlik, samaradorlik va inklyuzivlikni ta'minlash uchun chatbotlar va avtomatik tahlil tizimlarining imkoniyatlarini tadqiq qilgan [8], [10]. Estevez va Janowski katta hajmdagi davlat ma'lumotlarini boshqarishda prognozlash modellari va resurslarni optimal taqsimlash usullarini ko'rsatgan, Rana va Dwivedi esa SI orqali korrupsiyani kamaytirish va ishonchni oshirish mexanizmlarini taklif etgan. Xalqaro miqyosda OECD hisobotlari Estoniya, Janubiy Koreya va Singapur tajribasiga asoslanib, biometrik autentifikatsiya, proaktiv xizmatlar va foydalanuvchi markazida bo'lgan boshqaruv yondashuvlarini e-gov tizimining kelajagi sifatida taqdim etgan [9].

Bugungi kunda Elektron hukumat tizimi zamonaviy davlat boshqaruvida muhim o'rin egallaydi. Ushbu tizim davlat xizmatlarini avtomatlashtirish, byurokratik jarayonlarni qisqartirish va fuqarolar uchun qulay muhit yaratish orqali iqtisodiyotga sezilarli ta'sir ko'rsatadi. O'zbekiston Respublikasi ham so'nggi yillarda elektron hukumatni rivojlantirishga alohida e'tibor qaratib, bu borada keng qamrovli islohotlarni amalga oshirdi. Ushbu maqolada biz aniq ko'rsatkichlar va xalqaro reytinglar asosida elektron hukumatning O'zbekiston iqtisodiyotiga ta'sirini tahlil qilamiz. Xalqaro reytinglardagi o'sish sezilarli darajada ortgan. Ya'ni, O'zbekistonning elektron hukumatni rivojlantirish bo'yicha xalqaro reytinglardagi o'rni yildan-yilga yaxshilanmoqda. 2024-yilda O'zbekiston Birlashgan Millatlar Tashkiloti (BMT)ning Elektron hukumat rivojlanish indeksi (EGDI) bo'yicha 63-o'rinni egalladi. Bu 2022-yilga nisbatan 6 pog'ona yuqoriladi [3], [7].

EGDI indeksi 0,7999 bo'lib, O'zbekistonni "Juda yuqori EGDI" guruhiga kiritdi. EGDI uchta asosiy komponentdan iborat bo'lib, O'zbekiston har bir ko'rsatkich bo'yicha ijobiy natijalarga erishdi:

Onlayn xizmatlar indeksi (OSI): 0,76

Telekommunikatsiya infratuzilmasi indeksi (TII): 0,87

Inson kapitali indeksi (HCI): 0,75

Bundan tashqari, O'zbekiston Elektron ishtirok etish indeksi (EPI) bo'yicha 0,60 ball to'pladi, bu fuqarolarning davlat boshqaruvida onlayn ishtirok etish darajasini ko'rsatadi. Elektron hukumatning iqtisodiyotga ta'siri quyidagi asosiy yo'nalishlarda sezilarli bo'ldi:

Davlat xarajatlarini qisqartirish

Davlat xizmatlarini avtomatlashtirish natijasida qog'oz hujjatlar, pochta va boshqa vositalarga sarflanadigan xarajatlar kamaydi.

Davlat organlari samaradorligi oshdi, fuqarolar va tadbirkorlarning vaqti tejaldi [2] [6].

Shu qatorda bir qator davlat xizmatlari sun'iy intellekt yordamida takomillashtirildi hamda yo'lga qo'yildi, bular:

Litsenziya va ruxsatnomalarni onlayn berish jarayoni soddalashtirildi, bu tadbirkorlar uchun vaqt va mablag' tejalishiga olib keldi.

Biznesni ro'yxatdan o'tkazish jarayonining avtomatlashtirilishi yangi biznes boshlashni ancha yengillashtirdi.

Davlat mablag'larini tejash amalga oshirildi. Onlayn soliq deklaratsiyasini topshirish tizimining joriy etilishi soliq to'lash jarayonini soddalashtirib, tushumlarning oshishiga yordam berdi.

"Yashirin iqtisodiyot" hajmining qisqarishi hisobiga davlat byudjetiga qo'shimcha mablag'lar kirib kela boshladi. Yangi ish o'rinlarini yaratildi.

AKT sohasidagi rivojlanish natijasida yangi ish o'rinlari paydo bo'ldi. Elektron xizmatlarni yaratish va qo'llab-quvvatlash uchun mutaxassislar soni ortib bormoqda. Xususiy sektor ham AKT xizmatlariga bo'lgan talab ortishi tufayli yangi imkoniyatlardan foydalanmoqda [5], [9].

O'zbekistonda elektron hukumat (e-gov) sohasi samaradorligini oshirishda bir qator qiyinchiliklarni hamda tizimini yanada takomillashtirish yo'lida bir qator muammolar kuzatishimiz mumkin, bular (yechimlari bilan birga):

AKT infratuzilmasining yetarli (90%dan past ko'rsatkichda) darajada rivojlanmaganligi – ayrim (olis va chekka) hududlarda yuqori tezlikdagi internetga kirish imkoniyati biroz qiyinligi (olis va chekka hududlarda aloqani yaxshilash).

Kiberxavfsizlik muammolari – fuqarolar va korxonalarning ma'lumotlarini himoya qilish uchun zamonaviy xavfsizlik texnologiyalarini joriy etish zarur [4], [6].

II. TADQIQOT NATIJASI

Tadqiqot natijalariga ko'ra, https://my.gov.uz — O'zbekiston Respublikasining yagona interaktiv davlat xizmatlari portali bo'lib, u fuqarolar, tadbirkorlar va tashkilotlarga davlat xizmatlarini onlayn ko'rinishda taqdim etish uchun yaratilgan. Portalning asosiy vazifasi — xizmatlarni olish jarayonini soddalashtirish, byurokratik bosqichlarni qisqartirish va davlat bilan muloqotni ochiq, tez va qulay qilishdir. Ushbu platforma 24/7 rejimda ishlaydi va foydalanuvchilar internetga ulana oladigan har qanday joydan unga kirishi mumkin. Bu esa fuqarolarga vaqt va mablag'ni tejash imkonini beradi.

1-jadval

Respublika miqyosida davlat xizmat raqamlashtirish bosqichlari

Yil	Statistika va natijalar
2015	20 dan ortiq xizmat avtomatlashtirildi.
2016	Portal orqali murojaatlar soni 100 mingdan oshdi.
2017	50+ interaktiv xizmat.
2018	5 mln ID-karta chiqarildi.
2019	Davlat xizmatlari shaffofligi oshdi.
2020	200 dan ortiq xizmat onlayn ko‘rinishga o‘tdi.
2021	15 mln foydalanuvchi.
2022	BMT e-Government indeksida 87-o‘rin.
2023	My.gov.uz orqali avtomatik javoblar soni oshdi.
2024	90% davlat xizmatlari raqamlashtirildi.

My.gov.uz orqali taqdim etilayotgan asosiy xizmatlar:

- har oy 2 mln dan ortiq murojaat
- 2023-yil oxirida foydalanuvchilar soni: 20 mln+
- 450+ xizmat avtomatlashtirilgan

O‘zbekistonda elektron hukumat (e-gov) sohasi TOP 3 davlat bilan solishtiadigan bo‘lsan quyidagi farqlarni ko‘rishimiz mumkin:

2-jadval

O‘zbekistonda elektron hukumat (e-gov) sohasi TOP 3 davlat bilan solishtirish jihatlari

Davlat	Xususiyatlar	O‘zbekiston bilan farqi
Estoniya	Har bir fuqaroga raqamli ID, AI bilan boshqariladigan sog‘liqni saqlash tizimi	To‘liq raqamlashtirilgan davlat
Janubiy Koreya	Sun’iy intellekt yordamida barcha davlat xizmatlari bir tizimda	AI yordamida real vaqtli xizmat ko‘rsatish
Singapur	Smart Nation strategiyasi, AI orqali fuqaro ehtiyojlari tahlili	Hukumat va fuqaro o‘rtasida AI vositachilik qiladi

Amalga oshiriladigan elektron hukumat sohasidagi loyihalar va dasturlar har bir davlat organi va tashkiloti raqamli rivojlanishining ustuvor yo‘nalishlaridan kelib chiqib belgilangan.

3-jadval

O‘zbekistonda tadbiq qilinishi mumkin bo‘lgan AI-loyihalarni tahlili

Loyiha nomi	Mazmuni	Kutilayotgan natija
AI-ID portal	Barcha xizmatlarga sun’iy intellekt asosida kirish	24/7 xizmat, inson aralashuvi kamayadi
AI-huquqshunos	Hujjatlarni avtomatik tekshirish	Notarial xizmatlar avtomatlashadi
Smart Murojaat	AI foydalanuvchining murojaatini tahlil qiladi va kerakli xizmatga yo‘naltiradi	Javob berish vaqti 3 baravar tezlashadi

Ularni amalga oshirish bosqichlari muntazam nazorat qilib boriladi va Raqamli hukumat loyihalarini boshqarish markazi muvofiqlashtiriladi. Bu borada “Raqamli O‘zbekiston – 2030” strategiyasi doirasida 2 mingdan ortiq loyihalar Raqamli hukumat loyihalarini boshqarish markazining doimiy nazoratida.

III.Xulosa

YIDXM samaradorligini oshirish — bu faqat texnologiyani yangilash emas, balki tashkiliy islohotlar, kadrlar salohiyatini oshirish va aholi bilan samarali aloqa tizimini yo‘lga qo‘yishdir. Shu uchlik uyg‘un ishlaganda markazlar nafaqat xizmat ko‘rsatish punktlari, balki raqamli boshqaruvning tayanch nuqtalari sifatida ishlaydi. 2021–2025 yillar 760 dan ortiq davlat xizmatlari raqamlashtirilib, 10 million fuqaro ulardan foydalangan AI infratuzilmasi uchun 50 million AQSh dollar ajratilib, milliy AI modeli yaratish hamda 1 million mutaxassis tayyorlash rejalashtirilgan IT-Park tashkil etilib, digital texnologiyalar eksporti, Inklusivlik, IT ishchi kuchini tayyorlash kabi yo‘nalishlar rivojlandi va internet tezligi oshirildi, raqamli infratuzilma kengaytirildi. Shu bois, Estoniya misolida Bürokratt va Singapurdagi AI asosidagi xizmatlar singari, O‘zbekistonda “Davlat yordamchisi” nomli virtual yordamchi ishlab chiqilib, interaktiv xizmatlarni avtomatlashtirish mumkin.

Estoniya va Ukraina misolida raqamli ID (e-ID) tizimini joriy etish — xavfsiz autentifikatsiya, shaxsiy ma’lumotlarni nazorat qilishni kuchaytiradi. Britaniyada ham shunga o‘xshash tashabbuslar ko‘rib chiqilayotganini inobatga olsak, mamlakatimizda ham joriy qilish xavfsizlik nazoratini yanada kuchaytiradi.

Shu qatorda, O‘zbekiston 2015–2025 yillarda raqamli transformatsiya, e-gov va AI sohasida sezilarli yutuqlarga erishganini kuzatdik. Bular, 700+ xizmat onlayn, AI strategiyasi, IT-Park va infratuzilma kengayishidir. Global yetakchilar — Daniya, Estoniya, Singapur — interaktiv va AI asosli xizmatlarda ilg‘orlikda ularning amaliy tajribasidan quyidagilarni O‘zbekistonda joriy qilish maqsadga muvofiq:

Virtual AI yordamchi (chatbot / ovozli yordamchi)
Birdo‘st platforma orqali xizmatlarni integratsiya qilish
Proaktiv, hayot boshqichiga mos xizmatlar
Raqamli ID tizimi
Ochiq ma’lumotlar portali

Bu tashabbuslar davlat boshqaruvi samaradorligini oshiradi, fuqarolarning ishonchini mustahkamlaydi va raqamli transformatsiyaning barqarorligini ta’minlaydi..

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DIGITAL TRANSFORMATION AND COMMERCIAL OPPORTUNITIES IN THE EFFICIENT MANAGEMENT OF RESERVOIRS IN UZBEKISTAN

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Abstract. The article offers an in-depth examination of water resources and reservoirs in Uzbekistan, emphasizing their importance for sustainable water management in the region. It presents comprehensive data on the current state of these reservoirs, categorizing them by type and highlighting the primary challenges they face regarding water resource utilization. Key issues such as siltation, overgrowing, and reduced useful volumes are discussed in detail, alongside the implications of these problems for the efficiency of water use. The article further explores the methodologies employed to assess sediment distribution within the reservoirs and the techniques used to quantify sedimentation volumes. By understanding these dynamics, stakeholders can better address the pressing issues affecting water availability and reservoir functionality. In conclusion, the article suggests practical strategies and innovative solutions to mitigate these challenges, aiming to promote more rational use of water resources and enhance the long-term viability of Uzbekistan's reservoirs in the face of environmental change.

1. INTRODUCTION

Reservoirs are a vital part of the infrastructure of many countries, including Uzbekistan. This article examines the state of reservoirs in Uzbekistan and discusses prospects and possible solutions for effective water management [1]. As is known, many reservoirs have been built for the purpose of rational use and regulation of water resources. In recent ears, as a result of global climate change and periodic water shortages, certain problems have arisen in economic sectors. The Republic of Uzbekistan is located in the Aral Sea basin, its main sources of water are the Amu Darya, Syr Darya and Zarafshan rivers, as well as inland rivers, sais and groundwater. The average long-term annual water flow of all sources of the Aral Sea basin is 116.2 billion cubic meters, of which more than 67.4 percent is formed in the Amu Darya basin, less than 32.6 percent - in the Syr Darya basin. The total reserve of groundwater is 31.2 billion cubic meters, 47.2 percent of which falls in the Amu Darya basin, 52.8 percent - in the Syr Darya basin [2]. According to the schemes for the integrated use and protection of water resources in the Amu Darya and Syr Darya basins, the average long-term water intake limit for the Republic of Uzbekistan is 51 billion cubic meters, of which 10.2 billion (20%) is formed on the territory of the republic, 40.8 billion (80%) is formed on the territory of neighboring countries. [2]. The distribution of water resource use is as follows: agriculture – 90%, industry and energy – 5%, public utilities – 4%, fish farming – 1% [2]. The area of irrigated land in the republic is 4.3 million hectares, on average 90-91 percent of all water resources are used in agriculture. Natural water resources are distributed unevenly throughout the ear in our republic, and the rational use of water resources, the fight against floods and mudflows, and the development of industry and agriculture are of great importance. [3, 4]. Currently, reservoirs with a total volume of 19.93 billion m3 are used, including the total volume of reservoirs in the Syr Darya basin is 5.93 billion m3 , and the total volume of reservoirs in the Amu Darya basin is 14.0 billion m3 . [2, 4]. There are mainly two types of reservoirs: flood reservoirs and channel reservoirs [5].

The total depth of reservoirs belonging to the group of reservoirs located in mountainous areas is up to 200 m, and the greatest depth of reservoir emptying during the reservoir operation is up to 100 m. Even when such reservoirs are emptied less, the water level changes sharply, but the surface area of the water does not change significantly.Since the territory of our republic is geographically diverse, the reservoirs are also geographically different [6, 7]: reservoirs in mountainous areas, reservoirs in foothill areas, reservoirs on plains and in lowlands (Figure 1).

Fig. 1. Main reservoirs of the Republic of Uzbekistan.

Reservoirs belonging to the third group have a normal backwater level (NBL) above 1200 m. The accumulation of sediment in reservoirs located in mountainous areas is the main reason for the increase in the volume of river runoff during floods, which are usually caused by precipitation, as well as erosion. Examples of a group of reservoirs located in mountainous areas are Akhangaran, Charvak, Tupalang and Hisarak. [8, 9]. Rational use of the reservoir is associated with many factors [10, 11]. The main problems are: Lack of water resources. Uzbekistan faces an acute problem of water shortage, which seriously limits the possibilities of agriculture and daily water consumption by the population. Water shortage has a negative impact on the economy and social well-being of the country [12]; Uneven distribution of water. Many rivers flowing through the territory of Uzbekistan are of an international nature, which leads to difficulties in sharing water with neighboring countries. This problem requires careful international cooperation to find sustainable solutions; Water losses due to evaporation.

After the construction of a reservoir, an additional area covered by water is formed, therefore, additional water losses due to evaporation occur, since evaporation from the water surface is significantly higher than from the land surface. The larger the surface area of the reservoir, the higher the water losses due to evaporation. Due to the overgrowing of reservoirs, additional evaporation occurs; Siltation of the reservoir. Most of the existing large reservoirs in the territory of the Republic of Uzbekistan were built and commissioned in the 20th century. Over the years, under the influence of certain changes, natural and anthropogenic factors, reservoirs become silted up, which leads to changes in morphometric indicators and changes in the hydrobiological regime [13, 14]. The consequence of which is a decrease in the useful volume, an increase in water losses due to evaporation, filtration, etc., as well as a deterioration in the ecological state of the region.

The main reasons for the filling of the useful volume of reservoirs with sediments are as follows: the formation of reservoir banks under the influence of water, sediments brought by the flow of rivers, canals, sediments brought by the flow of mudflows. In the mountainous and hilly regions of our republic, the category of turbulent flows includes mudflows and floods caused by atmospheric precipitation. Therefore, with each observed mudflow, a large amount of sediment flows down and causes siltation of the useful volume of reservoirs.

A sharp decrease in the useful volume negatively affects the normal and reliable operation of reservoirs [15]. Siltation of a reservoir is a loss of water volume caused by an increase in the absolute mark of the bottom. The influx of suspended sediments into the catchment area, wind transfer of sand from land, sediments of chemical compounds, biomass of aquatic vegetation, wave coastal erosion and other factors lead to siltation of reservoirs. boundary - these are the reasons. Siltation of a reservoir is a complex process [13]. The main method recommended for combating siltation is flushing sediments with water discharged from the reservoir. However, the current situation with water resources does not allow these measures to be taken, since, due to a decrease in the water content of rivers, reservoirs are often not completely filled. It is common practice to leave the reservoir without water for the winter if there is no need for it. This is not done during the growing season and in the presence of higher aquatic vegetation (reeds, cane, etc.), growing over the area of the water area with a water depth of less than 1.5 m [16]. For each specific reservoir, methods for combating siltation are selected based on local conditions and on the basis of a technical and economic justification. The referenced literature outlines the process of siltation caused by sediments in water bodies across various terrains worldwide, highlighting the primary contributing factors. It includes calculations of the relationship between the speed of sediment layer transport (particularly bottom sediments) and water flow. Einstein formulated the relationship between the inflow of turbid sediment particles from the channel bottom and sediment consumption as follows. The most effective works for removal of deposited sediments are reservoir flushing: shallow, deep, with regulation of turbidity of flushing flow. The choice of flushing method is determined by technical and economic analysis, capabilities of the power system, requirements of water users and other local factors. However, they become insufficient and new approaches are required [17]. On the other hand, as studies of recent ears show, almost all reservoirs have lost their useful capacity due to siltation.

2. METHODS

As is known, the equation of water balance of a reservoir is written in general form:

$$\sum К - \sum Ч \pm А \pm Д = 0, \quad (1)$$

where: ∑ K - the amount of water entering the reservoir, ∑ Ч - amount of water leaving a reservoir, А - accumulation; Д – sediment.

At different stages of construction and operation of the reservoir, the interaction of individual elements of water exchange may differ. During the period of filling the reservoir with water, the elements of water exchange change more intensively due to the increase in its volume and surface area. During the operation of the reservoir, a fairly strong correlation is formed between the elements of the hydrological cycle, which is characteristic of different reservoirs [4]. It should be noted that during this period, the elements of the water balance change significantly. One of the factors affecting the useful volume of a reservoir is siltation. When the reservoir volume is filled with sediment, the technical characteristics of the reservoir deteriorate, large sedimentary silts enter irrigation canals and culverts, and the efficiency of reservoir management decreases. The above and other difficulties necessitate sedimentation forecasting, which negatively affects the technical condition and economic indicators of reservoirs [10, 18].

The results of scientific studies conducted in the field show that existing methods for assessing reservoir siltation do not always reflect the volume of siltation. Rational regulation of the amount of sediment in reservoirs holds significant practical and theoretical value. On the one hand, it enables more accurate digital modeling and forecasting of reservoir siltation volumes, which is crucial for sustainable water management. On the other hand, river sediments can be considered as a commercial resource: fine-grained particles rich in minerals may be repurposed as eco-friendly fertilizers or raw materials for industrial use. In the context of Uzbekistan, integrating modern digital technologies such as remote sensing, GIS, and big data analytics allows not only more precise calculation of sedimentation dynamics but also the identification of innovative business opportunities in the reuse of sediments. Building on the approaches in [13, 14], the calculation of sediment particle deposition in reservoirs can be expressed through the equation of change in the kinetic energy of turbidity, which serves as a scientific basis for applying digital tools to optimize reservoir management.

$$dE/dl = Fi - R\,, \tag{2}$$

then: Fi- gravity and Archimedes:

$$Fi = -(\rho_T - \rho)V_T n\, sin\alpha\,, \tag{3}$$

Rx – resistance force:

$$R_x = -\frac{1}{2} p V_t n \frac{dv^2}{dl}, \tag{4}$$

Then, let's put it (3) and (4) to (2):

$$\frac{dE}{dl} = -(\rho_T - \rho)V_t n \cdot sin\alpha + \frac{1}{2} p V_t n \frac{dv^2}{dl}, \tag{5}$$

here: n is the number of solid particles per unit volume; sin α is the flow angle; ρ_T ; ρ – Density of solid particulars and liquid respectively; V_T - size of solid particles; g - acceleration of gravity; ϑ – average flow rate. Kinetic energy of turbid flow:

$$E = \frac{2 p_t V_t v^2 n}{3}\,, \tag{6}$$

Substituting expression (6) into expression (5), we have:

$$\frac{dE}{dl} = -(\rho_T - \rho)V_T \frac{3}{2}\frac{E}{P_t V_t v^2} \cdot sin\alpha + \frac{3}{2}\rho V_T \frac{E}{P_t V_t v^2}\frac{dv^2}{dl} \tag{7}$$

Integrating the last expression and moving from the number of turbidity particles to the turbidity concentration, expression (7) is written as follows:

$$\frac{s_i}{s_0} = \left(\frac{\omega_i}{\omega_0}\right)^{n_1} \cdot exp\; t\, \frac{3 g_1}{p_T}\frac{p_i - p'}{Q^2}\int_0^L sin\, a\, w^2\, dl \tag{8}$$

Bearing in mind that the turbidity consumption:

$$P_i = S_i\,; \tag{9}$$

Volume of turbidity:

$$V_i = S \cdot t\,; \tag{10}$$

Considering the surface area of the flow in the section under consideration as a function of depth;

$$\omega_i = (H_i)\,, \tag{11}$$

substituting (11) and (10) into (8), we obtain the following expression:

$$Vi\frac{v_i}{V_{НПУ}^2} = K\left(\frac{H_i}{H_{H\cdot ПУ}}\right)^{n_1} \tag{12}$$

where: НПУ – depth corresponding to normal water level, VНПУ – reservoir volume corresponding to normal backwater level, к and n1 - coefficients are determined on the basis of in situ field studies. The derived formula (11) expresses the relative volume of turbidity in the reservoir as a function of the relative depth of water in the reservoir.

3. RESULTS

Effective use of the above formula (12) requires quantitative determination of n1 and k. Analytical determination of the sum of these coefficients is complicated by the variability of the reservoir volume. Therefore, the values of n1 and k are determined based on data obtained in field studies, for which data collected from several reservoirs are used [19, 20]. Analysis of field study data shows that the volume of sediment in

many reservoirs is 1.5-3 times higher than the design values. Comparison of the calculated values of reservoir volume reduction and data obtained as a result of observations carried out during the operation of reservoirs shows that the proposed method gives good results.

4. CONCLUSION

Reservoirs in Uzbekistan play a crucial role in ensuring the country's sustainable water supply and overall economic stability. However, challenges such as siltation, overgrowth, and increasing water shortages—exacerbated by climate change and declining precipitation—require innovative solutions. To address these issues effectively, it is essential to adopt digital technologies, including remote sensing, geographic information systems, and big data analytics, while also leveraging international best practices. The rational and efficient use of reservoirs through digital transformation not only strengthens water management but also creates new commercial opportunities, such as the utilization of sediments as valuable resources. This integrated approach will significantly enhance the long-term sustainability and economic value of Uzbekistan's reservoirs.

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ELEKTRON TIJORATDA TOVARNING BOJXONA QIYMATINI STATISTIK REGRESSIYA MODELLARI ORQALI ANIQLASH: CHIZIQLI VA PARABOLIK YONDASHUV

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Annotatsiya: ***Ushbu maqola tashqi savdoni elektron tijorat vositalari yordamida tashkil etish va bu jarayonda tovarning bojxona qiymatini aniqlash masalasiga chiziqli va parabolik regressiya modellarini tatbiq etishga bag'ishlangan. Mazkur masalada xalqaro tajriba va ilmiy manbalar tahlil qilinib, tovar qiymati va bojxona to'lovlari o'rtasidagi bog'liqlik regression tahlil asosida modellashtirilgan va kelajakdagi bojxona to'lovlarini prognozlash uchun matematik asos yaratilgan. Maqolada real ma'lumotlar asosida regressiya koeffitsiyentlari hisoblash, model aniqligini baholash va natijalarni amaliyotga tatbiq etishga alohida ahamiyat berilgan. Ishlab chiqilgan algoritmni amaliyotda qo'llash natijalari muhokama etilgan.***

Kalit so'zlar: ***bojxona nazorati, bojxona qiymati, chiziqli regressiya, parabolik regressiya, matematik va statistik modellash, bojxona to'lovlari, prognozlashtirish.***

I. KIRISH

Global savdo munosabatlarining jadal rivojlanishi va raqamlashtirish jarayonlarining chuqurlashib borayotgan sharoitida bojxona to'lovlarini aniq va samarali hisoblash tashqi iqtisodiy faoliyatning barqarorligi va davlat byudjetiga tushumlar kafolatining muhim omiliga aylanmoqda. Bojxona qiymatini aniqlash nafaqat to'lovlarni hisoblashning asosiy bo'g'ini, balki ichki bozorni himoya qilish, adolatli raqobatni ta'minlash va bojxona xavfi tahlilini avtomatlashtirishda muhim rol o'ynaydi.

Bugungi kunda bojxona sohasida avtomatlashtirilgan tizimlar, matematik modellar va prognozlashtirish mexanizmlaridan keng foydalanilmoqda. Jumladan, mamlakatlar davlat byudjetini tahlil etish va prognozlashda statistik regressiya usullari keng qo'llanib kelinmoqda.

Shu bilan birgalikda, bugungi kundagi tahlillar xalqaro elektron tijoratning mislsiz suratlar bilan rivojlanayotganligi va dunyo savdosida o'zining mustahkam o'rnini egallayotganligini ko'rsatmoqda. Xususan, elektron tijoratda chakana savdo hajmi 2020-yilda 3932,4 mlrd. AQSH dollarini tashkil etgan holda, bu ko'rsatkich 2016-yilga nisbatan 2,1-martaga o'sgan. Ushbu ko'rsatkich 2024-yilga borib, 6065,9 mlrd. AQSH dollarini tashkil etgan.

Dunyodagi eng katta elektron chakana tijorat korxonalari – Amazon.com, Alibaba.com va eBay savdo maydonchalarida amalga oshirilib, 2019-yilda Amazon.com AQSHning elektron tijorat bozorining 50 foizini egalladi. Xitoyda 30% oziq-ovqat mahsuloti elektron tijorat orqali sotiladi, elektron tijoratning 80 % atrofidagi ulushi Alibaba.com orqali amalga oshirilmoqda [1].

Mamlakatimizda ham elektron tijoratni rivojlantirish davlat siyosati darajasiga ko'tarilgan bo'lib, bu masalaga alohida qonun va hukumat qarorlari bag'ishlangan [2].

Mazkur obyektiv reallik tashqi elektron tijorat asosida harakatlanuvchi tovarlar ustidan samarali bojxona nazoratini o'rnatish va bojxona to'lovlarini to'g'ri, adolatli va to'liq undirilishini ta'minlash masalasini kun tartibiga tobora qat'iy qo'ymoqda. Bu esa mazkur tovarlarning bojxona qiymatni to'g'ri va qat'iy ravishda milliy qonunchilik normalari asosida aniqlashni talab etadi. Chunki davlat byudjetiga bojxona to'lovlari ko'rinishidagi tushumlar tashki savdo tovarlarining bojxona qiymatiga uzviy bog'liq ravishda aniqlanadi.

Shu munosabat bilan, ushbu maqolada tashqi savdoni elektron tijorat vositalari yordamida tashkil etish

jarayonida tovarning bojxona qiymatini aniqlash masalasiga chiziqli va parabolik regressiya modellarini qo'llash hamda uning algoritmlarini amaliyotga tatbiq etish masalasi ko'rilgan.

II. ASOSIY QISM

Tovarlarning bojxona qiymatini aniqlashda baholash va prognozlash modellarining solishtirma tahlili

Bojxona to'lovlari va tovarlarning bojxona qiymatni belgilash yuzasidan asosiy milliy qonunchilik normalari Bojxona kodeksi [3] va Soliq kodeksiga [4] asoslangan bo'lib, ularda bojxona to'lovlarining turlari, ularni hisoblash va to'lash tartibi belgilab berilgan.

Shuningdek, mazkur masalaga mas'ul xalqaro tashkilotlarning me'yoriy hujjatlari qabul qilingan bo'lib, unga Jahon Savdo Tashkilotining "Bojxona qiymati bo'yicha Baho berish kelishuvi" [5] hamda Jahon Bojxona Tashkilotining bojxona tartib-taomillarini standartlashtirish va soddalashtirishga qaratilgan tavsiyalari [6] bojxona qiymatini aniqlashda asosiy xalqaro hujjat hisoblanadi

Bojxona to'lovlari va tovarlarning bojxona qiymatni belgilash masalasi muhim ilmiy - amaliy ahamiyatga ega bo'lib, bu yo'nalishda bir qator olimlar tomonidan ilmiy tadqiqotlar olib borilgan. Masalan, bojxona tartib-taomillarini soddalashtirish masalasi Braun va uning hamkasblari tomonidan tadqiq etilgan bo'lib unda elektron ma'lumotlar bazalarini joriy etish yaxshi samara berishi ta'kidlanadi [7].

Bojxona to'lovlarini hisoblash va prognozlashtirish uchun matematik modellar va ma'lumotlar bazasidan foydalanish masalasi Liu va Van tadqiqotlarida o'z aksini topgan [8]. Bojxona to'lovlarini hisoblashda avtomatlashtirilgan tizimlardan foydalanish tashqi savdoni rag'batlantirish va shaffofligini ta'minlashga xizmat qilishi Smit va Jonson tadqiqotlarida tahlil etilgan[9]. Bojxona to'lovlarini prognozlash va tashqi savdoni rejalashtirishda statistik usullarni qo'llash Kim va Li maqolasida asosiy o'rinni egallaydi. Unda chiziqli regressiya biznes subyektlariga kelajakdagi xarajatlarni taxmin qilish va moliyaviy rejalarni tuzishda yordam berishi isbotlangan [10].

Yuqorida keltirilgan tartib-tamoyillar hamda ilmiy tadqiqot natijalari turli holatlarda bojxona to'lovlarini prognozlash va tovarlarning bojxona qiymatni baholash imkoniyatini bersa-da, ushbu usullarning tatbiqini statistik regressiya modellari bilan boyitish hisoblash jarayonini aniqlash, tezlashtirish va avtomatlashtirish imkonini yaratadi.

Shu munosabat bilan quyida elektron tijoratda tovarning bojxona qiymatini baholashning quyidagi bir qator modellarni ko'rib chiqamiz:

1. Chiziqli regressiya (Linear Regression) tovarning kuzatuv hujjati (invoys) ma'lumotlari asosida qo'llaniladi. Bunda bojxona to'lovini hisoblash formulasi quyidagicha hisoblanadi:

$$Y = \beta_0 + \beta_1 x + \epsilon$$

Masalan: $\beta_0 = 500$, $\beta_1 = 0{,}25$, $x = 5\,000$ \$ bo'lsa,
$Y = 500 + 0.25 \cdot 5000 = 1\,750$ \$

Bu yerda:

- Y — bojxona to'lovlari (bashorat qilinadigan qiymat);
- x - tovar qiymati (mustaqil o'zgaruvchi);
- β_0 — to'lovning doimiy qismi (bojxona xarajatlari);
  - tovar qiymati $x = 0$ bo'lganda ham bojxona to'lovi mavjud bo'ladi, β_0 bojxona xizmatlari, hujjatlashtirish, minimal xarajatlarni aks ettiradi.
  - Real holatda $x = 0$ bo'lmasligi mumkin, lekin β_0 regressiya chizig'ining Y o'qi bilan kesish nuqtasi hisoblanadi.
- β_1 - tarif koeffitsiyenti (stavka);
  - Tovar qiymati (x) 1 birlikka (masalan: 1 USD) ortganda bojxona to'lovi qanchaga oshishini ko'rsatadi.
  - β_1 — bojxona to'lov stavkasiga teng yoki unga yaqin bo'lishi mumkin (masalan: $0.3 \rightarrow 30\%$).
- ϵ – epsilon xatolik.
  - regressiya modeli barcha ta'sir qiluvchi omillarni to'liq qamrab ololmasligi natijasida yuzaga keladigan farq

2. Parabolik regressiya (Polynomial Regression, d=2) tovarning kuzatuv hujjati (invoys) ma'lumotlari mavjud bo'lmagan va ma'lumotlar bazasida avval qayd etilgan aynan bir xil yoki o'xshash tovarlar uchun qo'llaniladi. Bunda bojxona to'lovini hisoblash formulasi [11]:

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \epsilon$$

Masalan: $\beta_0 = 500$, $\beta_1 = 0{,}25$, $\beta_2 = 0.00001$, $x = 5\,000$ \$ bo'lsa,
$Y = 500 + 0.25 \cdot 5000 + 0.00001 \cdot (5000)^2$
$= 500 + 1250 + 250 = 2\,000$ \$

3. Ko'p omilli regressiya (Multivariate Linear Regression) tovarning kuzatuv hujjati (invoys) ma'lumotlari mavjud bo'lmagan va ma'lumotlar bazasida avval qayd etilgan bir qator aynan bir xil yoki o'xshash tovarlar uchun qo'llaniladi. Bunda bojxona to'lovini hisoblash formulasi:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \epsilon$$

Bu yerda $x_1, x_2 \dots x_n$ tovarning vazni, hajmi, ishlab chiqarilgan mamlakati kabi kabi omillar.

Masalan: 1 ta tovarda bir nechta omillar hisobga olinganda ja'mi bojdxona to'lovlarining hisoblanishi 1-javdalda keltirilgan

1-javdal

Omil	**Simvol** (x_n)	**Qiymat**	**Koeffitsiyent** (β_n)	**Hissa**
Qiymat	x_1	*5 000 $*	*0.25*	*1 250*
Vazn	x_2	*20 kg*	*-10*	*-200*
Opreatsiyalar soni	x_3	*6 ta*	*-50*	*-300*
Doimiy xarajat	-	-	*500*	*500*
Jami to'lov: (Y)				**1 250 $**

4. Ridge va Lasso regressiya (regulyarizatsiyali modellar) tovar to'g'risida yetarli miqdordagi xarakteristikalar va korrellyatsiya mavjud bo'lgan holatlar qo'llaniladi.

Ridge Regression formulasi:

$$\hat{\beta} = argmin\{\|y - X\beta\|^2 + \tau\|\beta\|^2\}$$

- $\tau -$ regulyarizatsiya koeffitsiyenti;
- $\|\beta\|^2 -$ *barcha koeffitsiyentlarning kvadratining yig'indisi;*
- $\tau > 0$ *bo'lsa, model koeffitsiyentlarni kichiklashtirishga majbur qiladi.*

Lasso Regression formulasi:

$$\hat{\beta} = argmin\{\|y - X\beta\|^2 + \tau\|\beta\|_1\}$$

- $\|\beta\|_1 -$ *koeffitsiyentlarning absolyut qiymatlarining yig'indisi;*
-
- *Ayrim* β_i *lar 0 bo'lishi mumkin (omillarni model tashlab yuboradi).*

Masalan: yuqoridagi holatda faqat 1 ta omil $x = 5\ 000$ $ bo'lsa, regulyarizatsiyaning ta'siri juda kam bo'ladi, chunki:

- $\beta_1 = 0.25$ *kichik qiymat,*
- *Agar* τ *kichik bo'lsa (<0.001)*

$Y \approx 1\ 750$ $ $(\pm 1 - 2$ $ *fatq bo'lishi mumkin*$)$

5. Random Forest va Decision Tree Regressor (AI modellar) tovar to'g'risida yetarlicha katta ma'lumot bazasi (Big Data) mavjud bo'lganda qo'llaniladi.

Yuqorida keltirilgan regressiya modellari uchun aniqlik koeffitsiyentini $\boldsymbol{R^2}$ deb belgilasak, u bojxona to'lovlarini prognoz qilishini ko'rsatuvchi statistik ko'rsatkichni ifodalaydi va quyidagicha hisoblanadi [12].

$$R^2 = 1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \overline{y_i})^2}$$

- $y_i -$ *haqiqiy to'lov qiymatlari*
- $\hat{y}_i -$ *model prognozi*
- $\overline{y_i} -$ *o'rtacha to'lov qiymati*

Ushbu koeffitsiyent qiymatlari orqami modelning samaradorligini quyidagicha aniqlash mumkin:

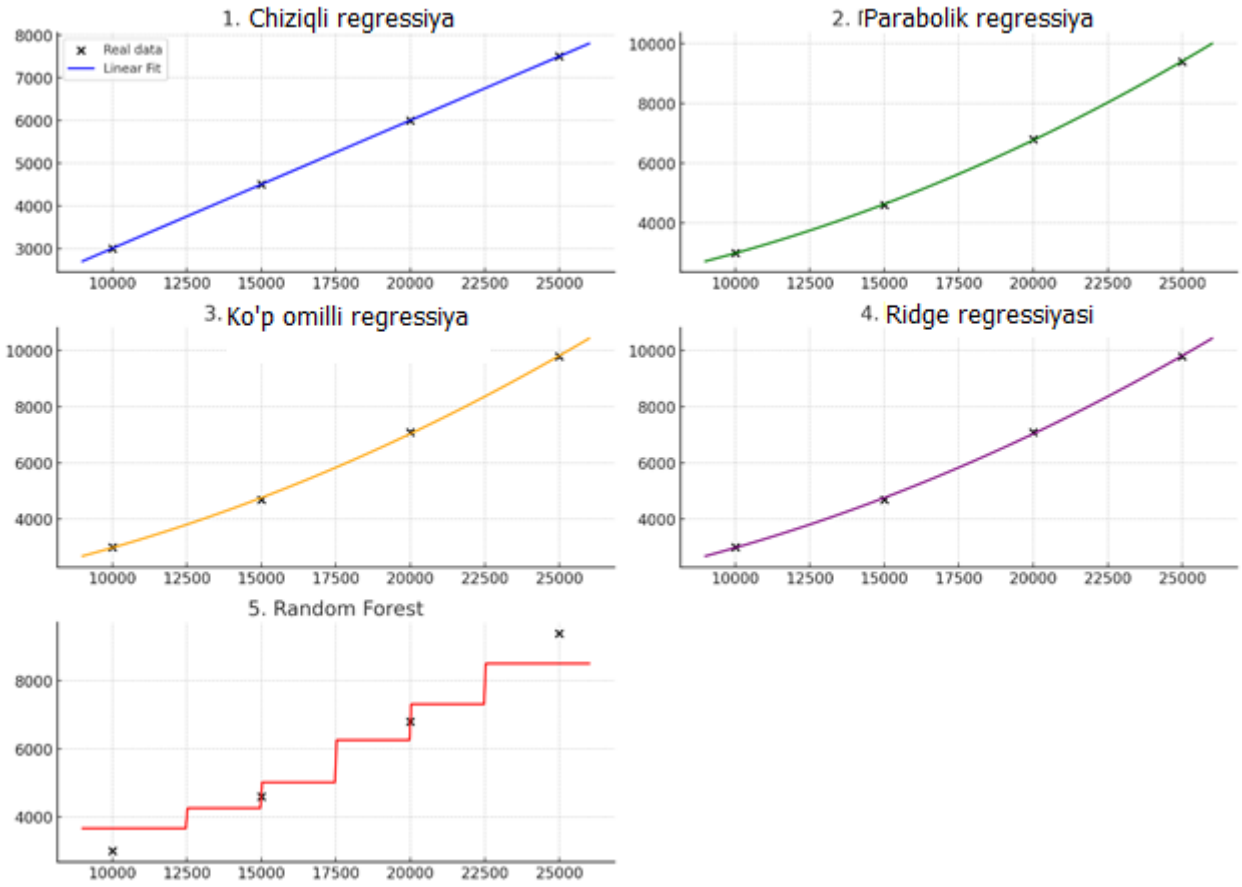
$$\begin{cases} R^2 = 1, & ideal\ muvofiqlik - barcha\ ma'lumotlar\ to'g'ri \\ R^2 \geq 0.95, & yuqori\ ishonch - samarali\ prognoz \\ 0.7 \leq R^2 \leq 0.9, & o'rtacha - ishlatish\ mumkin, lekin\ ehtiyot\ bo'lish\ kerak \\ R^2 < 0.7, & ishonchsiz - model\ noto'g'ri\ yoki\ kam\ ma'lumot\ bor \end{cases}$$

Tashqi elektron tijorat tovalarining bojxona qiymatini aniqlashdagi 5 ta asosiy regressiya modelini taqqoslash jadvali 2-jadvalda keltirilgan.

2-jadval

Model tur	Aniqlik	Qiyinlik	Afzalligi
Chiziqli regressiya	●●●●○	●●○○○	Oddiy, tez, tushunish oson
Parabolik regressiya	●●●●○	●●●○○	Egri chiziqli regressiv munosabatlar uchun
Ko‘p omilli regressiya	●●●●●	●●●○○	Bir nechta omilga asoslangan modellashtirish
Ridge/Lasso	●●●●○	●●●●○	Regulyarizatsiya, korrelyatsiya muammosini hal qiladi
Random Forest	●●●●●	●●●●●	Mashina o‘rganish, insonsiz tahlil

Tashqi elektron tijorat tovalarining bojxona qiymatini aniqlashdagi 5 ta asosiy regressiya modelini vizual tarzda taqqoslash 1-rasmda keltirilgan.



1-rasm. Tashqi elektron tijorat tovalarining bojxona qiymatini aniqlashdagi 5 ta asosiy regressiya modellari grafigini taqqoslash

III. XULOSA

Elektron tijoratda tovarning bojxona qiymatini hamda bojxona to‘lovlari va kafolat summasini hisoblashning yuqorida keltirilgan usullari va algoritmlari bugungi kunda bojxona axborot tizimlari tarkibida amaliyotga joriy etilgan. Amaliyotga joriy etilgan axborot tizimlari tashqi elektron tijoratda savdoning muvaffaqiyatli amalga oshirilishida o‘z samaradorligi ko‘rsatmoqda.

Avtomatlashtirilgan tizimlar, matematik modellar va chiziqli regressiyadan foydalanish hisob-kitoblarning aniqligini oshiradi va prognozlashtirish imkonini beradi.

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RAQAMLI HUKUMAT DOIRASIDA ONLAYN TA'LIMNI RIVOJLANTIRISH

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Anotatsiya: **Mazkur maqolada raqamli hukumat (e-government) doirasida onlayn ta'limni rivojlantirish masalalari tahlil qilingan. So'nggi yillarda global raqamli transformatsiya jarayonlari ta'lim tizimiga sezilarli ta'sir ko'rsatayotgani, axborot-kommunikatsiya texnologiyalarining jadal rivojlanishi esa masofaviy ta'limning yangi imkoniyatlarini yuzaga keltirayotgani yoritib berilgan. Maqolada raqamli hukumat va onlayn ta'lim integratsiyasining asosiy yo'nalishlari – elektron platformalar, masofaviy ta'lim tizimlari, sun'iy intellekt asosida moslashtirilgan ta'lim, ochiq ma'lumotlardan foydalanish imkoniyatlari – keng qamrovda tahlil etilgan. Shuningdek, xalqaro tajriba (Janubiy Koreya, Daniya, Estoniya) va BMTning EGDI ko'rsatkichlari misolida elektron hukumat hamda onlayn ta'limning o'zaro uyg'unlashuvi ko'rsatib o'tilgan. O'zbekiston tajribasi va "Raqamli O'zbekiston – 2030" strategiyasi doirasida amalga oshirilayotgan islohotlar alohida tahlil qilinib, onlayn ta'limni rivojlantirishning asosiy omillari – texnologik infratuzilma, pedagog kadrlar salohiyati, raqamli kontent sifati, huquqiy baza va kiberxavfsizlik masalalari ilmiy asosda yoritilgan. Yakunda, onlayn ta'limni rivojlantirish mamlakatning xalqaro raqobatbardoshligini oshirish, inson kapitalini rivojlantirish va aholining barcha qatlamlari uchun teng imkoniyatli ta'limni ta'minlashning muhim sharti ekani ta'kidlangan.**

Kalit so'zlar: raqamli hukumat, onlayn ta'lim, elektron hukumat, masofaviy ta'lim, raqamli transformatsiya, axborot-kommunikatsiya texnologiyalari (AKT), sun'iy intellekt, EGDI, raqamli kontent, kiberxavfsizlik, Raqamli O'zbekiston – 2030.

I. Kirish

So'nggi yillarda global miqyosda yuz berayotgan raqamli transformatsiya jarayonlari inson faoliyatining barcha jabhalariga, jumladan, ta'lim tizimiga ham chuqur ta'sir ko'rsatmoqda[1]. Axborot-kommunikatsiya texnologiyalarining jadal rivojlanishi ta'lim jarayonlarini tashkil etish, boshqarish va monitoring qilishda tamoman yangi imkoniyatlarni yuzaga keltirdi[2]. Raqamli hukumat (e-government) kontsepsiyasi esa nafaqat davlat boshqaruvini modernizatsiya qilish, balki ta'lim sohasida sifatli, ochiq va innovatsion xizmatlar ko'rsatish uchun ham strategik poydevor vazifasini o'taydi[3].

Elektron hukumat tizimining joriy etilishi davlat organlari, ta'lim muassasalari va fuqarolar o'rtasidagi o'zaro aloqalarni tezkor, samarali va shaffof mexanizmlar asosida yo'lga qo'yish imkonini beradi[6]. Bunday sharoitda onlayn ta'lim raqamli hukumatning ajralmas tarkibiy qismi sifatida qaralib, bilim olish jarayonini barcha ijtimoiy qatlamlar uchun teng imkoniyatlarni ta'minlashga xizmat qiladi[1][2].

Xalqaro tajriba ham shuni ko'rsatadiki, elektron hukumat va raqamli ta'lim o'zaro uzviy bog'liq bo'lib, ular birgalikda raqamli iqtisodiyotning asosiy drayverlaridan biriga aylanmoqda[3][6]. Masalan, Janubiy Koreya, Daniya, Estoniya kabi davlatlarda elektron hukumat infratuzilmasi bilan integratsiyalashgan onlayn ta'lim tizimlari nafaqat milliy miqyosda, balki xalqaro darajada ham muvaffaqiyatli qo'llanilmoqda[6][7]. Ushbu yondashuv ta'limning sifati, uzluksizligi va qulayligini ta'minlash bilan birga, inson kapitalini samarali rivojlantirishga xizmat qiladi.

Sun'iy intellekt, katta ma'lumotlar (big data), bulutli texnologiyalar va blokcheyn kabi ilg'or raqamli yechimlarning joriy etilishi esa o'quv jarayonlarini individuallashtirish, masofaviy ta'lim platformalarini takomillashtirish va ochiq ta'lim resurslaridan foydalanish imkoniyatlarini kengaytiradi[5]. Shu jihatdan olganda, raqamli hukumat doirasida onlayn ta'limni rivojlantirish nafaqat texnologik, balki ijtimoiy-iqtisodiy taraqqiyotning ham muhim omili sifatida namoyon bo'lmoqda.

II. Asosiy qism

A. Raqamli hukumat va onlayn ta'lim integratsiyasi

Raqamli hukumat tizimi davlat boshqaruvi, xizmat ko'rsatish va fuqarolar bilan o'zaro muloqot jarayonlarini zamonaviy axborot-kommunikatsiya texnologiyalariga asoslangan holda takomillashtirishni nazarda tutadi. Bu jarayon ta'lim sohasida ham yangi imkoniyatlar yaratib, onlayn ta'lim tizimining barqaror rivojlanishi uchun zarur shart-sharoitlarni ta'minlaydi. Xususan, elektron hukumat va ta'lim tizimi integratsiyasi bilim olish jarayonini ochiq, shaffof, moslashuvchan va samarali mexanizmga aylantiradi. Ushbu integratsiyani quyidagi asosiy yo'nalishlarda ko'rish mumkin:

1. **Onlayn platformalar va elektron resurslar yaratish.**
Davlat tomonidan qo'llab-quvvatlanayotgan yagona ta'lim portallari, masalan, **Milliy ta'lim portali, elektron kutubxonalar va masofaviy o'quv platformalari** o'quvchilar, talabalar va pedagoglar uchun keng imkoniyatlar yaratmoqda[1][2]. Bu resurslar orqali turli yo'nalishlarda bepul yoki arzon

onlayn kurslar, elektron darsliklar va multimedia materiallaridan foydalanish mumkin. Shuningdek, xalqaro miqyosda Coursera, EdX, Khan Academy kabi ochiq ta'lim platformalari bilan integratsiya ham milliy ta'lim sifatini oshirishda muhim ahamiyat kasb etadi.

2. **Masofaviy ta'lim tizimlari.**

COVID-19 pandemiyasi sharoitida butun dunyoda masofaviy ta'lim keng joriy qilindi va qisqa vaqt ichida ta'lim jarayonining ajralmas qismiga aylandi[2][3]. Bugungi kunda raqamli hukumat siyosati doirasida masofaviy ta'lim tizimlari mustahkamlanib, ulardan nafaqat favqulodda vaziyatlarda, balki doimiy ta'lim shakli sifatida foydalanish kengaymoqda. Masalan, ayrim oliy o'quv yurtlari darslarning ma'lum qismini onlayn shaklda tashkil etib, talabalar uchun qulaylik yaratmoqda.

3. **Sun'iy intellekt va moslashtirilgan ta'lim.**

Zamonaviy raqamli hukumat tizimida sun'iy intellekt texnologiyalari ta'lim jarayonini individuallashtirish imkonini beradi. AI asosidagi o'quv platformalari har bir o'quvchining bilim darajasi, qiziqishi va ehtiyojini tahlil qilib, unga moslashtirilgan ta'lim kontentini taklif etadi[5]. Masalan, adaptiv test tizimlari va interaktiv simulyatorlar yordamida bilimlarni nazorat qilish samaradorligi oshmoqda. Bu esa o'quvchilarda mustaqil fikrlash va muammoli vaziyatlarni yechish ko'nikmalarini shakllantiradi.

4. **Ochiq ma'lumotlar siyosati.**

Raqamli hukumat doirasida davlat organlari tomonidan taqdim etilayotgan ta'lim statistikasi, ilmiy ma'lumotlar va ochiq resurslar ta'lim tizimini tahlil qilish, sifat monitoringini olib borish va samarali qarorlar qabul qilishda muhim manba hisoblanadi. Ochiq ma'lumotlar nafaqat ta'lim jarayonining shaffofligini ta'minlaydi, balki mustaqil tadqiqotchilar, talabalar va keng jamoatchilik uchun yangi ilmiy izlanishlar olib borish imkonini ham yaratadi[4][7].

Shunday qilib, raqamli hukumat va onlayn ta'lim integratsiyasi o'zaro uyg'unlashgan holda ta'lim tizimining samaradorligi, ochiqligi va raqobatbardoshligini oshiradi. Bu integratsiya natijasida **"hayot davomida ta'lim olish" (lifelong learning)** konsepsiyasi amaliyotda kengroq tatbiq etilib, zamonaviy bilim va ko'nikmalarga ega bo'lgan kadrlarni tayyorlash imkoniyati yaratilmoqda.

B. Xalqaro tajriba va EGDI ko'rsatkichlari

Elektron hukumatning rivojlanish darajasini baholash uchun xalqaro miqyosda qo'llaniladigan asosiy mezonlardan biri bu — **BMT tomonidan ishlab chiqilgan Elektron hukumat rivojlanish indeksi (EGDI — E-Government Development Index)** hisoblanadi. Mazkur indeks mamlakatlarda axborot-kommunikatsiya texnologiyalarining joriy etilishi, davlat xizmatlarining raqamlashtirilishi, telekommunikatsiya infratuzilmasining rivojlanish darajasi hamda aholining raqamli savodxonligini o'zida aks ettiradi. EGDI ko'rsatkichlari nafaqat davlat boshqaruvi, balki ta'lim, sog'liqni saqlash va boshqa ijtimoiy sohalardagi raqamli transformatsiya darajasini ham bevosita ko'rsatib beradi.

Xalqaro tajriba shuni ko'rsatadiki, elektron hukumatning samarali joriy etilishi ta'lim tizimining raqamlashtirilishi bilan chambarchas bog'liq[6]. Masalan:

- **Janubiy Koreya** dunyo reytinglarida EGDI bo'yicha doimiy ravishda yetakchi o'rinlarda qayd etilib, ta'lim tizimida raqamli texnologiyalardan keng foydalanmoqda. Bu davlatda maktab va universitetlarda yagona elektron ta'lim portallari, sun'iy intellekt asosida ishlovchi test tizimlari hamda masofaviy ta'limning to'liq integratsiyasi joriy qilingan.
- **Daniya** EGDI ko'rsatkichida yuqori natijalarga erishgan bo'lib, onlayn ta'limni davlat xizmatlari bilan integratsiya qilish orqali o'quvchilarga qulay imkoniyatlar yaratmoqda. Masalan, har bir o'quvchi yagona raqamli identifikatsiya tizimi orqali ta'lim resurslariga erkin kira oladi.
- **Estoniya** esa "raqamli davlat" modeli bilan mashhur bo'lib, barcha ta'lim jarayonlari raqamli hukumat infratuzilmasi bilan bog'langan. Elektron darsliklar, bulutli ta'lim platformalari va ochiq ma'lumotlar bazasi ta'limning shaffofligi va samaradorligini ta'minlamoqda[6][7].

O'zbekiston tajribasi. So'nggi yillarda mamlakatimiz ham EGDI ko'rsatkichlarini yaxshilash borasida sezilarli natijalarga erishmoqda. 2020-yilda O'zbekiston **0.661 ball** ko'rsatkich bilan 87-o'rinda qayd etilgan bo'lsa, 2024-yilga kelib mazkur indeksda yanada yuqori natijaga erishdi[6]. Bu esa davlat tomonidan amalga oshirilayotgan **"Raqamli O'zbekiston – 2030"** strategiyasi, onlayn xizmatlarning kengaytirilishi, ta'lim portallarining rivojlantirilishi va aholining raqamli savodxonligini oshirish bo'yicha chora-tadbirlarning samaradorligini ko'rsatadi.

1-jadval. O'zbekistonda EGDI ko'rsatkichlarining so'nggi yillardagi o'sishi

Yil	EGDI ko'rsatkichi	Jahon reytingi
2018	0.585	81-o'rin
2020	0.661	87-o'rin
2022	0.675	69-o'rin
2023	0.702	66-o'rin

Shuni alohida ta'kidlash joizki, EGDI reytingida yuqoriga ko'tarilish faqatgina texnologik infratuzilmaning rivojlanishini emas, balki aholining keng qatlamlari, ayniqsa yoshlarning onlayn ta'lim resurslaridan faol foydalanayotganini ham ifodalaydi. Bu esa mamlakatning xalqaro raqobatbardoshligini oshirish bilan birga, ta'lim sohasida ham **inklyuzivlik, uzluksizlik va ochiqlik tamoyillarini** kengroq tatbiq etishga imkon bermoqda.

V. Onlayn ta'limni rivojlantirish omillari

Onlayn ta'lim zamonaviy ta'lim tizimining ajralmas qismi sifatida o'quvchilarning o'z-o'zini nazorat qilish imkoniyatlarini kengaytirmoqda. Raqamli

transformatsiya jarayonlari, axborot-kommunikatsiya texnologiyalarining jadal rivojlanishi hamda ta'lim jarayonida qo'llanilayotgan innovatsion pedagogik yondashuvlar onlayn ta'limni jamiyatning barcha qatlamlari uchun samarali va ommabop shaklga aylantirmoqda.

1. Texnologik infratuzilma

Onlayn ta'limning asosiy poydevori — ishonchli va keng qamrovli infratuzilma. Bunga quyidagilar kiradi: yuqori tezlikdagi keng polosali internet, mobil tarmoqlar (4G/5G), ma'lumotlarni saqlash va qayta ishlash uchun bulutli serverlar, lokal va global CDN tizimlari, shuningdek talabalar va o'qituvchilar uchun yetarli miqdorda raqamli qurilmalar (kompyuter, planshet, smartfon). Infratuzilmaning mavjudligi va sifati ta'lim jarayonining uzluksizligi, media-boy kontentning yetkazilishi, onlayn sinovlarning o'tkazilishi va real-vaqt interaktiv darslar o'tkazilishiga bevosita ta'sir qiladi. Siyosat darajasida: hududlararo raqamli tengsizlikni kamaytirish, jamoat-Wi-Fi zonalari, ta'lim uchun qurilmalarni subsidiyalash va mahalliy server infratuzilmasini mustahkamlash zarur.

2. Kadrlar salohiyati (pedagoglarning raqamli kompetensiyalari)

Texnologiyalarni samarali qo'llash uchun pedagoglarning metodik va texnik ko'nikmalari yetarli bo'lishi shart. Bu — nafaqat kompyuter savodxonligi, balki onlayn pedagogika (andragogika), interaktiv materiallar yaratish, baholashning elektron usullari va o'quv jarayonini dizayn qilish ko'nikmalarini ham o'z ichiga oladi. Davlat va oliy ta'lim muassasalari tomonidan uzluksiz malaka oshirish dasturlari, treninglar, mentorlik va onlayn hamjamiyatlar (communitiyes of practice) tashkil etilishi tavsiya etiladi. Pedagoglarning raqamli kompetensiyalari o'lchanadigan indikatorlar (CPD soatlari, sertifikatlar, kurslarning samaradorligi) joriy etilishi kerak.

3. Raqamli kontent va sifat kafolati

Elektron darsliklar, videodarslar, interaktiv testlar, virtual laboratoriyalar va simulyatsiyalar ta'lim jarayonini jonli va samarali qiladi. Kontent ishlab chiqishda xalqaro va milliy standartlar (masalan SCORM, xAPI), ochiq ta'lim resurslari (OER) prinsiplari, accessibility talablariga (WCAG) rioya qilish muhim. Shuningdek, kontentning pedagogik mosligi — milliy o'quv dasturi va baholash mezonlariga mosligi ham ta'minlanishi lozim. Sifatni baholash uchun tahririy ishlov, ekspert baholari, pilot sinovlar va foydalanuvchi feedback mexanizmlari joriy etilishi kerak.

4. Huquqiy baza va siyosat (governance)

Masofaviy ta'limni tartibga soluvchi qonunlar va normativlar — akkreditatsiya, ta'lim muassasalarining elektron diplomlarini tan olish, onlayn baholash natijalarini qabul qilish qoidalari, intellektual mulk va kontent litsenziyalari, hamda ma'lumotlarni himoya qilish qonunlarini o'z ichiga oladi. Bundan tashqari, tizimlararo interoperabilitet uchun ochiq API-lar, ma'lumot almashinuvi standartlari va davlat-xususiy sheriklikni tartibga soluvchi hujjatlar muhim. Sifat va ishonchlilikni ta'minlash uchun monitoring, audit va akkreditatsiya mexanizmlari zarur.

5. Xavfsizlik va maxfiylik (kiberxavfsizlik)

Onlayn ta'lim platformalarida foydalanuvchilarning shaxsiy ma'lumotlari, akademik natijalar va intellektual mulklari himoya qilinishi lozim. Bunga ma'lumotlarni shifrlash, xavfsiz autentifikatsiya (SSO, eID), rollarga asoslangan ruxsatlar, muntazam zaxira nusxalari, kibertahdidlarni aniqlash va javob berish (incident response) tizimlari kiradi. Axborot xavfsizligi siyosati doimiy ravishda yangilanib, pedagoglar va talabalar uchun kiberxavfsizlik bo'yicha xabardorlik dasturlari o'tkazilishi zarur.Ushbu omillar birgalikda ishlaganda onlayn ta'limning samaradorligi maksimal darajaga erishadi. Siyosat ishlab chiqishda tizimli yondashuv, ya'ni texnologiya + kadrlar + kontent + huquqiy baza + xavfsizlik tamoyillarini birdek hisobga olish muhim. Loyihalarning ta'sirini baholash uchun KPIlar (masalan, keng polosali ulanish darajasi, pedagoglarning raqamli CPD soatlari, kurslar bo'yicha yakuniy baholar, foydalanuvchi qoniqishi, EGDI ichidagi tegishli komponentlarning o'sishi) joriy etilishi kerak.

III. Xulosa

Raqamli hukumat doirasida onlayn ta'limni rivojlantirish nafaqat zamon talabi, balki mamlakatning raqobatbardoshligini oshirish, yuqori malakali mutaxassislarni tayyorlash hamda aholining barcha qatlamlari uchun teng imkoniyatli ta'limni ta'minlashning eng samarali yo'llaridan biridir. Onlayn ta'lim orqali o'quv jarayonida vaqt va makon chegaralarining bartaraf etilishi bilim olish imkoniyatlarini kengaytiradi, ta'lim jarayonining moslashuvchanligini ta'minlaydi va inson kapitalini rivojlantirishda muhim omil sifatida xizmat qiladi.

O'zbekiston Respublikasi so'nggi yillarda raqamli transformatsiya, axborot-kommunikatsiya texnologiyalari va elektron ta'lim platformalarini joriy etish borasida sezilarli yutuqlarga erishmoqda. Xususan, masofaviy ta'lim tizimlari, elektron resurslar bazasining boyitilishi hamda xalqaro onlayn kurslarga integratsiya qilish yo'lidagi sa'y-harakatlar mamlakatda sifatli ta'lim tizimini shakllantirishga xizmat qilmoqda.

Kelgusida esa, sun'iy intellekt asosida bilimni baholash tizimlarini keng joriy etish, ta'lim jarayonida gamifikatsiya va virtual/augmented reality (VR/AR) texnologiyalarini qo'llash hamda xalqaro hamkorlikni kengaytirish orqali O'zbekistonning ta'lim tizimi global miqyosda yanada raqobatbardosh bo'lishi kutilmoqda. Shu bois, onlayn ta'limni rivojlantirish milliy rivojlanish strategiyasining ustuvor yo'nalishlaridan biri sifatida e'tirof etilishi maqsadga muvofiqdir.

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АВТОМАТИЗИРОВАННОЕ УПРАВЛЕНИЕ ПРОЦЕССОМ ФЛОТАЦИИ С ПРИМЕНЕНИЕМ СИСТЕМЫ МАШИННОГО ЗРЕНИЯ

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***Аннотация*—В данной статье рассматривается применение промышленных систем машинного зрения для автоматизации и оптимизации процесса флотации на обогатительных фабриках. Проведен сравнительный анализ современного коммерческого программного обеспечения и аппаратных решений от ведущих поставщиков, таких как Metso Outotec FrothSense, FLSmidth Froth Camera и Stone Three. Подробно описаны ключевые визуальные параметры пены (размер и форма пузырьков, скорость движения, текстура и цвет), используемые для управления процессом. Представлена поэтапная дорожная карта внедрения систем машинного зрения, включая пилотные проекты, интеграцию с системами управления (APC, DCS) и эксплуатационные аспекты. Особое внимание уделено прогнозу экономического эффекта от внедрения технологий на примере Алмалыкского (АГМК) и Навоийского (НГМК) горно-металлургических комбинатов, демонстрирующему значительное повышение извлечения ценных металлов и сокращение расходов на реагенты. Делается вывод о том, что машинное зрение является ключевым инструментом для перехода к интеллектуальным и полностью автоматизированным обогатительным фабрикам.**

Keywords*—*машинное зрение, флотация, пена, пузырьки, автоматизация, обогатительная фабрика, искусственный интеллект, экономический эффект, АГМК, НГМК.

I. Введение

Современное обогащение минерального сырья характеризуется высокой сложностью технологических процессов, многостадийностью операций и большим количеством трудно контролируемых факторов. Флотация является одной из ключевых операций в обогащении руд цветных и благородных металлов. Управление этим процессом осложняется его многостадийностью, нелинейностью и высокой чувствительностью к изменениям минералогического состава. Цифровые решения для флотации основаны на развитии возможностей инструментального измерения явлений на различных стадиях флотационного цикла, управления данными в реальном времени и анализа этих данных с применением методов машинного обучения и искусственного интеллекта. Технология машинного зрения обеспечивает эффективное средство мониторинга и управления флотационными схемами за счет извлечения данных из цифровых изображений пены. В последние годы промышленность активно внедряет системы машинного зрения, позволяющие анализировать параметры пенной поверхности в режиме реального времени. Современные системы машинного зрения позволяют не только мониторить поверхность пены, но и интегрироваться в систему управления обогатительными фабриками. Внедрение таких решений на практике требует поэтапного подхода, особенно в условиях переработки золото-сульфидных руд, где устойчивость процесса и извлечение благородных металлов напрямую связаны с экономической эффективностью и имеют критическое значение.

Роль машинного зрения во флотации

Традиционные методы контроля флотационных процессов основаны на использовании датчиков pH, плотности, расхода воздуха и дозирования реагентов. Однако эти параметры не дают полной картины визуальных характеристик пенной поверхности, напрямую связанных с качеством

разделения минералов. Системы машинного зрения позволяют:

- фиксировать геометрию пузырьков (размер, распределение, форма),
- отслеживать устойчивость пены и её текстурные характеристики,
- анализировать цвет и отражательную способность пенной поверхности как косвенные показатели минералогического состава.

Таким образом, машинное зрение обеспечивает дополнительный уровень наблюдения и предиктивного анализа, дополняя классические сенсорные системы.

Принципы работы промышленных систем

Большинство современных систем машинного зрения во флотации включают:

- Оптические камеры высокой разрешающей способности – устанавливаются над флотационными машинами, фиксируя динамику поверхности пульпы.
- Алгоритмы компьютерного зрения и машинного обучения – обеспечивают выделение признаков (размер пузырьков, скорость коалесценции, дисперсия пузырьковой фазы).
- Интеграцию с SCADA/DCS-системами – автоматический анализ данных используется для корректировки подачи реагентов, воздуха и других параметров.

Промышленные реализации

Outotec FrothSense – система, широко применяемая в горно-обогатительных фабриках, использует камеры и алгоритмы обработки изображений для анализа характеристик пены и автоматической коррекции параметров флотации.

Metso VisioFroth – обеспечивает комплексное наблюдение за пенным слоем и интеграцию с системами управления процессом.

Пилотные проекты Кольской ГМК (Россия) – внедрение систем машинного зрения в сочетании с алгоритмами искусственного интеллекта позволило повысить извлечение цветных металлов и снизить расход реагентов.

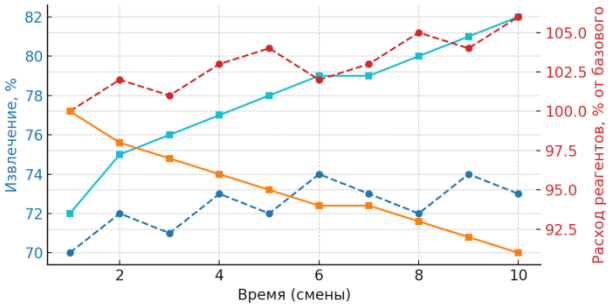

Рис.1. Влияние внедрения систем машинного зрения. (Источник: адаптировано по FLSmidth (2019), Philippine-resources.com (2020), Metso (2020)). График показывает положительное влияние внедрения машинного зрения (МЗ) на показатели извлечения и расход реагентов. Отмечается рост извлечения при одновременном снижении удельного расхода реагентов.

Шаги внедрения системы машинного зрения

1. Быстрый аудит. Выявление проблемных зон — вариабельность уровня, воздуха, переливов и перекачивания пульпы между контурами.
2. Пилот на 1–2 банках. Установка камер и освещения, синхронизация с датчиками уровня и воздуха, сбор первичного датасета в течение 2–4 недель.
3. Надёжная интеграция. Связывание признаков пены с системами APC (многомерное предиктивное управление, нечеткая логика). Начинать с мягких контуров (уровень, воздух), затем перейти к регулированию дозировок реагентов. Практика FLS показала рост извлечения на ≈4% при сохранении требуемого качества концентрата.
4. Метрики внедрения. Построение изо-кривых «извлечение–сорт», анализ расхода реагентов, оценка вариабельности тяготения и перетоков, устойчивости уровня.
5. MLOps-практика. Версия датасетов и моделей, мониторинг дрифта, использование симуляторов на исторических данных, периодическое дообучение моделей.
6. Эксплуатация. Регламенты очистки оптики, защита от запотевания, калибровка освещения, планы тестирования по сменам и партиям руды. В условиях пылевой нагрузки необходимы кожухи с продувкой и обдувом (опыт Metso).

ТАБЛИЦА 1. ЭТАПЫ ВНЕДРЕНИЯ СИСТЕМЫ МАШИННОГО ЗРЕНИЯ

Этап	Действия	Ожидаемый результат
1. Аудит	Анализ проблемных зон процесса	Карта узких мест
2. Пилот	Установка камер и датчиков на 1–2 банках	Первичный данные 2–4 недели
3. Интеграция	Связь признаков пены с APC	+4% извлечения (опыт FLS)
4. Метрики	Изо-кривые, реагенты, устойчивость	Четкие KPI внедрения
5. MLOps	Мониторинг дрифта, дообучение	Стабильные модели
6. Эксплуатация	Очистка оптики, защита от пыли	Надежная работа в промышленных условиях

Источник: адаптировано по FLSmidth (2019), Metso (2020), Nad Alona (2021).

График ниже отражает динамику роста извлечения и стабильности процесса по мере прохождения этапов внедрения. На начальной стадии видна высокая вариабельность параметров, которая снижается после пилота и интеграции.

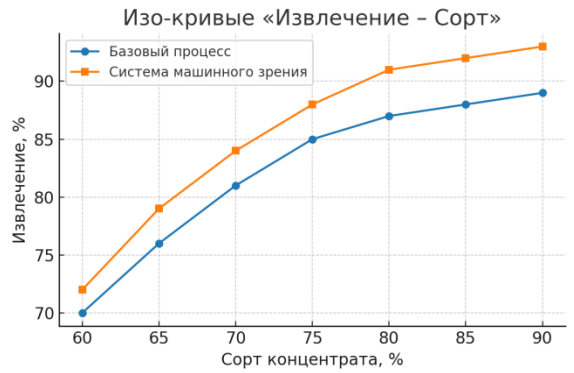

Рис.2. Изо-кривые «Извлечение – Сорт» (Источник: адаптировано по Nad Alona (2021), Forbes (2007), собственная разработка). График демонстрирует, что использование систем машинного зрения позволяет повысить извлечение при одинаковом качестве концентрата.

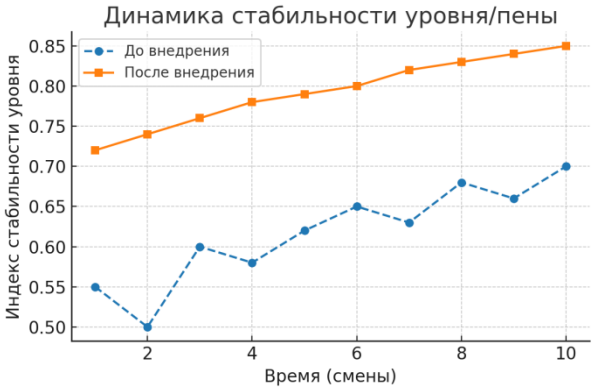

Рисунок 3. Динамика стабильности уровня/пены (Источник: адаптировано по Kaartinen (2002), Neethling & Brito (2018)).

ТАБЛИЦА 2. СРАВНЕНИЕ ФУНКЦИЙ СИСТЕМ МАШИННОГО ЗРЕНИЯ

Система	Параметры	Интеграция	Особенности
Metso FrothSense+	Размер пузырьков, скорость, цвет, высота пены	SCADA/DCS (OPC)	Нейросети, множественные ROI
FLSmidth Froth Camera	Скорость, стабильность, сорт	ECS/Process Expert	LiDAR + нейросети
Stone Three	Пена и пульпа (BSD, Jg)	Локальные серверы	Bubble Sizer, Pulp Sensor

Классические методы анализа изображений, на ранних стадиях исследования флотации применялись методы традиционной обработки изображений:

- выделение контуров (операторы Sobel, Canny); анализ текстур (GLCM-матрицы, признаки Харалика);
- морфологические операции (dilation, erosion, watershed).

Эти методы просты и не требуют больших вычислительных ресурсов, но их устойчивость к изменениям условий съёмки низкая. (Источник: Engineering Applications of Artificial Intelligence, 2024).

ТАБЛИЦА 3 – СРАВНЕНИЕ КЛАССИЧЕСКИХ И СОВРЕМЕННЫХ АЛГОРИТМОВ

Подход	Примеры	Точность %	Устойч. к шуму	Треб. к данным	Онлайн-применение
Классические методы	Canny, Sobel, GLCM, Watershed	60–75	Низкая	Мин.	Ограниченное
Mask R-CNN	Сегментация пузырьков	85–90	Средняя	Большая	Near-real-time
YOLOv7	Онлайн-детекция пузырьков	80–85	Средняя	Большая	Online
U-Net++	Сегментация пены	90	Средняя	Большая	Средняя скорость
EfficientNet/ViT/Swin	Классификация состояния пены	90–92	Высокая	Очень большая	С задержкой

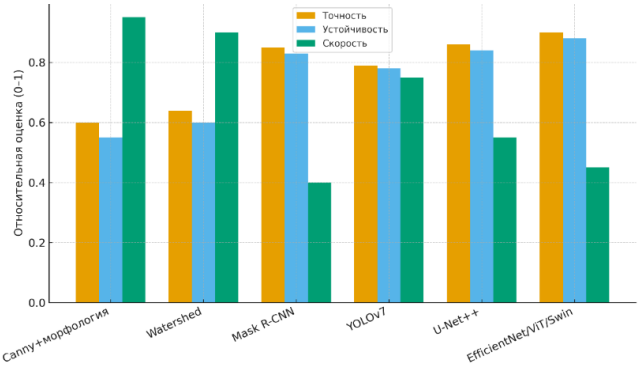

Рисунок 4 – Сравнение эффективности классических и современных методов сегментации пузырьков (Источник: Engineering Applications of AI, 2024; MDPI Minerals, 2023).

Система машинного зрения состоит из видеокамеры и источника света, размещенных над поверхностью пены. Собранные изображения передаются в компьютер, где специальное программное обеспечение анализирует их и извлекает визуальные признаки пены для управления процессом. Системы машинного зрения позволяют автоматически извлекать такие признаки, как цвет, размер и форма пузырьков, скорость движения и текстура пены. Эти признаки подразделяются на три категории: физические, статистические и динамические.

II. ОСНОВНАЯ ЧАСТЬ

Алмалыкский горно-металлургический комбинат (АГМК) перерабатывает медно-порфировые и полиметаллические руды, где флотация играет ключевую роль в извлечении меди, цинка и благородных металлов. В процессе обогащения таких руд требуется высокоточный контроль технологических параметров, так как от стабильности флотации напрямую зависит качество конечного концентрата.

Навоийский горно-металлургический комбинат (НГМК) преимущественно перерабатывает золото-сульфидные руды. Для данного типа сырья критически важно поддерживать устойчивость флотации, так как

даже незначительные колебания параметров могут привести к значительным потерям золота и серебра, что оказывает прямое влияние на экономическую эффективность предприятия.

Обе фабрики сталкиваются с типичными проблемами, характерными для флотационных процессов: высокой изменчивостью состава руды, колебаниями качества пенной поверхности, высокой зависимостью от опыта и субъективного мнения операторов, а также с перерасходом флотационных реагентов. Дополнительно наблюдается необходимость постоянной ручной корректировки параметров — уровня пульпы, подачи воздуха и дозировки реагентов, чтобы удерживать качество концентрата в допустимых пределах. Всё это увеличивает производственные расходы, снижает предсказуемость технологических результатов и повышает риски недоизвлечения ценных компонентов из перерабатываемого минерального сырья. В современных условиях данные проблемы могут быть решены внедрением цифровых технологий, включая системы машинного зрения и элементы искусственного интеллекта.

Прогноз экономического эффекта внедрения машинного зрения (пример для АГМК и НГМК)

Формулы для расчета

1. Масса металла в руде (т/сут)

$$M_{руда} = P \times \frac{C}{100}$$

P — производительность фабрики, т/сут

C — среднее содержание металла в руде, %

АГМК

$$200 \times \frac{0.8}{100} = 160 \frac{т}{сут} меди + цинка$$

2. Извлечение металла (т/сут)

$$M_{извлечение} = M_{руда} \times \frac{R}{100}$$

R — коэффициент извлечения, %

АГМК до внедрения

$$160 \times \frac{85}{100} = 136 \frac{т}{сут}$$

После внедрения:

$$160 \times \frac{87.5}{100} = 140 \text{ т/сут}$$

3. Прирост металла (т/сут)

$$\Delta M = M_{после} - M_{до}$$

АГМК

$$140 - 136 = 4 \text{ т/сут}$$

4. Доход от прироста ($/сут)

$$D = \Delta M \times P_{металла}$$

$P_{металла}$ — цена металла за 1 т

АГМК

$$4 \times 8500 = 34000\$ \text{ в сутки}$$

5. Экономия реагентов ($/сут)

$$E = R_{реагенты} \times \frac{S}{100}$$

$R_{реагенты}$-расходы на реагенты до внедрения, $/сут

S — процент экономии

АГМК

$$50000 \times \frac{7}{100} = 3500\$ \text{ в сутки}$$

6. Общий эффект ($/сут)

Общий эффект = D+E

АГМК

34 000+3 500=37 500 $ в сутки

Эти же формулы применялись для НГМК, только содержание металла пересчитывалось по золоту (г/т → т), а цена металла бралась **60 000 $/т** (≈ 60 $/г).

ТАБЛИЦ 4 - ПРОГНОЗ ЭКОНОМИЧЕСКОГО ЭФФЕКТА ВНЕДРЕНИЯ МАШИННОГО ЗРЕНИЯ (ДЛЯ АГМК И НГМК)

Показатель	АГМК (Cu/Zn)	НГМК (Au)
Извлечение до, т/сут	136	262,5
Извлечение после, т/сут	140	273,75
Прирост металла, т/сут	4	11,25
Доход от прироста, $/сут	34000	675000
Экономия реагентов, $/сут	3500	3200
Общий эффект, $/сут	37500	678200

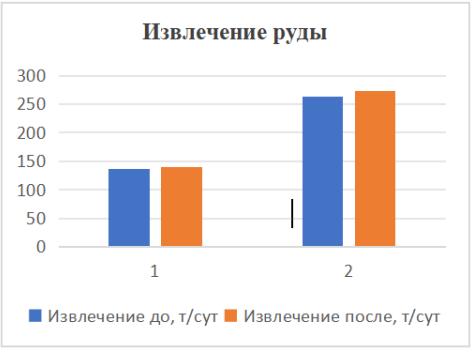

Рис.5. Извлечение руды.

Рис.6. Прирост металла.

Рис.7. Прирост дохода и экономия реагентов.

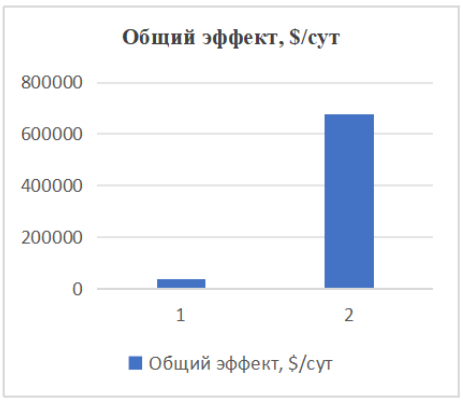

Рис.8. Общий экономический эффект.

ТАБЛИЦ 5. ПРОГНОЗ ЭКОНОМИЧЕСКОГО ЭФФЕКТА ВНЕДРЕНИЯ МАШИННОГО ЗРЕНИЯ (ПРИМЕР ДЛЯ АГМК И НГМК)

Показатель	АГМК (Cu/Zn)	НГМК (Au)
Производительность, т/сут	20 000	15 000
Среднее содержание металла	0,8 % (Cu/Zn)	2,5 г/т (Au)
Металл в руде, т/сут	160	375 (в пересчёте на золото ~ кг → т)
Извлечение до внедрения	85 %	70 %
Извлечение после внедрения	87,5 %	73 %
Извлечено до, т/сут	136	262,5
Извлечено после, т/сут	140	273,75
Прирост металла, т/сут	+4,0	+11,25
Цена металла, $/т	8 500 (медь/цинк)	60 000 (золото, пересчёт)
Доход от прироста, $/сут	34 000	675 000
Расход реагентов до, $/сут	50 000	40 000
Экономия реагентов, %	7 %	8 %
Экономия реагентов, $/сут	3 500	3 200
Общий эффект, $/сут	37 500	678 200
Показатель	АГМК (Cu/Zn)	НГМК (Au)
Производительность, т/сут	20 000	15 000

В АГМК внедрение машинного зрения даёт примерно 37,5 тыс. $/сут (≈ 13,7 млн $ в год). Это достигается за счёт повышения извлечения меди и цинка, стабилизации качества концентрата и сокращения расходов на флотационные реагенты.

В НГМК — около 678 тыс. $/сут (≈ 247 млн $ в год). Такой эффект объясняется ростом извлечения золота и серебра, снижением потерь в флотационных хвостах и уменьшением человеческого фактора при управлении сложными флотационными процессами. Дополнительно внедрение систем машинного зрения формирует предпосылки для перехода к интеллектуальной автоматизации и созданию «умных фабрик» нового поколения в Узбекистане.

ТАБЛИЦА 6. ВНЕДРЕНИЯ МАШИННОГО ЗРЕНИЯ ВО ФЛОТАЦИЮ В АГМК И НГМК.

Предприятие	Проблема	Решение с машинным зрением	Ожидаемый эффект
АГМК (Алмалыкский ГМК)	Нестабильный уровень и качество пены → потери меди и цинка в хвостах	Установка камер над флотационными машинами; анализ размера и устойчивости пузырьков; автоматическая подстройка воздуха и реагентов	+2–3% к извлечению Cu/Zn, снижение расхода реагентов на 5–8%
АГМК	Перерасход ксантогенатов и вспенивателей из-за отсутствия визуального контроля	Связь системы машинного зрения с APC/DCS для точного регулирования дозировок	Экономия реагентов, снижение себестоимости концентрата
НГМК (Навоийский ГМК)	Золото-сульфидные руды с высокой вариабельностью → нестабильный процесс флотации	Камеры и нейросетевые алгоритмы (YOLO/U-Net) для сегментации пузырьков и контроля устойчивости пены	+2–4% к извлечению золота, стабилизация качества концентрата
НГМК	Высокая запылённость → ухудшение работы камер и снижение	Использование защитных кожухов с продувкой и антизапотеван	Надёжная работа системы в промышленных

	точности анализа	ием (опыт Metso/FLS)	условиях
Обе фабрики	Зависимость от опыта операторов, субъективная оценка пены	Машинное зрение + ИИ для объективного анализа цвета, размера, текстуры пузырьков	Снижение влияния человеческого фактора, повышение стабильности процесса
Обе фабрики	Отсутствие предиктивного анализа (работа «по факту»)	Внедрение MLOps: сбор исторических данных, дообучение моделей, цифровые двойники	Предиктивное управление, повышение эффективности всей фабрики

Таким образом, внедрение систем машинного зрения в процессы флотации на предприятиях АГМК и НГМК открывает широкие возможности для повышения эффективности производства и сокращения затрат. Современные цифровые решения позволяют в режиме реального времени анализировать поверхность пены, определять её характеристики — размер, форму и устойчивость пузырьков, цвет и текстуру, — и на основе этих данных автоматически корректировать технологические параметры. Это обеспечивает более точное и стабильное управление флотацией, снижает зависимость от человеческого фактора и способствует переходу к концепции «умной фабрики».

В условиях АГМК, где перерабатываются медно-порфировые и полиметаллические руды, внедрение машинного зрения позволит увеличить извлечение меди и цинка на 2–3%, сократить расход ксантогенатов и вспенивателей на 5–8% и обеспечить более стабильное качество конечного концентрата. Для НГМК, перерабатывающего золото-сульфидные руды, ожидается рост извлечения золота на 2–4%, снижение колебаний качества концентрата и уменьшение перерасхода извести и коллекторов.

Совокупный эффект выражается не только в экономии реагентов и увеличении объёма получаемого металла, но и в повышении общей предсказуемости процессов, устойчивости технологических режимов и возможности создания интеллектуальной цифровой инфраструктуры. Это является важным шагом в направлении модернизации горно-металлургической отрасли Узбекистана.

Внедрение систем машинного зрения в АГМК и НГМК, даст экономический эффект за счёт повышения извлечения и снижения затрат на реагенты, уменьшит зависимость от человеческого фактора, станет шагом к «умной фабрике» (Smart Mining/Smart Processing) в Узбекистане.

Выводы

Проведенный анализ демонстрирует, что внедрение систем машинного зрения является не просто инновационным трендом, а стратегической необходимостью для модернизации флотационных процессов на современных обогатительных фабриках. Эта технология переводит управление флотацией на качественно новый уровень, заменяя субъективную визуальную оценку оператора на объективный, непрерывный и количественный анализ ключевых параметров пены в реальном времени. Интеграция алгоритмов компьютерного зрения и глубокого обучения позволяет с высокой точностью отслеживать динамику пузырьков, стабильность пены и её текстуру, что напрямую коррелирует с эффективностью разделения минералов. Как показывают данные от ведущих производителей (Metso, FLSmidth) и пилотные проекты, результатом внедрения становится устойчивый рост извлечения ценных металлов на 2–4% и значительное сокращение потребления реагентов за счёт более точного их дозирования.

Для предприятий Узбекистана, таких как АГМК и НГМК, внедрение данных систем открывает значительный экономический потенциал. Прогнозируемый эффект, исчисляемый миллионами долларов в год, достигается не только за счёт увеличения выпуска продукции, но и благодаря снижению операционных затрат и минимизации влияния человеческого фактора.

Таким образом, системы машинного зрения выступают краеугольным камнем в построении «умной фабрики» и цифровой трансформации горно-металлургического комплекса. Их дальнейшее развитие, связанное с интеграцией цифровых аналогов и более сложных AI-моделей, окончательно закрепит за ними роль незаменимого инструмента для обеспечения максимальной эффективности, стабильности и предсказуемости технологических процессов обогащения.

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TO THE QUESTION OF DETERMINING THE PROSPECTS FOR USING THE CAPABILITIES OF MODERN VIRTUAL TECHNOLOGIES IN THE INFORMATION SYSTEM OF SOCIETY

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***Abstract*—**The growth of research interest in the field of natural science, social and philosophical knowledge towards the problem of virtualization of society occurred at the end of the last century.

At this time, the term itself was introduced into scientific circulation, a new direction in philosophy emerged - virtualistics, within the framework of which virtual processes were studied. The topic of virtuality is beginning to be actively discussed in various fields of science.

Social cognition records the increase in the scale of virtualization of society. A number of theorists note the emerging contradiction between the rapidly growing processes of virtualization and their scientific understanding.

The modern era is characterized by the rapid development of computer technology and computer technology. The development of information technology has brought to the forefront a specifically new form of transmission, storage and reproduction of data, which is associated with the use of electronic technologies for the virtualization of reality.

The article analyzes the prospects for using the capabilities of modern virtual technologies in the information system of society, the strategic importance of socio-philosophical evaluation of indicators of virtual reality manifestation, the direction of research on virtuality, the impact of virtual reality on humanity and its significance in the organization and regulation of human life.

Keywords - information society, Internet, virtual reality, digital technologies, transformation, social institution, e-government

I.INTRODUCTION

In the system of the world information society, the effective use of the possibilities of modern virtual technologies is becoming more and more important.

This topic has already created virtual reality - beyond the boundaries of the field of cybernetics, and has become an object of research in fields such as social philosophy, psychology and culture.

Today, the process of wide implementation of information and communication technologies in world practice is also characterized by the virtualization of human activity. Because, as stated by M.Kastels, one of the founders of the information society, "networked structures form the basis of the modern world." [1].

The information explosion at the end of the 20th century - the 21st century is connected with new information and communication technologies, which in turn caused the formation of a new virtual reality, a new space where a person can exist. Among the technologies of virtual data transmission, its advantage is that the Internet not only transmits information, but also serves as a tool for interpersonal, group, and individual communication, and it continues to develop in parallel with the process of information collection, storage, transmission, and protection.

These, in turn, create the need to solve problems at various levels in the socialpolitical, spiritual-cultural life of the society, education and training system.

We believe that the modern age is an informational age that creates a global media environment based on high and digital technologies, which is reflected in every aspect of our lives. As a result, the widespread use of digital economy and management methods based on it in practice has become one of the main factors in the development of the world economy. We believe that the modern age is an information age that creates a global media environment based on high and digital technologies, which is reflected in every aspect of our lives.

II.WHAT DOES VIRTUAL REALITY IMITATE?

It can be known from the researches that the problem of virtuality was first of all attempted to be based on a scientific theoretical basis in the studies of postmodernists at the end of the 20th century, to characterize the conflict between scientific and technical development and culture.

On the other hand, the expansion of the scope of this problem is related to the development of the theory of information society, according to which virtuality is defined as the main and decisive feature of modernity. Different directions of theoretical research of virtuality have been defined. On the basis of such a classification, two ontologies

were defined: the study of reality and virtuality according to the ratio of concepts. Thus, three directions were defined. First, the modernity of this phenomenon of virtuality and its man-made nature are studied separately - theories of virtual reality, virtualization, as well as postmodernist theories within this topic. A common feature of such studies is the contrast between virtuality and reality. Second, this approach has become a rather broad and well-described philosophical tradition.

Virtual reality is reality. The concept of "virtual" mass media is often used in the sense of "invented", "does not exist in reality". However, in the scientific discourse, "virtuality" has begun to be accepted as a type of reality. "Virtual reality, which is being talked about a lot these days, is not just another reality that we step into from time to time, but the reality that we actually live in.

In the early stages of the term virtual reality, panorama was understood. Panorama is Greek for field of vision. There are different forms of panoramas, such as drawn, shaped, photographed and video-film types. In IT, a panorama is a 360-degree view. The impact of virtual reality on humanity is clearly manifested in organizing and regulating human life, creating a new form of communication between people, increasing the positive impact of the main spheres of society's life on the spheres of politics, economy, art and tourism, etc.

Virtuality is an object or situation that does not exist in reality, does not exist in reality, but can occur under certain conditions. In virtuality, these conditions are implemented in different approaches. Ontologically speaking, we can learn that virtuality means a certain potential state of being, the existence of a certain active principle in it, a tendency to the occurrence of certain events or situations under certain conditions. With the help of modern technical means, we can even dive deeper into virtual reality, in which we as a subject cannot separate the things and events of the real and virtual world from each other. Because this world affects a person directly through his emotions.

What VR imitates Virtual reality (VR, English virtual reality, VR, artificial reality) is a world created by technical means, transmitted to a person through his sensations: sight, hearing, touch and others. virtual reality?

Virtual reality simulates both exposure and responses to exposure.

To create a convincing set of sensations of reality, a computer synthesis of the properties and reactions of virtual reality is performed in real time.

Virtual reality objects usually behave close to the behavior of similar objects of material reality.

The user can influence these objects in accordance with the real laws of physics (gravity, water properties, collision with objects, reflection, etc.).

However, often for entertainment purposes, users of virtual worlds are allowed more than is possible in real life (for example: fly, create any objects, etc.).

Virtual reality should not be confused with augmented reality.

Their fundamental difference is that virtual reality constructs a new artificial world, while augmented reality only introduces individual artificial elements into the perception of the real world.

Technical tasks that are solved when providing immersion in virtual reality: *Image Broadcast ○ VR Headsets ○ MotionParallax3D Displays *Virtual retinal monitor *Sound broadcast *Simulated tactile sensations ○ Leap Motion ○ Gloves ○ Controllers *Tracking ○ Optical ○ Ultrasonic STRUCTURING OF VR

Although there is a classification to define a specific type of "reality", there is also a classification by types within the concept of virtual reality [3] Passive virtual reality - an autonomous graphic image and its sound accompaniment, not controlled by a person. Exploratory virtual reality - the ability to select options for image and sound scenarios provided to users in a limited number.

Interactive virtual reality (interactive virtual reality) is a virtual environment that the user can control and manipulate according to the laws of the synthesized world using special devices with the tracking function.

Tracking in virtual reality is a special technology that underlies human interaction with the virtual world.

It is aimed at accurately determining the coordinates and position of a real object (for example, a hand, head, or device) in a virtual environment using three coordinates (x, y, z) of its location and three angles (a, b, g) that specify its orientation in space.

III.APPLICATIONS OF VIRTUAL REALITY

Virtual reality is becoming more and more popular.

Despite the fact that the initial impetus for the development of VR was received from the gaming industry, in recent years VR has found its way into areas such as medicine, military affairs and astronautics.[4] Virtual reality differs from objective reality, including our everyday life, because it is a specific state of consciousness. Similarly, virtual reality technologies are researched in the system of philosophy, psychology, aesthetics and social and humanitarian sciences in general. From this point of view, now it is of urgent importance to research virtual reality technologies, to determine the criteria of their application, their role in knowledge and practical activities, their relationship with the category of probability, the nature of virtuality in general with the properties of the universe and existence. According to B.V.Markov, telecommunications technologies enable democratization at the transnational level.

A unique definition of virtual reality is given in S.S. Khoruzhii's article: "Virtual reality, virtual events always have the characteristic of partially realized and relative existence, and are characterized by the lack or non-existence of one or another event of empirical reality". The fundamental research on the phenomenon of virtualization is the monograph "Virtualization of society" by D.V. Ivanov. It explains the logic of virtual reality as replacing real objects and actions with images -simulations. The author distinguishes three main characteristics of virtual reality: immaterial effect (what is depicted creates the effect

of existing objects); conditionality of parameters (objects are artificial and changeable); ephemerality (freedom of entry/exit, i.e. allowing for re-existence in case of interruptions). Also, the author offers solutions to several problems in the work.

IV.CONCLUSION AND DISCUSSIONS

First, in order to apply the dichotomy "real/virtual", it is necessary to observe and research the genesis of social reality. Secondly, in order to create a model of social changes such as "from reality to virtuality", it is necessary to generalize various empirical phenomena. Secondly, social changes such as "from reality to virtuality" can provide a solution to this problem as a result of research on the processes that took place in the 20th21st centuries and formed the social core of the proposed concepts - virtualization can provide an example and a single principle of social changes. In order to create a model, it is necessary to generalize various empirical phenomena.

Thirdly, in order to determine the theoretical status of the concept of virtualization, it is necessary to compare it with the models of society transformation used in the modern socio-humanitarian field. So, we can say that the ontological nature of virtual reality and virtualization mechanisms is still in the process of understanding and understanding in the modern scientific world. The main part of the research is carried out within the framework of electronic virtual reality, and when the researchers talk about this process, i.e., the new view of the transformation of society, about its "virtualization", they mainly mean the virtualization related to the space of the Internet network.

Today, we are witnessing that the virtual space is increasingly covering the human socio-cultural sphere and how true the above scientific hypothesis is. On the one hand, technical support creates the necessary conditions for socio-cultural activities and provides the necessary weapons, on the other hand, the availability of such weapons to everyone does not leave the need to turn to experts in the field. For example, opening a page of an event on a social network can certainly arouse great interest in the Internet audience. But on the other hand, the virtual world also attracts those who are eager to attend the event in reality. Because it is possible to observe every event without going, without spending financial, emotional and physical effort. According to F. Hammit, virtual reality is "a direction created on the basis of a "friendly" functional-interactive interface for human action in the world of electronic information.

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RAQAMLI TEXNOLOGIYALAR VA GAMIFIKATSIYA VOSITALARI ASOSIDA TALABALAR MOTIVATSIYASINI OSHIRISHNING INNOVATSION YONDASHUVLARI

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***Annotatsiya**: Ushbu maqolada ta’lim jarayonida gamifikatsiya va raqamli texnologiyalarni qo‘llash orqali talabalar motivatsiyasini oshirish masalalari ko‘rib chiqiladi. Innovatsion platformalar va o‘yin mexanizmlari asosida shakllantirilgan o‘quv muhitining samaradorligi tahlil qilinadi. Xalqaro tajriba hamda O‘zbekiston ta’lim tizimidagi amaliy natijalar solishtirilib, kelajak istiqbollari belgilab beriladi.*

Kalit so‘zlar: Gamifikatsiya, raqamli ta’lim, motivatsiya, innovatsion yondashuv, talabalar

Kirish

Zamonaviy ta’lim tizimida talabalarni o‘quv jarayoniga faol jalb etish va ularning ichki motivatsiyasini kuchaytirish eng muhim vazifalardan bir hisoblanadi. So‘nggi yillarda global miqyosda ta’lim sohasida raqamli transformatsiya jarayonlari jadallashib bormoqda. Natijada ta’lim tizimiga sun’iy intellekt, katta ma’lumotlar (Big Data), bulutli texnologiyalar va mobil ilovalar keng joriy etilmoqda. Bu texnologiyalar an’anaviy o‘qitish usullarini to‘ldiribgina qolmay, balki o‘quv jarayonini shaxsiylashtirish, talabalarni faol ishtirokchi sifatida jalb etish va ta’lim samaradorligini oshirishga xizmat qilmoqda[1].

Shu innovatsion yondashuvlar orasida gamifikatsiya alohida o‘rin tutadi. Gamifikatsiya – bu ta’lim jarayoniga o‘yin mexanizmlari va elementlarini (ball, reyting, badge, darajalar, progress monitoring va boshqalar) tatbiq etish orqali talabalarni rag‘batlantirish va ularda raqobatbardoshlik ruhini kuchaytirish jarayonidir.

O‘zbekiston Respublikasi Prezidentining “Raqamli O‘zbekiston – 2030” strategiyasi ta’lim sohasini raqamlashtirishni ustuvor yo‘nalish sifatida belgilagan. Shu asosda “Elektron universitet”, “Onlayn maktab” platformalari, masofaviy imtihon tizimlari va elektron kutubxonalar joriy qilinmoqda. Bu tashabbuslar ta’limning inklyuzivligi, samaradorligi va shaffofligini oshirishga xizmat qilmoqda.

Tadqiqotlar shuni ko‘rsatmoqdaki, raqamli texnologiyalardan foydalanilgan darslarda talabalar:

- bilimlarni 30% tezroq o‘zlashtiradi;
- mustaqil ishlash ko‘nikmalari 40% ga ortadi;
- darsga qatnashuv va motivatsiya an’anaviy usullarga nisbatan sezilarli darajada yuqori bo‘ladi[2].

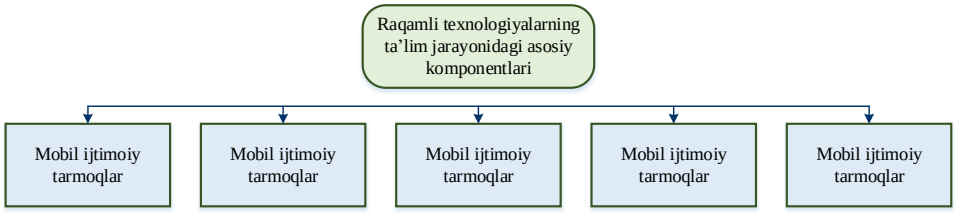
Xalqaro tajriba shuni ko‘rsatadiki, gamifikatsiya elementlari integratsiya qilingan raqamli ta’lim platformalari (Duolingo, Kahoot, Coursera, Quizizz va boshqalar) talabalarda yuqori faollik, o‘zlashtirish darajasining oshishi va o‘quv jarayoniga ijobiy munosabat shakllanishiga yordam bermoqda. O‘zbekiston ta’lim tizimi ham bosqichma-bosqich ushbu yondashuvlarni joriy etmoqda, biroq hali ularning to‘laqonli samarasi keng miqyosda kuzatilgani yo‘q. Shu nuqtayi nazardan, ushbu maqolada gamifikatsiya elementlari va raqamli platformalardan foydalanishning nazariy asoslari, amaliy qo‘llanish imkoniyatlari hamda ta’lim samaradorligiga ta’siri ilmiy tahlil qilinadi.

Asosiy qism

So‘nggi yillarda ta’lim jarayoniga raqamli texnologiyalarni joriy etish zamonaviy o‘qitish metodologiyasining eng muhim yo‘nalishiga aylandi. Virtual laboratoriyalar, masofaviy ta’lim platformalari, sun’iy intellekt asosidagi maslahat tizimlari va mobil ilovalar talabalar uchun o‘quv jarayonini qulaylashtiribgina qolmay, ularning mustaqil o‘rganish ko‘nikmalarini ham rivojlantirmoqda. Shu bilan birga, raqamli vositalar yordamida o‘qituvchi o‘quvchilarning bilim darajasini onlayn monitoring qilish, o‘z vaqtida tahlil etish va individual yondashuvni amalga oshirish imkoniyatiga ega bo‘ladi[3].

Raqamlashtirish – bu obyektiv, muqarrar jarayon bo‘lib, uni to‘xtatib bo‘lmaydi. Muassasalarning raqamli transformatsiya jarayoni yangi axborot texnologiyalari rivojlanishi va ularning butun dunyo bo‘ylab faol tarqalishiga javob bo‘lib xizmat qiladi.

Raqamlashtirish natijalari va uning komponentlarini (1-rasm) amaliyotda qo‘llash an’anaviy boshqaruv shakllariga qaraganda yuqori samaradorlikka erishish imkonini beradi. Raqamli texnologiyalarga o‘tish – bu kompyuterlar va bilimlarga asoslangan mutlaqo yangi turdagi jamiyat va iqtisodiyot barpo etish demakdir[4].



1-rasm. Raqamli texnologiyalarning ta’lim jarayonidagi asosiy komponentlari.

Innovatsion yondashuvning mohiyati — **raqamli ta’lim ekotizimida gamifikatsiya elementlarini uyg‘unlashtirish**dir. Bu orqali:

- talabalarda o‘qishga bo‘lgan qiziqish ortadi;
- raqobatbardoshlik muhitida bilim olish kuchayadi;
- mustaqil o‘rganish ko‘nikmalari rivojlanadi;
- raqamli vositalar orqali ta’lim jarayoni shaffof va samarali bo‘ladi.

Zamonaviy ta’lim tizimida raqamlashtirish jarayonining muvaffaqiyati bir qator innovatsion texnologiyalar uyg‘unligi bilan belgilanadi. Quyida ular ilmiy asosda yangicha yondashuvda bayon qilinadi:

1. Mobil ijtimoiy tarmoqlar. Mobil ijtimoiy tarmoqlar ta’lim jarayonida sosial konstruktivizm nazariyasiga mos ravishda interaktiv hamkorlikni rivojlantiradi. Ular talabalar va o‘qituvchilar o‘rtasida tezkor kommunikatsiya, bilim almashinuvi va virtual jamoalar tashkil etish imkonini beradi. Ilmiy tadqiqotlar (OECD, 2022) shuni ko‘rsatadiki, mobil ijtimoiy platformalardan foydalanish talabalar motivatsiyasini 30–40% ga oshiradi.

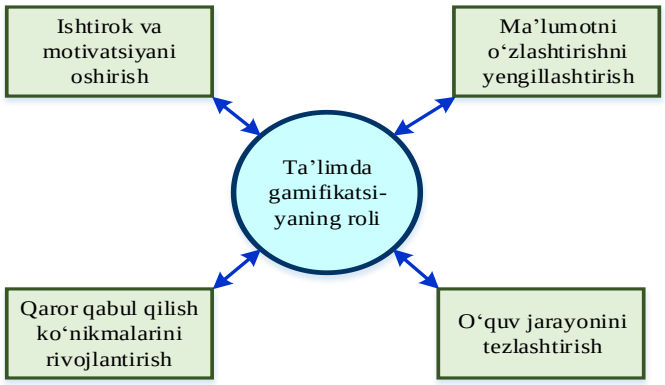
2. Sun’iy intellekt texnologiyalari. Sun’iy intellekt (SI) ta’limni moslashtirilgan tarzda tashkil etish imkonini beradi. Adaptive Learning tizimlari yordamida SI talabalar bilim darajasini real vaqt rejimida tahlil qilib, individual topshiriqlarni shakllantiradi. Ilmiy yangilik shundaki, SI asosida ta’lim jarayonini proaktiv boshqarish mumkin – ya’ni, talabani faqat nazorat qilish emas, balki uning kelajakdagi ehtiyojlarini ham oldindan prognoz qilish.

3. Bulutli texnologiyalar. Bulutli xizmatlar ta’limda resurslarni markazlashtirilgan holda saqlash, ulardan istalgan joy va vaqtda foydalanish imkonini beradi. Ilmiy jihatdan ular ta’lim jarayonining barqarorligi va inkluzivligini ta’minlash vositasi sifatida qaraladi. Masalan, Google Workspace for Education yoki Microsoft Azure kabi platformalar pandemiya sharoitida ta’lim jarayonini to‘xtamasdan davom ettirish imkonini berdi.

4. “Narsalar interneti” (IoT). IoT texnologiyalari ta’lim muassasalarida aqlli kampus konsepsiyasini shakllantiradi. IoT qurilmalari yordamida laboratoriya jihozlari, sinfxona uskunalari, xavfsizlik tizimlari birlashtirilib, talabalar uchun innovatsion muhit yaratiladi. Ilmiy yangilik shundaki, IoT asosida o‘quvchilar faoliyati monitoring qilinib, ta’lim jarayonining samaradorligi bo‘yicha katta hajmdagi ma’lumotlar yig‘ilishi mumkin.

5. Sensor tarmoqlar. Sensor tarmoqlar ta’lim muhitida real vaqtli kuzatuv va o‘lchov imkoniyatlarini yaratadi. Masalan, sog‘liqni saqlash, biologiya yoki muhandislik sohalaridagi laboratoriya mashg‘ulotlarida sensorlar yordamida to‘plangan ma’lumotlar o‘quv jarayoniga integratsiya qilinadi. Ilmiy yangilik shundaki, sensor tizimlari orqali ta’lim jarayoni nafaqat nazariy, balki eksperimental va empirik asosga ega bo‘lmoqda[4].

Gamifikatsiya ta’lim jarayonida motivatsiyani oshirishning samarali usuli sifatida ko‘plab tadqiqotlarda isbotlangan. Masalan, J. Hamari va hamkorlari tomonidan olib borilgan meta-tahlillar shuni ko‘rsatadiki, o‘yin elementlari qo‘llangan ta’lim jarayonida talabalar faolligi va darslarga qiziqishi 20–30% ortadi. Duolingo, Coursera, EdX, Kahoot va Quizizz kabi global platformalar gamifikatsiya mexanizmlarini qo‘llab, talabalarni o‘rganishga rag‘batlantirmoqda. Ta’limda gamifikatsiya bir qator vazifalarni hal etishda yordam beradi (2-rasm).



2-rasm. Ta’limda gamifikatsiyaning roli.

Ishtirok va motivatsiyani oshirish. Ballar, reytinglar va mukofotlar xodimlarni ta’lim dasturlarida faol ishtirok etishga va hamkasblari bilan raqobatlashishga undaydi. Maqsadlarga erishish esa o‘z-o‘zini baholash va ishonchni kuchaytiradi.

Ma’lumotni o‘zlashtirishni yengillashtirish. O‘yin topshiriqlari, kvestlar va simulyatsiyalar o‘quv jarayonini yanada qiziqarli va esda qolarli qiladi. O‘quvchilar ma’lumotni passiv emas, balki faol o‘zaro ta’sir orqali egallaydilar.

Qaror qabul qilish ko‘nikmalarini rivojlantirish. O‘yinda passiv bo‘lib bo‘lmaydi — o‘quvchilar vaziyatni tahlil qilishlari, qaror qabul qilishlari va strategiyalar tuzishlari kerak bo‘ladi. Bu esa tanqidiy fikrlash va real sharoitlarda muammolarni hal etish ko‘nikmalarini rivojlantiradi.

O‘quv jarayonini tezlashtirish. O‘yin formatidagi ta’lim xodimlarga yangi bilim va ko‘nikmalarni an’anaviy metodlarga qaraganda tezroq o‘zlashtirish imkonini beradi. Bu cheklangan vaqt va tez o‘zgarayotgan bozor sharoitida juda muhim.

Ta’lim jarayonida gamifikatsiyaning asosiy usullari ko‘rib chiqamiz. Gamifikatsiya ta’lim jarayonini yanada qiziqarli va samarali qilishga xizmat qiluvchi innovatsion yondashuvdir. 3-rasmda gamifikatsiya usullari keltirilgan.

3-rasm. Gamifikatsiya usullari.

Quyida ta’lim jarayonida qo‘llash mumkin bo‘lgan eng keng tarqalgan gamifikatsiya usullari va uslublari keltirilgan:

Kvestlar. Ta’limiy kvestlarda talabalar vazifalarni bajarishi va bir vaqtning o‘zida yangi mavzularni o‘rganishi yoki mavjud bilimlarini mustahkamlashi kerak bo‘ladi. Motivatsiyani oshirish uchun ishtirokchilarga ballar va mukofotlar beriladi. Kvestlar yordamida o‘qishni qiziqarli jarayonga aylantirish va talabalarning jalb qilinish darajasini oshirish mumkin.

Roli o‘yinlari. Bunday shakldagi gamifikatsiya nafaqat ma’lumotni yaxshiroq eslab qolishga yordam beradi, balki jamoada ishlash ko‘nikmalarini ham rivojlantiradi. Bundan tashqari, talabalar haqiqiy ish sharoitiga yaqin vaziyatlarda o‘z ko‘nikmalarini sinab ko‘rishlari mumkin.

Reytinglar. Talabalar to‘plagan ballar soniga ko‘ra saralanadi. Platformalarda bu jarayon avtomatlashtirilgan tarzda amalga oshirilishi mumkin. Metod talabalar natijalarini vizual tarzda taqqoslashga yordam beradi va birinchi o‘ringa chiqish uchun qancha ball kerakligini ko‘rsatadi. Reyting tizimi talabalarda sog‘lom raqobat uyg‘otadi, administratorlar va o‘qituvchilarga esa talabalar rivojlanishini qulay kuzatish imkonini beradi.

Yig‘ma ballar. An’anaviy baholarni ballar bilan almashtirish mumkin. Talabalar topshiriqlarni bajarish, munozaralarda qatnashish, testlardan muvaffaqiyatli o‘tish kabi faoliyatlari uchun ball to‘plashadi. Ushbu ballardan

reyting tuzishda foydalanish yoki ularni mukofotlarga almashtirish mumkin. Masalan, ta’lim platformasida “Mukofotlar do‘koni” bo‘lib, u yerga moddiy sovg‘alar yoki nomoddiy rag‘batlantirish turlari qo‘shilishi mumkin.

Darajalar. Kompyuter o‘yinlariga o‘xshash tarzda, talaba topshiriqlarni bajargan sayin yangi darajalarga ko‘tariladi. Har bir yangi daraja oldingisidan murakkabroq bo‘ladi.

Xulosa

Tadqiqotlar natijalari shuni ko‘rsatadiki, turli xalqaro ta’lim platformalarida gamifikatsiya elementlarining qo‘llanilishi o‘quvchilarning motivatsiyasi va jalb etilishiga sezilarli ta’sir ko‘rsatmoqda.

Jumladan, Duolingo misolida, dastlab foydalanuvchi ushlanish (retention) darajasi atigi 12 foizni tashkil etgan bo‘lsa, gamifikatsiya mexanizmlarini (badge, darajalar, kundalik mashg‘ulotlar eslatmalari va boshqalar) joriy etish natijasida bu ko‘rsatkich sezilarli darajada oshgan. Shuningdek, foydalanuvchilarni rag‘batlantirish tizimlari tufayli referral darajasi 116 foizga ko‘tarilgan. Bugungi kunda Duolingo’da kunlik faol foydalanuvchilar soni 19 milliondan ortiqni tashkil etmoqda. Yuqoridagi tahlillardan ko‘rinib turibdiki, raqamli texnologiyalar va gamifikatsiya vositalarini ta’lim jarayoniga integratsiya qilish zamonaviy ta’lim samaradorligini oshirishning eng muhim omillaridan biridir. Raqamlashtirishning asosiy komponentlari – mobil ijtimoiy tarmoqlar, sun’iy intellekt, bulutli texnologiyalar, narsalar interneti va sensor tarmoqlar – ta’lim jarayonining interaktivligini, shaxsiylashtirilganligini va moslashuvchanligini ta’minlaydi.

Gamifikatsiya esa bu jarayonni yanada kuchaytirib, talabalarni faol ishtirokchi sifatida ta’limga jalb etish, ularda raqobatbardoshlik, mustaqil o‘rganish va hamkorlik ko‘nikmalarini rivojlantirishga xizmat qiladi. Xalqaro tajribalar (Duolingo, Coursera, EdX, Kahoot, Quizizz va boshqalar) shuni ko‘rsatmoqdaki, gamifikatsiya elementlari (ballar, reytinglar, darajalar, kvestlar, rol o‘yinlari, nishonlar) qo‘llangan ta’lim jarayonida talabalar motivatsiyasi 20–40% ga ortadi, o‘zlashtirish darajasi sezilarli ravishda yaxshilanadi.

O‘zbekiston ta’lim tizimida ham “Raqamli O‘zbekiston – 2030” strategiyasi doirasida ushbu yondashuvlar bosqichma-bosqich joriy etilmoqda. Shu jarayonda gamifikatsiya elementlarini raqamli platformalar bilan uyg‘unlashtirish orqali ta’limning samaradorligi, shaffofligi va inkluzivligi sezilarli darajada oshadi. Shunday qilib, raqamli texnologiyalar va gamifikatsiya vositalariga asoslangan innovatsion yondashuv nafaqat ta’lim sifatini oshiradi, balki zamonaviy jamiyat talablariga javob bera oladigan, kreativ va raqobatbardosh kadrlarni tayyorlashda strategik ahamiyat kasb etadi.

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O‘ZBEKISTON SHAROITIDA YAGONA DAVLAT RAQAMLI PLATFORMASINI SHAKLLANTIRISH: MUAMMOLAR, YECHIMLAR VA XALQARO TAJRIBA ASOSIDA TAKOMILLASHTIRISH IMKONIYATLARI

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Annotatsiya: Maqolada O‘zbekiston sharoitida yagona davlat raqamli platformasini shakllantirish masalalari tahlil qilingan. Davlat boshqaruvi tizimini raqamlashtirishda mavjud texnologik, tashkiliy va huquqiy muammolar ko‘rib chiqilib, ularning yechimlari taklif etilgan. Xalqaro tajribadan o‘rinli foydalanish, zamonaviy texnologiyalar (sun’iy intellekt, blockchain, bulutli hisoblash, Big Data)ni joriy etish orqali yagona raqamli platforma samaradorligini oshirish imkoniyatlari yoritilgan. Shu bilan birga, platformaning aholiga ko‘rsatadigan qulayliklari, davlat xizmatlari sifatini yaxshilashdagi roli va iqtisodiy samaralari tahlil qilinadi. Tadqiqot natijalari O‘zbekistonning “Raqamli hukumat” konsepsiyasini amalga oshirishda muhim nazariy va amaliy asos bo‘lib xizmat qiladi.

Kalit so‘zlar: Yagona davlat raqamli platforma, raqamli hukumat, elektron davlat xizmatlari, O‘zbekiston, raqamli transformatsiya, sun’iy intellekt, blockchain, Big Data, kibermuhofaza, xalqaro tajriba.

Kirish

So‘nggi yillarda davlat boshqaruvi tizimida raqamli transformatsiya jarayonlari nafaqat rivojlangan mamlakatlarda, balki rivojlanayotgan davlatlarda ham jadal sur’atlar bilan rivojlanmoqda. Global miqyosda “raqamli hukumat” (e-government) konsepsiyasi davlat xizmatlarini aholiga yanada tezkor, samarali va shaffof tarzda yetkazib berish, davlat boshqaruvi tizimida byurokratiyani kamaytirish hamda fuqarolar ishtirokini kuchaytirishni maqsad qiladi[1,2]. Bunday transformatsiya, bir tomondan, aholiga qulaylik yaratadi, ikkinchi tomondan esa davlatning ochiqligi, hisobdorligi va samaradorligini oshirishga xizmat qiladi.

Xususan, Estoniya, Singapur, Janubiy Koreya kabi mamlakatlar raqamli hukumat konsepsiyasini amaliyotga joriy etishda ilg‘or tajribaga ega bo‘lib, ular davlat xizmatlarini yagona platformalar asosida integratsiya qilgan[3,4,5]. Natijada, mazkur davlatlarda aholining 90 foizdan ortiq qismini qamrab oluvchi elektron xizmatlar tizimi shakllangan va fuqarolar kundalik faoliyatida davlat organlariga murojaat qilishning aksariyatini onlayn shaklda amalga oshirish imkoniyatiga ega.

O‘zbekiston ham ushbu global tendensiyalardan chetda qolmay, o‘z milliy modelini shakllantirish jarayonini boshlagan. 2020-yilda tasdiqlangan “Raqamli O‘zbekiston – 2030” strategiyasi mamlakatimizda davlat xizmatlarini to‘liq raqamlashtirish, axborot-kommunikatsiya texnologiyalaridan keng foydalanish va yagona davlat raqamli platformasini joriy etishni ustuvor yo‘nalishlardan biri sifatida belgilab berdi[3]. Strategiyada elektron davlat xizmatlarining ulushini sezilarli darajada oshirish, davlat idoralari o‘rtasida ma’lumot almashuvini avtomatlashtirish, fuqarolarning yagona identifikatsiya tizimi orqali xizmatlardan foydalanishini soddalashtirish kabi masalalar asosiy vazifa qilib qo‘yilgan.

Mazkur dastur doirasida davlat xizmatlarini aholiga tez va sifatli ko‘rsatish, korrupsiya xavfini kamaytirish, shuningdek, iqtisodiyotning turli tarmoqlarini raqamli transformatsiya qilish orqali mamlakatning global raqobatbardoshligini oshirish ko‘zda tutilgan. Shu bois, yagona davlat raqamli platformasini yaratish O‘zbekistonning ijtimoiy-iqtisodiy rivojlanishida muhim bosqich hisoblanadi[7].

Yagona davlat raqamli platformasi – bu davlat organlari o‘rtasida ma’lumot almashinuvi va integratsiyani ta’minlaydigan, fuqarolarga barcha elektron xizmatlarni

yagona nuqtadan taqdim etadigan axborot tizimidir[1,3]. Mazkur platformani samarali shakllantirish orqali aholiga ko'rsatiladigan xizmatlar tezlashadi, davlat boshqaruvida shaffoflik ortadi va iqtisodiy samaradorlik oshadi.

Asosiy qism

Raqamli hukumat – bu davlat boshqaruvi jarayonlarini zamonaviy raqamli texnologiyalar asosida tashkil etishni nazarda tutuvchi konsepsiya bo'lib, uning asosiy maqsadi davlat xizmatlarini aholiga tezkor, qulay, shaffof va ishonchli tarzda yetkazib berishdir. Raqamli hukumatning markaziy elementi sifatida yagona davlat raqamli platformasi alohida o'rin tutadi. Ushbu platforma davlat boshqaruvi tizimidagi barcha axborot oqimlarini yagona standart asosida boshqarish va integratsiya qilishga xizmat qiladi.

Yagona platforma quyidagi imkoniyatlarni taqdim etadi:

- barcha davlat organlarining yagona axborot tizimi orqali ishlashini ta'minlash;
- fuqarolarga elektron shaklda, "bir darcha" tamoyili asosida davlat xizmatlarini ko'rsatish;
- davlat idoralari o'rtasida ma'lumot almashuvini avtomatlashtirish va inson omilini kamaytirish;
- xizmatlarning ochiqligini ta'minlash hamda korrupsiyaviy xavflarni qisqartirish.

Xalqaro tajribaga nazar tashlasak, bir qator mamlakatlar ushbu yo'nalishda sezilarli yutuqlarga erishgan. Quyida BMTning elektron hukumatlar rivojlanish darajasi bo'yicha reytingi keltirib o'tilgan.

Davlatlar reytingi	Davlat	EGDI ko'rsatkichi
1	Denmark	0.9847
2	Estonia	0.9727
3	Singapore	0.9691
4	Republic of Korea	0.9679
5	Iceland	0.9671
6	Saudi Arabia	0.9602
7	United Kingdom	0.9577
8	Australia	0.9577
9	Finland	0.9575
10	Netherlands	0.9538
63	Uzbekistan	0,7999

1-jadval. BMTning elektron hukumatlar rivojlanish darajasi bo'yicha reytingi

Estoniya – X-Road tizimi. Estoniya dunyoda raqamli hukumatning eng muvaffaqiyatli namunasi sifatida tan olingan. X-Road tizimi davlat va xususiy sektor o'rtasidagi barcha axborot almashuvini yagona platforma asosida amalga oshiradi. Fuqarolar 99% davlat xizmatlarini masofadan turib, onlayn tarzda olish imkoniga ega. Shu orqali Estoniya iqtisodiyotida vaqt va mablag' tejalishi, shaffoflik darajasi esa keskin oshishi ta'minlandi.

Singapur – Smart Nation dasturi. Singapur hukumatining "Aqlli millat" (Smart Nation) dasturi davlat xizmatlari bilan bir qatorda shahar infratuzilmasini, transport tizimini va sog'liqni saqlash xizmatlarini ham raqamlashtirishni ko'zda tutadi. Yagona platforma yordamida nafaqat davlat xizmatlari, balki biznes va aholiga ko'rsatiladigan xizmatlar ham integratsiyalashgan holda boshqariladi. Natijada, Singapur aholisi real vaqt rejimida davlat xizmatlaridan foydalanib kelmoqda.

Janubiy Koreya – Digital Government modeli. Janubiy Koreya elektron hukumat indeksida yetakchi davlatlardan biri bo'lib, uning raqamli hukumat modeli fuqarolar, davlat organlari va biznes sub'yektlari o'rtasidagi hamkorlikni kuchaytirishga qaratilgan. Davlat xizmatlari mobil ilovalar, yagona portallar va avtomatlashtirilgan tizimlar orqali aholiga taqdim etiladi. Bu esa davlat boshqaruvida samaradorlik va ishonchlilikni oshirdi.

Mazkur tajribalar shuni ko'rsatadiki, yagona davlat raqamli platformasi nafaqat davlat xizmatlarini elektron shaklga o'tkazadi, balki iqtisodiyotni rivojlantirish, aholiga qulay muhit yaratish va davlat boshqaruvining shaffofligini ta'minlashda hal qiluvchi omil hisoblanadi. O'zbekiston uchun ham ushbu davlatlar tajribasini o'rganish va milliy sharoitga moslashtirish strategik ahamiyat kasb etadi.

O'zbekistonda so'nggi yillarda raqamli hukumat yo'nalishida sezilarli ishlar amalga oshirilmoqda. Xususan, davlat xizmatlarini yagona portal orqali taqdim etish, elektron raqamli imzo tizimini joriy qilish, ayrim davlat organlarining ichki axborot tizimlarini modernizatsiya qilish bo'yicha qator loyihalar yo'lga qo'yildi. Quyida O'zbekistonda Yagona interaktiv davlat xizmatlari portalidan foydalanish statistikasi keltirilgan.

Foydalanuvchilar	11.6 mln
Jami xizmatlar	775
Ulardan mobil ilovada	565
Tashriflar	34 mln

CLIII. 2-JADVAL. PORTAL SAMARADORLIGI STATISTIKASI

Bounce rate (bir sahifalik tashriflar foizi)	8%
Sharhlar	420.1 ming
Qoniqish darajasi	84%
Shikoyatlar soni	308.2 ming

3-jadval. Foydalanuvchilar qoniqish darajasi

Biroq, yagona davlat raqamli platformasini shakllantirish jarayonida qator muammolar mavjud bo'lib, ularni quyidagi toifalarga ajratish mumkin:

Davlat organlari tizimlarining integratsiya qilinmaganligi. Har bir davlat idorasi o'zining alohida

axborot tizimidan foydalanadi, natijada ularning o‘zaro ma’lumot almashinuvi qiyinlashadi. Bu esa “yagona darcha” tamoyilini to‘liq amalga oshirishga to‘sqinlik qiladi.

Ma’lumotlar bazalarining fragmentatsiyasi. Aksariyat ma’lumotlar turli shakl va formatlarda saqlanadi, yagona standartlar mavjud emas. Bu esa ma’lumotlarni qayta ishlash, tahlil qilish va fuqarolarga xizmat ko‘rsatishda ortiqcha vaqt va resurs sarflanishiga olib keladi.

Hududlar bo‘yicha infratuzilmaning notekis rivojlanishi. Ayrim viloyat va tumanlarda internet tezligi pastligi, server xonalarining texnik imkoniyatlari cheklanganligi yagona platformaning barqaror ishlashiga salbiy ta’sir ko‘rsatmoqda.

Huquqiy muammolar. Shaxsiy ma’lumotlarni himoya qilish bo‘yicha qonunchilik bazasining yetarli darajada rivojlanmaganligi. Raqamli hukumat tizimlarida fuqarolarning shaxsiy ma’lumotlari katta hajmda to‘planadi. Ularni himoya qilish, ruxsatsiz foydalanishning oldini olish uchun xalqaro standartlarga mos kuchli qonunchilik talab qilinadi. Raqamli imzo va autentifikatsiya tizimlarining yetarli qo‘llanilmasligi. Amaliyotda raqamli imzo orqali hujjat aylanishi joriy qilingan bo‘lsa-da, uning qo‘llanish doirasi tor, ko‘plab xizmatlar hanuz qog‘oz shaklida amalga oshirilmoqda.

Tashkiliy muammolar. Davlat organlari o‘rtasida ma’lumot almashinuvi sustligi. Idoralar ko‘pincha o‘z ma’lumotlarini boshqa organlar bilan baham ko‘rishga tayyor emas, bu esa byurokratiya va takroriy hujjatlar talab qilinishiga sabab bo‘ladi.

Loyiha boshqaruvi va koordinatsiya mexanizmlarining zaifligi. Yagona platformani yaratish kabi yirik loyihalar samarali koordinatsiyani talab qiladi. Ammo ayrim hollarda idoralararo hamkorlik sust bo‘lib, vazifalarning takrorlanishi yoki to‘liq bajarilmasligi kuzatiladi.

Xavfsizlik muammolari. Davlat axborot tizimlariga kiberhujumlar xavfining yuqoriligi. Raqamli hukumat tizimlari global tarmoqlarga ulanganligi sababli ular doimiy ravishda xakerlik hujumlariga duch kelishi mumkin. Bu esa davlat axborot resurslari xavfsizligiga jiddiy tahdid tug‘diradi.

Shaxsiy ma’lumotlarning noqonuniy tarqalishi xavfi. Fuqarolar haqidagi katta hajmdagi ma’lumotlar noto‘g‘ri qo‘llar qo‘liga tushsa, bu ularning huquq va erkinliklariga putur yetkazishi mumkin. Shu sababli, axborot xavfsizligini ta’minlash muhim ustuvor yo‘nalish bo‘lib qolmoqda.

Yechimlar va rivojlantirish yo‘nalishlari. O‘zbekistonda yagona davlat raqamli platformasini shakllantirishda mavjud muammolarni bartaraf etish uchun kompleks yondashuv talab etiladi. Buning uchun nafaqat texnologik yangiliklarni joriy etish, balki huquqiy, tashkiliy va kadrlar salohiyatini rivojlantirish yo‘nalishida ham keng qamrovli ishlarni amalga oshirish zarur. Quyidagi yo‘nalishlar alohida ahamiyatga ega:

1. Davlat organlari tizimlarini yagona integratsiyalashgan platformaga birlashtirish

Davlat xizmatlarini “bir darcha” tamoyili asosida ko‘rsatish uchun barcha vazirlik va idoralarning mavjud axborot tizimlarini yagona standartlar asosida integratsiya qilish muhimdir. Bu orqali takroriy ma’lumot so‘rash bartaraf etilib, aholiga xizmat ko‘rsatish jarayonlari tezlashadi. Shuningdek, idoralararo ma’lumot almashinuvi avtomatlashtiriladi.

2. Blockchain texnologiyasidan foydalanish

Blockchain texnologiyasi ma’lumotlarning o‘zgarmasligi va ishonchliligini ta’minlashda samarali vosita hisoblanadi. Ushbu texnologiyani davlat reyestrlari, kadastr tizimlari va elektron hujjat aylanishida qo‘llash orqali korrupsiya xavfi kamayadi, shaffoflik darajasi ortadi va ma’lumotlar ishonchliligi kafolatlanadi.

3. Sun’iy intellektni joriy etish

Sun’iy intellekt (SI) texnologiyalarini davlat xizmatlariga tatbiq qilish orqali fuqarolar murojaatlarini avtomatik qayta ishlash, xizmat ko‘rsatishda individual yondashuvni ta’minlash va xizmatlarning sifatini oshirish mumkin. Masalan, chat-botlar yordamida oddiy so‘rovlarni avtomatlashtirish yoki ma’lumotlarni tahlil qilish orqali davlat siyosatini optimallashtirish imkoniyatlari mavjud.

4. Big Data asosida tahliliy tizimlar yaratish

Yagona platforma katta hajmdagi ma’lumotlarni yig‘ish va qayta ishlash imkonini beradi. Big Data texnologiyalari asosida qaror qabul qilish jarayonlarini ilmiy asoslash, iqtisodiy prognozlar ishlab chiqish va aholining ehtiyojlarini aniqlash imkoniyatlari kengayadi. Bu esa davlat boshqaruvida samaradorlikni oshirishga xizmat qiladi.

5. Bulutli hisoblash texnologiyalarini keng qo‘llash

Bulutli infratuzilma axborot tizimlarining barqarorligini oshirish va resurslardan tejamkorlik bilan foydalanish imkonini beradi. Davlat organlari o‘rtasida bulutli xizmatlarni joriy etish orqali IT infratuzilmani optimallashtirish, server xarajatlarini kamaytirish va tizimlarning barqarorligini ta’minlash mumkin.

6. Yagona identifikatsiya tizimini takomillashtirish

Fuqarolar va tadbirkorlik sub’yektlari davlat xizmatlaridan foydalanishda yagona identifikatsiya tizimi orqali autentifikatsiyadan o‘tishi muhim. ID.gov.uz tizimini yanada takomillashtirish, uni xalqaro standartlarga moslashtirish va xususiy xizmatlar bilan integratsiya qilish aholiga qulayliklar yaratadi.

7. Davlat xizmatchilarining raqamli ko‘nikmalarini oshirish

Yagona platformaning samarali ishlashi faqat texnologik yechimlarga emas, balki kadrlarning salohiyatiga ham bog‘liq. Shu sababli davlat xizmatchilari uchun maxsus o‘quv dasturlari, malaka oshirish kurslari va raqamli kompetensiyalarni rivojlantirishga qaratilgan

treninglar tashkil etilishi zarur. Bu jarayon davlat sektorida raqamli madaniyatni shakllantirishga xizmat qiladi.

O'zbekistonda yagona davlat raqamli platformasini shakllantirish mamlakatning ijtimoiy-iqtisodiy rivojlanishida muhim bosqich hisoblanadi. Ushbu platforma fuqarolar, tadbirkorlar va davlat organlari o'rtasidagi o'zaro munosabatlarni yangi sifat bosqichiga olib chiqib, davlat boshqaruvida samaradorlikni sezilarli darajada oshiradi. Natijada quyidagi ijobiy samaralarga erishish kutiladi:

Davlat xizmatlari tezligi va sifati oshadi. Yagona platforma orqali davlat xizmatlari to'liq elektron shaklda, onlayn tarzda ko'rsatiladi. Bu jarayon nafaqat xizmatlarni olish muddatini qisqartiradi, balki inson omilini kamaytirib, xizmatlarning sifatini ham yaxshilaydi. Fuqarolar istalgan hududdan davlat xizmatlaridan foydalanish imkoniyatiga ega bo'ladilar.

Fuqarolar uchun vaqt va mablag' tejaladi. Yagona platforma fuqarolarning turli idoralarga borib, hujjatlar yig'ish, navbat kutish kabi ortiqcha vaqt sarflanishining oldini oladi. Elektron xizmatlar transport xarajatlarini kamaytiradi va xizmatlardan foydalanishning qulayligini oshiradi. Shu orqali aholining davlatga bo'lgan ishonchi va qoniqishi ham ortadi.

Davlat boshqaruvida shaffoflik kuchayadi. Platforma orqali barcha ma'lumotlar elektron tarzda qayd etiladi va nazorat qilinadi. Bu esa davlat idoralari faoliyatida ochiqlikni ta'minlab, aholiga ko'rsatilayotgan xizmatlar bo'yicha aniq statistika yuritishga imkon beradi. Natijada davlat boshqaruvida hisobdorlik kuchayadi va fuqarolar ishtiroki ortadi.

Korrupsiyaviy omillar kamayadi. Xizmat ko'rsatishda inson omilining kamayishi korrupsion risklarni sezilarli darajada qisqartiradi. Hujjatlarni avtomatik tarzda shakllantirish, ma'lumotlarni elektron tarzda tekshirish hamda jarayonlarning onlayn monitoringi davlat xizmatlarida adolat va shaffoflikni ta'minlashga xizmat qiladi.

Milliy iqtisodiyotning raqamli rivojlanishiga turtki beriladi. Yagona davlat raqamli platformasini joriy etish natijasida biznes uchun qulay sharoit yaratiladi. Tadbirkorlar hujjatlarni tezroq rasmiylashtirish, litsenziya va ruxsatnomalarni onlayn olish imkoniga ega bo'ladilar. Bu esa biznes muhitining jozibadorligini oshiradi va raqamli iqtisodiyotning rivojlanishiga kuchli turtki beradi. Shu bilan birga, mamlakatning xalqaro maydondagi raqobatbardoshligi ham ortadi.

Xulosa

O'zbekiston sharoitida yagona davlat raqamli platformasini shakllantirish davlat boshqaruvini zamonaviy bosqichga olib chiqadigan eng muhim islohotlardan biridir. Ushbu platforma orqali nafaqat davlat xizmatlarini tezkor, sifatli va shaffof tarzda ko'rsatish, balki fuqarolar hamda tadbirkorlik sub'yektlari uchun qulay raqamli muhit yaratish imkoniyati yuzaga keladi.

Mazkur platformani samarali joriy etish uchun quyidagi chora-tadbirlarni amalga oshirish tavsiya etiladi:

Davlat axborot tizimlarini integratsiyalashgan holda yagona standart asosida birlashtirish. Bu orqali idoralararo ma'lumot almashinuvi avtomatlashtiriladi, takroriy hujjatlar talab qilinishi kamayadi va fuqarolar uchun xizmat ko'rsatish tezlashadi. Shaxsiy ma'lumotlarni himoya qilish va kibermuhofaza bo'yicha xalqaro standartlarga mos qonunchilikni kuchaytirish. Fuqarolarning raqamli ishonchini mustahkamlash uchun axborot xavfsizligini ta'minlash va maxfiy ma'lumotlarning tarqalishining oldini olish muhim ahamiyat kasb etadi. Blockchain, sun'iy intellekt va Big Data texnologiyalarini bosqichma-bosqich joriy etish. Bu texnologiyalar xizmatlarning ishonchliligi va samaradorligini oshirish, ma'lumotlarni tahlil qilish asosida qaror qabul qilish jarayonlarini optimallashtirish imkonini beradi. Xalqaro tajribadan faol foydalanish. Xususan, Estoniya (X-Road), Singapur (Smart Nation) va Janubiy Koreya (Digital Government) kabi ilg'or modellarning afzalliklarini o'rganib, milliy sharoitga moslashtirilgan yechimlarni ishlab chiqish zarur.

Davlat xizmatchilarining raqamli savodxonligini oshirishga qaratilgan maxsus o'quv dasturlarini joriy etish. Raqamli hukumatning muvaffaqiyati bevosita inson resurslariga bog'liq bo'lib, davlat xizmatchilarining zamonaviy raqamli ko'nikmalarga ega bo'lishi hal qiluvchi omil hisoblanadi. Shu tariqa, yagona davlat raqamli platformasini shakllantirish nafaqat davlat xizmatlari sifatini oshiradi, balki O'zbekistonning xalqaro miqyosdagi raqamli iqtisodiyotga integratsiyasini jadallashtirib, mamlakatning innovatsion rivojlanishida muhim turtki bo'lib xizmat qiladi.

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TA’LIM TIZIMIDA ELEKTRON HUKUMAT, UNING O’RNI. TA’LIM SOHASIDA ELEKTRON BIZNES

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Annotatsiya: Raqamlashtirishning muhim ko‘rinishlaridan biri bu elektron hukumat bo‘lib, u davlat, fuqarolar va biznes o‘rtasidagi o‘zaro aloqalarni elektron xizmatlar orqali samarali tashkil etishga qaratilgan tashkiliy, texnologik va huquqiy yechimlar majmuasidir. Elektron hukumat endilikda faqatgina davlat xizmatlarini qulay shaklda taqdim etuvchi platforma emas, balki demokratiya institutlarini rivojlantirish, davlat hokimiyati shaffofligini oshirish, fuqarolarning davlat tuzilmalariga bo‘lgan ishonchini mustahkamlash va barqaror ijtimoiy-iqtisodiy taraqqiyotni ta’minlashning muhim vositasiga aylanib bormoqda.

Ta’lim tizimida elektron hukumatni ijro etilishi davlat xizmatlarini raqamlashtirish orqali ta’lim sohasida samaradorlik, shaffoflik va adolatni ta’minlash jarayoni hisoblanadi. Ta’lim sohasi elektron hukumatning muhim yo‘nalishlaridan biridir. Bunda zamonaviy ta’lim jarayoni davlat, ta’lim muassasalari, o‘qituvchilar, talabalar va ota-onalar o‘rtasidagi keng qamrovli hamkorlikni talab qiladi.

Kalit so‘zlar: ta’lim tizimi, **elektron hukumat, masofaviy ta’lim, raqamlashtirish**

I. KIRISH

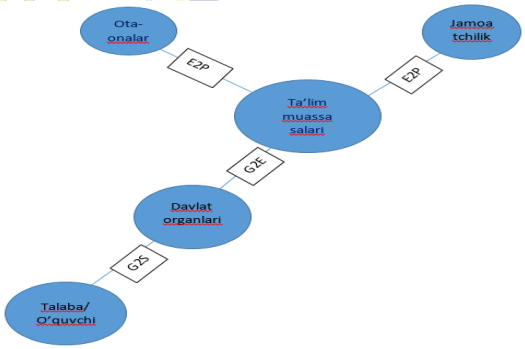
Bugungi kunda dunyo miqyosida ta’lim sohasini raqamlashtirish va zamonaviy texnologiyalarni keng qo‘llash jarayoni jadal sur’atlarda kechmoqda. Shu jihatdan elektron hukumat tizimi ta’lim jarayoniga ham faol joriy etilib, uning samaradorligini oshirishda muhim vositaga aylanmoqda. Elektron hukumat nafaqat davlat boshqaruvida, balki ta’lim tizimida ham shaffoflikni ta’minlash, byurokratik to‘siqlarni kamaytirish, o‘quvchilarga hamda talabalar uchun qulaylik yaratishda katta ahamiyat kasb etadi.

Elektron hukumat davlat boshqaruvi jarayonlarini axborot-kommunikatsiya texnologiyalari orqali avtomatlashtirish, fuqarolar, tashkilotlar hamda davlat organlari o‘rtasidagi aloqalarni samarali tashkil etish tizimi bo’lib hisoblanadi.

Elektron hukumatning o‘quv tizimidagi modeli davlat organlari, ta’lim muassasalari, talabalar/o‘quvchilar, ota-onalar va jamoatchilik o‘rtasidagi elektron aloqalarni o‘z ichiga oladi. Quyida G2E, G2S, E2S, E2P va E2E aloqalari batafsil yoritilgan.

Government → Education (G2E) - (Davlat → Ta’lim muassasalari) maqsadi ta’lim siyosatini raqamli boshqarish, nazorat va moliyalashtirishni shaffof qilishdan iborat bo’lib, uning foydali tomonlari byurokratiyaning kamayishi va resurslarning adolatli taqsimlanishidir. Government → Student (G2S) - (Davlat → Talaba/O‘quvchi) maqsadi esa davlat xizmatlarini bevosita talaba/o‘quvchiga yetkazish va onlayn qabul, grant arizalari, diplom/sertifikatni tekshirish, stipendiya va kreditlar kabi xizmatlardan foydalanishdir. Education → Student (E2S)- (Ta’lim muassasasi → Talaba/O‘quvchi) o’rtasidagi xizmatlarga LMS, baholash tizimi, elektron kutubxona, shaxsiy kabinetlar va uning maqsadi esa maqsadi esa o‘quv jarayonini to‘liq raqamlashtirishdan iboratdir.— Education → Parent (E2P)- (Ta’lim muassasasi → Ota-ona) – bu ota-ona ishtirokini kuchaytirish va mas’uliyatni oshirish, farzandining davomat va baholari, kontrakt/to‘lov holati, onlayn yig‘ilishlar. Bunda muammo erta aniqlanadi, maktab-oila hamkorligi kuchayadi.— Education ↔ Education (E2E)- (Muassasadan muassasaga) tizimlararo hamkorlik, ma’lumot almashinuvi va sifatni boshqarish maqsadida, akademik kreditlarni ko‘chirish, qo‘shma dasturlar, o‘quv rejalari almashinuvi xizmatlarini bajarishlar amalga oshiriladi [1].

Elektron hukumat modeli sxemasini quyidagi diagrammada davlat organlari, ta’lim muassasalari, talabalar/o‘quvchilar, ota-onalar va jamoatchilik o‘rtasidagi G2E, G2S, E2S, E2P va E2E aloqalari ko‘rsatilgan:



1-rasm. O’quv tizimida elektron hukumat modeli

Elektron hukumatning ta’limdagi o‘rnini quyidagilarda ko’rish mumkin. Axborotga ochiq va tezkor kirishda ta’lim muassasalari faoliyati, qabul jarayonlari, grantlar, imtihon natijalari va boshqa ma’lumotlar davlat portalida shaffof holda taqdim etiladi, o‘quvchilar va ota-onalar uchun zarur ma’lumotlarni onlayn olish imkoniyati yaratiladi. Masofaviy xizmatlardan foydalanishda hujjat topshirish, o‘qishga qabul qilish, stipendiya va grantlarga ariza berish jarayonlari elektron shaklda amalga oshiriladi, masofaviy ta’lim tizimlari davlat tomonidan qo‘llab-quvvatlanadi va yagona platformalarda muvofiqlashtiriladi. Davlat va ta’lim muassasalari o‘rtasida samarali hamkorlik (G2E, G2S)larga vazirlik va idoralar ta’lim muassasalari faoliyatini nazorat qilish, hisobotlarni qabul qilish, litsenziya va akkreditatsiya jarayonlarini onlayn shaklda yuritadi**.** Talaba va ota-onalar bilan aloqalar (E2S, E2P) elektron kundalik va reyting

tizimlari orqali ota-onalar farzandining o'zlashtirish darajasini kuzatishi mumkin, talabalar davlat grantlari, kreditlari, turli ijtimoiy dasturlar haqida tezkor ma'lumot oladi. Shaxsiylashtirilgan ta'lim imkoniyatlari bu elektron hukumat portallari orqali talabalarning shaxsiy ma'lumotlari, o'quv natijalari va malaka ko'nikmalari yagona elektron bazada yuritiladi. Shaffoflik va korrupsiyani kamaytirish tushunchasini yoritadigan bo'lsak qabul jarayonlari, stipendiya taqsimoti, imtihon natijalarini e'lon qilish kabi jarayonlar elektron shaklda yuritilishi orqali adolat va shaffoflikni ta'minlash mumkin [4].

Ta'lim sifatini oshirishda elektron hukumat ta'lim tizimini monitoring qilish, reytinglarni shakllantirish va xalqaro standartlarga moslashtirishda muhim vosita bo'lib xizmat qiladi [2].

Elektron hukumatning eng asosiy afzalliklaridan biri bu shaffoflikdir. Ta'lim tizimida qabul jarayonlari, imtihon natijalari va grant taqsimoti elektron shaklda e'lon qilinadi. Bu esa inson omilidan kelib chiqadigan xatoliklar va turli adolatsizliklarning oldini oladi. Natijada har bir abituriyent yoki talaba o'z bilimiga yarasha natija olishini ta'minlashga xizmat qiladi.

Elektron hukumat orqali abituriyentlar va talabalar hujjat topshirish, kontrakt to'lovlarini amalga oshirish, stipendiyalar haqida ma'lumot olish kabi jarayonlarni uyidan chiqmagan holda bajarishi mumkin. Bu esa nafaqat vaqtni, balki mablag'ni ham tejash imkonini beradi.

An'anaviy ta'lim tizimida hujjat yig'ish va turli tashkilotlarga borib kelish ko'p vaqtni oladi. Elektron hukumat esa bu jarayonlarni onlayn shaklga o'tkazib, byurokratik to'siqlarni sezilarli darajada kamaytiradi.

COVID-19 pandemiyasi Yevropa bo'ylab masofaviy ta'limga o'tishni tezlashtirdi va raqamli ta'limning imkoniyatlari hamda kamchiliklarini namoyon qildi. Elektron hukumat infratuzilmasini (raqamli ID, o'zaro ishlaydigan ma'lumot tizimlari, milliy ta'lim platformalari va o'qituvchilarni qo'llab-quvvatlash dasturlari) samarali yo'lga qo'ygan mamlakatlar bu jarayonga ancha tez va sifatli moslasha oldilar. Ushbu maqola Yevropa mamlakatlari tajribasi asosida siyosiy saboqlarni, texnik va pedagogik eng yaxshi amaliyotlarni tahlil qiladi hamda ta'lim sohasida elektron hukumatni joriy etishni istagan siyosatchilar va rahbarlar uchun amaliy yo'l xaritasini taklif etadi [3].

Elektron hukumat masofaviy ta'limni milliy miqyosda samarali va ishonchli tashkil etish uchun asosiy tayanch xizmatlarni taqdim etadi: xavfsiz autentifikatsiya, ma'lumot tizimlari o'rtasida hamkorlik, yagona ta'lim platformalari, raqamli ma'muriy xizmatlar (qabul, grant, sertifikatlash), shuningdek, vazirlik, maktab, o'qituvchi, ota-ona va o'quvchilar o'rtasidagi tezkor aloqa kanallaridir.

Samarali tizimning asosiy tarkibiy qismlariga:

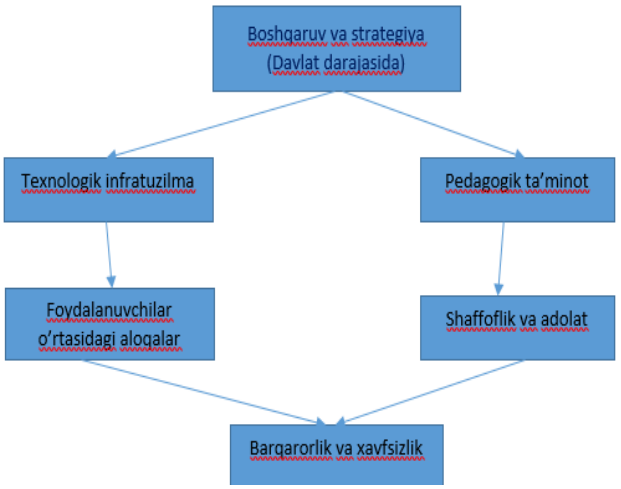
I. Raqamli identifikatsiya va xavfsiz kirish
II. Milliy yoki o'zaro ishlaydigan ta'lim platformalari
III. Internet va qurilmalarga ishonchli kirish
IV. O'qituvchilarni tayyorlash
V. Ma'lumotlarni himoya qilish va inklyuziya

Masofaviy ta'lim faqat texnologiyaga emas, balki samarali pedagogikaga asoslanishi kerak: faol o'qitish, muntazam fikr-mulohaza berish, sinxron va asinxron darslarni uyg'unlashtirish. Baholashda esa loyihalar, portfellar va o'qituvchi tomonidan nazorat qilingan topshiriqlar samarali hisoblanadi.

Elektron hukumat asosida masofaviy ta'lim quyidagilardan tashkil topadi:

Markaziy boshqaruv + yagona ta'lim portali + elektron identifikatsiya + o'qituvchilarni raqamli tayyorlash + shaffof baholash tizimi + inklyuziv ta'lim imkoniyatlari.

Natijada, ta'lim jarayoni samarali, shaffof, adolatli va barcha uchun teng imkoniyatli bo'ladi.



2-rasm. Elektron hukumat va masofaviy ta'lim modeli

Hozirgi kunda raqamli texnologiyalar jamiyat hayotining barcha jabhalariga, shu jumladan ta'lim sohasiga ham kirib bordi. An'anaviy o'quv jarayonlari asta-sekin elektron shakllarga o'tayotgani kabi, boshqaruv va xizmat ko'rsatish tizimida ham **elektron biznes (e-biznes)** tamoyillari keng qo'llanilmoqda. E-biznes ta'lim sifatini oshirish, resurslardan oqilona foydalanish va barcha ishtirokchilar o'rtasida samarali aloqa o'rnatishda muhim rol o'ynaydi. E-biznes vositalari orqali talabalar o'z uyidan chiqmagan holda kurslarga yozilishi, kontrakt to'lovlarini amalga oshirishi, elektron kutubxona va o'quv resurslaridan foydalanishi mumkin. Bu esa nafaqat vaqt va mablag'ni tejaydi, balki ta'limni yanada **moslashuvchan va hammabop** qiladi. Ayniqsa, chekka hududlardagi yoki imkoniyati cheklangan talabalar uchun katta imkoniyatlar yaratadi.

Ta'lim muassasalari e-biznes tizimlari yordamida o'quv jarayonini boshqarish, talabalar hujjatlari, moliyaviy

operatsiyalar va reytinglarni yuritishda tezkorlikka erishadi.

Shu bilan birgalikda E-biznesning eng muhim jihatlaridan biri — bu onlayn ta’lim platformalari (Coursera, Udemy, Khan Academy kabi) orqali bilim olish imkoniyatidir. Bu platformalar e-biznes modeli asosida ishlaydi: kurslar pullik yoki tekin taqdim etiladi, to‘lovlar onlayn amalga oshiriladi, talaba va o‘quvchilar esa sertifikat olish imkoniga ega bo’ladi va dunyo miqyosida bilim almashinuvi va hamkorlik rivojlanadi. E-biznes ta’lim muassasalari va talabalar uchun yangi imkoniyatlar yaratadi. Talabalar onlayn loyihalar ustida ishlash, startaplar tashkil etish yoki yangi ta’lim texnologiyalarini ishlab chiqishda amaliy ko‘nikmalarga ega bo‘lishdir. Bu esa ularni raqamli iqtisodiyot uchun raqobatbardosh mutaxassislar bo’lishga yordam beradi.

Ta’lim sohasida e-biznesning o‘rni tobora kuchayib bormoqda. U nafaqat ta’limga kirishni osonlashtiradi va samaradorlikni oshiradi, balki talabalarni zamonaviy iqtisodiyot talablariga mos ravishda tayyorlaydi. Kelajakda ta’lim tizimi yanada elektron biznesga integratsiyalashgan holda rivojlanib, innovatsion va global raqamli makonda o‘z o‘rnini mustahkamlamoqda.

Ta’lim sohasi bilan elektron biznesni bir-biri bilan bog'liqliginiquyidagi ko'rinishda ko’rish mumkin:

1-jadval

Ta’lim sohasi	Elektron biznesdagi ko‘rinishi	Bog‘liqligi
Talabalarni qabul qilish	Onlayn ro‘yxatdan o‘tish tizimlari, elektron ariza topshirish	Talabalar uchun qulaylik, tezkor jarayon
To‘lov jarayonlari	Elektron to‘lov tizimlari (Payme, Click, karta orqali)	Moliyaviy jarayonlarning shaffofligi va tezligi
Dars materiallari	Onlayn kutubxonalar, elektron darsliklar, video darslar	O‘quv resurslariga istalgan joydan kirish imkoniyati
O‘qitish jarayoni	Virtual sinflar, MOOC platformalari (Coursera, Udemy)	Ta’limning moslashuvchanligi, global imkoniyatlar
Baholash va nazorat	Onlayn testlar, elektron reyting tizimlari	Shaffof va tezkor baholash jarayoni
Diplom va sertifikat berish	Elektron sertifikat, raqamli diplomlar	Hujjatlarning ishonchliligi va tezkor taqdim etilishi
Ota-onalar bilan aloqa	Elektron kundaliklar, onlayn monitoring tizimlari	Ota-onalar farzandi natijalarini kuzatib boradi
Ma’muriy boshqaruv	Avtomatlashtirilgan axborot tizimlari, CRM platformalari	Boshqaruvda samaradorlik va vaqtni tejash
Hamkorlik va hamjihatlik	Video konferensiya, onlayn forumlar, muloqot platformalari	Talaba, o‘qituvchi va muassasa o‘rtasida faol aloqa
Innovatsiya va tadbirkorlikni rivojlantirish	Startap platformalari, onlayn loyiha boshqaruvi vositalari	Talabalar raqamli iqtisodiyot uchun tayyorlanadi

O‘quv tizimida elektron hukumat modeli davlat, ta’lim muassasalari, talabalar, ota-onalar va jamoatchilik o‘rtasidagi samarali raqamli hamkorlikni ta’minlaydi. Bu tizim ta’lim jarayonida shaffoflik, tezkorlik va qulaylikni oshirishda muhim vosita hisoblanadi. Texnologiya bu vosita, ammo uni samarali boshqarish elektron hukumat orqali amalga oshiriladi. Yevropa tajribasi shuni ko‘rsatadiki, elektron ID, milliy platformalar, o‘qituvchilarni qo‘llab-quvvatlash, moliyalashtirish va ma’lumotlarni himoya qilishni uyg‘unlashtirgan davlatlar masofaviy ta’limni muvaffaqiyatli tashkil etmoqda. Bu tajriba boshqa mamlakatlar uchun ham universal model bo‘lib xizmat qilishi mumkin. Ta’lim sohasida e-biznesning o‘rni tobora kuchayib bormoqda. U nafaqat ta’limga kirishni osonlashtiradi va samaradorlikni oshiradi, balki talabalarni zamonaviy iqtisodiyot talablariga mos ravishda tayyorlaydi. Kelajakda ta’lim tizimi yanada elektron biznesga integratsiyalashgan holda rivojlanib, innovatsion va global raqamli makonda o‘z o‘rnini mustahkamlamoqda.

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СТРАТЕГИИ ФОРМИРОВАНИЯ И РАЗВИТИЯ ЭЛЕКТРОННОГО ПРАВИТЕЛЬСТВО В РЕГИОНАЛЬНОМ МАСШТАБЕ

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Аннотация: *рассматриваются вопросы развития электронного правительства в региональном масштабе, отмечается что, электронное правительство - социальный феномен, характеризующийся переносом посредством информационно-коммуникационных технологий внутригосударственных информационных потоков, информационных потоков между государством и его гражданами и информационных потоков между государством и негосударственными институтами в виртуальную информационную среду, развитие которого проходит четыре этапа: информационное присутствие, интерактивное взаимодействие, транзакционное взаимодействие, трансформация, при этом базовая модель управления становлением и развитием электронного правительства состоит из четырех этапов: построение ИКТ-инфраструктуры государства, реализация пилотных проектов, интеграция межведомственных информационных ресурсов на основе единых стандартов, трансформация и эволюция системы государственного управления на основе электронного правительства, также отмечается, для того чтобы эффективно реализовать электронное правительство в государственном масштабе, необходимо улучшить механизмы межуровневого взаимодействия властей с помощью следующих действий: модификация инфраструктуры управления электронным правительством на федеральном уровне, совершенствование механизмов межуровневого взаимодействия властей па основе ИКТ, масштабирование типовых технологических решений с учетом особенностей каждого региона, развитие регионального электронного правительства в тесной увязке с административной реформой и усилением роли муниципального уровня управления. Необходимо также синхронизировать процессы информатизации государства и общества.*

Ключевые слова: *частичная, слабая, автоматизация; стихийная, несистемная, интенсивная информатизация; управляемая, системная, трансформирующая информатизация.*

Интенсивное развитие информационно-коммуникационных технологий (ИКТ) и компьютерных сетей началось в 60-х годах XX века, причем при непосредственном участии государства. И несмотря на то, что традиции использования ИКТ, сложившиеся в государственном секторе, имеют наиболее давнюю историю, вплоть до середины 90-х годов XX века ИКТ приносили максимальную прибыль и успех коммерческому сектору, в первую очередь транснациональным ИТ-корпорациям: Microsoft, Intel, IBM. Однако в середине 90-х годов XX века в мире оформился ряд тенденций, позволивших утверждать, что дальнейшее развитие, усиление, выживание национальных государств возможно только при условии системного и всеохватывающего использования ИКТ.

Во-первых, процесс глобализации означает необходимость более тесного и интенсивного сотрудничества на межгосударственном уровне, координации усилий в экономике, политике. Единственный способ реализовать взаимодействие в условиях формирующейся глобальной информационной среды - это разработать систему международных коммуникаций на основе ИКТ и Интернета. В этой связи подписание Окинавской хартии в 2000 г. странами «большой восьмерки», дальнейшая выработка совместных действий по глобальному развитию ИКТ в рамках рабочей группы DOT FORCE в Генуе в 2001 г., разработка системы ежегодного мониторинга и оценки развития ИКТ на уровне государств международными организациями (ООН, ОЭСР, Мировой Банк) говорят о стремлении использовать ИКТ как стратегический ресурс государственного развития.

Во-вторых, успехи коммерческих компаний, активно использующих ИКТ в своей деятельности, объясняются высоким качеством услуг и продуктов, создаваемых в условиях информационного общества при индивидуальном подходе к каждому клиенту. Осознанной потребностью социума по отношению к государству становится требование изменения «профессионального подхода» к потребностям гражданина, формирования более эффективной и результативной системы коммуникаций между государством и обществом.

В-третьих, очевидный кризис развития государства как бюрократической машины, выражающийся в постоянном воспроизводстве и даже увеличении числа государственных ARPA - агентство Министерства обороны США, разработавшее сеть ARPANET-Опыт разработок ARPA был использован и при создании сети Интернет.

Для успеха реализации ЦП «Электронный Узбекистан», необходимо обеспечить ее адекватность потребностям национального общества. Выявив потребности социума, государство должно из потребителя опыта коммерческих корпораций в сфере использования ИКТ превратиться в ключевого игрока, формулирующего и финансирующего социальные проекты, которые можно эффективно реализовать на основе ИКТ.

Термин «электронное правительство» используется для обозначения процесса электронизации» государственного управления как составной части государственной стратегии развития информационного общества. Если необходимо подчеркнуть системный или целостный подход с вовлечением в государственную информатизацию помимо исполнительной власти еще и законодательной и судебной, употребляется термин «электронное государство».

Определилось несколько подходов к реализации электронного правительства. Технократический (или архитектурный) подход требует ревизии существующих в государственных организациях процессов, процедур, регламентов с последующей их формализацией и фиксацией с помощью информационных систем. Несмотря на то, что этот подход является способом переосмысления существующих в государственном секторе управленческих механизмов, такие социальные факторы, как структура неформальных связей, основанные на определенных культурных особенностях поведенческие модели индивидов в организации и т.п. не рассматриваются. Альтернативным является подход «институционализации ИКТ», в котором применению ИКТ предшествует изучение сложившейся в государственной организации как социальной системе культурно-ценностных установок, структуры вертикальных и горизонтальных коммуникаций, управленческой методологии. Сторонники данного подхода рассматривают, в первую очередь, социальные детерминанты, определяющие процесс развития электронного правительства. Иными словами, то, какие ИКТ и как будут применены в контексте государственной организации как социальной системы.

Еще одним предельно практическим подходом является так называемый «государственный информационный менеджмент». В отличие от архитектурного для данного подхода актуальны проблемы трансформации внутренних и внешних отношений государственной организации, анализа системы ценностей организации и ее структуры, увеличение роли информации и знаний в повседневной работе государственных служащих, пересмотр внутренних процедур и функций как результата появления дополнительных электронных каналов коммуникации внутри организации. Этот подход предполагает разработку и применение комплекса мер, направленных на максимально эффективное практическое внедрение информационных систем и продуктов в государственной организации на основе активного заимствования опыта внедрения ИКТ коммерческими компаниями.

В условиях информационного общества право определять приоритеты развития социума переходит от делового сообщества к правительству при условии, что правительство продолжает развивать инновационную и научную сферу исследований. Именно представители науки и эксперты-профессионалы приобретут политический вес в государственной бюрократической среде, становясь в силу собственного профессионализма новой государственной элитой, поскольку обладание полнотой информации и знаний является определяющим фактором в постиндустриальную эпоху, в отличие от решающей роли финансового богатства. У правительств появятся новые технологические инструменты для расчета эффективности и полезности затрат, совершенствования механизма принятия решений. Однако «когда какое-либо агентство, обладающее властью, устанавливает бюрократические нормы и стремится во что бы то ни стало насаждать их, создается угроза злоупотреблений». Государственные информационные злоупотребления могут выражаться в желании получить о гражданине информации больше, чем это определено законом, либо в распространении или использовании конфиденциальной (приватной) информации о гражданине без его санкции.

Распространение ИКТ и их широкое использование влекут за собой появление «информационального капитализма» и «нового общества», в котором доминирует сетевой принцип организации не только социальных связей, но и деятельности коммерческих компаний. Кастельс подчеркивает, что наибольшую экономическую ценность приобретает производство информации (знаний), при этом основные капиталистические ценности (получение прибыли, частная собственность, власть рынка) остаются неизменными. «Новое общество» характеризуется возникновением сетевых движений, ориентированных на проект (например, феминизм), а также трансформацией не справляющихся с возрастающими информационными потоками вертикальных, иерархических структур и связей в государственных организациях и в коммерческих корпорациях в горизонтальные или сетевые.

В условиях функционирования сетевого общества и развития глобальной ИКТ-инфраструктуры, государство лишается возможности контролировать не только деятельность граждан, но и вынуждено считаться с увеличивающейся финансовой и управленческой автономией своих административных единиц. При этом государство не перестает играть сколько-нибудь значительную роль

в сетевом обществе. Оно должно использовать ИТ и Интернет как новый канал для налаживания взаимодействия с гражданами, упрочивая тем самым свою легитимность.

Электронное правительство определило новый этап системного использования ИКТ в государственном управлении. Здесь речь идет о новой парадигме государственного управления, в которой правила, механизмы управления функционируют на основе информационных систем или, другими словами, об институционализации ИКТ в системе государственного управления. Но можно ли говорить о «статическом встраивании» ИКТ в государственное управление? Под «статичностью» ИКТ подразумевается зафиксированные технологичные решения, претендующие на универсальность в разрешении проблем и вызовов, стоящих перед современными государствами. Проблема состоит в частой и систематической замене устаревающих технологий на новые. Причины замены могут быть продиктованы как объективными факторами, например, увеличением производительности, так и желанием крупнейших коммерческих ИТ-корпораций обеспечить продвижение своих новых ИТ-продуктов на мировые рынки.

На современном этапе развития Узбекистан выбрал стратегию перехода к публичному типу государственного управления. Одним из важнейших направлений реализации данной стратегии является модернизация системы государственного управления посредством осуществления государственных проектов развития электронного правительства. Закрепившиеся в государственных органах власти традиционные схемы организации деятельности, ориентированные па решение типовых проблем в соответствии с формализованными алгоритмами и функциональным подходом, существенно осложняют внедрение современных инновационных методов работы. Решение задачи модернизации системы публичного управления невозможно с помощью бюрократических методов, что послужило императивом широкого использования проектного подхода при формировании и развитии электронного правительства. Однако, как показала практика, немало таких проектов в последние годы оказались малорезультативными. Данный факт определяет необходимость создания четкого и адекватного инструментария управления государственными проектами на базе трансферта и адаптации управленческих подходов, активно используемых бизнес-структурами. Для распространения технологий менеджмента, неоднократно доказавших свою эффективность в бизнес-среде, а также в целях развития публичного управления в стране, целесообразно развивать государственно-частное партнерство в форме аутсорсинга части государственных функций по исполнению проекта. Поэтому разработка направлений повышения эффективности управления государственными проектами в сфере развития электронного правительства на основе внедрения проектного подхода в деятельность органов власти является актуальной научной и практической задачей.

При разработке «корпоративной» концепции управления проектами для каждого органа власти или государственной организации на основе существующих стандартов должна учитываться совокупность факторов: Во-первых, особенности государственных проектов как объекта управления: целеполагание, жесткие нормативно-правовые рамки, заинтересованные стороны, управление бюджетными финансами и рисками, подотчетность общественности, необходимость оценки социальной эффективности и другое. Во-вторых, это специфическая сфера применения проектно-управленческих методологических решений. Другими словами, требуется анализ целей, задач, особенностей проектов развития электронного правительства, которые, с одной стороны, ориентированы на развитие информационно-коммуникационных технологий, а с другой стороны, предполагают перестройку административных процедур, организационной структуры и, в целом, ценностей системы государственного управления. В-третьих, существующий уровень зрелости использования проектного управлении, а также восприимчивость государственных структур и способность принять новую управленческую концепцию, сделав ее фактически частью своей деятельности. Причина широкого распространения проектного управления - это синергетический эффект функционирования системы институтов и взаимодополняющих друг друга стандартов, использования концепции управления социальными и техническими сторонами проекта на основе особого построения организационных структур, комплексного управления жизненными стадиями и функциональными областями проекта с помощью интеграции набора высокоэффективных методов и инструментов управления проектом, его содержанием, сроками, стоимостью, качеством, человеческими ресурсами, коммуникациями, рисками, закупками и заинтересованными сторонами. В силу существования определенных проблем и противоречий, а также функциональных особенностей государственными проектами российской её современное системы управления состояние можно охарактеризовать следующими детерминантами: методы и инструменты проектного управления применяют 13,4 % государственных органах исполнительной власти (ГОИВ), 12,5 % органов исполнительной власти субъектов РУз (ОИВ субъектов РУз) и 81,5 % госкомпаний; термины проектного управления используются в 69,2 % ГОИВ, 70 % ОИВ субъектов РУз и в 100 % компаний с государственным участием; «проектный комитет» (коллегиальный 15 орган по координации

использования методов и инструментов проектного управления в органах исполнительной власти или его аналог) создан в 23,1 % ГОИВ, 18,7 % ОИВ субъектов РУз и 72,7 % госкомпаний; «проектный офис» (или его аналог) создан в 38.5 % ГОИВ, 31.2 % ОИВ субъектов РУз и 100 % госкомпаний.

Большинство региональных органов исполнительной власти, участвующих в исследовании, демонстрируют низкий уровень использования проектных принципов деятельности: не распространены организационные структуры проектного управления, отсутствует соответствующее обучение и мотивация сотрудников. При этом компании с государственным участием проявляют большую активность в развитии данного подхода, что является проявлением одного из преимуществ государственно-частного партнерства.

Итоги проведенного анализа состояния системы государственного управления позволяют выделить императивы, определяющие перспективы развития и практического внедрения проектного управления в органах власти: 1) активная деятельность основных институтов развития проектного управления в органах власти по расширению соответствующей методологической и нормативно-правовой базы. Основным таким институтом является Совет по внедрению проектного управления в органах исполнительной власти при Минэкономразвития РУз, который аккумулирует наиболее успешный опыт проектного управления, проводит совещания по обсуждению достижений пилотных площадок внедрения данного подхода; 2) проектное управление должно стать неотъемлемым элементом реализации стратегических целей государства; 3) преодоление заблуждений и пассивного сопротивления при внедрении проектного управления, а также уход от функционального подхода к реализации проектов на основе «живой методологии»; 4) привлечение к управлению государственными проектами профессионалов проектного управления в индивидуальном порядке в качестве консультантов, а также на основе создания совместных государственно-частных проектных офисов; 6) повсеместное обучение государственных служащих современным методам проектного управления и организации сертификации по специально разработанному для узбекских госструктур стандарту проектного управления; 7) мотивирование государственных служащих и должностных лиц к участию в работе проектных офисов и к использованию технологий проектного управления, в том числе на основе включения этих критериев в систему оценки их деятельности; 8) создание и распространение унифицированного, гибкого и доступного программного обеспечения поддержки проектной деятельности в органах власти.

С точки зрения развития публичного характера управления можно выделить три укрупненных модуля электронного правительства: модуль «Электронная демократия и участие» (голосование, порталы, социальные сети и т.д.); модуль «Электронные публичные услуги» (порталы и многофункциональные центры предоставления муниципальных услуг и т.д.); модуль «Электронные функциональные средства» (ситуационные центры, защищенные каналы связи, специализированные программные средства и т.д.). Благодаря такой структуре электронное правительство способствует устранению «организационного лага» в реализации стратегии модернизации государственного управления и развитию новой модели публичного управления в стране, делая деятельность государственных структур более прозрачной и эффективной.

Процесс модернизации государственного управления на основе создания электронного правительства был так же, как и в большинстве европейских стран, инициирован сверху. Единое понимание стратегии развития электронного правительства в пределах региона и в масштабах всей страны позволит достичь синергетического эффекта от многочисленных государственных проектов и систематизировать опыт управления проектами.

Процесс построения национального электронного правительства развивается в разных государствах по-разному. Однако, по нашему мнению, можно выделить группы государств, для которых процесс построения электронного правительства протекает похожим образом в силу наличия общих принципов в социальном, политическом и экономическом развитии. Различия внутри группы не носят принципиального характера с точки зрения построения электронного правительства. Прежде чем предложить классификацию национальных моделей электронного правительства, выделим основные параметры, предопределяющие процесс развития национального электронного правительства.

Государственная стратегия развития электронного правительства, учитывающая комплекс взаимосвязанных мероприятий в отраслевых сферах деятельности государства, с указанием сроков, бюджетов, организаций-исполнителей, организаций-заказчиков, отвечающих за результат проекта. Нормативная база, регулирующая использование ИКТ в государственном секторе. Государственная структура управления электронным правительством, в которую входят: организация, финансирующая проекты ЭП, организация - разработчик стратегии, организация - главный исполнитель стратегии ЭП и сотрудничающие с ней в реализации ЭП региональные и муниципальные организации, координационный экспертный совет, включающий представителей государства, бизнеса, гражданского общества.

Совокупность реализованных и реализуемых проектов государственной информатизации. Межуровневые взаимоотношения органов власти, особенности государственной службы, традиции и особенности государственного управления. Система культурных ценностей, социальные приоритеты, потребности и стимулы в развитии общества.

В основу предлагаемой классификации мирового опыта электронного правительства легла гипотеза о том, что на то, как будет протекать реализация ЭП и какие результаты предполагается достигнуть, наибольшее влияние оказывают сложившаяся в ходе объективного исторического развития система государственного управления и государственной службы, характеризующиеся национальными традициями, системой общественных верований, убеждений и мифов. Таким образом, прогнозируется, что электронное правительство лишь отразит характерные черты и особенности национального государства и не может рассматриваться лишь как технологический феномен. Анализ процессов государственной информатизации позволяет утверждать, что последние лишь подчеркивают систему ценностных и социально-культурных особенностей государства. Для обоснования данной гипотезы логично воспользоваться разработками сравнительной политологии, концепциями государственного управления и фактологическим материалом истории развития электронного правительства в государстве.

Несмотря на существующую классификацию государств в сравнительной политологии: северные страны, страны англо-саксонского мира, страны юго-восточной Азии, европейские страны, не удается применить данную типологию по отношению к электронным правительствам, создаваемым в этих странах. Например, несмотря на очевидные различия в государственной службе и особенностях бюрократий в Германии и США, с точки зрения информатизации эти государства попадают в одну группу, поскольку исповедуемые ими подходы совпадают. Куда более продуктивным является подход по классификации государственной информатизации с точки зрения концепций государственного управления: классическая бюрократия, Новый Государственный Менеджмент (New Public Management, NPM), Хорошее управление (Good Governance). Однако в данном случае классификацию придется ограничивать лишь узким набором характерных черт, которые принципиально отличают один вид концепции государственного управления от другой.

Во-первых, ни NPM, ни Good Governance не отказывают государственной бюрократии в существовании. Совершенно очевидно, что можно ограничить пределы распространения бюрократических принципов в государственном секторе, но как раз не в той его части, в которой принимаются ключевые политические и стратегические государственные решения. NPM, появившись раньше, чем Good Governance был, в первую очередь, способом преобразовать неэффективную бюрократию. В то же время, если бы NPM удалось разрешить большую часть накопившихся проблем в государственном управлении (экономическая эффективность без социальной справедливости, непрочное положение государственного служащего и его зависимость от начальства, проблема единства управления в связи с пересмотром вертикальных и горизонтальных связей), то не появилась бы концепция Governance, а затем и Good Governance.

Реальные проблемы, с которыми сталкиваются власть и граждане, решаются на региональном и муниципальном уровнях государственного управления. В то же время из-за слабого финансирования и отсутствия нужного числа квалифицированных государственных кадров не удается в полной мере оценить преимущества электронного правительства на региональном уровне. Выявление общего и отличного в процессах реализации электронного правительства на региональном уровне позволит внести коррективы в планы развития аналогичных государственных программ и на региональном уровне.

Выбор в качестве базы для социологического исследования именно регионального уровня обусловлен целым рядом причин. Во-первых, существующие на сегодняшний день исследования в области электронного правительства уделяли основное внимание именно государственному уровню. Среди исследований регионального уровня можно упомянуть лишь книгу «Региональное электронное правительство: стратегия создания, архитектура, типовые решения», которая носит не столько исследовательский, сколько рекомендательный характер, и посвящено в большей степени тому, как должно быть организовано электронное правительство на региональном уровне. Таким образом, фактически не существует серьезных открытых исследований того, что же в действительности происходит с электронным правительством в стране на региональном уровне.

В то же время не следует недооценивать значение регионального уровня электронного правительства. Ведь именно на этих уровнях оказываются основные государственные услуги населению и, следовательно, здесь должны развиваться и технологии оказания услуг в режиме он-лайн. В то же время государственный уровень не дает достаточно интересного материала для анализа, поскольку управление в современном государстве Узбекистан сконцентрировано на верхних уровнях власти. В условиях недостаточного финансирования даже существующего объема государственных услуг местного уровня, большая часть регионов не имеют возможности разрабатывать сложные информационные системы, финансовая отдача от

которых пока даже в самых успешных случаях не покрывает издержек. Как показывает практика, при разработке информационных систем в регионах инициатива исходит именно из регионального центра, администрации субъекта страны. Государственный центр может участвовать в процессе формирования стратегии электронного правительства через рекомендации, общее направление развития, частичное финансирование, однако решение по конкретным проектам, их дизайну, внедрению, поддержке остается на уровне региона. Причем зачастую развитие «электронного региона» во многом зависит от первого лица субъекта страны, его элементарной компьютерной грамотности и склонности к реформированию существующей организационной структуры.

С другой стороны, в силу неоднородности республиканских регионов, асимметрии их отношений с государственным центром рассмотрение электронного правительства не может дать адекватной картины применения ИКТ в государственном управлении в целом. Для этой цели также региональный уровень исследования подходит в наибольшей степени, поскольку, как правило, регион представляет собой территорию более или менее однородного уровня развития.

Наконец, региональный уровень представляется плодотворным полем для исследования, поскольку он предоставляет широкие возможности для сравнительного анализа. К примеру, для выявления ключевых факторов успеха или неуспеха «э-проектов» возможно сравнение сходных по уровню развития ИКТ регионов или, напротив, сопоставление электронных правительств в регионах одного уровня социально-экономического развития. Исследование еще не завершено, и еще рано говорить о его окончательных результатах, однако промежуточные данные позволяют утверждать, что высокий экономический потенциал региона и наличие большого объема финансовых средств являются важным, но далеко не единственным фактором развития ИКТ. Характерным контрпримером является республика Узбекистан, несколько более подробно рассмотренная ниже: при достаточно скромных стартовых возможностях и отсутствии значительных природных ресурсов, этот регион по многим параметрам является лидером среди азиатских регионов. Особенно подчеркивает успех Республики Узбекистан пример таких соседних регионов, как Республика Таджикистан, обладающая несравненно более высоким экономическим, социальным, образовательным потенциалом, однако не достигшая сколько-нибудь значимых достижений в терминах электронного правительства.

Поэтому целью проводимого исследования было выявить особенности формирования и развития электронного правительства Республики Узбекистан в контексте эффективности управленческих механизмов межуровневого взаимодействия властей в региональном масштабе. В качестве задач исследования мы видим следующие:

Оценить степень готовности в разрезе регионов к электронному правительству.

На основе эмпирического материала сформировать классификацию моделей развития регионального электронного правительства в стране.

Определить барьеры, препятствующие развитию регионального электронного правительства в стране.

Предложить рекомендации по повышению эффективности взаимодействия уровней власти в процессе управления созданием и развитием ЭП.

В основе нашего исследования лежит следующая гипотеза: формирование и реализация стратегии развития электронного правительства на региональном уровне определяет успех информатизации в стране в национальном масштабе.

Таким образом, эволюция электронного правительства предопределяется, с одной стороны, необходимостью осуществления технологических инноваций, а с другой стороны – непрекращающимся развитием государственного управления как такового: появлением новых управленческих концепций, реализацией административных реформ, непрерывным совершенствованием законодательной базы, постоянной выработкой и уточнением государственных стандартов, регламентации и правил. Развитие электронного правительства как элемента системы государственного управления, как социального феномена, востребованного обществом, позволяет судить о правильности выбора и реализации стратегии перехода к информационному обществу, чьей составной частью и является электронное государственное управление.

С точки зрения управления информационными потоками в рамках концепции электронного правительства прослеживаются две тенденции, не зависящие от отраслевой специфики деятельности государства: растущая информационная наполняемость доступных из внешней для государства среды информационных ресурсов и интеграция информационных ресурсов внутренних государственных информационных систем.

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JAMIYATNI RAQAMLASHTIRISH JARAYONIDA ELEKTRON TIJORAT TIZIMINI TAKOMILLASHTIRISH TENDENSIYALARI

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Annotatsiya: **Elektron tijorat - bu tashkilotlarga global bozorlarni o'rganish imkonini beruvchi biznes modeli bo'lib. Keyinchalik, elektron tijorat ko'plab xaridlar ishtirokchilari o'rtasidagi aloqalarni ifodalashi mumkinligi, lekin asosan B2C modeli orqali qo'llanilishi ta'kidlandi. Elektron tijoratni qabul qilish turli xil internet texnikasi va vositalari bilan bog'liq bo'lib, bu bir qator afzallik va xavflarga ega. Ushbu tadqiqot, shuningdek, elektron tijoratning globallashuv, elektron bozorlar va platformalar bilan bog'liqligini ta'kidlaydi. Elektron savdo, marketing va mijozlarga xizmat ko'rsatish nuqtai nazaridan taqdim etadilar, ular elektron sotuvchilar elektron tijorat strategiyasini va elektron xaridorlarning bir hil guruhlarini yaratish uchun ishlatilishi kerak bo'lgan yosh segmentatsiyasi mezonlarini belgilashda hisobga olishlari kerak.**

Kalit so'zlar: Jamiyatni raqamlashtirish, elektron tijorat (e-commerce), raqamli transformatsiya, raqamli to'lov tizimlari, mobil savdo (M-commerce), transchegaraviy e-tijorat, logistika va yetkazib berish tizimi, ijtimoiy tarmoqlarda savdo (social commerce), Raqamli iqtisodiyot.

I. Kirish

Yangi davrga o'tish, inson faoliyatining o'zgarishi va raqamlashtirilishi aynan elektron tijorati sohasida, shuningdek, butun iqtisodiyotda savdo aylanmasining jadal rivojlanishi va o'sishiga xizmat qildi. Internet platformasi savdo o'sib borayotgan soha va ayni paytda iqtisodiyot uchun kuchli asos bo'lib xizmat qilmoqda. Savdoning yangi turi aholi bandligini ta'minlash, o'zini-o'zi ish bilan ta'minlash uchun yangi istiqbollarni ochib, xususiy tadbirkorlik rivojiga turtki bo'lmoqda. Biroq, bu hodisa unchalik yangi emas, chunki elektron tijoratga birinchi qadamlar o'tgan asrning 70- yillarida qo'yilgan. Elektron tijoratning paydo bo'lish tarixi juda o'ziga xosdir negaki, shakllanish bosqichida elektron tijorat alohida soha sifatida emas, balki mijozlarni jalb qilish uchun xizmatning bir qismi sifatida yaratilgan. Raqamli texnologiyalariga tayanib, onlayn savdo asta-sekin rivojlandi. O'shandan beri sanoat rivojlanishning uchta keng bosqichidan o'tdi. Hozirgi bosqichda elektron tijorat, xuddi boshqa savdo turlari kabi, huquqiy tartibga solish va tushunchalarning huquqiy ta'rifini talab qiladi. Yillar davomida rivojlanib borayotgan elektron jarayonlar har bir sohada o'z o'rniga ega bo'lmoqda. Qaysi sohani tadqiq qilmaylik, internetning ish quroli sifatida faol ishlayotganligini ko'rishimiz mumkin. Shu jumladan elektron tijorat ham internetning bir mahsuli sifatida takomillashib bormoqda, hozirgi kunga kelib bu soha kirib bormagan hayotning biron jabhasi qolmadi.

II. Asosiy qisim

Elektron tijorat, elektron biznes va elektron marketing

Elektron biznes kelib chiqishiga nazar tashlaydigan bo'lsak, XX asrning ikkinchi yarmi boshlarida axborot texnologiyalari sohasi taraqqiy eta boshlagani bunga turtki bo'lganini kuzatishimiz mumkin. Tabiiyki, korxonalar o'rtasida va ularning ichida ma'lumotlar almashuvini soddalashtirish va arzonlashtirishda axborot-kommunikatsiya texnologiyalarining (AKT) roli beqiyos.

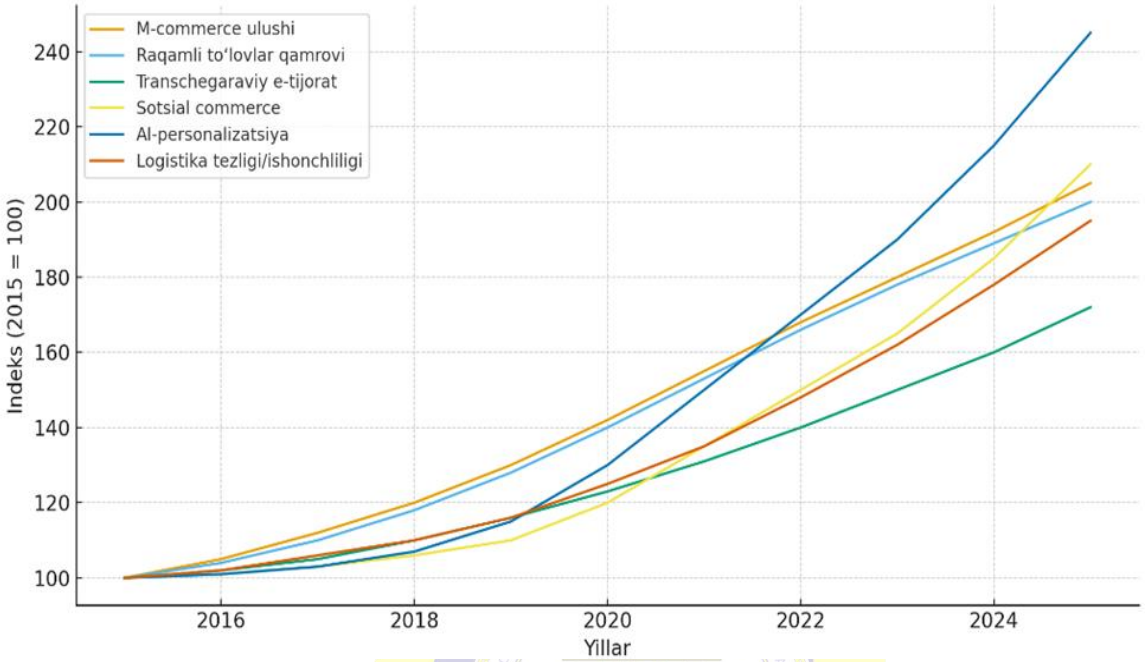
Elektron tijorat dasturlari tobora keng qamrovli yo'nalishlarni taqdim qilib bormoqda, qo'llanilishning ham yangi yo'nalishlari paydo bo'la boshladi. Buguni kunda bir necha to'liq shakllangan elektron tijorat tizimlarini sanab o'tishimiz mumkin.

Kompaniyaning bozor strategiyasiga qarab, Internetdagi quyidagi shakllari mavjud:

- elektron biznes karta;
- elektron katalog;
- elektron do'kon;
- internet do'kon.
- savdo internet-tizimlar;

Elektron biznes kartasi bir necha sahifalardan iborat bo'lgan kompaniya va uning faoliyati haqida ma'lumot. Bunday saytning asosiy vazifasi – potensial mijozga oddiy biznes ma'lumotnomasi yoki reklama e'loniga o'xshash bo'lib kompaniyaning xizmatlari

bilan tanishish uchun imkoniyat berish. Mijozni xabardor qilishning yanada rivojlangan shakli – bu tovarlar va xizmatlar haqida batafsil ma'lumot beruvchi va ko'pincha hozirgi narxlar bilan xabardor qiluvchi elektron katalog. Elektron do'kon sizga nafaqat mahsulot yoki xizmatni tanlash, balki Internet orqali buyurtma berish va xarid qilish imkoniyatini beradi.



1-rasm. Dunyoda elektron tijoratni o'sish dinamikasi

Elektron tijorat turlari

Biznesni rejalashtirishda mavjud bo'lgan turli xil elektron tijorat turlarini bilish muhim va foydalidir.

B2C (biznesdan iste'molchiga);

B2B (biznesdan biznesga);

C2B (iste'molchidan biznesga);

C2C (iste'molchidan iste'molchiga);

P2P (Peness) va (Peness);

G2B / C2G (Davlatdan biznesga / Iste'molchidan hukumatga).

Biznesdan iste'molchiga (B2C) elektron tijorat - bu kompaniya va yakuniy iste'molchi o'rtasidagi munosabatlarni tartibga soluvchi elektron biznes modeli.

Biznesdan biznesga (B2B) elektron tijorat: bu ko'proq xarajatlarni kamaytirish maqsadida tashkilotlar o'rtasida mahsulot va xizmatlarning tijorat tijorat tranzaksiyalarini amalga oshirishga imkon beruvchi elektron tijorat shakli.

Iste'molchidan iste'molchiga (C2C) elektron tijorat: iste'molchilardan iste'molchilarga bo'lgan operatsiyalarni nazorat qiluvchi elektron tijorat biznes modeli.

Iste'molchidan biznesga (C2B) elektron tijorat: ushbu platforma iste'molchi-biznes munosabatlarini rivojlantirishga xizmat qiladi, bunda iste'molchi kompaniya faoliyati to'g'risida fikr-mulohazalarini bildiradi[1,2].

Biznesdan xodimga (B2E) Elektron tijorat: B2E kompaniya-xodim o'rtasidagi barcha jarayonlarni, shu jumladan ikkalasi o'rtasidagi munosabatlarni, malakali jamoalarni jalb qilish va saqlash bo'yicha amalga oshirilgan tadbirlarni, ishga yollash operatsiyalarini bajarishni, taklif qilingan imtiyozlar va afzalliklar haqida ma'lumot berishni, o'qitish imkoniyatlarini va boshqalarni boshqaradigan elektron onlayn tijorat shakli sifatida aniqlanadi.

Mobil e-tijorat yoki M-Commerce: mahsulotlar xarid qilish, narxlarni taqqoslash, sayohatlarni bron qilish, bank hisobini tekshirish, istalgan joydan pul o'tkazmalarini amalga oshirish va boshqalar kabi faoliyat turlari turlicha bo'lgan ilovalar va mobil tarmoqlar va simsiz tarmoqlardan foydalangan holda onlayn tijorat operatsiyalarini amalga oshirish uchun smartfon va planshetlardan foydalanishni nazarda tutadi.

Ijtimoiy elektron tijorat: ushbu elektron tijorat shakli ijtimoiy tarmoqlarda bo'lib o'tadi va onlayn xarid vositalarini takomillashtirishga qaratilgan, kontent "yoqdi" va "baham ko'rish" soni orqali baholanadigan sahifalar haqida bildirishnomalar, ijtimoiy tarmoqlardagi "do'stlar" tavsiyalari va boshqalar

Elektron tijoratning boshqa ko'plab tasniflarini topish mumkin, ammo mualliflar odatda konsensual tarzda uchtasini aniqlaydilar: B2B, B2C va C2C.

Elektron tijoratning foydalari va xavflari

Elektron tijorat jamiyatni raqamlashtirish jarayonida iqtisodiy faoliyatning eng muhim yo'nalishlaridan biri sifatida alohida ahamiyat kasb etadi. Uning afzalliklari avvalo tezkorlik va qulaylikda

namoyon bo'ladi, ya'ni xaridor istalgan joyda va istalgan vaqtda mahsulot yoki xizmatlarni buyurtma qilish imkoniyatiga ega bo'ladi. Bundan tashqari, bozorda raqobat kuchayishi natijasida narxlarning pasayishi, mahsulot va xizmatlar sifatining oshishi, shuningdek, mijozlarga kengroq tanlov imkoniyatining yaratilishi elektron tijoratning ijobiy jihatlaridan hisoblanadi. Elektron platformalar orqali biznes yuritish kichik va o'rta korxonalar uchun yangi imkoniyatlar ochadi, ular geografik chegaralardan mustasno ravishda global bozorga chiqish imkoniyatiga ega bo'ladilar.

Shu bilan birga, raqamli texnologiyalar asosida ishlovchi to'lov tizimlari, elektron hujjat almashinuvi va avtomatlashtirilgan logistika jarayonlari savdo jarayonini ancha samarali qiladi. Biroq elektron tijorat bilan bog'liq xavflar ham mavjud. Eng avvalo, axborot xavfsizligi masalalari dolzarb bo'lib, mijozlarning shaxsiy ma'lumotlari va to'lov rekvizitlarining himoyasi talab etiladi. Firibgarlik, soxta mahsulotlar savdosi, kiberhujumlar elektron tijoratning asosiy xatarlaridan hisoblanadi. Shuningdek, yetkazib berishdagi kechikishlar, mahsulot sifati va kafolat masalalari iste'molchilar ishonchiga ta'sir ko'rsatadi. Shu sababli elektron tijorat tizimini takomillashtirish jarayonida nafaqat texnologik innovatsiyalar, balki xavfsizlik, huquqiy tartibga solish va iste'molchilar huquqlarini himoya qilish mexanizmlarini kuchaytirish muhim ahamiyatga ega[3,4].

Elektron tijorat, internet va 5G texnologiyasi

Elektron tijoratning rivojlanishi internet texnologiyalari va mobil aloqaning yangi bosqichlari bilan bevosita bog'liq bo'lib, ayniqsa 5G tarmog'ining joriy etilishi ushbu jarayonni yanada tezlashtirmoqda. Internet global miqyosda savdo-sotiqni amalga oshirish uchun asosiy platforma bo'lib xizmat qilmoqda, u orqali xaridorlar va sotuvchilar o'rtasida tezkor aloqa, to'lovlarni amalga oshirish, shuningdek, mahsulotlar haqida ma'lumot almashish jarayoni sodir bo'ladi. 5G texnologiyasi esa yuqori tezlikdagi ma'lumot uzatish, past kechikish va kengroq qamrov orqali elektron tijoratni yangi darajaga olib chiqadi. Bu texnologiya yordamida mobil ilovalar, onlayn-do'konlar va raqamli to'lov tizimlari yanada tezroq va ishonchli ishlaydi. Masalan, virtual va kengaytirilgan reallik asosidagi xarid qilish tajribasi 5G orqali yanada sifatli taqdim etiladi, bu esa iste'molchilarga mahsulotlarni realistik ko'rinishda sinovdan o'tkazish imkoniyatini beradi. Bundan tashqari, logistika tizimlarida IoT qurilmalari va aqlli sensorlar orqali tovarlarning real vaqt rejimida kuzatilishi ta'minlanadi. Natijada, 5G nafaqat elektron tijoratni tezkor va samarali qiladi, balki mijozlar uchun yangi xizmat turlarini yaratishga ham zamin hozirlaydi. Shu tariqa internet va 5G texnologiyasi elektron tijoratning kelajakdagi asosiy harakatlantiruvchi kuchlari sifatida namoyon bo'lmoqda.

Elektron savdo va globallashtirish

Global miqyosda elektron tijorat bozori doimiy ravishda kengayib, umumiy chakana savdo hajmining sezilarli qismini tashkil etmoqda. So'nggi yillarda elektron savdo sohasidagi yillik o'sish sur'ati 10-15% atrofida bo'lib, bu an'anaviy savdo shakllariga nisbatan ancha yuqori ko'rsatkichdir. Osiyo-Tinch okeani mintaqasi, Shimoliy Amerika va Yevropa elektron tijorat rivojlanishida yetakchi hududlar hisoblanadi. Ayniqsa, Xitoy va AQSh kabi mamlakatlar global elektron tijorat hajmida yetakchilik qilmoqda. Masalan, Xitoyning elektron savdo bozori 2024-yilda 2,8 trillion AQSh dollariga yetishi kutilmoqda, bu esa global elektron tijorat hajmining qariyb 50% ini tashkil etadi.

Dunyo miqyosida elektron tijorat platformalarining savdo hajmlari yildanyilga ortib bormoqda. Bu sohaga bo'lgan talabning o'sishi global bozorda yirik kompaniyalarning o'rnini mustahkamlashga olib kelmoqda. Quyida dunyoning eng yirik elektron tijorat platformalarining 2023-yildagi savdo hajmlari va ularning bozordagi o'rni batafsil yoritiladi. Amazon kompaniyasi global elektron tijoratning eng yirik ishtirokchilaridan biri hisoblanadi. 2023-yilda Amazon'ning umumiy savdo hajmi taxminan 600 milliard AQSh dollarini tashkil etdi. Ushbu ko'rsatkich kompaniyaning chakana savdo bozoridagi yetakchiligini tasdiqlaydi. Amazon mijozlarga keng mahsulot tanlovini, tezkor yetkazib berish xizmatlarini va raqamli texnologiyalar asosida rivojlangan to'lov tizimlarini taqdim etadi. Ayniqsa, Amazon Prime xizmati orqali obunachilar uchun tezkor yetkazib berish va eksklyuziv chegirmalar mavjudligi kompaniyaning mijozlar bazasini sezilarli darajada kengaytirishiga yordam berdi[5,6].

XULOSA

Jamiyatni raqamlashtirish jarayonida elektron tijorat tizimini takomillashtirish global iqtisodiy rivojlanishning muhim tarkibiy qismiga aylanmoqda. Raqamli transformatsiya sharoitida elektron tijorat nafaqat onlayn savdo platformalarini kengaytirish, balki innovatsion to'lov tizimlari, mobil savdo (m-commerce) imkoniyatlari, va logistika zanjirlarini optimallashtirish orqali ham shakllanmoqda. So'nggi yillarda ijtimoiy tarmoqlarda savdo (social commerce) va elektron tijoratning tez sur'atlarda o'sishi kuzatilmoqda. Bu jarayonlar iste'molchilarga qulaylik yaratish, korxonalarga esa yangi bozorlarni egallash imkonini bermoqda. Shuningdek, raqamli iqtisodiyotning rivojlanishi elektron tijorat tizimini yanada takomillashtirishni talab etmoqda.

Elektron tijorat tizimining dinamikasini tahlil qilish shuni ko'rsatadiki, uning muvaffaqiyatli rivojlanishi raqamli to'lov infratuzilmasi, ma'lumotlar

xavfsizligi, logistika samaradorligi va innovatsion texnologiyalarning joriy etilishi bilan bevosita bog‘liq. Jamiyatni raqamlashtirish jarayoni kuchaygani sari elektron tijorat global savdoning barqaror o‘sish omillaridan biriga aylanadi. Shu bois kelgusida elektron tijorat tizimini yanada takomillashtirish uchun davlat, xususiy sektor va ilmiy tadqiqot muassasalari hamkorligida kompleks strategiyalar ishlab chiqish dolzarb vazifa bo‘lib qolmoqda.

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RAQAMLI HUKUMAT TIZIMIDA INSON KAPITALI SUBINDEKSINI RIVOJLANTIRISHNING BENCHMARKING TAHLILI

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Annotatsiya **– Ushbu maqolada raqamli hukumatda inson kapitali subindeksini rivojlantirish masalalari benchmarking tahlili asosida yoritilgan. Inson kapitali — ta’lim, sog‘liqni saqlash, malaka va innovatsion faoliyat orqali jamiyatning raqobatbardoshligini oshiruvchi asosiy omil hisoblanadi. Raqamli hukumat sharoitida mazkur subindeksni rivojlantirish davlat xizmatlari sifatini oshirish, axborot texnologiyalaridan samarali foydalanish hamda fuqarolarning ijtimoiy faolligini kuchaytirishni talab etadi. Benchmarking tahlili esa ilg‘or tajribalarni solishtirish, milliy modelni takomillashtirish hamda barqaror raqamli transformatsiyani ta’minlash imkonini beradi.**

Kalit so‘zlar – raqamli hukumat, inson kapitali subindeksi, benchmarking tahlili, elektron hukumat, EGDI, OSI, TII, HCI, raqamli transformatsiya, davlat xizmatlari, raqamli savodxonlik, ta’lim tizim

I. KIRISH

Axborot-kommunikatsiya texnologiyalarining jadal rivojlanishi davlat boshqaruvi tizimida ham muhim o‘zgarishlarga sabab bo‘ldi. Bugungi kunda elektron hukumat (e-government) tushunchasi davlat xizmatlarini raqamlashtirish va avtomatlashtirish orqali fuqarolar va tadbirkorlik subyektlari bilan samarali muloqotni ta’minlash vositasi sifatida keng qo‘llanilmoqda. Ushbu tizim fuqarolar uchun davlat xizmatlaridan foydalanishni osonlashtirib, davlat idoralari faoliyatini shaffof va samarali qilishga xizmat qiladi[1,2].

Elektron hukumatning joriy etilishi davlat boshqaruvining samaradorligini oshirish, byurokratik jarayonlarni soddalashtirish hamda korrupsiyaga qarshi kurashish kabi muhim omillar bilan bog‘liq. Raqamli transformatsiya tufayli fuqarolar davlat xizmatlarini onlayn rejimda olish imkoniyatiga ega bo‘lib, vaqt va mablag‘ tejash imkoniyati yaratilmoqda.

O‘zbekiston Respublikasi ham elektron hukumat tizimini rivojlantirish bo‘yicha faol ish olib bormoqda. Xususan, “my.gov.uz” yagona interaktiv davlat xizmatlari portali orqali fuqarolar turli xizmatlardan foydalana oladi. Bundan tashqari, elektron imzo tizimi, soliq va bojxona xizmatlarining raqamlashtirilishi, mobil ilovalar orqali davlat xizmatlarining taqdim etilishi ushbu tizimning muhim jihatlaridan biri hisoblanadi.

II. ASOSIY QISM

O‘zbekiston Respublikasi Prezidentining 2023-yil 14-sentabrdagi PQ-308-son qaroriga muvofiq, mamlakatimizda elektron hukumatni rivojlantirish reytingining yangi subindekslari bo‘yicha chora-tadbirlar rejasini ishlab chiqish va amalga oshirish belgilangan. Ushbu qaror asosida, Birlashgan Millatlar Tashkilotining “Elektron hukumat tadqiqoti” hisobotidagi ko‘rsatkichlarni yaxshilash maqsadida quyidagi yo‘nalishlarda ishchi guruhlar tashkil etilgan[3,4,5].

1. Online Service Index (OSI) – Onlayn xizmatlar subindeksi;
2. Telecommunication Infrastructure Index (TII) – Telekommunikatsiya infratuzilmasi subindeksi;
3. Human Capital Index (HCI) – Inson kapitali subindeksi.

2022-yilda asosiy e’tibor EGDI (E-Government Development Index) uch komponenti – OSI, TII, va HCI – rivojlantirish tadqiqot metodologiyasidagi o‘zgarishlar;

2024-yilda bu indeksdan tashqari “Transformational Government” qaratilgan:

- Hukumatning raqamli yetukligi;
- Raqamli xizmatlar orqali real transformatsion natijalar;

• Ijtimoiy tenglik va inklyuzivlikka ta'siri;
• AI integratsiyasi indikatorlari (misol: chatbot, tahliliy tizimlar, prediktiv xizmatlar);
• Open Government Data (OGD) samaradorlik ko'rsatkichlari;
• User-centric design – xizmatlar foydalanuvchi ehtiyojlariga mos yoki yo'qligi.

Inson kapitali subindeksi bo'yicha olib borilgan benchmarking tahlili jarayonida Osiyo, Yevropa va Amerikaning yetakchi mamlakatlarining HCI bo'yicha 5 ta alohida indikatorlari asosida ko'rsatkichlar tahlil qilindi. *Tahlil uchun ishlatilgan manba:* Birlashgan millatlar tashkilotining (UN) "E-Government Survey 2024" Barqaror rivojlanish uchun raqamli transformatsiyani jadallashtirish nomli to'liq hisoboti va texnik ilovalari.

1-jadval. Rivojlangan davlatlarning 2024-yil natijalariga ko'ra HCI va EGDI indeks ko'rsatkichlari

Mamlakat	HCI 2024	HCI subindikatorlari					EGDI 2024
		Adult Literacy (%) – AL	Gross Enrollment Ratio (GER)	Expected Year of Schooling (EYS)	Mean Year of Schooling (MYS)	E-government Literacy (EGI)	
Daniya	0.9584	99	105.94	18.77	13	0.8333	0.9847
Estoniya	0.9497	99.87	98.85	15.94	13.5	1	0.9727
Singapur	0.9362	97.13	118.1	16.9	11.9	1	0.9691
Janubiy Korea	0.912	98.8	99.06	16.51	12.5	0.8333	0.9679
Islandiya	0.995	99	102.62	19.11	13.8	0.9444	0.9671
Saudiya Arabistoni	0.9067	97.59	96.81	16.1	11.3	1	0.9602
Buyuk Britaniya	0.945	99	99.47	17.63	13.4	0.8333	0.9577
Finlandiya	0.9836	99	117.54	19.23	12.9	0.9444	0.9575
Gollandiya	0.9688	99	103.75	18.58	12.6	0.9444	0.9538
Germaniya	0.9672	99	98.35	17.34	14.1	0.9444	0.9382
Yaponiya	0.9117	99	89.58	15.46	13.4	1	0.9351
AQSH	0.8842	99	96.96	16.41	13.7	0.6111	0.9194
Qozog'iston Respublikasi	0.8403	99.78	93.58	14.82	12.3	0.6667	0.9009
Shvetsariya	0.9026	99	94.6	16.58	13.9	0.7222	0.9003
Turkiya	0.9192	96.74	114.9	19.68	8.6	0.9444	0.8913
Xitoy	0.7902	97.15	89.96	14.2	7.6	0.9444	0.8718
Rossiya Federatsiyasi	0.8319	99.93	97.61	15.52	12.8	0.4444	0.8532
O'zbekiston Respublikasi	0.758	100	78.88	11.99	11.9	0.7222	0.7999

Tahlil natijalari: 2024-yil natijalariga ko'ra, Daniya, Estoniya va Singapur davlatlari elektron hukumatni rivojlantirish indeksi (EGDI) bo'yicha kuchli 3 talikdan joy olgan bo'lib, ushbu davlatlarning inson kapitali indeksi (HCI) bo'yicha ko'rsatkichlari hamda afzallik tomonlari quyidagi jadvalda keltirib o'tilgan[6,7,8].

2-jadval. HCI ko'rsatkichi bo'yicha eng yuqori 3 ta mamlakat ko'rsatkichlari va afzalliklari

Mamlakat	HCI 2024 ko'rsatkichi (%)	Afzallik tomonlari

Daniya	0.9584	Daniyada bolalar 3–5 yoshdan boshlab maktabgacha ta'limga deyarli to'liq qamrab olinadi. Daniyada majburiy ta'lim 10 yil (boshlang'ich va o'rta). Daniyada aholining 60–70% ga yaqini oliy ta'limga kiradi, shuning uchun hisob natijaga kuchli ta'sir qiladi. O'z navbatida Daniyada "life-long learning" (umr bo'yi ta'lim olish) keng tarqalgan. Yoshi kattalar ham ta'lim dasturlariga jalb etiladi, bu statistikani oshiradi. Yuqoridagilar ta'lim tizimi qamrovi (GER) hamda kutilayotgan ta'lim olish yili (EYS) indikatorining yuqori ko'rsatkichiga olib kelgan va bu ko'rsatkichlar mos ravishda 105.94 va 18.77 ni tashkil qiladi. Lekin elektron hukumat savodxonligi ko'rsatkichi nisbatan pastroq, taxminan 83-84% ni tashkil qiladi.
Estoniya	0.9497	Estoniyada maktabgacha ta'lim keng qamrab olingan. Bolalarning 5 yoshgacha yashab qolish ehtimoli taxminan 99,7% ni tashkil qiladi. Estoniya dunyoda raqamli ta'limni eng muvaffaqiyatli joriy qilgan davlatlardan biri bo'lib dars jarayonida raqamli platformalar keng qo'llaniladi. Boshlang'ich, o'rta ta'lim va gimnaziyalarda o'qish muddati jami 12 yil oliy ta'lim esa asosan 3 yilni tashkil qiladi. Boshlang'ich va o'rta ta'lim qamrovi 100%, oliy ta'lim qamrovi esa 60-70% ni tashkil qiladi. Estoniya o'quvchilari PISA testlarida dunyoda yetakchi hisoblanadi (matematika, tabiiy fanlar, o'qish bo'yicha Yevropada eng yuqori natijalarga erishgan). Yuqoridagilar ta'lim tizimi qamrovi (GER) hamda kutilayotgan ta'lim olish yili (EYS) indikatorining yuqori ko'rsatkichiga olib kelgan va bu ko'rsatkichlar mos ravishda 98.85 va 15.94 ni tashkil qiladi. O'z navbatida elektron hukumat savodxonligi ko'rsatkichi 100% ni tashkil qiladi.
Singapur	0.9362	Singapurda maktabgacha ta'lim 4-6 yosh oralig'ida bo'lib, bolalar to'liq qamrab olingan.Majburiy ta'lim 10- 11 yil bo'lib, undan tashqari Junior college yoki Polytechnic institutlarida o'qish 2-3 yilni tashkil qiladi. Aholining katta qismi universitet yoki politexnika institutlariga kiradi. Singapurda ham Strategik "SkillsFuture" dasturi doirasida "life-long learning" siyosati tufayli kattalar ham ta'lim oladi. Yuqoridagilar ta'lim tizimi qamrovi (GER) hamda kutilayotgan ta'lim olish yili (EYS) indikatorining yuqori ko'rsatkichiga olib kelgan va bu ko'rsatkichlar mos ravishda 118.1 va 16.9 ni tashkil qiladi. O'z navbatida elektron hukumat savodxonligi ko'rsatkichi 100% ni tashkil qiladi.

Inson kapitalini rivojlantirish subindeksi bo'yicha jahondagi TOP-5 va MDH TOP-3 yetakchi mamlakatlar tajribasini o'rganish tahlili.

1. Singapur Inson kapital indeksi (HCI): 0.88 – 0.90
2. Janubiy Koreya HCI: 0.82 – 0.84
3. Yaponiya HCI: 0.83 – 0.85
4. Shveytsariya HCI: 0.84 – 0.86
5. Kanada HCI: 0.78 – 0.80

Ta'lim: Singapur o'quvchilari PISA reytingida muntazam ravishda birinchi o'rinni egallab kelmoqda. Dasturlar STEM (science, technology, engineering, math) yo'nalishiga asoslangan.

Sog'liqni saqlash: Profilaktika va raqamli sog'liqni saqlash xizmatlari bilan aholini bolalik yoshidan kuzatish.

Kadrlar siyosati: Tanlov asosidagi davlat xizmatlari, ishchi kuchini moslashtirish bo'yicha doimiy o'qitish va tayyorlash markazlari (SkillsFuture dasturi).

Janubiy Koreya HCI: 0.82 – 0.84

Texnologik savodxonlik: Raqamli ko'nikmalarni bolalik yoshidan rivojlantirish.

Kuchli ta'lim tizimi: O'quvchilarning o'zlashtirish darajasi yuqori bo'lib, ular xalqaro testlarda muvaffaqiyatli natijalar ko'rsatishmoqda.

Kadrlar tayyorlash siyosati: Hukumat tomonidan moliyalashtirilgan professional o'qitish va IT, muhandislik sohalariga yo'naltirilgan grantlar.

Yaponiya HCI: 0.83 – 0.85

Kuchli intizomga asoslangan ta'lim: Yuqori intizom va STEM bo'yicha chuqur bilim.

Tibbiy texnologiyalarni joriy etish: Yaponiyada aholining keksa qatlami ko'pligiga qaramay, sog'liqni saqlash tizimi zamonaviy texnologiyalarga asoslangan.

Ishlab chiqarishdagi inson omili: Ishchilarni uzluksiz o'qitish va ishlab chiqaruvchanlikni oshirishda zamonaviy menejment yondashuvlari.

Shveytsariya HCI: 0.84 – 0.86

Dual ta'lim tizimi: O'rta maktabdan boshlab kasb-hunar va akademik ta'lim
chambarchas bog'langan.

Kuchli tibbiy xizmatlar: Innovatsion tibbiyot texnologiyalari, yuqori umr ko'rish darajasi rivojlangan.

Tashabbusni rag'batlantirish: Yoshlarga innovatsion loyihalar va startaplar uchun grantlar taqdim etilmoqda.

Kanada HCI: 0.78 – 0.80

Yuqori sifatli bepul ta'lim tizimi: Kanada bolalar bog'chasidan boshlab kollej va universitetlargacha bo'lgan ta'limda yuqori sifatni ta'minlanmoqda.

Sog'liqni saqlash tizimi: Kanada sog'liqni saqlash tizimi universal va bepul (Medicare), ya'ni har bir fuqaro va rezident bepul asosiy tibbiy xizmat olmoqda.

Ishchi kuchini doimiy rivojlantirish: Katta yoshdagilar uchun doimiy ta'lim va qayta kasbiy tayyorgarlik dasturlari mavjud.

Har yili minglab ishchilarga yangi ko'nikmalarni egallash uchun kasbga o'qitish kurslari (skilling, upskilling, reskilling) taklif etiladi.

Ko'p madaniyatli integratsiya siyosati: Immigratsiya orqali kelgan insonlar ham asosiy inson kapitali manbai sifatida ko'riladi.

Immigrantlar uchun til kurslari, ish topish, kasbga yo'naltirish dasturlari mavjud.

Kanada o'zini "ko'pchilikdan tashkil topgan birlik" (unity in diversity) deb ataydi va ijtimoiy barqarorlikni saqlab turadi.

Ilm-fan, tadqiqot va innovatsiyaga sarmoya: Kanada har yili oliy o'quv yurtlari, ilmiy markazlar va texnologik startaplar orqali inson aql-zakovatiga sarmoya kiritmoqda.

Innovatsion ekotizim, texnoparklar, tadqiqot fondlari orqali yosh olimlar va ixtirochilarga keng imkoniyatlar yaratilmoqda.

Barqaror mehnat bozori siyosati: Ishsizlikka qarshi samarali dasturlar (Employment Insurance), vaqtinchalik moliyaviy yordam ko'rsatilmoqda.

Kam daromadli oilalar uchun Child Benefit, tax credits, social assistance dasturlari mavjud.

Ish beruvchilar va ishchilar o'rtasida muvozanatli mehnat qonunchiligi ishlab chiqilgan.

Gender tengligi va inklyuzivlik: Ayollar, nogironlar, tub aholi (Indigenous peoples), hamjamiyat a'zolari uchun alohida ijtimoiy va iqtisodiy qo'llab-quvvatlovchi dasturlari mavjud.

Ish joylarida teng imkoniyat, homiladorlik ta'tili va gender tenglik bo'yicha o'quv seminarlari muntazam o'tkaziladi.

Inson kapitalini rivojlantirish subindeksi bo'yicha jahondagi MDH TOP-3 yetakchi mamlakatlar tajribasini o'rganish tahlili.

Mustaqil Davlatlar Hamdo'stligi (MDH) mamlakatlari inson kapitalini rivojlantirishda turli darajada natijalarga erishgan. Jahon bankining 2024-yilgi Inson Kapitali Indeksi (HCI) ma'lumotlariga ko'ra (eng so'nggi keng qamrovli ma'lumotlar), MDHdagi yetakchi mamlakatlar quyidagilar:

1. Belarus (HCI: 0.70)
2. Rossiya Federatsiyasi (HCI: 0.68)
3. Qozog'iston (HCI: 0.63)

Bu mamlakatlar inson kapitali rivojlanishi bo'yicha MDHda yuqori o'rinlarni egallagan bo'lib, ularning tajribasini o'rganish muhim ahamiyatga ega. Quyida ushbu mamlakatlarning inson kapitalini rivojlantirishdagi asosiy yutuqlari va tajribalari umumlashtirilgan.

Belarus Respublikasi (HCI: 0.70)

Belarus Respublikasi MDHda inson kapitali bo'yicha eng yuqori ko'rsatkichlardan biriga ega. Bu ko'rsatkich asosan quyidagilar bilan bog'liq.

Sog'liqni saqlash tizimi: Belarus davlatida aholi salomatligini saqlashga katta e'tibor berilmoqda. Sog'liqni saqlash tizimi asosan davlat tomonidan moliyalashtiriladi va qamrab olinadi. Bolalar o'limini kamaytirish va aholining o'rtacha umr ko'rish davomiyligini oshirish bo'yicha sezilarli yutuqlarga erishilgan. Yuqori darajadagi emlash qamrovi va profilaktik tibbiy xizmatlar bunga misol bo'la oladi.

Ta'lim tizimi: Belarus davlatida ta'lim tizimi yuqori sifatli va barcha darajalarda mavjud. Maktabgacha ta'lim, umumiy o'rta ta'lim, kasb-hunar ta'limi va oliy ta'limga katta e'tibor qaratilgan. Ta'limga qamrov darajasi yuqori, bu esa ishchi kuchining malakasini oshirishga yordam beradi. Fan va texnologiyaga yo'naltirilgan ta'lim dasturlari rivojlangan.

Texnologiya va innovatsiya: Belarus davlati IT sohasida faol rivojlanmoqda. Hukumat dasturiy ta'minotni ishlab chiqish va yangi texnologiyalarni joriy etishga sarmoya kiritmoqda, bu esa yuqori malakali ishchi kuchiga bo'lgan talabni oshirmoqda va ta'lim tizimini yangi talablarga moslashtirishga undamoqda.

Ijtimoiy himoya: Aholining ijtimoiy himoyasi yaxshi yo'lga qo'yilgan bo'lib, bu inson kapitalini shakllantirish uchun qulay muhit yaratadi.

Rossiya Federatsiyasi (HCI: 0.68)

Rossiya MDHda inson kapitali bo'yicha ikkinchi o'rinda turadi. Rossiyaning tajribasi quyidagilarni o'z ichiga oladi.

Yuqori sifatli ta'lim an'analari: Rossiya, ayniqsa, texnik va tabiiy fanlar bo'yicha kuchli ta'lim tizimiga ega. Sovet davridan qolgan kuchli ilmiy-texnik baza mavjud. Oliy ta'lim muassasalarining keng tarmog'i va ilmiy tadqiqot institutlari inson kapitalini rivojlantirishga hissa qo'shmoqda.

Sog'liqni saqlash sohasidagi islohotlar: Rossiya sog'liqni saqlash tizimini modernizatsiya qilishga katta e'tibor qaratmoqda, garchi bu jarayon ba'zi hududlarda turli darajada bo'lsa-da. Onalik va bolalikni muhofaza qilish dasturlari, yuqumli kasalliklarga qarshi kurash bo'yicha samarali choralar amalga oshirilmoqda.

Fan va innovatsiyalarga investitsiyalar: Rossiya fan va innovatsiyaga sarmoya kiritishni davom ettirmoqda. Bu esa ilmiy kadrlar tayyorlash va zamonaviy texnologiyalarni joriy etish orqali inson

kapitalini rivojlantirishga xizmat qiladi. Ilmiy-texnik va innovatsion markazlar tashkil etilmoqda.

Mehnat bozorini rivojlantirish: Ishchi kuchi malakasini oshirish va qayta tayyorlash dasturlari orqali mehnat bozorining ehtiyojlariga moslashishga harakat qilinmoqda.

Qozog'iston (HCI: 0.63)

Qozog'iston Markaziy Osiyo mintaqasidagi MDH mamlakatlari orasida yetakchi o'rinni egallaydi va umumiy MDH reytingida kuchli uchlikka kiradi. Qozog'istonning tajribasi quyidagilarni o'z ichiga oladi.

Ta'lim sohasidagi islohotlar: Qozog'iston ta'lim tizimini xalqaro standartlarga moslashtirishga faol harakat qilmoqda. Jumladan, "Bo'lajak" nomli xalqaro stipendiya dasturi orqali minglab yoshlarga xorijning yetakchi universitetlarida ta'lim olish imkoniyati yaratilgan. Uch tilli ta'lim(qozoq, rus, ingliz)ni rivojlantirishga e'tibor qaratilmoqda.

Sog'liqni saqlashni modernizatsiya qilish: Qozog'iston sog'liqni saqlash tizimiga katta sarmoyalar kiritmoqda, tibbiy infratuzilmani yaxshilash va tibbiy xizmatlar sifatini oshirishga e'tibor qaratilmoqda. Majburiy ijtimoiy tibbiy sug'urta tizimi joriy etilmoqda.

Raqamlashtirish va innovatsiyalar: Qozog'iston raqamlashtirish va innovatsiyani rivojlantirishga katta e'tibor bermoqda. "Raqamli Qozog'iston" davlat dasturi doirasida ta'lim, sog'liqni saqlash va davlat xizmatlarini raqamlashtirish bo'yicha ishlar olib borilmoqda. Bu esa aholining bilim va ko'nikmalarini oshirishga, shuningdek, davlat xizmatlaridan foydalanish imkoniyatini yaxshilashga xizmat qiladi.

Yoshlarga e'tibor: Yoshlarning ta'lim olishi, bandligini ta'minlash va ularning salohiyatini ro'yobga chiqarish uchun turli dasturlar amalga oshirilmoqda.

O'zbekistonda inson kapitali subindeksini rivojlantirish tendensiyalari

1. Maktabgacha ta'limda barcha maktabgacha yoshdagi bolalarni to'liq qamrab olish (3-6 yosh). O'zbekistonda 3 mln nafarga yaqin 3-7 yoshli bolalar bo'lib, ularni maktabgacha ta'lim bilan qamrab olish darajasi 74% tashkil qilmoqda.
2. Oliy ta'lim qamrovini yanada oshirish (2024/2025 o'quv yili boshiga ko'ra ushbu ko'rsatkich qamrovi 43% ni tashkil qiladi)2
3. Raqamli texnologiyalar, muhandislik va boshqa sohalar hamda yo'nalishlarda yoshi kattalar uchun "life-long learning" dasturlarini ishlab chiqish va bosqichma - bosqich amalga oshirish.
4. E-government Literacy subindikatori ko'rsatkichlarini oshirish maqsadida e-hukumat xizmatlar sonini yanada oshirish, sifatli tashkil qilish va ulardan foydalanish ko'rsatkichlarini yanada yaxshilash. E-government Literacy yangi joriy qilingan subindeksini rivojlantirish bo'yicha Universitetning chora-tadbirlar rejasi ishlab chiqilgan.

III. XULOSA

Raqamli hukumat sharoitida inson kapitalini rivojlantirish va uning subindeksini yuksaltirish davlat boshqaruvining eng muhim ustuvor yo'nalishlaridan biri hisoblanadi. Chunki inson kapitali – bilim, salomatlik, raqamli ko'nikmalar, malaka va innovatsion salohiyat orqali mamlakatning ijtimoiy-iqtisodiy taraqqiyotini belgilovchi asosiy omildir.

Ushbu maqolada inson kapitali subindeksini rivojlantirishga qaratilgan benchmarking tahlili olib borildi va unda ilg'or xorijiy tajribalar, xalqaro reytinglar hamda milliy ko'rsatkichlar taqqoslandi.

Natijada, O'zbekiston uchun dolzarb bo'lgan qator ustuvor vazifalar belgilandi: raqamli ta'lim tizimini rivojlantirish, kadrlar malakasini oshirish, sog'liqni saqlash xizmatlarini raqamlashtirish, davlat xizmatlari samaradorligini oshirish hamda fuqarolarning raqamli savodxonligini kengaytirish.

Benchmarking tahlili shuni ko'rsatadiki, inson kapitali subindeksini oshirish orqali raqamli hukumatning samaradorligi hamda fuqarolarga ko'rsatiladigan interaktiv xizmatlar sifati sezilarli darajada yaxshilanadi. Bundan tashqari, ilg'or davlatlar tajribasidan foydalanish, milliy strategiyalarni takomillashtirish va raqamli transformatsiya jarayoniga moslashtirish mamlakatning xalqaro reytinglardagi o'rnini mustahkamlashga xizmat qiladi.

Inson kapitalini rivojlantirish benchmarking yondashuvi asosida olib borilsa, raqamli hukumatning barqarorligi, samaradorligi va xalqaro maydondagi raqobatbardoshligi ta'minlanadi.

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DEVELOPMENT STAGES OF THE ELECTRONIC ARCHIVAL SYSTEM IN UZBEKISTAN

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***Abstract*— This paper analyzes the development of the electronic archive system in Uzbekistan through two distinct phases. The first phase (2010–2019) focused on infrastructure development of state archives, while the second phase (2020–2024) emphasized the digital transformation and implementation of electronic archival information systems. The study outlines institutional structures, statistical indicators, technological integration challenges, and service efficiency gains resulting from system digitization. The paper also presents the architecture of the Integrated Corporate Electronic Archive and evaluates its effectiveness in delivering online archival services.**

Keywords*— *Electronic archives, digitization, public service delivery, Uzbekistan, archival system

I. Introduction

The digitization of archival systems has become essential in the modern governance framework, where transparency, accessibility, and efficiency are paramount. Uzbekistan, with its rich documentary heritage dating back to the 9th century, embarked on an ambitious journey to modernize its archival infrastructure. The effort was structured in two strategic stages: modernization of infrastructure (2010–2019) and digital transformation (2020–2024).

II. Structure of the Archival System in Uzbekistan

Currently, there are a total of 226 state archives in Uzbekistan, with the entire archival sector under the supervision of the "Uzarchive" Agency, operating under the Ministry of Justice. Out of these, three archives have the status of National Archives. Specifically:

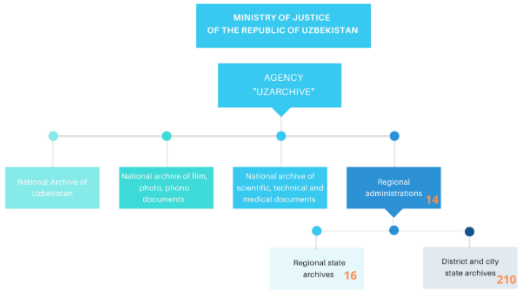
The Uzbekistan National Archive preserves paper-based historical documents from the earliest periods.

The Uzbekistan National Archive of Cinema, Photo, and Phono Documents preserves audiovisual materials only.

The Uzbekistan National Archive of Scientific, Technical, and Medical Documents preserves documents related to science, technology, and healthcare.

The remaining 223 archives operate at regional, district, and city levels, covering almost all institutions throughout the territory of Uzbekistan, as shown in Figure 1.

Figure 1. Structure of the Archival System in Uzbekistan



III. Archival Document Retention and Holdings

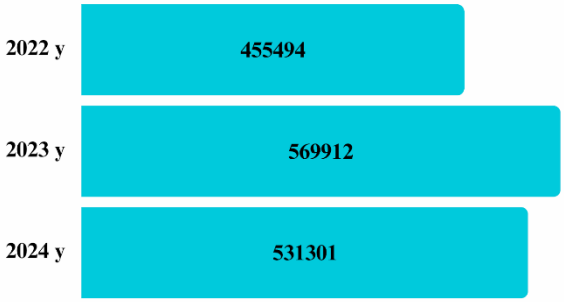
According to Uzbek legislation, permanent records must be stored in republican organizations for 15 years, in regional organizations for 10 years, and in district and city organizations for 5 years before being transferred to state archives for long-term preservation [1].

As of today, more than 16 million record units (folders) of paper-based documents are stored in Uzbekistan's state archives, along with over 551,000 photo documents, more than 16,000 audio documents, and over 21,000 video materials [2]. The preservation of these documents is managed by approximately 2,500 archival staff members. Uzbekistan's archives are considered the richest in Central Asia, with the oldest documents dating back to the 9th century. Some paper documents reach lengths of up to 80 meters [3], [4].

IV. Rationale for Digital Reform

Among the types of services provided by the state archives, ten have the highest demand among citizens. According to statistical data, the number of requests for these services increases year by year, as shown in Figure 2.

Figure 2. Number of Citizen Requests Submitted to State Archives



As seen from the above figures, the number of requests is high, and previously, citizens faced many inconveniences and difficulties when accessing archival services.

Before the pandemic, in order to access services, citizens had to personally visit each individual archive and submit a physical application. For instance, if someone needed an archival certificate, they had to write a request at the archive and return 30 days later to receive a response. Moreover, if the individual had worked in a different region, they had to visit the archive of that specific region. The same inconveniences applied when requesting document copies or access to reading rooms.

At the same time, service provision processes in state archives were also complex. Each request had to pass through five steps before reaching the executor. As a result, service fulfillment often took 30 or more days.

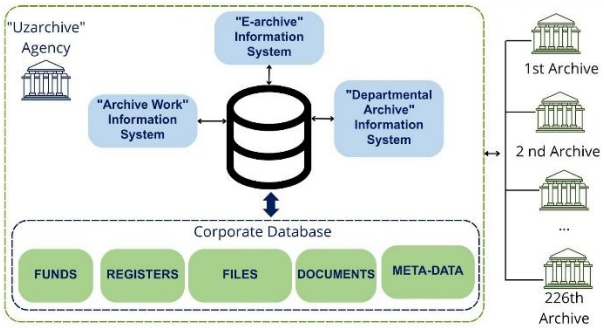
V. Architecture of the Archive Information Systems

After the pandemic was declared globally, it became necessary to rethink archival operations, radically improve service delivery conditions, and fully integrate information technologies into archival activities. This required the development and implementation of an Electronic Archive System across all state archives [5],.

In the process of developing the Electronic Archive System in Uzbekistan, a number of scientific studies by foreign scholars were also examined. Notably, the findings of Feaster, Vancour, and Witherspoon (2020), Yang, Du, and Shi (2020), Ukata and Wechie (2019), and Obotu, Soloman, and Ogezi (2018) were thoroughly analyzed and taken into consideration [6], [7], [8], [9], [10], [11].

One of the most complex challenges was to create a centralized information system and connect all 226 state archives in the republic to it. Based on this objective, an integrated corporate electronic archival structure was developed, and its subsystems were defined, as shown in Figure 3.

FIGURE 3. Integrated Corporate Electronic Archive System Architecture



These core systems represent the most essential components of the electronic archive infrastructure. The "Archive work" information system is designed to provide online archival services; the "E-archive" information system is intended for digitizing archival documents and integrating them into a unified platform; and the "Idoraviy arxiv" information system is designed for the acceptance of electronic documents formed within organizations into state archival custody.

It must be acknowledged that the implementation process of these information systems was quite complex and challenging. This is because, in order to connect each state archive to a unified system, it was necessary to work individually with every archive.

For instance, speaking about the " Archive work" information system, which is aimed at delivering online archival services, 226 state archives have been connected to this system. A separate cabinet was set up for each of them, and the information system itself consists of two components: the front office, which serves the users, and the back office, which covers the internal workflow processes of the state archives.

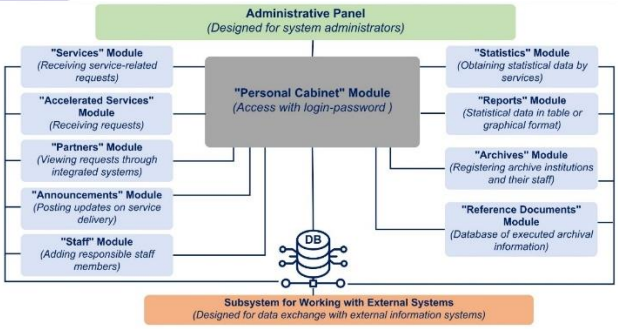
To make the system even more user-friendly, we integrated it with the Unified Interactive Public Services Portal, enabling all archival services to be accessed through this portal as the front office.

In addition to this, for citizens who may face difficulties in using information technologies, the system was also integrated into the information system of the Public Services Centers, thereby expanding access and creating broader opportunities for users to benefit from archival services.

One of the greatest advantages of providing archival services through Public Services Centers is that citizens can visit the center closest to their place of residence and access services through the center's operators.

In addition, archive staff can generate archival data directly within this system, and these records can also be signed by the archive director within the same platform. From the moment service requests are received to their full processing through all stages within the archive and the delivery of results to the user — every step is carried out exclusively within this system, as shown in Figure 4.

FIGURE 4. "Functional Structure of the "Archive work" System



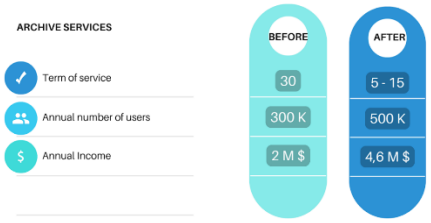
Previously, requests to archives from courts, pension departments, and law enforcement agencies were received in paper format. To digitize these processes as well, we integrated our information system with the information systems of these organizations. As a result, the processes of receiving and fulfilling archive-related requests have been fully digitized.

VI. Efficiency and Economic Impact

After successfully completing all stages of implementation, all the most popular and in-demand archival services are now digitized and provided online.

Due to the increased convenience of accessing archival services, the revenue generated by state archives has also grown. For example, the total income of all archives amounted to USD 2.1 million in 2019, and by 2024 this figure has reached USD 4.6 million. The service delivery time has been reduced from 30 days to just 5 days, and the number of users has increased from 300,000 to 500,000 as shown in Figure 5.

FIGURE 5. EFFECTIVENESS OF THE ELECTRONIC ARCHIVE INFORMATION SYSTEMS



VII. CONCLUSION

The development and implementation of a centralized Electronic Archive System in Uzbekistan mark a major milestone in the modernization of public administration and archival governance. Through a two-phase national strategy spanning from 2010 to 2024, Uzbekistan successfully transitioned from traditional, paper-based archives to an integrated digital ecosystem that connects 226 state archives under a unified infrastructure.

Moreover, the integration of archival services into the Unified Government Portal and Public Service Centers has democratized access to archival records. Citizens no longer need to travel between regions or endure lengthy queues, making archival services more inclusive and user-friendly.

Uzbekistan's experience demonstrates that successful archival digitization requires not only technical infrastructure but also legal regulation, staff training, and cross-sectoral interoperability. The challenges faced—such as connecting diverse archives, training personnel, and integrating systems with courts and law enforcement—were overcome through phased planning and centralized coordination by the "Uzarchive" agency.

Going forward, the lessons learned from Uzbekistan's case can serve as a blueprint for other developing nations aiming to modernize their archival systems.

In conclusion, the electronic archive system of Uzbekistan stands today as one of the most advanced in the Central Asian region, representing a successful example of digital governance, archival innovation, and citizen-centric public service delivery.

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Обнаружение пневмонии на основе конкатенированной CNN с использованием модуля нечеткого улучшения

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***Аннотация t*— В данном исследовании предложена модель конкатенированной CNN для обнаружения пневмонии, совмещённая с методом улучшения изображений на основе нечеткой логики. Процесс улучшения изображений с использованием нечеткой логики основан на новом алгоритме уточнённой фаззификации, который значительно повышает качество изображений и эффективность извлечения признаков для модели CCNN. Для обучения алгоритма использовались четыре набора данных: исходные изображения и изображения, обработанные с использованием нечеткой энтропии, стандартного отклонения и выравнивания гистограммы. Было показано, что использование улучшенных наборов данных значительно повысило производительность CCNN, при этом наилучшие результаты продемонстрировал набор данных с добавленной нечеткой энтропией.**

Ключевые слова—Глубокое обучение, свёрточным нейронным сетя, фаззификация.

CLIV. Ввидение

Эффективность моделей глубокого обучения (DL) в задаче классификации медицинских изображений, в частности при диагностике таких заболеваний, как пневмония, в значительной степени зависит от качества методов предобработки изображений. Исследователи показали, что использование усовершенствованных методов предобработки может значительно повысить производительность моделей за счёт улучшения чёткости изображений и снижения уровня шума [1–3]. Одним из таких подходов является использование нечеткой логики, которая всё чаще интегрируется в модели глубокого обучения для повышения точности медицинской диагностики. Cosimo и соавт. [4] представили модель глубокого обучения на основе нечеткой логики, специально разработанную для выявления пневмонии. В их модели алгоритм обнаружения контуров с применением нечеткой логики используется на этапе предобработки. Другой инновационный подход был предложен Shin и соавт. [5], которые разработали алгоритм выравнивания гистограммы с использованием нечеткой логики для улучшения рентгеновских снимков грудной клетки. Этот метод корректирует контраст медицинских изображений с помощью функций принадлежности, основанных на нечеткой логике, что делает такие важные особенности, как затемнения в лёгких, более различимыми. Для точного выявления пневмонии в данном исследовании были объединены преимущества нечетких методов и глубокого обучения в одной модели, а именно: нечеткая логика с возможностью локального анализа контраста и извлечения признаков, а также обучающая способность моделей глубокого обучения. Интегрированный метод позволил повысить точность обнаружения пневмонии по сравнению с ранее предложенными моделями глубокого обучения.

CLV. Методология

Предлагаемая структура модели включает следующие модули:

- **Входное изображение**. Данный блок принимает рентгеновские снимки.
- **Улучшение изображений.** В этом блоке используется новый алгоритм процедуры фаззификации для повышения качества изображений. Техника оптимизирует процесс фаззификации с помощью математического метода для нахождения функции принадлежности.
- **Модель Concatenated CNN.** Предлагаемая конкатенированная CNN-модель обучается на наборе данных, улучшенном с помощью нечеткой логики. Подробная информация о процессе формирования набора данных представлена в следующем разделе. CNN-модель получает способность различать области с признаками пневмонии и нормальные участки за счет использования признаков, извлечённых из улучшенных изображений.
- **Выход.** Результатом работы модели является определение случая пневмонии либо нормы.

Предлагаемая модель для обнаружения пневмонии объединяет метод обработки изображений с использованием нечеткой логики для их улучшения с преимуществами CNN-моделей, такими как извлечение признаков, высокая точность и обучающая способность. Данный метод обеспечивает более гибкое и детализированное представление для изучения и анализа изображений, поскольку учитывает присущую реальным изображениям неоднозначность и неточность.

$$F = \left\{ \left\langle f(x,y),\ \mu_F(f(x,y)) \right\rangle \middle| f(x,y) \in \{0,\ldots,L-1\} \right\}, \quad (1)$$

где $x\in\{1,...,M\}, y\in\{1,...,N\}$, $\mu_F(f(x,y))$ означают соответственно степень принадлежности пикселя (x,y) множеству в соответствии со свойствами изображения. При решении задач обработки изображений, связанных с неопределённостью, нечеткие изображения оказываются весьма полезными. Нечёткость может быть особенно эффективной при сегментации объектов на изображении, в частности тогда, когда границы объектов трудно различимы.

Шаг 1. Нормализация:

$$u(x,y) = l\frac{f(x,y)-f_{\min}}{f_{\max}-f_{\min}}. \quad (2)$$

Шаг 2. Фаззификация:

$$\mu_F^i(x,y) = \frac{1}{1+\frac{u(x,y)-c_i}{\sigma_f}},\ i=\overline{1,k}. \quad (3)$$

Шаг 3. Уточнение фаззификации:

$$\mu_F^i(x,y) = \begin{cases} 2(\mu_F^i(x,y))^2, & 0 \le \mu_F^i(x,y) \le \frac{1}{2}, \\ 1-2(1-\mu_F^i(x,y))^2, & \frac{1}{2} < \mu_F^i(x,y) \le 1. \end{cases} \quad (4)$$

Шаг 4. Квантование локального контраста играет важную роль в обработке изображений, так как позволяет упростить оценку изменений контраста между различными областями изображения.

Расчёт локального контраста:

$$C(x,y) = (C_{\max} - C_{\min})/255 \quad (5)$$

Расчёт глобального контраста:

$$C(x,y) = \frac{\left(2\frac{\sum_{j=1}^{\eta}\left\|f_j - M\right\|^2 \mu_j}{\sum_{j=1}^{\eta}\mu_j}\right)^{0.5}}{255}, \quad (6)$$

где C_{max} и C_{min} - максимальное и минимальное значения яркости в окрестности пикселя. Понимание характеристик и структуры локальных окрестностей играет ключевую роль при вычислении локального контраста. Это связано с тем, что для достижения требуемых результатов разные типы окрестностей могут потребовать применения различных методов оценки контраста или разных параметров обработки.

Шаг 5. Для увеличения количественной меры локального контраста применяется нелинейное преобразование локальных значений контраста в соответствии с определённым правилом:

$$C^*(x,y) = \begin{cases} B_0 + \left(\frac{R}{2} - A_0\right)\left(\frac{C(x,y)-C_{\min}}{\hat{C}-C_{\min}}\right)^{\alpha}, & C(x,y) \le \hat{C}, \\ R - A_0 - \left(\frac{R}{2} - A_0\right)\left(\frac{C_{\max}-C(x,y)}{C_{\max}-\hat{C}}\right)^{\alpha}, & C(x,y) > \hat{C}, \end{cases}$$

где: R – максимально возможное значение локального контраста (R=1R = 1R=1), C(x,y) – исходное значение локального контраста элемента изображения с координатами (x,y).

Шаг 6. Используя улучшенные значения локального контраста, осуществляется реконструкция изображения путём замены модифицированных компонентов на их исходные позиции. Этот этап позволяет интегрировать усиленные локальные детали во всё изображение. Проектирование функции преобразования локального контраста является важнейшим этапом обработки изображений.

Предложенная модель Concatenated CNN (CCNN) использует многоветвевую архитектуру, состоящую из трёх отдельных входных потоков, каждый из которых соответствует определённому методу улучшения изображений: нечёткая энтропия, нечёткое стандартное отклонение и гистограммное выравнивание.

Архитектура была разработана для обработки рентгеновских снимков грудной клетки размером 512×512, и общая структура предложенной модели CCNN показана на Рисунке 1.

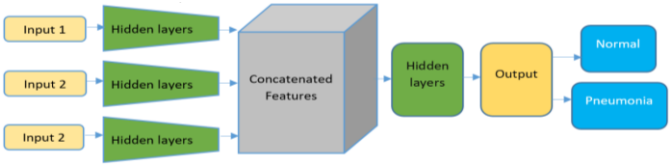

Рисунок 1. Архитектура предлагаемой модели CCNN.

Эффективность модели была проверена экспериментально с использованием различных альтернативных моделей. Рисунок 2 представляет результаты сравнения производительности модели Concatenated CNN (CCNN) с другими нейронными сетевыми моделями. Метрики оценки, включающие точность (accuracy), прецизионность (precision), F1-меру (F1-score), площадь под ROC-кривой (AUC) и полноту (recall), дают полное представление о классификационных возможностях каждой модели. Почти все показатели демонстрируют, что предложенная модель CCNN показывает лучшие результаты и выделяется наибольшими значениями.

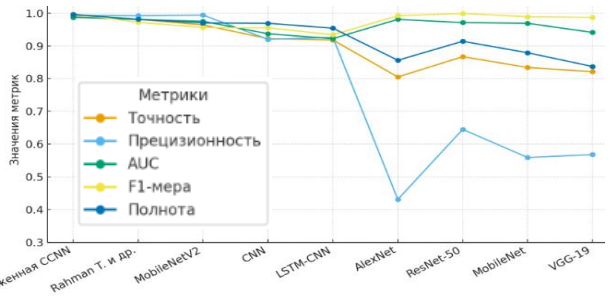

Рисунок 2. Сравнение производительности моделей CNN.

На Рисунке 2 показано, что CCNN демонстрирует наилучшие результаты, достигая максимальных значений по следующим метрикам: recall — 99.6%, F1-score — 99.8%, accuracy — 98.9%, precision — 99.3%. Её выдающаяся способность к различению классов дополнительно подтверждается значением AUC = 98.7%. Исключительно высокая эффективность CCNN частично объясняется её архитектурой, которая объединяет

несколько наборов признаков. Практически безупречная F1-мера указывает на оптимальное соотношение полноты и точности, сводя к минимуму как ложноположительные, так и ложноотрицательные результаты.

CLVI. Заключение

Основная инновация данного исследования заключается в интеграции улучшения изображений на основе нечеткой логики с моделями глубокого обучения, в частности, с архитектурой каскадных сверточных нейронных сетей (CCNN), которая обеспечивает значительные улучшения по сравнению с традиционными методами обработки изображений и глубокого обучения. Этот гибридный метод эффективно сочетает в себе сильные стороны нечеткой логики (обработка неопределенности и повышение качества изображений) и сверточных нейронных сетей (надежное извлечение и классификация признаков), что приводит к заметному росту таких показателей производительности, как точность, достоверность, F1-оценка и полнота.

1. Улучшение изображений на основе нечеткой логики: Методы нечеткой энтропии, нечеткого стандартного отклонения и разброса гистограмм, использованные в данном исследовании, являются новыми благодаря своей способности оптимизировать контрастность и выделять едва заметные особенности изображения. Эти методы позволяют CCNN улавливать мелкие детали, которые часто упускаются традиционными методами улучшения, такими как CLAHE. В отличие от предыдущих моделей, которые опирались на необработанные или слегка улучшенные изображения, наш подход систематически улучшает качество изображений с помощью специально разработанного алгоритма фаззификации. Это приводит к значительному улучшению визуального качества набора данных, оцениваемого по шкале BRISQUE, и повышает способность CCNN выявлять сложные случаи пневмонии.

2. Архитектура каскадной сверточной нейронной сети: Предлагаемая модель CCNN уникальна тем, что включает три отдельные входные ветви, соответствующие различным методам улучшения изображений (нечеткая энтропия, стандартное отклонение и выравнивание гистограммы). Такая многоветвевая структура позволяет модели объединять взаимодополняющие признаки каждого метода улучшения, что приводит к более высокой точности классификации. В то время как традиционные модели CNN фокусируются на отдельных наборах данных, способность CCNN использовать несколько улучшенных наборов данных является ключевым отличием. Такая структура обеспечивает большую устойчивость и надежность классификации, особенно при различении нормальных случаев и случаев пневмонии при различных состояниях изображения. 3. Сравнение с существующими методами: Большинство предыдущих исследований, например, с использованием предварительно обученных сверточных нейронных сетей (ResNet, VGG, MobileNet), основаны на методах переноса обучения и глобального улучшения изображений. В отличие от этого, наша CCNN, основанная на нечетком улучшении, обучается с нуля, используя нечеткую логику для повышения качества изображений на уровне пикселей. Этот подход непосредственно решает проблемы, связанные с низкокачественными или зашумленными медицинскими изображениями, делая модель более эффективной в клинических условиях, где качество изображений может варьироваться. Демонстрируя превосходную производительность на различных наборах данных и превосходя современные модели с точки зрения точности, достоверности и полноты, данное исследование подтверждает, что CCNN является более универсальным и адаптируемым решением для диагностики пневмонии. Сочетание этих методов улучшения в рамках CCNN приводит к заметному повышению точности (98,9%), достоверности (99,3%), F1-оценки (99,8%) и полноты (99,6%), превосходя альтернативные модели, такие как AlexNet, ResNet-50 и MobileNetV2.

В заключение следует отметить, что данное исследование представляет собой новое сочетание нечеткой логики и глубокого обучения, обеспечивающее повышенную точность, надежность и диагностическую достоверность по сравнению с предыдущими методами. Этот гибридный подход устраняет ограничения традиционных методов улучшения изображений.

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INFLYATSIYA KO'RSATKICHLARINI HISOBLASH JARAYONLARINI RAQAMLI TEXNOLOGIYALAR ASOSIDA TASHKIL ETISHNING XORIJIY TAJRIBASINI TAHLIL QILISH

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Annotatsiya—Mazkur maqolada inflyatsiya ko'rsatkichlarini shakllantirish jarayonida zamonaviy raqamli texnologiyalardan foydalanish bo'yicha xorijiy tajriba atroflicha tahlil etilgan. Xususan, katta hajmdagi ma'lumotlarni qayta ishlash (Big Data analytics), sun'iy intellekt algoritmlari, veb skreping texnologiyalari, bulutli hisoblash, blokcheyn tizimlari hamda buyumlar interneti kabi ilg'or yechimlar iste'mol narxlari indeksini aniqlashda samaradorlik va ishonchlilikni oshirishi yoritilgan. Shuningdek, AQSh, Kanada, Germaniya, Yaponiya, Buyuk Britaniya va boshqa rivojlangan davlatlar misolida statistik kuzatuvlarning CAPI, CAWI va TAPI texnologiyalari orqali tashkil etilishi, ularning ustunlik va cheklovlari ilmiy jihatdan muhokama qilingan.

Kalit so'zlar— inflyatsiya, raqamli texnologiyalar, iste'mol narxlari indeksi, Big Data, sun'iy intellekt, veb skreping, blokcheyn, CAWI, CAPI, TAPI.

CLVII. I. KIRISH

Globallashuv va raqamli transformatsiya sharoitida milliy iqtisodiyotlarning barqaror rivojlanishini ta'minlashda statistik axborotlarning tezkorligi, aniqligi va ishonchliligi hal qiluvchi ahamiyat kasb etmoqda. Shu nuqtayi nazardan, makroiqtisodiy muvozanatni baholashda asosiy indikatorlardan biri bo'lgan Iste'mol narxlari indeksi (CPI) inflyatsiya bosimini o'lchashda hamda iqtisodiy siyosatni shakllantirishda muhim o'rin egallaydi [1]. An'anaviy usullarda CPI hisoblash ko'p hollarda qog'oz asosidagi statistik so'rovnomalar, cheklangan kuzatuv nuqtalari va qo'lda qayta ishlash amaliyotiga tayanar edi. Ammo so'nggi yillarda ma'lumotlarning hajm jihatdan keskin ortishi va ularni qayta ishlash imkoniyatlarining kengayishi natijasida raqamli texnologiyalar asosida yangi yondashuvlar shakllanmoqda.

CLVIII. II. RAQAMLI TEXNOLOGIYALAR ASOSIDA CPI HISOBLASH

CLIX. BIG DATA VA SUN'IY INTELLEKTNING AHAMIYATI

Katta ma'lumotlar tahlili yordamida turli manbalardan olingan narxlar ma'lumotlarini integratsiya qilish, real vaqt rejimida qayta ishlash hamda statistik kuzatuvlarda aniqlikni oshirish mumkin. Masalan, onlayn chakana savdo platformalari, tranzaksiya yozuvlari va ijtimoiy tarmoqlardan olinadigan ma'lumotlarni birlashtirish orqali iste'mol narxlari dinamikasi yanada keng qamrovli tarzda kuzatiladi. Sun'iy intellekt algoritmlari esa bozor segmentlari o'rtasidagi yashirin korrelyatsiyalarni aniqlash, bashoratlash hamda indikatorlarning barqarorligini ta'minlashda qo'llaniladi.B. CAWI, CAPI va TAPI texnologiyalari

Tadqiqotlarimiz shuni ko'rsatmoqdaki, dunyoning bir qancha mamlakatlarida Iste'mol narxlari indeksini shakllantirish uchun ma'lumotlarni to'plashda kompyuter yordamida shaxsiy intervyu CAPI (Computer-Assisted Personal Interviewing), internet yordamida shaxsiy intervyu CAWI (Computer-assisted web interviewing) va telefon yordamida shaxsiy intervyu TAPI (Telephon Application Programming Interface) texnologiyalaridan ham keng foydalanilmoqda. Ushbu texnologiyalar ma'lumotlar yig'ish jarayonlarini soddalashtirish, ma'lumotlarning aniqligini oshirish va samaradorlikni oshirishga yordam bermoqda. Xususan, AQSH, Kanada, Germaniya va Yaponiyada iste'mol narxlari indeksi bilan bog'liq ma'lumotlarni yig'ish uchun CAPI va TAPI kombinatsiyasidan foydalanilmoqda. Ular CAPI texnikasidan foydalangan holda shaxsiy suhbatlar o'tkazadilar va ma'lumotlarni yig'ishning muayyan jihatlari uchun telefon so'rovlaridan TAPI foydalanmoqdalar. Ammo, Buyuk Britaniya, Fransiya va Avstraliyada iste'mol narxlari indeksi ma'lumotlarini yig'ish uchun CAWI va CAPI usullarini qo'llamoqdalar. Ular vebga asoslangan intervyular, ya'ni CAWI orqali so'rovlar o'tkazadilar, shuningdek, yuzma-yuz suhbatlar uchun CAPI usullaridan foydalanmoqlar.Statistika faoliyatida CAPI, CAWI va TAPI texnologiyalaridan samarali va aniq ma'lumotlarni to'plash uchun foydalanish respondentlarning javob yukini kamaytirishga va standartlashtirilgan intervyu protokollari va avtomatlashtirilgan ma'lumotlarni kiritish orqali ma'lumotlar sifatini yaxshilashga yordam beradi. Ammo, ushbu texnologiyalardan foydalanilganda inson omili oqibatida ma'lumotlarning sifati buzilishiga olib kelishi mumkin. Shu boisdan, hozirgi vaqtda rivojlangan mamlakatlar milliy statistika tashkilotlari tomonidan iste'mol narxlari indeksi ma'lumotlarini yig'ish va qayta ishlashda raqamli texnologiyalardan keng foydalanishga katta e'tibor qaratilmoqda.

Shu bilaan birgalikda rivojlangan mamlakatlarda inflyatsiya ko'rsatkichlarini ishlab chiqish jarayonida katta hajmli ma'lumotlar tahlili va sun'iy intellekt texnologiyalaridan samarali foydalanilayotgan bo'lsa, iste'mol narxlari indeksi uchun zarur ma'lumotlarni to'plashda veb skreping, mobil ilovalar, bulutli hisoblash

texnologiyalari va buyumlar internetidan keng foydalanilmoqda.

CLX. VEB SKREPING VA PLATFORMALAR SAMARADORLIGI

Xususan, veb skreping platformalari iste’mol narxlari indeksi ma’lumotlarini to‘plashda quyidagi bir qator muhim afzalliklarni taqdim etmoqda:

1) onlayn manbalardan, jumladan, elektron tijorat veb-saytlari va raqamli bozorlardan keng va xilma-xil narx ma’lumotlarini yig‘ishni ta’minlaydi;

2) ma’lumotlarni yig‘ish jarayonini avtomatlashtirish orqali veb skreping ma’lumotlarni qo‘lda kiritish bilan bog‘liq vaqt va mehnat xarajatlarini kamaytiradi;

3) veb skreping iste’mol narxlari indeksi ma’lumotlarining geografik va mahsulot qamrovini yaxshilaydi.

Tahlillarimiz shuni ko‘rsatmoqdaki, bugungi kunda rivojlangan mamlakatlar statistika idoralari tomonidan iste’mol narxlari indeksi ma’lumotlarini yig‘ishda bir qator veb skreping platformalaridan foydalanilmoqda.

Zamonaviy iqtisodiy statistikada veb skreping texnologiyalari muhim ahamiyat kasb etmoqda. Jumladan, Scrapy va Beautiful Soup platformalari yuqori samaradorligi bilan ajralib turadi. Selenium, Octoparse va ParseHub o‘rta samaradorlikka ega bo‘lsa-da, keng qo‘llanilmoqda. Shu bilan birga, Import.io va Content Grabber platformalari iste’mol narxlari indeksini hisoblashda nisbatan pastroq reytinglarga ega bo‘lgan.

CLXI. III. XORIJ TAJRIBASIDAN CHIQARILADIGAN XULOSALAR

Xalqaro amaliyot shuni ko‘rsatmoqdaki, raqamli texnologiyalar CPI hisoblash jarayonini tezlashtirish, xatoliklarni kamaytirish va hududiy qamrovni kengaytirish imkonini bermoqda. Bu esa o‘z navbatida milliy statistika tizimlarining global standartlarga moslashuvini ta’minlab, iqtisodiy siyosatni shakllantirishda yanada sifatli va tezkor qarorlar qabul qilish imkoniyatini yaratadi.

CLXII. IV. XULOSA

Raqamli texnologiyalar inflyatsiya ko‘rsatkichlarini shakllantirish jarayonida an’anaviy usullarni bosqichma-bosqich siqib chiqarmoqda. Katta hajmdagi ma’lumotlarni tahlil qilish, sun’iy intellekt va veb skreping texnologiyalari iste’mol narxlari indeksini hisoblashda aniqlikni oshiribgina qolmay, balki iqtisodiy barqarorlikni ta’minlash uchun zarur bo‘lgan tezkor va ishonchli ma’lumotlar oqimini yaratmoqda. Shu boisdan, O‘zbekiston Respublikasida ham milliy statistika tizimini modernizatsiya qilishda ushbu ilg‘or texnologiyalarni keng joriy etish muhim ahamiyat kasb etadi.

CLXIII. FOYDALANILGAN ADABIYOTLAR

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O‘ZBEKISTONDA RAQAMLI IQTISODIYOT SHAROITIDA XIZMAT KO‘RSATISH SOHASINING RIVOJLANISHI

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TATU mustaqil tadqiqotchi

Kirish.

Bugungi globallashuv davrida raqamli iqtisodiyot dunyo mamlakatlarining iqtisodiy taraqqiyotida hal qiluvchi rol o‘ynamoqda. Axborot-kommunikatsiya texnologiyalarining jadal rivojlanishi ishlab chiqarish, ta’lim, tibbiyot, moliya va xizmat ko‘rsatish sohalariga chuqur kirib bordi. O‘zbekistonda ham ushbu yo‘nalishga katta e’tibor qaratilib, “Raqamli O‘zbekiston – 2030” dasturi orqali barcha sohalarni modernizatsiya qilish rejalashtirilmoqda. Xizmat ko‘rsatish sohasi esa aholi turmush darajasini bevosita belgilaydigan va milliy iqtisodiyotning samaradorligini oshiradigan muhim tarmoqlardan biridir. Shu sababli, xizmat ko‘rsatish sohasining raqamli iqtisodiyot sharoitida rivojlanishini o‘rganish ilmiy va amaliy jihatdan dolzarbdir.

Kalit so‘zlar: raqamli iqtisodiyot, xizmat ko‘rsatish sohasi, elektron hukumat, elektron savdo, mobil to‘lovlar, masofaviy ta’lim, telemeditsina.

Asosiy qism. O‘zbekistonda raqamli iqtisodiyotning ulushi yil sayin ortib bormoqda. Bu jarayonda davlat siyosati, xalqaro hamkorlik va xususiy sektor faol ishtirok etmoqda. Axborot texnologiyalariga yo‘naltirilgan investitsiyalar xizmat ko‘rsatish sohasida zamonaviy yechimlarni kengaytirmoqda. Misol uchun, bank va moliya tizimida elektron to‘lov tizimlari va mobil banking xizmatlari joriy etilishi naqd puldan foydalanishni sezilarli darajada kamaytirdi. Bu esa iqtisodiy shaffoflikni oshirishga xizmat qilmoqda.

Elektron hukumat tizimi bugungi kunda aholiga ko‘plab qulayliklar yaratmoqda. MyGov va Davlat xizmatlari portali orqali fuqarolar turli hujjatlarni onlayn topshirish, soliqlarni to‘lash, transport vositalarini ro‘yxatdan o‘tkazish kabi xizmatlardan tezkor foydalanmoqda. Bu jarayon byurokratiyani kamaytirib, vaqt va resurslarni tejashga yordam bermoqda.

O‘ZBEKISTONDA XIZMAT KO‘RSATISH SOHASI BO‘YICHA STATISTIK MA’LUMOTLAR

№	Ko‘rsatkich	Ma’lumot	Sana
1	My.gov.uz portali xizmatlar soni	2024 oxirigacha 700 dan oshgan	2024
2	My.gov.uz foydalanuvchilar soni	10 milliondan oshdi	2024
3	My.gov.uz orqali foydalanishlar/ murojaatlar soni (arizalar)	10 milliondan oshdi	2024
4	My.gov mobil ilovasi foydalanuvchilari	33 milliondan ortiq	2024
5	Yagona portal (mygov) orqali pullik elektron davlat xizmatlarining tranzaksiyalari	+4 milliondan oshdi (2024 ga nisbatan)	2024
6	Qog‘oz tejash, ekologik foyda	50 milliondan ortiq tranzaksiya	2024
7	Mygov orqali foydalanuvchilar uchun chegirmalar	128 mlrd so‘m mablag‘ tejaldi va 160 tonna qog‘oz kam ishlatildi; ~3,2 mingdan ortiq daraxt saqlab qolindi	2024
8	Moliyaviy xizmatlar bozori o‘sishi	~ 149,5 mlrd so‘mdan ortiq	2024
9	Mobil aloqa operatorlari, tijorat banklari, to‘lov tashkilotlari orqali mobil ilovalar orqali yagona portal pulli xizmatlari	2025 yil 1-choragida moliyaviy xizmatlar hajmi 36,4 trln so‘mga yetib, o‘tgan yilning shu davriga nisbatan 19,6% ga oshdi; eng	2025

		katta ulush Toshkent shahri – bozorning ~59,7% ichi	
10	Elektron davlat xizmatlar ulushini oshirish maqsadi	2025-yil 1-noyabrdan imkoniyat yaratiladi	2025
11	Radio-televizor infratuzilmasi, optik tolali aloqa liniyalari	Elektron davlat xizmatlari ulushi 70% ga yetkazilishi rejalanmoqda — hudud va tarmoqlarda	2025-2026

Elektron savdo platformalari, xususan OLX va ZoodMall ichki bozorda raqobatni kuchaytirmoqda. Ular orqali kichik va o'rta biznes vakillari o'z mahsulotlarini onlayn sotish imkoniga ega bo'lib, bu tadbirkorlikni rivojlantirishga xizmat qilmoqda.

Mobil to'lov tizimlari (Click, PayMe, Upay) keng qo'llanilayotgani aholining kundalik hayotida sezilarli o'zgarishlar qilmoqda. Endilikda kommunal xizmatlar uchun to'lovlar, kreditlarni qaytarish va boshqa moliyaviy amaliyotlar soniyalarda amalga oshirilmoqda.

Masofaviy ta'lim platformalari (ZiyoNet, EduPortal) va telemeditsina xizmatlari (Doktor24, Telemed) esa aholining bilim olish va tibbiy maslahat olish imkoniyatlarini kengaytirmoqda. Ayniqsa, chekka hududlarda yashovchilar uchun bunday xizmatlar katta ahamiyat kasb etmoqda.

Biroq xizmat ko'rsatish sohasida ham qator muammolar mavjud. Ayrim hududlarda internet infratuzilmasining sustligi raqamli xizmatlarning to'liq ishlashiga to'sqinlik qilmoqda. Qishloq joylarda raqamli savodxonlik darajasi past bo'lgani uchun aholining katta qismi mavjud imkoniyatlardan foydalana olmayapti. Bundan tashqari, kiberxavfsizlik masalasi ham dolzarb bo'lib qolmoqda. Shu bois infratuzilmani rivojlantirish, maxsus ta'lim dasturlarini kengaytirish va qonunchilikni mustahkamlash zarur.

Elektron savdo ham xizmatlar sektorining muhim bo'lagi hisoblanadi. So'nggi uch yil davomida O'zbekistonda elektron savdo hajmi 3 baravarga ortdi. Bu esa, bir tomondan, iste'molchilarga qulaylik yaratgan bo'lsa, ikkinchi tomondan, tadbirkorlarga yangi bozorlarni egallash imkoniyatini berdi. Onlayn platformalar orqali nafaqat ichki, balki xalqaro bozorlar bilan ham savdo qilish yo'lga qo'yildi.

Shuningdek, telemeditsina xizmatlari aholi salomatligini saqlashda muhim o'rin egallamoqda. Masofadan turib shifokor bilan maslahatlashish, dori-darmon buyurtma qilish va tibbiy ma'lumotlarni elektron tarzda olish imkoniyatlari qishloq joylarda yashovchi aholiga katta qulayliklar yaratmoqda. Bu esa sog'liqni saqlash tizimida tenglikni ta'minlashda muhim qadamdir.

Xulosa.

Xizmat ko'rsatish sohasi raqamli iqtisodiyotning asosiy tayanchlaridan biri bo'lib, O'zbekistonda bu yo'nalishning rivoji nafaqat iqtisodiy samaradorlikni oshiradi, balki aholi hayot sifatini ham yaxshilaydi. Kelgusida raqamli xizmatlarning jadal kengayishi yangi ish o'rinlari yaratadi, tadbirkorlikni rag'batlantiradi va xalqaro bozorlarda raqobatbardoshlikni oshiradi. Shu bois, raqamli iqtisodiyotni rivojlantirish jarayonida xizmat ko'rsatish sohasiga strategik ustuvorlik berish dolzarb masala bo'lib qolmoqda.

Raqamli xizmatlarning kengayishi iqtisodiy samaradorlikni oshirish bilan birga, yangi kasblarning paydo bo'lishiga ham sabab bo'lmoqda. IT-mutaxassislar, kiberxavfsizlik bo'yicha ekspertlar, elektron savdo menejerlari va raqamli marketing bo'yicha mutaxassislar bugungi kunda eng talabgir kasblar sirasiga kiradi. Bu esa xizmatlar sektorini nafaqat ichki, balki xalqaro mehnat bozorida ham raqobatbardosh qilish imkonini beradi.

Foydalanilgan adabiyotlar:

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O‘ZBEKISTONDA MOBIL XIZMATLARNING RIVOJLANISHI VA ULARNING AHAMIYATI

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TATU mustaqil tadqiqotchi

Kirish.

Zamonaviy hayotimizni mobil texnologiyalarsiz tasavvur qilish mushkul. Mobil xizmatlar moliya, savdo, ta’lim, sog‘liqni saqlash va davlat boshqaruvi sohalariga jadal kirib bormoqda. O‘zbekistonda ham mobil xizmatlar tizimi oxirgi yillarda keng miqyosda rivojlanib, aholiga tezkor va sifatli xizmat ko‘rsatishda muhim o‘rin egallamoqda. Ayniqsa, pandemiya davrida mobil xizmatlarning ahamiyati yanada yaqqol namoyon bo‘ldi. Shu sababdan, mobil xizmatlarning rivojlanishini tahlil qilish ularning iqtisodiy va ijtimoiy ahamiyatini ochib berishda muhimdir.

Kalit so‘zlar: mobil xizmatlar, mobil banking, m-commerce, masofaviy ta’lim, telemeditsina, mobil davlat xizmatlari.

Asosiy qism. Bugungi raqamli transformatsiya jarayonlari butun dunyoda iqtisodiy, ijtimoiy va ma'naviy sohalarda tub o‘zgarishlarga sabab bo‘lmoqda. Ayniqsa, mobil texnologiyalarning tez sur’atlar bilan rivojlanishi jamiyat hayotining deyarli barcha jabhalarida yangicha xizmat turlarining paydo bo‘lishiga, ular orqali aholiga tez, qulay va interaktiv xizmatlar ko‘rsatishga imkon yaratmoqda.

O‘zbekiston ham ushbu jarayonlardan chetda qolmay, so‘nggi yillarda **mobil xizmatlar bozorini rivojlantirish, raqamli infratuzilmani mustahkamlash va aholi orasida raqamli savodxonlikni oshirish** borasida izchil islohotlarni amalga oshirmoqda. Xususan, “Raqamli O‘zbekiston – 2030” strategiyasida mobil texnologiyalar orqali aholiga davlat va xususiy sektor xizmatlarini tezkor yetkazib berish asosiy ustuvor yo‘nalishlardan biri sifatida qayd etilgan.

Mazkur тезисда O‘zbekistonda **mobil xizmatlarning shakllanishi, rivojlanish bosqichlari, mavjud infratuzilma**, shuningdek, **mobil xizmatlarning ijtimoiy-iqtisodiy ahamiyati** ilmiy jihatdan tahlil qilinadi. Shuningdek, mavjud muammolar va istiqbollar o‘rganilib, tegishli tavsiyalar shakllantiriladi.

Mobil xizmatlar — bu foydalanuvchilarga simsiz aloqa tarmoqlari (GSM, 3G, 4G, 5G va Wi-Fi) orqali real vaqt rejimida turli axborot, aloqa, moliyaviy va boshqa xizmatlarni taqdim etishga asoslangan faoliyat turi hisoblanadi. Ular odatda mobil telefon, planshet yoki boshqa ko‘chma qurilmalar orqali ishlatiladi.

Mobil xizmatlarga quyidagilar kiradi:

- mobil aloqa va internet xizmatlari;
- mobil bank va to‘lov tizimlari (Payme, Click, Apelsin);
- mobil ilovalar orqali ta’lim, tibbiyot, transport, tijorat xizmatlari;
- elektron davlat xizmatlari (my.gov.uz, Davlat xizmatlari agentligi ilovalari).

Click, PayMe, Upay kabi mobil ilovalar yordamida foydalanuvchilar kreditlarni to‘lash, kommunal xizmatlar uchun hisob-kitob qilish, pul o‘tkazish kabi jarayonlarni tez va qulay amalga oshirmoqda. Bu xizmatlarning kengayishi moliyaviy tizimda innovatsion o‘zgarishlarga sabab bo‘lib, bank-mijoz munosabatlarini yangi bosqichga olib chiqmoqda.

ZoodMall, OLX va boshqa platformalar orqali mahsulotlarni mobil telefon yordamida xarid qilish odatiy holga aylangan. Bu ichki bozorni rivojlantirib, iste’molchilar uchun qo‘shimcha imkoniyat yaratmoqda. Shu bilan birga, kichik biznes uchun yangi savdo kanallarini ochib bermoqda.

ZiyoNet, EduPortal kabi ta’lim platformalari hamda Doktor24, Telemed kabi xizmatlar pandemiya sharoitida masofaviy ta’lim olish va shifokor maslahati olish imkonini berdi. Bu xizmatlar bugungi kunda ham dolzarbligini yo‘qotmagan bo‘lib, aholi uchun muhim qo‘shimcha imkoniyat yaratmoqda.

“MyGov” ilovasi yordamida fuqarolar hujjat topshirish, soliqlarni to‘lash, transport vositalarini ro‘yxatdan o‘tkazish kabi xizmatlarni masofadan turib amalga oshirmoqda. Bu aholining davlat xizmatlaridan foydalanish jarayonida vaqt va resurslarini tejash imkonini bermoqda.

Mobil xizmatlar O‘zbekistonda nafaqat moliyaviy operatsiyalarni yengillashtirish, balki aholi turmush tarzini tubdan o‘zgartirishda ham muhim o‘rin tutmoqda. So‘nggi besh yil ichida mobil internet foydalanuvchilari soni ikki baravarga oshdi, bu esa mobil xizmatlarning tez sur’atlar bilan ommalashayotganidan dalolat beradi.

Mobil to‘lov tizimlari orqali aholining 70 foizdan ortig‘i kamida oyiga bir marta elektron to‘lov amalga oshirmoqda. Bu esa naqd pul aylanmasini kamaytirib, moliyaviy tizimning shaffofligini oshirmoqda. Shu bilan birga, soliqlar va davlat xizmatlari uchun to‘lovlarni mobil ilovalar orqali amalga oshirish imkoniyati fuqarolarga katta qulaylik yaratmoqda.

Mobil savdo platformalari kichik tadbirkorlar uchun yangi imkoniyatlarni ochmoqda. Ijtimoiy tarmoqlar va mobil ilovalar yordamida minglab tadbirkorlar o‘z mahsulotlarini mijozlarga yetkazmoqda. Ayniqsa, pandemiya davrida mobil savdoning ahamiyati ortib, aholiga zaruriy mahsulotlarni tezkor yetkazib berishda muhim rol o‘ynadi.

Mobil ta’lim xizmatlari yoshlarning bilim olish imkoniyatlarini kengaytirdi. Masalan, EduPortal va boshqa onlayn kurslar orqali talabalar dunyoning yetakchi universitetlari darslariga masofadan turib qatnashmoqda.

Bu esa ta'lim sifatini oshirish va kadrlar malakasini kuchaytirishda katta ahamiyat kasb etmoqda.

Xulosa.

O'zbekistonda mobil xizmatlarning keng joriy etilishi iqtisodiy samaradorlikni oshirib, aholiga kundalik hayotda qulaylik yaratmoqda. Mobil xizmatlar nafaqat vaqt va resurslarni tejaydi, balki iqtisodiy faoliyatni shaffoflashtiradi. Kelajakda ushbu xizmatlarning yanada kengayishi raqamli iqtisodiyotning barqaror rivojlanishiga xizmat qiladi, innovatsion yechimlarni rag'batlantiradi va aholining turmush tarzini yangi bosqichga olib chiqadi.

Mobil sog'liqni saqlash xizmatlari (mHealth) ham tobora rivojlanmoqda. Statistik ma'lumotlarga ko'ra, telemeditsina orqali masofadan maslahat olgan bemorlarning soni yiliga o'rtacha 25 foizga ortmoqda. Bu tizimning rivojlanishi sog'liqni saqlash tizimiga bosimni kamaytirib, aholiga tezkor yordam ko'rsatish imkonini bermoqda. Kelgusida Sun'iy intellekt asosidagi xizmatlar, aqlli shahar tizimlari, onlayn tibbiy monitoring va boshqa innovatsion yechimlar mobil xizmatlarning yanada samarali va qulay bo'lishiga xizmat qiladi. Mobil xizmatlar — O'zbekistonda xizmat ko'rsatish sohasining eng tez sur'atlar bilan rivojlanayotgan yo'nalishidir.Ular nafaqat iqtisodiy samaradorlik, balki aholining turmush sifati, raqamli inklyuzivlik va ijtimoiy tenglikni ta'minlashda ham muhim rol o'ynaydi. Mavzuga oid adabiyotlar yetarli, lekin ayrim yangi texnologiyalar (5G, eSIM, mobil AI xizmatlar) bo'yicha ilmiy izlanishlar kam.Kelgusida raqamli savodxonlik, mobil xavfsizlik, mobil moliyaviy xizmatlar va ularning qishloq hududlaridagi joriy etilishi bo'yicha chuqurroq tadqiqotlar talab etiladi.

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SMART CITIES: ISSUES OF CIVIL LAW REGULATION

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Abstract

This article provides a comprehensive overview of the smart cities concept and examines issues related to the regulation of civil legal relations within these urban systems. The rapid development of digital technologies and the acceleration of urbanization processes necessitate the introduction of new legal approaches in citizens' daily lives. Based on analysis of international experience, the article develops recommendations for improving civil legal relations in the process of developing smart cities in Uzbekistan. In addition, scientific theoretical approaches, legal foundations, and innovative management models are examined.

Keywords: smart cities, civil law, digital technologies, urbanization, legal regulation, e-governance.

Introduction

In the 21st century, urbanization processes are accelerating at an unprecedented pace. Today, nearly 56.2% of the world's population lives in urban areas, and according to the United Nations World Urbanization Prospects 2022 revision, this figure is projected to reach 68.4% by 2050 [1]. This rapid growth exerts significant pressure on urban infrastructure, environmental balance, and the overall quality of life of citizens. The sharp increase in urbanization brings with it critical challenges such as traffic congestion, shortages of energy resources, air pollution, and waste management issues. For instance, according to data from the World Health Organization (WHO), air pollution causes the premature death of approximately 6.7 million people worldwide each year [2].

In such circumstances, innovative approaches are required to manage cities efficiently and improve the quality of life for citizens. The modern solution to this challenge is the smart cities concept. Smart cities represent integrated systems designed to optimize urban infrastructure, create comfortable living environments for citizens, and ensure efficient use of urban resources through various information and communication technologies (ICT), the Internet of Things (IoT), artificial intelligence (AI), and big data analytics. This concept introduces not only technological improvements but also new demands and opportunities in social, economic, and legal spheres.

Globally, the smart cities concept has been widely adopted. For example, cities such as Singapore, Seoul (South Korea), and Barcelona (Spain) are leading models of smart city development. According to the International Institute for Management Development (IMD) Smart City Index 2023, the use of digital technologies in these cities has led to a 25-35% reduction in traffic congestion and a 20-40% decrease in the wastage of communal resources [3]. Moreover, digital services have enhanced transparency in communication between city administrations and citizens, significantly reducing bureaucratic barriers.

Urbanization processes are also rapidly developing in Uzbekistan. According to 2024 statistical data, approximately 50.5% of the population lives in urban areas, with the urbanization rate increasing by an average of 1.4% per year [4]. In particular, Tashkent and regional centers face high population density, intensifying challenges in public utilities, transportation, and housing sectors. To address these issues, the Government of Uzbekistan has launched a series of smart city projects within the framework of the "Digital Uzbekistan – 2030" strategy [5]. Notable initiatives include the introduction of intelligent traffic management systems, digital public services, online government platforms, and environmental monitoring systems in Tashkent, Samarkand, Bukhara, and Fergana.

However, this process requires not only technological advancements but also substantial legal reforms. For smart cities to operate effectively, citizens' rights and obligations must be clearly defined, modern mechanisms for personal data protection must be developed, and the legal regulatory framework must be strengthened. For example, smart city elements such as video surveillance systems, biometric databases, and online public services directly involve the collection and processing of citizens' personal data. This makes it necessary to adopt international standards, such as the General Data Protection Regulation (GDPR) of the European Union, to ensure transparency and security [6].

This issue is particularly relevant for Uzbekistan. While the country is advancing rapidly in digital transformation, legislation related to digital security and the legal protection of citizens requires further development. Therefore, establishing a robust legal framework for smart cities will not only protect citizens' rights but also strengthen trust between the government and society while supporting the sustainable development of the nation's digital economy.

The significance of this research lies in its focus not only on the technological development of smart cities but also on addressing the civil legal relations within them and proposing modern legal solutions tailored to the context of Uzbekistan.

Literature Review

An analysis of international and domestic scientific studies on the smart cities concept indicates that this field is regarded globally not only as a technological innovation but also as a complex integrated system that encompasses legal and social processes. In particular, numerous foreign scholars have extensively explored various aspects of smart cities from different perspectives.

Anthony Townsend, in his influential work "Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia", examines the smart city concept from the standpoint of information and communication technologies (ICT) and urban governance [7]. According to him, smart cities are not limited to the introduction of digital infrastructure alone, but also enhance interactive relations between citizens and the government, thereby contributing to the sustainable development of cities.

The OECD and UN-Habitat reports of 2023 highlight global trends in the development of legal frameworks for smart cities, the protection of personal data, digital security, and ensuring citizens' access to online public services [8]. These reports particularly emphasize the importance of legal mechanisms for data management and guaranteeing information security.

Rob Kitchin, in his works, deeply analyzes the management of big data collected from smart cities and its legal implications [9]. He argues that the use of big data must strictly adhere to international standards on personal data protection, which should serve as the fundamental guiding principle.

Robert Hall's research focuses on innovative governance models for smart cities and their legal foundations [10]. He emphasizes that collaboration between government agencies and the private sector is a key factor in ensuring the efficiency and success of smart city initiatives.

Russian scholars V.E. Chebotarev and A.N. Novosyolov, in their studies, examine the interaction between e-government systems and the smart city concept, with particular focus on legal mechanisms for protecting personal data and enhancing the digital rights of citizens [11].

In the context of South Korea, Kim Jong Ho and his co-authors analyze the smart city platforms in Seoul, highlighting their crucial role in improving citizens' quality of life and transforming public services into a fully digital format [12].

This body of literature demonstrates that while the technological development of smart cities is essential, equal attention must be given to the legal frameworks, privacy protection, and governance models that ensure their sustainable and citizen-centered implementation.

Research Methodology

This study employed comparative legal analysis, normative-legal analysis, and a systematic approach as its primary research methods. The comparative analysis examined smart city legal frameworks across multiple jurisdictions, focusing on data protection mechanisms, property rights frameworks, and governance models. The normative-legal analysis evaluated existing Uzbekistan legislation and identified regulatory gaps, while the systematic approach organized findings into coherent analytical categories for comprehensive evaluation.

Analysis and Results

The findings of the research indicate that the process of developing the smart city concept in Uzbekistan holds strategic importance, particularly in terms of regulating civil legal relations, which have not yet been sufficiently established in this area. Smart cities are designed to manage various aspects of citizens' lives through digital technologies, and this process involves the collection and processing of vast amounts of data, making related issues highly relevant.

First and foremost, the protection of personal data requires special attention. Within smart cities, various platforms such as video surveillance systems, biometric identification, intelligent traffic management systems, digital public utilities, and online government services collect large volumes of information about citizens. If these data are not adequately protected by legal mechanisms, there is a significant risk of unlawful use or abuse, which poses a serious threat to the privacy and integrity of citizens' personal lives.

The GDPR framework of the European Union serves as one of the most effective legal mechanisms for regulating such processes [6]. It clearly defines the rights of individuals and establishes requirements for consent regarding the collection, storage, and processing of personal data.

Although Uzbekistan has enacted the Law on Personal Data, its practical implementation remains insufficient [13]. In particular, there are no clear and transparent mechanisms regarding where data collected through video surveillance systems are stored, for what purposes they are used, and how their security is ensured.

Therefore, it is crucial for Uzbekistan to align its data protection practices with international standards and to establish an independent regulatory body to oversee this process. This would not only safeguard the personal rights of citizens but also strengthen public trust in digital services, thereby driving the development of the digital economy in the country.

Analysis of legal and civil issues in the development of smart cities

№	Key Areas	Current Situation (Uzbekistan)	International Experience	Relevance and Challenges	Suggestions and Recommendations
1	**Civil Law and Protection of Personal Data**	The Law on Personal Data exists, but its practical implementation is insufficient. Transparency is low regarding where	In the European Union, the GDPR framework establishes strict requirements and accountability for personal	High risk of data misuse and low public trust in digital services.	Develop a national framework similar to GDPR and establish an independent regulatory body for data protection.

		data is stored and how it is used.	data protection.		
2	**Property Rights in Smart Infrastructure**	In managing smart homes and shared resources, property rights and common property use are not clearly defined.	In Singapore and South Korea, clear legal agreements between the government and the private sector are in place.	Ambiguity in property rights increases risks in attracting investments.	Develop specific legislation and regulatory documents that clearly define property rights.
3	**Integration of E-Government and Legal Processes**	Services are provided through my.gov.uz, but integration is incomplete, and many services are still in pilot mode.	In Estonia and Canada, e-government systems allow citizens to conduct all legal processes fully online.	Corruption risks, limited access to services, and additional bureaucracy remain.	Along with developing e-government, strengthen its legal framework and enhance integration.
4	**Opportunities and Challenges of Implementation in Uzbekistan**	Pilot projects are being implemented in cities such as Tashkent, Samarkand, and Bukhara. Digital services have been introduced.	International practice ensures broad citizen participation and strong government-private sector cooperation in projects.	Lack of clear definitions in legislation, low levels of digital literacy and legal awareness, delays in adopting regulatory documents.	Improve legislation, increase citizens' digital literacy, and expand public-private partnerships.

At the same time, in the management processes of infrastructure within the framework of smart cities, clearly defining property rights is of crucial importance. In relations related to smart homes and shared resources, distinguishing between private and communal property helps to prevent legal disputes. For instance, in the housing sector, processes such as energy distribution or water supply managed through smart meters require clear definitions of each citizen's rights and obligations regarding the use of resources.

In global practice, such relations are regulated through specific laws and normative documents adopted by local government authorities. For example, in Singapore and South Korea, clear legal agreements between the state and the private sector have been developed for managing smart home infrastructure [14]. In Uzbekistan, however, such a system has not yet been fully established, and significant legal gaps are observed, especially in projects involving private investors. This situation increases risks during the implementation of new technologies and financing of projects. Therefore, creating a solid legal framework that clearly defines property rights will not only protect the interests of citizens but also play an important role in attracting private sector participation.

Smart cities also create significant opportunities for the development of e-government systems. E-government simplifies interactions between citizens and state bodies by allowing legal requests to be processed electronically. This not only saves time and resources but also reduces corruption risks and increases transparency in public services.

International experience shows that the effective operation of e-government depends not only on modern information technologies but also on the strength of the legal framework. For instance, in Estonia, Canada, and South Korea, all legal processes—from birth registration to property rights formalization—are carried out entirely online [15].

In Uzbekistan, several electronic services are provided through platforms like my.gov.uz, but these services are not yet fully integrated [16]. Many services remain in pilot project form or operate only in certain regions. This significantly limits citizens' access to digital services. Therefore, along with the development of e-government systems, it is crucial to improve their legal foundations and strengthen the integration processes among state institutions.

The "Smart City" projects currently being implemented in Uzbekistan, particularly the pilot programs in Tashkent, Samarkand, and Bukhara, aim to create a comfortable environment for citizens and expand digital services. Examples include intelligent traffic management systems, digital public utility services, and online tax and banking services. However, there are still several legal and regulatory challenges associated with these services.

First, the lack of clear definitions and concepts in legislation creates contradictions in practice. In addition, insufficient mechanisms for personal data protection negatively impact citizens' trust in digital services. Furthermore, delays in adopting important regulatory documents and the low level of digital literacy and legal awareness among citizens lead to difficulties in the proper use of these services.

If these issues are not addressed in a timely manner, the effectiveness of ongoing projects will decrease, and public distrust in digital services will grow. This could negatively affect not only the digital transformation of cities but also the country's overall strategic development goals.

Overall, the analysis shows that the smart city concept is closely linked not only to technological innovations but also to comprehensive reform of the legal system. Protecting citizens' personal data, defining property rights, developing e-government systems, and creating a legal framework tailored to

local conditions are fundamental prerequisites for the successful development of smart cities in Uzbekistan. Therefore, it is essential to strengthen cooperation among state institutions, the private sector, and scientific organizations. This process will not only improve urban infrastructure but also contribute to the sustainable development of the country's digital economy and civil society.

Conclusion

The development of the smart city concept is closely linked to the rapid acceleration of urbanization processes in the 21st century and the widespread use of digital technologies. The findings of this research show that the effective functioning of smart cities depends not only on technological solutions but also on the regulation of civil legal relations in accordance with modern requirements.

First and foremost, the protection of personal data and the ensuring of citizens' digital security must be considered top priorities. Although Uzbekistan's current legislative framework provides a certain foundation in this area, it is essential to introduce mechanisms aligned with international standards, particularly the GDPR framework of the European Union. Such measures will enhance public trust in digital services and contribute to the sustainable development of the digital economy.

Secondly, it is crucial to clearly define property rights and usage rights in relation to smart homes and shared resources. Ambiguity in property rights discourages private sector investments, which negatively affects the effectiveness of projects. Therefore, property relations must be explicitly defined through the adoption of specialized laws and regulatory documents.

Thirdly, the development of e-government systems and their full integration with citizens' daily legal processes play a vital role. International examples, such as those of Estonia and South Korea, demonstrate that e-government reduces corruption risks, enhances the transparency of public services, and provides greater convenience for citizens.

The pilot projects currently being implemented in Uzbekistan, especially the "Smart City" programs in Tashkent and other major cities, offer significant opportunities for the country. However, these initiatives face key challenges, including gaps in legislation, limited digital literacy levels, and delays in the adoption of regulatory documents. If these issues are not resolved in a timely manner, the effectiveness of the projects may decline, and public distrust in digital services may grow.

In conclusion, collaboration between government institutions, the private sector, and citizens plays a crucial role in the development of smart cities. By integrating modern technological solutions and international legal standards into national legislation, Uzbekistan can achieve not only technological progress but also the sustainable formation of a rule-of-law state and a civil society. This will be a key factor not only in the digital transformation of cities but also in ensuring Uzbekistan's global competitiveness in the future.

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УМНЫЕ ГОРОДА И УСТОЙЧИВОЕ РАЗВИТИЕ: ГРАЖДАНСКО-ПРАВОВЫЕ МЕХАНИЗМЫ НА ОСНОВЕ ЗАРУБЕЖНОГО ОПЫТА

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Аннотация

В статье анализируются гражданско-правовые механизмы, необходимые для гармонизации концепции умных городов с целями устойчивого развития. На примере Эстонии, Сингапура, Барселоны, Амстердама и Сеула рассматриваются правовые решения по вопросам владения и использования данных, защиты персональных данных, условий государственно-частного партнёрства (ГЧП), интеллектуальной собственности, алгоритмической прозрачности, а также исков и ответственности, связанных с IoT и цифровой инфраструктурой. Автор предлагает поэтапный подход для Узбекистана – «Модель правового и технического синтеза (МПТС)», включающую: 1) матрицу прав на данные, 2) нормы прозрачности и согласия, 3) стандартизированные договорные условия (ГЧП, соглашения об уровне услуг), 4) регулятивные песочницы и алгоритмический аудит, 5) механизмы подачи исков и компенсаций для граждан. Предлагаемые меры соответствуют показателям ISO 37120/37122, ЦУР 11 (SDG 11) и открытым лицензиям на данные (ODC/CC BY).

Ключевые слова:

умные города, устойчивое развитие, гражданско-правовые механизмы, владение данными, защита персональных данных, ГЧП, интеллектуальная собственность, алгоритмическая прозрачность, ISO 37120, SDG 11.

Введение

Умные города сегодня рассматриваются как новый этап процессов урбанизации. По данным Департамента ООН по экономическим и социальным вопросам, к 2050 году прогнозируется, что 68% населения мира будет проживать в городских районах [1]. Это приведёт к значительному увеличению нагрузки на городскую инфраструктуру и усилит необходимость более эффективного использования ресурсов. В настоящее время в глобальном масштабе 56% населения живёт в городах, и этот показатель ежегодно увеличивается в среднем на 1,9% [2]. В связи с этим концепция умных городов – то есть организация городских услуг с помощью цифровых технологий, Интернета вещей (IoT), искусственного интеллекта, анализа данных и автоматизированных систем управления – рассматривается государствами как стратегический приоритет.

Основная цель умных городов заключается не только во внедрении технологических решений, но и в повышении благосостояния граждан, обеспечении экологической устойчивости и достижении экономической эффективности. Например, в Сингапуре в рамках проекта "Smart Nation" была внедрена цифровая система управления транспортом, что позволило сократить время пробок на дорогах на 25% [3]. В Эстонии электронные государственные услуги охватывают 99% населения, что обеспечивает экономию времени примерно на 820 лет в год для всей страны [4]. Согласно отчёту компании IDC за 2024 год, объём глобальных инвестиций в технологии умных городов к 2030 году может достичь 2,0 трлн долларов США [5].

Однако внедрение технологической инфраструктуры само по себе недостаточно. Социальная приемлемость, безопасность и устойчивость этих процессов должны основываться на прочной гражданско-правовой базе. Особенно важными являются вопросы защиты персональных данных, контроля над информацией, собираемой через системы мониторинга в реальном времени, прозрачности алгоритмических решений, а также чёткого разграничения прав собственности и ответственности в рамках платформенной экономики. Например, вступивший в силу в 2018 году GDPR (General Data Protection Regulation) Европейского Союза ввёл строгие нормы обработки персональных данных, что оказало значительное влияние не только на страны Европы, но и на деятельность глобальных технологических компаний [6]. В США в штате Калифорния был принят закон CCPA (California Consumer Privacy Act), который предоставляет гражданам право контроля над своими персональными данными [7].

Кроме того, в рамках концепции умных городов остаются актуальными такие задачи, как развитие сотрудничества между государственным и частным секторами – разработка договоров государственно-частного партнёрства (ГЧП),

стандартизация соглашений об уровне услуг (SLA) и внедрение механизмов рассмотрения жалоб граждан. По данным McKinsey Global Institute, комплексное внедрение технологий умных городов может снизить количество дорожно-транспортных происшествий на 8–15%, а коммунальные расходы – на 10–20% [8]. В то же время отсутствие прочной правовой базы и неконтролируемые алгоритмические решения могут привести к кризису доверия в обществе.

В Узбекистане процессы урбанизации также набирают темпы. По данным Государственного комитета по статистике, на конец 2024 года численность населения страны превысила 37 миллионов человек, из которых 52% проживают в городах [9]. В рамках стратегии "Цифровой Узбекистан – 2030" предусмотрено внедрение концепции умных городов [10]. Однако успех этого процесса напрямую зависит не только от технологической модернизации, но и от формирования прочных правовых механизмов.

В связи с этим в данной статье анализируется зарубежный опыт в сфере умных городов, а также рассматриваются гражданско-правовые основы, необходимые для их эффективного функционирования в условиях Узбекистана. На основе проведённого анализа автор предлагает практическую концептуальную модель, которая может стать важным стратегическим шагом в направлении инновационного управления, обеспечения экологической устойчивости и укрепления доверия граждан.

Анализ литературы по теме

Харрисон и Доннелли в проекте "Smarter Cities", поддержанном компанией IBM, разработали систему показателей для интегрированного управления городскими услугами. Эти показатели впоследствии легли в основу стандартов ISO [11].

Международный союз электросвязи (ITU-T) разработал рекомендации "Key Performance Indicators for Smart Sustainable Cities", которые предлагают глобальные критерии оценки умных городов [12]. В исследованиях Нейротти и коллег был проведён анализ более чем 70 крупных городов, в результате которого установлено, что использование индикаторов в четырёх ключевых направлениях – транспорт, энергетика, управление и здравоохранение – является наиболее эффективным [13].

Батти и соавторы в своих исследованиях ввели понятие "урбанизм больших данных" (big data urbanism), подчеркнув стратегическое значение больших данных в управлении городами [14]. В отчёте UN-Habitat за 2023 год отмечается необходимость развития открытых платформ данных и обеспечения цифрового равенства для усиления участия граждан в управлении [15]. Согласно исследованию ОЭСР "Digital Government Index", в странах, успешно реализующих политику открытых данных, уровень доверия граждан к государственным структурам повысился на 27% [16].

В исследованиях Мейджера и Боливара подчёркивается, что умные города следует рассматривать не только как технологические платформы, но и как "открытые инновационные экосистемы". По их мнению, прозрачность данных и участие граждан в системе управления городом повышают подотчётность властей и способствуют снижению уровня коррупции [17].

Каролью, Дель Бо и Найкамп установили, что успех умных городов зависит от трёх ключевых факторов: знаний и инноваций, социального капитала общества и высокого качества управления. Кроме того, они особо подчёркивают, что политика управления данными должна обеспечивать широкое вовлечение граждан в процесс принятия решений [18].

В развитии умных городов важную роль играют правовые вопросы, такие как защита персональных данных, интеллектуальная собственность, ответственность и государственно-частное партнёрство. Вступивший в силу в странах Европейского Союза с 2018 года GDPR (General Data Protection Regulation) ввёл строгие принципы обработки персональных данных, став обязательным стандартом и для глобальных компаний [19]. Гринлиф в своём научном исследовании отметил, что влияние GDPR распространяется не только на Европу, но также оказывает значительное воздействие на правовые системы стран Азии и Америки [20].

В Сингапуре был принят закон PDPA (Personal Data Protection Act), который обеспечивает сбалансированное управление обменом данными между бизнесом и государственными услугами. Хо, анализируя данный закон, подчеркнул его преимущество – защиту персональных данных без ограничения инновационной активности [21].

В Амстердаме и Барселоне внедрён "реестр алгоритмов", обеспечивающий прозрачность систем искусственного интеллекта и алгоритмического управления [22]. Зубофф в своей книге "Эпоха капитализма слежки" научно обосновала, что потеря контроля над персональными данными представляет собой наибольшую угрозу для свободы граждан [23].

Нам и Пардо, а также Ангелиду в своих исследованиях доказали, что сочетание технологических решений, участия людей и институциональной базы приводит к устойчивому развитию городов [24], [25].

Таким образом, по мнению зарубежных учёных, для Узбекистана стратегически важно внедрять концепцию умных городов именно на основе комплексного подхода, который объединяет технические стандарты, социальное участие и правовые механизмы.

Анализ и результаты

Успешное внедрение умных городов зависит не только от технологических решений, но и от правильного правового и институционального регулирования. В данном разделе подробно анализируются наиболее важные гражданско-правовые механизмы для умных городов и, на

основе изучения зарубежного опыта, разработаны предложения для их применения в Узбекистане.

Таблица 1

Анализ гражданско-правовых механизмов на основе зарубежного опыта в развитии умных городов

№	Направление	Проблема	Зарубежный опыт	Практический механизм для Узбекистана
1	Права собственности и обмена данными	Неопределённость, кому принадлежат данные, собираемые с устройств IoT и датчиков, и на каких условиях они могут быть переданы.	Эстония – принцип «однократного ввода данных» и интеграция через X-Road; Барселона/Амстердам – политика открытых данных и data-tracing.	Разработка матрицы прав на данные; стандартизация договоров Data Sharing Agreement.
2	Защита персональных данных и согласие	Интеллектуальные камеры, геолокация и системы «умного учёта» (smart metering) могут угрожать неприкосновенности частной жизни граждан.	ЕС GDPR – прозрачность, минимализм, принцип «privacy by design»; Сингапур PDPA – баланс между бизнесом и государством.	Обязательное проведение DPIA; создание центра управления согласием (consent dashboard); внедрение протоколов анонимизации и псевдонимизации данных.
3	ГЧП и SLA	Управление инфраструктурой умных городов частным сектором создаёт правовые пробелы в вопросах ответственности и гарантий качества.	Стандартизированные контракты ГЧП и SLA, включая положения по кибербезопасности, сбоям и компенсациям.	Адаптация ГЧП и SLA к национальным стандартам; локализация данных и внедрение системы национальной сертификации.
4	Интеллектуальная собственность и лицензии	Пересечение различных прав на программное обеспечение, алгоритмы и базы данных.	Для открытых данных – лицензии ODC-BY/CC BY; для открытого кода – GPL, MIT, Apache.	Чёткое разграничение прав подрядчика и города через «конфедеративную модель»; развитие политики открытых данных.
5	Алгоритмическая прозрачность и подотчётность	Риск ошибок алгоритмов и дискриминации.	Амстердам – «Реестр алгоритмов», система оценки рисков и механизм прозрачности.	Внедрение алгоритмического аудита; требования Explainable AI (XAI); строгие стандарты для систем высокого риска.
6	Безопасность IoT и ответственность за продукт	Сбои устройств, кибератаки и перебои в услугах могут нанести ущерб населению.	Сертификаты кибербезопасности и тесты на проникновение; политика responsible disclosure.	Чёткое распределение ответственности между производителем, интегратором и оператором; создание онлайн-системы претензий и арбитража.
7	Участие граждан и социальный контракт	Недостаток доверия граждан и низкая прозрачность процессов.	Расширение участия через онлайн-платформы и гражданские советы в процессе принятия решений.	Публикация открытых межквартальных отчётов; программы цифровой грамотности; обеспечение универсального доступа в интернет.
8	МПТС – Модель правового и технического синтеза	Несогласованность правовых и технических норм.	Глобальные стандарты, такие как ISO 37120/37122.	7-этапная модель МПТС: права на данные, DPIA, ГЧП и SLA, алгоритмический аудит, система претензий и компенсаций, гармонизация индикаторов, тестовые зоны (sandbox).

Первая ключевая проблема – определение прав собственности, использования и обмена данными. Сегодня устройства IoT, интеллектуальные датчики, мобильные приложения и системы коммунальных услуг генерируют огромные объемы данных. Однако часто не определено, кому принадлежат эти данные, на каких условиях они могут передаваться и использоваться в коммерческих целях. В качестве примера можно привести модель Эстонии. В этой стране внедрён принцип «однократного ввода данных» с использованием интеграционной платформы X-Road, которая позволяет гражданам полностью контролировать свои данные [26]. Каждый гражданин может через специальный электронный журнал отслеживать, какие организации получили доступ к его данным. В Барселоне и Амстердаме реализована политика открытых данных и система data-tracing, благодаря которой определяется правовой статус данных по категориям [27]. На основе этих практик для Узбекистана необходимо разработать матрицу прав на данные и стандартизировать договоры по обмену данными (Data Sharing Agreement). Такая матрица должна чётко определять владельца данных, цель их использования, возможности монетизации и право на удаление.

Вторая проблема – защита персональных данных и управление согласием. Технологии умных городов, такие как интеллектуальные камеры, сервисы геолокации и системы «умного учёта», могут представлять угрозу

неприкосновенности частной жизни граждан. В Европейском Союзе введён GDPR (General Data Protection Regulation), который стал глобальным стандартом в этой сфере и закрепил принципы прозрачности, минимализма, целевого использования данных и «privacy by design» [28]. В Сингапуре действует закон PDPA (Personal Data Protection Act), который не только обеспечивает защиту персональных данных, но и поддерживает непрерывность бизнес-процессов [29]. Для Узбекистана в качестве практического решения предлагается сделать обязательным проведение DPIA (Data Protection Impact Assessment), создать для граждан «центр управления согласием» (consent dashboard), а также внедрить протоколы анонимизации и псевдонимизации данных.

Третья проблема – государственно-частное партнёрство (ГЧП) и соглашения об уровне услуг (SLA). Проекты по развитию инфраструктуры умных городов часто реализуются и управляются частными компаниями, что создаёт правовые пробелы в вопросах ответственности, качества и непрерывности услуг. В зарубежной практике применяются стандартизированные контракты ГЧП, в которых чётко прописаны положения о правах на данные, кибербезопасности, техническом обслуживании и форс-мажоре [30]. Соглашения SLA регламентируют допустимые задержки, сбои, уровень ошибок, а также механизмы штрафов и компенсаций. Кроме того, для импортируемых платформ необходимо внедрять требования по локализации данных и национальной сертификации.

Четвёртая проблема – интеллектуальная собственность и лицензирование. В рамках решений для умных городов часто возникает пересечение прав на программное обеспечение, алгоритмы и базы данных. В зарубежных странах открытые данные регулируются лицензиями ODC-BY или CC BY, при этом конфиденциальная и коммерческая информация должна быть исключена [31]. Для программного обеспечения применяются лицензии открытого кода, такие как GPL, MIT или Apache. Кроме того, важно использовать «конфедеративную модель», при которой чётко разграничиваются права на интеллектуальную собственность подрядчиков и права города на данные.

Пятая проблема – обеспечение алгоритмической прозрачности и подотчётности. В системах умных городов, таких как управление дорожным движением, распределение ресурсов или кредитный скоринг, могут возникать ошибки алгоритмов или проявления дискриминации. В Амстердаме для минимизации этих рисков внедрён «реестр алгоритмов», где указывается цель каждого алгоритма, источники данных и оценка рисков [32]. Для Узбекистана рекомендуется внедрить регулярный алгоритмический аудит, проводимый независимыми организациями, а также реализовать принципы объяснимого искусственного интеллекта (Explainable AI – XAI) и установить более строгие требования к системам высокого риска.

Шестая проблема – безопасность IoT, ответственность за продукты и регулирование претензий. Сбои в работе устройств и датчиков, кибератаки или перебои в услугах могут причинить значительный ущерб населению. Поэтому необходимо чётко распределить ответственность между производителем, интегратором и оператором. Также следует внедрить стандарты кибербезопасности, систему сертификации, регулярные тесты на проникновение (penetration tests) и политику уведомления о выявленных уязвимостях (responsible disclosure) [33]. Процессы рассмотрения претензий и компенсаций можно упростить за счёт создания онлайн-системы арбитража и коллективных исков.

Седьмая проблема – участие граждан и развитие механизма социального контракта. Доверие граждан является важнейшим фактором для успешного внедрения технологий. Поэтому необходимо развивать гражданские советы и онлайн-платформы для оценки проектов, публиковать ежеквартальные открытые отчёты о деятельности городских служб, а также расширять программы цифровой грамотности и обеспечивать универсальный доступ к интернету [34]. Это не только повышает доверие граждан, но и ускоряет процесс принятия обществом интеллектуальных технологий.

В заключение для Узбекистана предлагается «Модель правового и технического синтеза (МПТС)», которая направлена на гармонизацию технологических инноваций и правовых норм. Модель состоит из семи ключевых этапов:

1. **Матрица прав на данные** – определение владельца данных (гражданин, город или поставщик услуг), цели использования, срока хранения и права на удаление.
2. **Согласие и DPIA** – обязательное проведение DPIA для систем высокого риска и внедрение механизмов отзывного согласия граждан.
3. **Стандарты ГЧП и SLA** – закрепление положений о кибербезопасности, локализации данных и штрафах за сбои в работе.
4. **Алгоритмический аудит и реестр** – ведение перечня высокорисковых алгоритмов и проведение их независимой проверки.
5. **Система претензий и компенсаций** – создание онлайн-портала для подачи претензий и механизма коллективных исков.
6. **Гармонизация индикаторов** – разработка правовых показателей, соответствующих международным стандартам ISO 37120 и ISO 37122, включая долю проведённых DPIA и процент выполнения SLA.

7. **Механизм песочницы (Sandbox)** – тестирование новых правовых и технических решений в таких ключевых секторах, как транспорт, энергетика и здравоохранение.

Предложенный подход позволит не только внедрить технологические инновации в Узбекистане, но и обеспечить высокий уровень правовой безопасности. Это приведёт к повышению качества городских услуг, укреплению доверия граждан и созданию прочной основы для устойчивого развития страны.

Заключение

Концепция умных городов на первый взгляд может показаться связанной исключительно с технологическими инновациями, однако на практике они должны рассматриваться не столько как технологический, сколько как правовой и институциональный проект. Анализ зарубежного опыта показывает, что ключ к успешному развитию умных городов заключается не только во внедрении технологий, но и в создании прочных правовых механизмов, регулирующих их функционирование.

В первую очередь важным является чёткое определение прав на данные, правил их использования и получения согласия граждан. Это особенно важно, поскольку данные, собираемые через устройства IoT, интеллектуальные камеры и цифровые сервисы, становятся центральным ресурсом в управлении городом. При отсутствии надлежащего правового регулирования возрастает риск нарушения частной жизни граждан, неправильного использования данных и снижения уровня доверия в обществе.

Не менее важным является правовое укрепление сотрудничества между государственным и частным сектором (ГЧП) и обеспечение качества и безопасности городской инфраструктуры через соглашения об уровне услуг (SLA). Опыт зарубежных стран показывает, что именно правильно выстроенные механизмы ГЧП обеспечивают стабильность городской инфраструктуры, высокий уровень технического обслуживания и кибербезопасности.

Кроме того, особое значение имеет прозрачность алгоритмических систем управления и проведение их регулярного аудита. Опыт таких городов, как Амстердам и Барселона, демонстрирует, что внедрение общественного контроля за алгоритмами снижает уровень дискриминации и ошибок, а также укрепляет доверие граждан.

Ещё одним важным фактором успеха умных городов является наличие у граждан реальных механизмов подачи претензий и получения компенсаций. Такие механизмы позволяют гражданам оперативно и эффективно защищать свои права в случаях их нарушения или снижения качества предоставляемых услуг.

Предложенная для Узбекистана Модель правового и технического синтеза (МПТС) направлена на гармонизацию технологических стандартов, международных показателей и национальных правовых норм. Пошаговая реализация этой модели позволит вывести систему городского управления на качественно новый уровень. Это приведёт не только к значительному повышению качества и эффективности городских услуг, но и к укреплению доверия граждан к государственным и цифровым инфраструктурам. В результате процессы урбанизации в Узбекистане будут ориентированы на устойчивое развитие, обеспечится экологическая безопасность и повысится общий уровень благосостояния общества.

Таким образом, правильное выстраивание правовых механизмов в развитии умных городов позволит сделать технологические достижения более эффективными и устойчивыми. Это станет прочной основой для создания современных и безопасных городов, соответствующих международным стандартам и долгосрочным стратегиям развития страны.

Список использованной литературы

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STAGES OF DIGITAL ECONOMY

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Abstract. This article analyzes the development of the digital economy from the perspective of creating conditions for the development of highly effective technologies and platforms, as well as related economic sectors and markets where suppliers and consumers of high-tech services, including financial services, directly interact. Adjustments to the gradation used to distinguish stages of digital economy development based on global experience are proposed.

Keywords: digitalization, digital economy, digital space, financial technology companies.

The concept of the "digital economy" was first coined by American scientist and University of Massachusetts professor Nicholas Negroponte in 1995. Its rapid development continues today. In terms of scale and impact, the digitalization process can be compared to the Industrial Revolution of the 18th and 19th centuries, which transformed the model of human development. Today, the digital economy's share of GDP in various countries is beginning to occupy a significant place. The United Kingdom leads the way with 12.4%, and forecasts indicate that by 2035, the digital economy will reach $16 trillion [1].

Electronic payment systems, online stores, and various electronic services are all integral attributes of modern life. Products of the digital economy have certain advantages over the real/material economy. For example, electronic goods are often cheaper and virtually unlimited in quantity, unlike goods exchanged through real/material exchange. In the modern world, IT companies typically have the highest market capitalization. At the beginning of 2018, the leading positions in the rankings were occupied by companies such as Apple, Microsoft, Amazon Inc., and Alphabet Inc.

The digital economy began to develop in the late 1950s. Since the 1960s, the world has seen a rapid expansion of processes and technologies. In 1960, IBM and American Airlines introduced the SABRE system (which operated until the early 2000s), which automated the process of reserving airline tickets and hotels. The British Videotex system gave impetus to the development of electronic trading in the 1970s. The creation of the Internet on January 1, 1983, was one of the major stages in the development of the digital economy [1].

The second stage of digitalization began around the mid-1990s, during which time the Internet and mobile communications spread globally across all spheres of public life [4]. In 1994, Stanford Federal Credit Union launched an online banking system. That same year, University of Toronto professor D. Tapscott's book "Digital Economy" was published [9]. According to Tapscott, innovation, virtualization, and globalization are driving the development of the digital economy, thereby changing the traditional interaction between consumers and producers, improving the quality of equipment, and creating "smart" urban infrastructure. Therefore, the use of new technologies in the education system, which is also expanding, is so important. Today, virtually every educational institution has internet access and a website. Online education is also gaining popularity; on sites such as Coursera, Udemy, Khan Academy, and others, users can take any course at their convenience. Universities are becoming active consumers of new technologies [2]. This aspect is also important in improving the financial literacy of the population, especially in light of the ongoing pension system reform [6].

It seems that today it is entirely possible to speak of a third stage of digitalization, associated with the spread of digital currencies and distributed ledger technology in the global economy, as different approaches are being used to interpret the concept of the digital economy – from the complete process of creating an end-to-end.

From a digital product to the use of online applications [5]. Bitcoin and other digital currencies have already established their place in the global financial market, and their number (as well as the scale of transactions with them) is expanding, thereby creating a new currency component of the global financial architecture [8] that meets the demands of the times and follows the financialization of the modern global economy.

It is believed that they have been in use since 2009, and over a period of 10 years, they have already proven their relevance and significance. Consequently, digitalization has the potential to significantly impact the very foundation of the global monetary system [7].

Fundamentally, the digital economy consists of three levels:

– an environment in which conditions are created for the development of highly effective technologies;

– technologies and platforms;

– economic sectors and markets in which service providers and consumers directly interact.

The digitalization process is impossible without the presence of platforms, corresponding infrastructure, and technologies. The digital economy program is primarily focused on the first two levels; for the state, the priority tasks are: creating an information environment and ensuring information security, as well as the formation of technological institutions [3].

Global experience shows that the digital economy enhances competitiveness, stimulates investment, and increases labor productivity. This is,

of course, provided it is appropriately regulated. The digital economy's share of GDP is constantly growing worldwide, and many corporate and government companies are developing specialized programs. Moreover, in the digital economy, redistributive relations are also beginning to move into the virtual realm of digital space, actively being implemented in the financial market – in the areas of settlements (transfers and payments), capital management, and project financing.

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STAGES OF DEVELOPMENT OF THE DIGITAL ECONOMY

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Abstract. This article analyzes the main trends in the development of digital technologies and the reasons for their spread and use in business. It examines the properties of network benefits and their impact on consumers and producers. The rapid development of the internet at the beginning of the 21st century has fundamentally changed the face of modern civilization. This is especially evident when compared to other changes occurring in developing countries at the turn of the century. Making the internet accessible, affordable, open, and secure has proven difficult for many. The World Bank's 2016 World Development Report analyzes the reasons for the slow pace of digital technology adoption and outlines a strategy for internet development. It helps understand how to spread the benefits and reduce the costs of digital technology development. At the beginning of the 21st century, when the advanced part of humanity lives in a post-industrial society, a "global digital divide" is becoming a characteristic feature of global polarization. Social polarization takes on a new dimension, dividing members of the global community into the internet haves and the internet have-nots. This article analyzes the structure of the digital economy and highlights the main stages of its development. To this end, an original definition of the digital economy is provided. A three-tiered structure necessary for its functioning is proposed. For each level, the underlying preconditions are identified. This allows us to formulate the priority tasks and challenges facing the economy on its path to digitalization. The conclusion examines the institutional factors hindering the development of the digital economy.

Keywords: digital economy; innovation; digital technologies; Industry 4.0.

Introduction

D. Bell linked the scientific and technological revolution primarily with the revolution in telecommunications. While in the 19th and first half of the 20th centuries, the two main forms of communication were newspapers, magazines, and books, on the one hand, and the telegraph, telephone, radio, and television, on the other, in the second half of the 20th century, the development of computer communications became paramount. In this regard, in his 1980 work "The Social Framework of the Information Society," he formulated five problems that, in his opinion, humanity must solve in the coming decades:

1. The merging of telephone and computer systems, telecommunications, and information processing into a single model;

2. The replacement of paper with electronic means;

3. The expansion of television service through cable systems;

4, Reorganization of computer-based information storage and retrieval systems into an interactive information network accessible to all;

5. Expansion of the education system based on computer-based learning (Bell, 1968, pp. 330–342).[1]

At the beginning of the 21st century, approximately 15–20% of humanity begins to live in a post-industrial society, 60–70% remain in industrial society, and another 15–20% fails to even undergo primary industrialization. This polarization is characterized by a "global digital divide" (Table 1). The previously existing social opposition between owners of the means of production and wage workers is being replaced, according to M. Castells, by a division between the internet haves and the internet have-nots. And in this new world, even after the reforms of the 1990s, Russia is not narrowing, but widening, its gap with developed countries.

Thus, theories of post-industrial society claim to be a new social philosophy that points both developed countries and humanity as a whole to strategic development guidelines. However, these theories have not yet reached the level where they can formulate direct, tactical recommendations for socio-economic regulation. Therefore, the formation of regulatory institutions took place in the second half of the 20th century. Either based on Keynesian theories, or even spontaneously. It is known that the preconditions for the emergence of the internet emerged in the mid-20th century. Its development occurred primarily in parallel in two competing countries: the USSR and the USA. It can be said that the Cold War served as the motivating backdrop for this activity, significantly influencing government demand for technological innovations in the field of security and providing the corresponding funding (Castells, 2004)[2]. It is now known that the internet failed to develop and spread under the Soviet system, whether due to bureaucracy or conflicts of interest on the part of the officials making the necessary decisions (Peters, 2016)[3].

The internet as we know it today is the result of the work of American scientists. Below is a chronology of the key events and dates that led to the establishment of the internet in its current form:

1958 – Founding of ARPA (Advanced Research Projects Agency) by the US Department of Defense;

1962 – Formation of the Information Processing Techniques Office (IPTO) within ARPA;

1969 – Creation of the ARPANET computer network by the IPTO and connection of the first university nodes to it;

1972 – Successful demonstration of ARPANET capabilities at an international conference in Washington;

1973 – Description of the basic architecture of the Internet in an article by Robert Kahn and Vint Cerf;

1978 – Development of the TCP protocol, and then TCP/IP, necessary for managing data transmission;

1980s – The US Department of Defense allocated funds to American computer manufacturers to add TCP/IP to their protocols in order to

commercialize Internet technology;

1990s – 1) Creation of the hypertext system for viewing and editing web pages, the World Wide Web (www), and its subsequent distribution; 2) Decommissioning of the technologically obsolete ARPANET; 3) Most computers in the US have the necessary networking capabilities; 4) Internet service providers create their own networks and gateways on a commercial basis, resulting in the development of the Internet as a global network (Castells, 2004)[2].

Making the internet accessible, affordable, open, and secure has proven difficult for many. The World Bank's 2016 World Development Report analyzes the reasons for the slow pace of digital adoption and outlines an internet development strategy. It helps understand how to spread the benefits and reduce the costs of digital development.

This is represented as the share of the population using the internet, so it's no surprise that relatively sparsely populated countries (Iceland, Luxembourg, Norway, and others) lead the way. Naturally, densely populated countries such as China, India, and Indonesia lag significantly in this area, but their role is rapidly increasing.

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A WEB 3.0-BASED NATIONAL JOURNAL PLATFORM FOR MONITORING SCIENTIFIC PUBLICATIONS

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Abstract

This paper presents the design and implementation of a Web 3.0-based monitoring system for national scientific journals. The proposed platform enables real-time tracking of article views, downloads, and submissions while analyzing readership across countries. By integrating bibliometric indicators and modern web technologies, the system aims to strengthen the visibility of Uzbek scientific publications in both national and international indexing databases. Furthermore, the paper provides an overview of theoretical foundations and related works on bibliometrics, Web 3.0 applications, and digital scholarly ecosystems.

Keywords— Web 3.0, scientific journals, bibliometrics, monitoring, Uzbekistan

A. I. INTRODUCTION

The rapid digitalization of science has transformed the way research is published, disseminated, and measured. Bibliometric indicators such as the h-index [1], g-index [2], R-index [3], and AR-index [4] are widely used to assess scientific impact. At the same time, the emergence of Web 3.0 technologies offers new opportunities to design intelligent platforms for managing and monitoring scholarly communication.

In Uzbekistan, the creation of a unified platform, uzjurnal.uz, has become a vital step toward centralizing national scientific journals. This platform provides integrated access to various journals, including Bulletin of TUIT, Problems of Computational and Applied Mathematics, and Muhammad al-Khorazmiy Avlodlari, among others.

However, the absence of comprehensive monitoring tools has limited the ability to measure real-time impact and global reach. The proposed monitoring module addresses this gap by incorporating SQL-based analytics, graphical dashboards, and bibliometric insights.

1) A. Review of Scientific and Theoretical Background

Scholarly communication has been reshaped by digital platforms that combine bibliometrics, scientometrics, and Web technologies. Studies emphasize that integrating semantic web standards into scholarly publishing enhances discoverability [5], while social networking features facilitate collaboration among researchers [6].

Theoretical research also highlights the universality of citation distributions [7], stability of bibliometric indices [8], and normalization challenges across disciplines [9]. Moreover, reviews of Web 3.0 in higher education [10] and digital libraries [11] underline the growing role of decentralized, intelligent services in academia.

Thus, the combination of bibliometric theory and Web 3.0 practice forms the foundation for the development of monitoring systems that not only track publication activity but also enhance scientific visibility and impact.

B. II. METHODOLOGY

The methodology relies on a relational database model (MySQL) where each journal entry stores data on article submissions, acceptance, views, downloads, and readership geography. The system uses SQL queries to extract real-time statistics, which are then visualized through web-based dashboards.

Key functionalities include:

- Tracking the number of submitted and published articles per journal.
- Measuring user engagement (views and downloads).
- Identifying the geographic distribution of readership (domestic vs. foreign).
- Generating comparative reports across multiple journals.

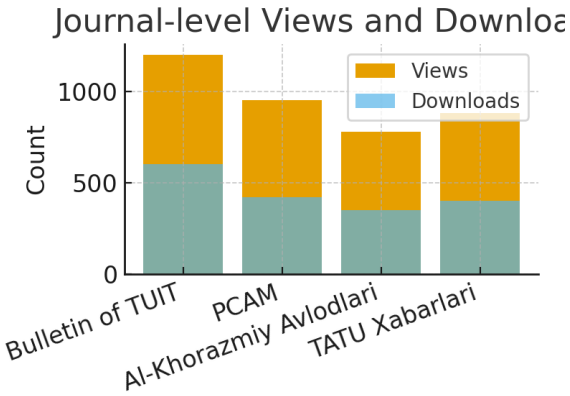

Fig. 1. Journal-level views and downloads (Source: uzjurnal.uz monitoring data, 2022–2024).

The monitoring model also integrates bibliometric calculations (h-index, g-index, R-index) for authors and journals, thereby linking publication activity with impact assessment.

C. III. RESULTS

The analysis of monitoring data from 2022–2023 shows that initial engagement was primarily from local users. However, recent statistics demonstrate a sharp increase in foreign readership, indicating the growing international interest in Uzbek research outputs. As shown in Fig. 1, the statistics by journal indicate strong readership growth.

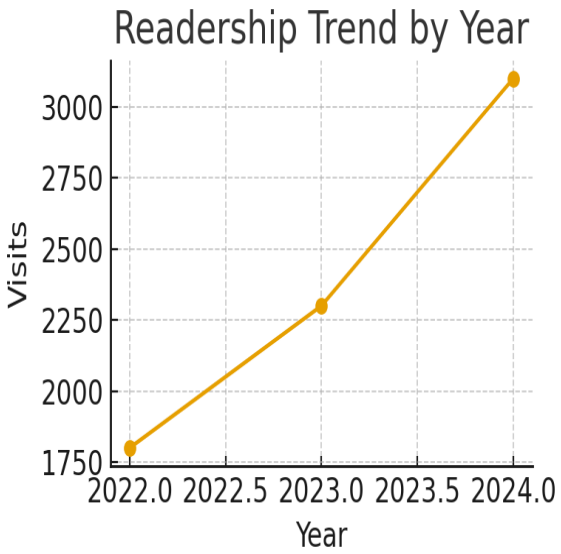

Fig. 2. Readership trend by year (Source: uzjurnal.uz monitoring data, 2022–2024).

For example, while domestic scholars accounted for the majority of visits in early stages, foreign scholars now represent a significant share of downloads and citations. This shift not only strengthens the national index but also contributes to global indexing visibility. The distribution of local versus foreign users is illustrated in Fig. 3.

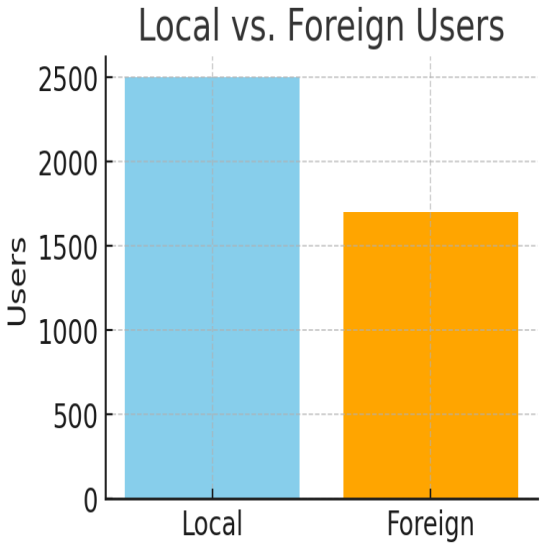

Fig. 3. Distribution of local vs. foreign users (Source: uzjurnal.uz monitoring data, 2022–2024).

Furthermore, topic-specific analysis shows that research on global challenges (e.g., climate change, digital transformation, applied mathematics) receives higher international attention. Fig. 2 presents the readership trend over recent years.

D. IV. DISCUSSION

The findings suggest that implementing a Web 3.0-based monitoring system enhances transparency, accessibility, and global reach of national scientific journals. Compared to traditional monitoring methods, the proposed system provides real-time, fine-grained insights into user behavior and scholarly impact.

From a theoretical perspective, integrating bibliometric models with Web 3.0 services aligns with the broader trend of intelligent scholarly ecosystems. Practically, the platform empowers journal editors, policymakers, and researchers to make data-driven decisions regarding publication strategies.

E. V. CONCLUSION

This study proposed a Web 3.0-based monitoring framework for national scientific journals in Uzbekistan. Results indicate that the system improves bibliometric evaluation, increases international readership, and aligns national journals with global indexing requirements. Future work will explore advanced semantic web integration, AI-based citation prediction, and interoperability with international databases.

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RAQAMLI TA'LIM EKOTIZIMINI RIVOJLANTIRISHDA ZAMONAVIY TEXNOLOGIYALAR: O'ZBEKISTON TA'LIMI MISOLIDA

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Ta'limni rivojlantirish respublika ilmiy-metodik markazi Axborot texnologiyalarini joriy etish va ta'lim jarayonlarini raqamlashtirish bo'limi bosh mutaxassisi
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Annotatsiya. Ushbu maqolada SCORM, xAPI va cmi5 kabi xalqaro elektron ta'lim (e-learning) standartlari tahlil qilinib, ularning zamonaviy raqamli ta'lim ekotizimidagi o'rni hamda ta'limni boshqarish tizimlari (LMS, Learning Management System) bilan integratsiyalash mexanizmlari yoritilgan. SCORM talablariga muvofiq ishlab chiqilgan va paketlangan raqamli ta'lim resurslarining turli LMSlar o'rtasida almashish hamda qayta foydalanish imkoniyatlari, xAPI texnologiyasining ta'lim jarayonlariga oid ma'lumotlarni yig'ish va ularni tahlil qilish uchun tayyor formatda saqlash imkonini beradigan afzalliklari, shuningdek cmi5 standartining SCORM va xAPIning eng yaxshi jihatlarini birlashtirgan holda yanada moslashuvchan va boshqariladigan tizim yaratishga qaratilganligi ko'rib chiqilgan.

Kalit so'zlar: SCORM, xAPI, cmi5, LMS, raqamli ta'lim resurslari, raqamli ta'lim ekotizimi, interfaol ta'lim resurslari

CLXIV. KIRISH

Globallashuv va raqamli texnologiyalarning jadal rivojlanishi natijasida zamonaviy ta'lim tizimlarini kompleks modernizatsiya qilish dolzarb bo'lib bormoqda. Xususan, umumiy o'rta ta'limda o'quvchilarning individual qobiliyatlarini erta aniqlash, zamonaviy ko'nikmalarni shakllantirish hamda uzluksiz pedagogik-metodik qo'llab-quvvatlash jarayonida raqamli yechimlardan foydalanish muhim ahamiyat kasb etmoqda. Masofaviy va onlayn ta'lim platformalari ta'lim tizimini transformatsiya qilishda samarali vositaga aylangan bo'lib, raqamli texnologiyalar asosida o'quv jarayonini shaxsga yo'naltirish, ta'lim ishtirokchilarining raqamli savodxonligini rivojlantirish va ta'lim samaradorligini oshirish imkoniyatlari kengaymoqda.

Xalqaro tajriba shuni ko'rsatadiki, davlat miqyosida milliy elektron ta'lim platformalarini yaratish ta'lim resurslarini keng auditoriyaga yetkazish, ta'limda inklyuzivlik va tenglikni oshirish hamda ta'lim sifatini yaxshilashga xizmat qiladi. Masalan, Saudiya Arabistoni, Janubiy Koreya va Xitoyning milliy onlayn ta'lim platformalari UNESCO tomonidan eng ilg'or raqamli ta'lim modellari deya e'tirof etilgan.

O'zbekistonda ham barcha sohalarda zamonaviy axborot-kommunikatsiya texnologiyalarini (AKT) joriy etishga qaratilgan tizimli islohotlar amalga oshirilmoqda. O'zbekiston Respublikasi Prezidenti Sh.Mirziyoyevning 2020-yil 5-oktyabrda qabul qilingan PF-6079-son farmoni bilan "Raqamli O'zbekiston – 2030" strategiyasi tasdiqlangan va barcha sohalarni raqamli transformatsiya qilishning huquqiy asosi yaratildi. Ta'lim sohasida mazkur strategiya doirasida raqamli ta'limni rivojlantirish, barcha maktabgacha va maktab ta'lim muassasalarini yuqori tezlikdagi internet bilan ta'minlash, AKT bo'yicha malakali mutaxassislar tayyorlash, yagona milliy masofaviy ta'lim platformasini joriy etish hamda milliy raqamli ta'lim resurslari va multimediali vositalarni yaratish kabi vazifalar belgilandi (Farmon, 2020). Bundan tashqari, O'zbekiston Respublikasi Prezidenti tomonidan 2023-yil 11-sentabrda qabul qilingan PF-158-son Farmonda 2030-yilgacha 1 000 ta multimedia dasturini ishlab chiqish va mobil ilovalar yordamida raqamli ta'limni rivojlantirish vazifasi qo'yildi (Farmon, 2023). Ushbu qat'iy choralar O'zbekiston ta'lim tizimini raqamli transformatsiya qilishga xizmat qilib, ayniqsa umumiy o'rta ta'lim maktablarini internet bilan ta'minlash, foydali raqamli resurslar yaratish va ularni amaliyotga tatbiq etishga keng e'tibor qaratilmoqda.

Shu bilan birga, mamlakatda turli loyihalar doirasida ishlab chiqilgan ko'plab raqamli ta'lim resurslari, multimedia vositalari, virtual laboratoriyalar, interfaol ta'lim xizmatlaridan yagona nuqtadan foydalanish imkoniyatini yaratish dolzarb masalaga aylangan. Xorij tajribasi shuni ko'rsatadiki, ta'lim ishtirokchilari (o'qituvchi, o'quvchi va boshqalar) uchun istalgan vaqtda va joyda mustaqil ta'lim olishga xizmat qiluvchi yagona ta'lim platformalarini joriy etish va ulardan samarali foydalanish raqamli ekotizimni shakllantirishning muhim omili hisoblanadi. Shunday ekan, O'zbekiston sharoitida raqamli ta'lim ekotizimini rivojlantirish uchun zamonaviy texnologiyalardan foydalanish, global tajribani o'rganish va mahalliy ehtiyojlarga mos innovatsion yechimlarni joriy etish alohida ahamiyat kasb etadi.

CLXV. MAVZUGA OID ADABIYOTLAR TAHLILI

A. SCORM (Sharable Content Object Reference Model) xalqaro standarti

Bu elektron ta'lim sohasidagi eng qadimgi va eng keng tarqalgan standart bo'lib, u ta'lim mazmunining ta'limni boshqarish tizimlari bilan o'zaro aloqasini tartibga soladi. Ushbu standart 2000-yillar boshida ishlab chiqilgan bo'lib, asosan veb texnologiyalarga asoslangan o'quv materiallarini (masalan, HTML fayllar, testlar va so'rovnomalar) bir platformadan ikkinchisiga osongina ko'chirish imkonini beradi. Kontent yaratish jarayoni mualliflik dasturiy vositalari (Authoring tools) (masalan, Articulate Storyline, Adobe Captivate) deb ataladigan dasturlar yordamida SCORM paketiga aylantiriladi. SCORM texnologiyasining asosiy mexanizmi o'quvchining kursni boshlagani, tugatgani, olgan ballari va o'zlashtirish holati kabi cheklangan ma'lumotlarni LMSga yuborishdan iborat. Bu

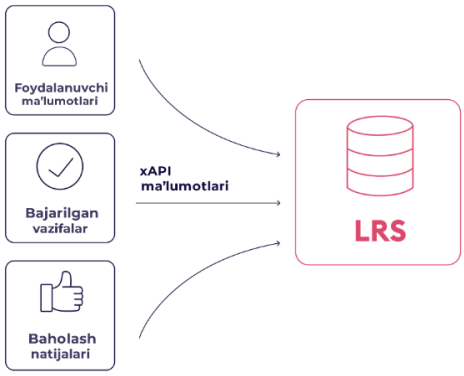
ma'lumotlar maxsus "SCORM package" paketida mundarija (manifest) ko'rinishidagi XML formatidagi fayllar va o'quv kontenti jamlangan ZIP arxiv fayli orqali uzatiladi.

1-rasm. SCORM ishlashining oddiy ko'rinishi

SCORMning o'ziga xos jihati shundaki, u tizimga o'qituvchining bevosita aralashuvisiz o'quvchining o'rganish jarayonini mustaqil ravishda kuzatish va uning natijalarini qayd etish imkonini beradi. Shu sababli xalqaro miqyosda SCORM an'anaviy onlayn kurslar, korporativ treninglar va ko'plab mashhur bo'lgan LMS (Moodle, Canvas) platformalarida keng qo'llanilib kelmoqda.

B. xAPI (Experience API) yoki Tin Can API standarti

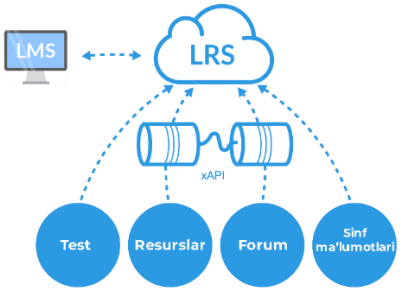
Bu SCORMdan keyingi avlod texnologiyasi bo'lib, u ta'lim jarayonlari haqidagi ma'lumotlarni uzatishda ancha moslashuvchanlikni taklif etadi. xAPIning asosiy maqsadi – faqatgina LMS platformasidagi rasmiy kurslar bilan cheklanib qolmasdan, balki o'quvchining deyarli har qanday o'quv tajribasi haqidagi ma'lumotlarni to'plash va kuzatishdir. Bu tajribalar nafaqat onlayn kursdagi faollikni, balki mobil ilovadan foydalanish, videoni tomosha qilish, virtual reallik (VR) simulyatsiyasida qatnashish natijasida bajariladigan jismoniy mashg'ulotlarni ham qayd eta oladi. xAPI standartida o'quvchining har bir faoliyatini "kim, nima qildi, nimani" ("Noun, Verb, Object") shaklida ifodalaydi . Bu oddiy format turli manbalardan (simulyatorlar, mobil ilovalar, o'yinlar) keladigan ma'lumotlarni yig'ishga yordam beradi.



2-rasm. xAPI ishlash prinsipi

Masalan, tizim "Talaba A -> bajardi -> 5-mashq" shaklida bayonot yozadi. Bunday bayonotlar RESTful API orqali LRS (Learning Record Store) deb nomlangan maxsus ma'lumotlar omboriga yuboriladi. xAPIning afzalligi shundaki, u ta'lim jarayonini yanada keng qamrovda, batafsilroq kuzatish va o'quvchining murakkab o'rganish yo'nalishlarini ham tahlil qilish imkonini beradi.

Shu o'rinda **LRS (Learning Record Store)** tushunchasi bu ta'lim jarayonida yuz beradigan barcha o'quv faoliyatlari to'g'risidagi ma'lumotlarni to'plash, saqlash va tahlil qilishga mo'ljallangan ma'lumotlar omboridir. An'anaviy LMS faqat o'z platformasi ichidagi harakatlarni qayd etsa, LRS bu cheklovlardan xoli bo'lib, o'quvchining har qanday o'quv tajribasi haqidagi ma'lumotlarni xAPI standartida qabul qila oladi.

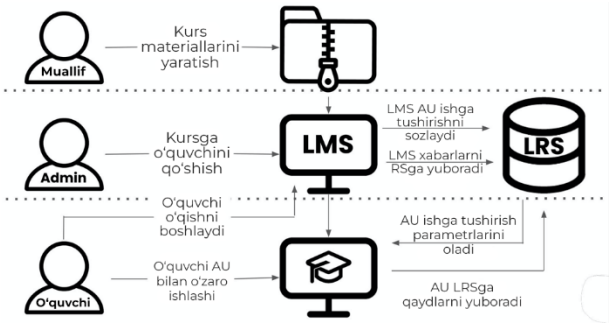


3-rasm. LRS ma'lumotlar ombori

Shu sababli, LRS turli platformalar va manbalardan keladigan ma'lumotlarni markazlashtirib, o'quvchining ta'lim yo'nalishi haqida to'liq va kompleks baza yaratishga xizmat qiladi. Aniqroq qilib aytganda, LRS bu o'quvchilarning faoliyati haqidagi xAPIdan kelgan ma'lumotlarni qabul qilib, ularni saqlovchi va boshqaruvchi ma'lumotlar bazasi hisoblanadi.

C. cmi5 (Computer Managed Instruction 5) standarti

Bu xAPI va SCORMning afzalliklarini o'zida birlashtirgan gibrid elektron ta'lim standart hisoblanadi. Uning asosiy maqsadi – xAPIning keng imkoniyatlaridan foydalangan holda, SCORMning LMS bilan integratsiyalashuvdagi aniq va ishonchli tizimini saqlab qolishdir. cmi5 standarti o'quv kontenti va LMS o'rtasidagi o'zaro aloqani tartibga soluvchi aniq qoidalar to'plamini belgilaydi, bu esa xAPIga nisbatan tizimlararo moslashuvchanlikni sezilarli darajada oshiradi. cmi5da har bir o'quv moduli yoki kurs bo'limi "AU" (Assignable Unit) deb ataluvchi alohida qism sifatida ishlaydi va o'quvchining kursni boshlash, yakunlash, tugatish holati kabi muhim ma'lumotlar LMSga bevosita yuboriladi (4-rasm).



4-rasm. cmi5 komponentlari va jarayoni

Kurs yaratishdan tortib hisobot berishgacha bo'lgan jarayon odatiy cmi5 holati uchun umumiy hisoblanadi. Shu bilan birga, xAPI imkoniyatlari tufayli cmi5 platformadan tashqaridagi faoliyatlarni ham kuzatishga imkon beradi.

1-jadval. SCORM, xAPI va cmi5 asosiy xususiyatlarini taqqoslash

Xususiyatlar	SCORM	xAPI	cmi5	Tavsif
Kontentni ishga tushirish qoidalari	+		+	SCORM va cmi5 kontentni ishga tushirish uchun belgilangan ko'rsatmalarga ega. *xAPI tizimida esa kiritilmagan.*
Istalgan faoliyatni qayd etish		+	+	*xAPI va cmi5 erkin ma'lumot elementlarini qo'llash imkonini beradi. SCORM aniq belgilangan to'plam bilan cheklangan.*

Xususiyatlar	SCORM	xAPI	cmi5	Tavsif
Standartlashgan hisobot ma'lumoti	+		+	*tizimlararo bir xil talqinda tushuniladigan ma'lumotlar modeli.*
Mobil ilovalar		+	+	*SCORM faqat brauzer orqali ishlaydi. cmi5 va xAPI esa LMSga mobil qurilmalar, to'g'ridan-to'g'ri LMS veb-brauzeridan foydalanish, veb-brauzerni o'z ichiga olgan mobil ilova orqali kirish imkonini beradi.*
Tarqatilgan/ masofaviy kontent		+	+	*Barcha SCORM kontenti LMS bilan bir xil server yoki domenda joylashgan bo'lishi shart. cmi5 yordamida esa kontentni istalgan joyda joylashtirish mumkin.*
Ma'lumotni ko'chirish qulayligi		+	+	*SCORM ma'lumotlari LMS ichida to'planadi va saqlanadi. xAPI va cmi5 texnologiyalari yordamida esa bu ma'lumotlarni turli tizimlar o'rtasida almashish imkoniyati mavjud.*
Kengaytiriluv-chanlik		+	+	*xAPI va cmi5 yordamida har qanday o'quv ma'lumotlarini qayd etish mumkin. LMS ikkala tizimni ham qo'llab-quvvatlash uchun muvofiqlashtirilgan LRSdan foydalanadi. LRS orqali LMSdan tashqari ta'lim ekotizimini yaratish va boshqa tizimlarga osonlik bilan bog'lanishi mumkin.*
Yakunlash mezonlari standartlari	+		+	*cmi5 o'quv faoliyatlarini yakunlash yoki o'zlashtirish darajasini aniqlash uchun o'zaro muvofiqlashtirilgan qoidalarni o'rnatadi. xAPI esa aniq belgilangan mezonlarga ega emas.*
Ko'p dars/bo'limli kurs tuzilmasi	+		+	*kurs ichida bir nechta dars/bo'lim (SCO/AU) bilan ishlash. SCORM va cmi5 qo'llab-quvvatlaydi; xAPI o'zi kurs tuzilmasini belgilamaydi.*

CLXVI. RAQAMLI TA'LIM TRANSFORMATSIYASI TADQIQOTLARI

Raqamli texnologiyalar yordamida ta'limni transformatsiya qilish zamonaviy global ta'lim tizimidagi eng muhim va tez o'zgaruvchan jarayonlardan biridir. YUNESKO, IQHT va Jahon banki kabi xalqaro tashkilotlar rivojlanayotgan mamlakatlarda raqamlashtirish bilan bog'liq imkoniyatlar va muammolarni o'rganishga alohida e'tibor qaratmoqda. Raqamli platformalar va vositalar o'quvchilarga istalgan vaqtda va joyda ta'lim resurslaridan foydalanish imkoniyatini berishini ko'rsatdi. Bu esa o'quv jarayonining moslashuvchanligi, inklyuzivligi va individuallashtirish darajasini oshirishga xizmat qilmoqda. Jahon banki, xususan, ta'limni tenglik, kambag'allikni kamaytirish va barqaror iqtisodiy o'sishni ta'minlaydigan eng muhim omil sifatida ta'kidlamoqda. UNESCO (2021) Ushbu hisobot Markaziy Osiyo mamlakatlarida ta'limning umumiy holatini, jumladan, pandemiyaning ta'limdagi inklyuzivlikka ta'sirini chuqur tahlil qilgan. OECD (2021) hisobotida esa rivojlanayotgan davlatlarda ta'limning raqamli transformatsiyasidagi infrastrukturaviy tafovutlar, pedagog kadrlarning tayyorgarligi (malakasi) va raqamli tengsizlik kabi qiyinchiliklar alohida ta'kidlangan.

Xususan, ushbu xalqaro tadqiqotlar ta'limning raqamli transformatsiyasida uchta omilga alohida e'tibor qaratish lozimligini ta'kidlaydi:

- **Infrastruktura va ulanishlar:** ko'plab mamlakatlarda internet tarmog'i va raqamli qurilmalar bilan ta'minlanish yetarli darajada emas, ayniqsa qishloq va olis hududlarda;
- Pedagog kadrlar salohiyati: o'qituvchilarning raqamli texnologiyalar bo'yicha malakasi va tayyorgarligi pastligi raqamli ta'lim joriy etilishiga to'siq bo'lmoqda, shu bois ularning doimiy ravishda malakasini oshirish talab etiladi;
- Raqamli tengsizlik: aholining turli qatlamlari o'rtasida (shahar-qishloq, boy-qashshoq, gender va boshqalar kesimida) raqamli texnologiyalarga ega bo'lish imkoniyati notekis bo'lib, bu ta'limda yangi tengsizliklarni keltirib chiqarmoqda.

Shuningdek, zamonaviy ilmiy ishlar raqamli ta'lim infratuzilmasini joriy etishda texnologik standartlar va platformalarning muhimligini ta'kidlamoqda. Masalan, **Rogers va Alexander (2022)** tadqiqotida ta'kidlanishicha, elektron ta'lim kontentini boshqarish va almashinuvida **SCORM** standarti muhim rol o'ynab, turli **LMS** platformalari o'rtasida o'zaro moslilikni ta'minlab kelgan. Shu bilan birga, 21-asr raqamli ta'lim jarayonlarida o'quvchilarning o'zaro faoliyatini batafsil kuzatish uchun yangi standartlar, xususan **Experience API (xAPI)** joriy qilinmoqda – ushbu standart o'quvchining raqamli muhitdagi har bir harakatini qayd etish va tahlil qilish imkonini beradi hamda turli tizimlar o'rtasida o'quv ma'lumotlarining "silos" holatida qolib ketmasligini ta'minlaydi. Shu bois, mutaxassislar raqamli ta'lim ekotizimini rivojlantirishda **SCORM** va **xAPI** kabi standartlarni keng tatbiq etish zarur, deb hisoblashmoqda. Xorijiy tadqiqotlar shuningdek zamonaviy **LMS platformalari**ning ahamiyatini qayd etadi – masalan, Reyad R. Aljad (2023) o'z sharhida Moodle kabi LMS tizimlari dunyo bo'ylab eng mashhur va samarali platformalarga aylangani, ular masofaviy ta'limni qulay, moslashuvchan va individual yondashuvga asoslangan shaklga keltirganini ta'kidlaydi. Bunday platformalar va standartlar ta'lim jarayonini yanada interaktiv va shaxsga yo'naltirilgan qilishga xizmat qilmoqda.

Mahalliy tadqiqotlarga e'tibor qaratadigan bo'lsak, O'zbekiston ta'lim tizimida raqamli texnologiyalarni joriy etish borasida ham so'nggi yillarda bir qator muhim ilmiy ishlar amalga oshirildi. Masalan, R. Suleymanova (2024) maqolasida "raqamli iqtisodiyotni rivojlantirish hamda ta'lim sohasida axborot-kommunikatsiya texnologiyalarini keng joriy etish" maqsadida keng ko'lamli chora-tadbirlar amalga oshirilayotgani qayd etiladi. Xuddi shunday, Z. Sharipova (2025) O'zbekiston misolida raqamli ta'limni joriy etishdagi bir qator muammolarni ta'kidlab o'tadi. U texnologik infratuzilmaning yetishmasligi va urbanizatsiya darajasi past bo'lgan hududlarda shahar va qishloq o'rtasidagi raqamli tafovutning mavjudligini alohida qayd etadi. Bundan tashqari, raqamli transformatsiyaning muvaffaqiyati ko'p jihatdan pedagog kadrlarning yangi texnologiyalarni qabul qilish va ulardan samarali foydalanish qobiliyatiga bog'liq ekanligiga

alohida e'tibor qaratadi. Shuningdek, M. Fayzullayeva (2023) olib borgan so'rov natijalariga ko'ra, chekka hududlardagi maktablarda raqamli ta'lim resurslarini joriy etish orqali kutilgan ijobiy samaraga erishilganligi ta'kidlanadi. Uning fikricha, bu maktablarda raqamli platformalar va interaktiv o'quv materiallari joriy qilinishi o'quv jarayonining samaradorligini oshirishga xizmat qilmoqda.

Tadqiqotlar tahlili shuni ko'rsatadiki, O'zbekistonda raqamli ta'lim ekotizimini shakllantirish va rivojlantirish borasida davlatning kuchli siyosiy irodasi va qo'llab-quvvatlashi mavjud. Jumladan, "Raqamli O'zbekiston - 2030" strategiyasida ta'limning barcha bosqichlarida raqamli texnologiyalarni joriy etish ustuvor vazifa sifatida belgilab qo'yilgan. Biroq, muvaffaqiyatning asosiy omili inson faktori, ya'ni o'qituvchilar va o'quvchilarning raqamli innovatsiyalarni o'zlashtirish darajasi hisoblanadi. Ilmiy manbalarga ko'ra, Zou Y. va boshqalar (2025) raqamli ta'limga o'tish jarayonida ikki tomonlama yondashuv zarur. Bir tomondan, davlat infratuzilmani yangilashni davom ettirishi, zamonaviy platformalarni yaratishi va qo'llab-quvvatlashi lozim. Boshqa tomondan esa, o'qituvchilarning raqamli kompetensiyasini uzluksiz rivojlantirish, o'quv jarayoni uchun sifatli mahalliy raqamli kontentni yaratishga e'tibor qaratish hamda jamiyatda raqamli savodxonlikni oshirish talab etiladi.

CLXVII. TAHLIL VA NATIJALAR

A. *SCORM, xAPI, cmi5, LMS texnologiyalarining pedagogik ahamiyati*

Raqamli ta'lim ekotizimini rivojlantirishda standartlashtirilgan texnologik yechimlar muhim o'rin tutadi. Xususan, SCORM, xAPI, cmi5 kabi xalqaro elektron ta'lim standartlari hamda zamonaviy **LMS platformalari** ta'lim jarayonini boshqarish, kontent almashinuvi va ta'lim natijalarini kuzatishda asosiy ahamiyatga ega. Elektron ta'lim standartlari – bu o'quv kontentini yaratish va yetkazib berish, shuningdek, turli ta'lim platformalarining o'zaro ishlash qoidalarini belgilovchi umumiy me'yorlar to'plamidir. Bunday standartlarning joriy etilishi zamonaviy ta'limda bir qator ustunliklarni beradi:

- SCORM standarti o'quv kurslarini maxsus formatda paketlab, har qanday SCORM mos LMSda ishlashini ta'minlaydi. Bu, o'z navbatida, o'quv kontentini bir platformadan boshqasiga bir necha bosqichda ko'chirishni osonlashtiradi. Masalan, agar maktab dastlab bitta platformada elektron kurs yaratib, keyinroq boshqa LMSga o'tishga qaror qilsa, **SCORM talablariga muvofiq tayyorlangan kursni yangi tizimga osongina import qilish mumkin**. Bu ta'lim resurslariga kiritilgan investitsiyalarni saqlab qoladi va platformaga qaramlik (vendor lock-in)ning oldini oladi. Shu bois, hozirgi kunda deyarli barcha yirik mualliflik tizimlari va LMSlar SCORMni qo'llab-quvvatlaydi.
- An'anaviy SCORM standarti kursning tugallanishi, baholari va sarflangan vaqt kabi asosiy ko'rsatkichlarnigina qayd etishga imkon bersa, uning zamonaviy davomi bo'lgan **xAPI esa ta'lim jarayonidagi deyarli barcha faoliyat haqida batafsil ma'lumotlarni yig'ish imkonini beradi**. xAPI standarti o'quvchi harakatlarini LRS maxsus ma'lumotlar bazalariga yuboriladigan "Noun, Verb, Object" (masalan, *"Talaba A -> bajardi -> 5-mashq"*) shaklidagi ketma ketlikda qayd etadi. Natijada pedagoglar va tizim administratorlari o'quvchilarning qaysi mashg'ulotlarda qiynalayotgani, qaysi mavzularni yaxshi o'zlashtirayotganini aniqroq kuzatib borishi va tahlil qilishi mumkin. Masalan, **xAPI yordamida nafaqat test natijalari, balki o'quvchi onlayn simulyatsiyada qancha vaqt faol bo'lgani yoki o'yinli ta'lim dasturida erishgan yutuqlari haqida ham ma'lumot olish mumkin**. Bu esa ta'lim jarayonini dalillarga asoslangan individuallashtirish uchun zamin yaratadi.
- cmi5 standarti aslida xAPI uchun maxsus profil bo'lib, u LMS va o'quv kontenti o'rtasidagi o'zaro aloqani tartibga soluvchi qo'shimcha format va qoidalarni belgilaydi. **cmi5 SCORMning kontentni ishga tushirish va boshqarishdagi yutuqlarini xAPIning moslashuvchan kuzatuv imkoniyatlari bilan birlashtiradi**. Boshqacha aytganda, cmi5 yordamida LMS interfeysi orqali xAPI faoliyatlarini "plug-and-play" usulida amalga oshirish, ya'ni har qanday kurs yoki mashg'ulotni LMSdan ishga tushirgan holda, uning natijalarini LRS ga xAPI ma'lumotlari orqali batafsil qayd etib borish imkoni paydo bo'ladi. Bu yechim kelajakda SCORM o'rnini bosuvchi universal standart sifatida ko'rilmoqda va u turli platformalararo to'liq o'zaro muvofiqlik hamda keng qamrovli tahliliy ma'lumot almashinuvini ta'minlaydi.
- Raqamli ta'lim ekotizimida LMSlar markaziy o'rin egallaydi. **LMS – bu onlayn kurslarni yuklash, tarqatish, topshiriqlar berish, baholash va o'quv faoliyatini monitoring qilishga mo'ljallangan dasturiy platforma**. Moodle, Canvas, Blackboard kabi ko'plab LMS tizimlari butun dunyo bo'ylab oliy va umumiy ta'limda keng qo'llanilmoqda. Ular o'qituvchilar va talabalar uchun virtual sinf xonasi vazifasini bajaradi, shuningdek, SCORM paketi ko'rinishidagi tarkibni qabul qilish va almashish hamda xAPI ma'lumotlarini LRSga uzatish kabi standartlarni qo'llab-quvvatlaydi. Tadqiqotlar shuni ko'rsatmoqdaki, O'zbekistonda pandemiya davrida Moodle, Google Classroom va Microsoft Teams singari LMS platformalaridan foydalanish keskin ortgan. Jumladan, 2021-yilda o'qituvchilarning 65 foizdan ko'prog'i raqamli platformalar orqali muntazam ravishda dars o'tgan. LMS yordamida dars jarayonlarini interfaol tarzda tashkil etish, topshiriqlarni avtomatik tekshirish, reytinglar va hisobotlarni shakllantirish kabi imkoniyatlari ta'lim samaradorligini oshirishga xizmat qilmoqda.

Yuqoridagi texnologik standart va tizimlar ta'lim jarayonini raqamlashtirishda **pedagogik jihatdan ham ijobiy ta'sir ko'rsatadi.** Birinchidan, **SCORM va cmi5 kabi standartlar tufayli ta'lim kontentining qayta foydalanish va platformalararo almashish imkoni oshadi**, o'qituvchilar sifatli elektron resurslarni bir platformadan boshqasiga erkin o'tkazib, yanada keng auditoriyaga yetkazishlari mumkin. Ikkinchidan, **xAPIga asoslangan ta'lim jarayonidagi tizimli tahlil har bir o'quvchining rivojlanishini individual kuzatib borib, ularga mos moslashuvchan o'quv trayektoriyalarini ishlab chiqishga xizmat qiladi**. Bu, o'z navbatida, o'quvchilarga shaxsiylashtirilgan bilim berish va ularda qiyinchilik sezilayotgan nuqtalarida o'z vaqtida qo'shimcha yordam ko'rsatish imkoniyatini ta'minlaydi. Masalan, xAPI tomonidan to'plangan ma'lumotlar asosida tizim o'quvchining qaysi mavzuda ko'p xato qilganini aniqlab, shu mavzu bo'yicha qo'shimcha material tavsiya qilishi mumkin. Uchinchidan, **standartlarning keng qo'llanishi ta'lim texnologiyalari bozorida ochiq ekotizim yaratadi,** turli ishlab chiquvchilar mahsulotlari bir-biri bilan integratsiyalasha oladi, bu esa innovatsion yangi vositalarni tez tatbiq etish, tanlovni kengaytirish va narxlarni pasaytirishga olib keladi.

B. *Raqamli ta'lim resurslari va interfaol xizmatlarning o'rni*

Raqamli ta'lim resurslari – bu elektron darsliklar, videodarslar, interfaol mashqlar, audio materiallar, virtual laboratoriyalar kabi har xil shakldagi o'quv kontenti tushuniladi. Interfaol ta'lim xizmatlari esa onlayn testlar, masofaviy o'qitish platformalari, o'quvchilar va o'qituvchilar o'rtasidagi muloqot tizimlari, elektron kutubxonalar kabi xizmat turlarini o'z ichiga oladi. Raqamli resurslar va xizmatlar ta'lim ekotizimining asosiy tarkibiy qismlari bo'lib, ularning to'g'ri integratsiyasi ta'lim sifati va qamroviga bevosita ta'sir qiladi. Zamonaviy raqamli ta'lim muhitida SCORM, xAPI va cmi5 kabi xalqaro standartlar o'quv kontentini turli platformalar va LMSlarda ishlashga moslashtiradi. Masalan, SCORM standarti kursni "har qanday platformada ishlashga imkon beruvchi" texnik me'yorlar to'plamini belgilaydi.

Masalan, elektron darsliklar an'anaviy bosma kitoblarga nisbatan qo'shimcha multimedia elementlariga ega bo'lib, mavzuni chuqurroq tushuntirishga yordam beradi. Misol uchun, Qozog'istonda "TopIQ" nomli raqamli ta'lim portali orqali

1-sinfdan 11-sinfgacha barcha fanlarning interfaol elektron darsliklari joriy qilingan bo'lib, ularning har biri audio, video materiallar, animatsiyalar va interfaol topshiriqlar bilan boyitilgan. TopIQ platformasidagi har bir elektron darslik keng qamrovli multimedia mahsuloti bo'lib, unda audio-vizual materiallar, animatsiyalar va interfaol topshiriqlar bilan boyitilgan. Bu resurslar o'quvchilar uchun qo'shimcha masalalar, testlar va interfaol topshiriqlarni o'z ichiga oladi, bu esa ta'lim jarayonini yanada mustahkamlaydi. Rossiyaning "Elektron maktab" (Российская электронная школа - РЭШ) platformasi 1-sinfdan 11-sinfgacha o'quvchilar uchun to'liq interfaol kurslar, videodarslar va diagnostik testlarni taklif etadi, bu esa o'quvchilarga mustaqil bilim olish jarayonida katta ko'mak beradi.

Interfaol ta'lim xizmatlari esa ta'lim ishtirokchilari o'rtasida samarali aloqa va qo'llab-quvvatlash tizimini yaratadi. Masalan, onlayn forumlar va chatlar orqali o'qituvchi, o'quvchi va ota-onalar orasida doimiy muloqot o'rnatish mumkin. O'zbekistonda Maktabgacha va maktab ta'lim vazirligi tomonidan yaratilgan "eMaktab" platformasi aynan shunday uch tomonlama interfaol muloqotni rivojlantirish, masofaviy va mustaqil ta'lim olish imkoniyatlarini kengaytirishga yo'naltirilgan. eMaktab platformasi orqali o'qituvchi dars jadvali, uy vazifasi, baholar va e'lonlarni o'quvchi hamda ota-onalarga yetkaza oladi, o'quvchilar esa o'z savollarini bevosita o'qituvchiga onlayn yo'llashi mumkin. Bunday uchrashuv va muloqotning raqamli formati, ayniqsa pandemiya davrida va undan keyingi davrda masofaviy ta'limda o'z samaradorligini namoyish etdi. Interfaol xizmatlarning yana bir muhim tomoni shundaki masofaviy ta'lim va qo'shimcha ta'lim imkoniyatlarini kengaytirishidir. O'zbekistonning "Maktab.uz" loyihasi 2020-yildan boshlab eng yirik onlayn maktab sifatida ishga tushirilib, u yerda umumta'lim maktablari dasturi bo'yicha videodarslar, shuningdek, dasturlash, robototexnika, chet tillari kabi zamonaviy kurslar ham joylashtirilgan. Bu platforma har bir o'quvchiga eng yaxshi o'qituvchilardan virtual tarzda saboq olish imkonini beradi – minglab o'quvchilar ushbu onlayn darslardan foydalanib, bilim va ko'nikmalarini boyitmoqda.

C. Ilg'or xalqaro tajribalar va O'zbekiston sharoiti: qiyosiy tahlil

So'nggi yillarda dunyoning ko'plab rivojlangan va rivojlanayotgan mamlakatlarida markazlashtirilgan milliy ta'lim platformalari raqamli ta'lim muhitini rivojlantirishda asosiy rol o'ynamoqda. Quyida ayrim ilg'or platformalarning imkoniyatlari va ularning O'zbekiston sharoiti bilan qiyosiy tahlili keltiriladi.

Turkiya – EBA (Eğitim Bilişim Ağı): Turkiyaning Milliy ta'lim vazirligi 2012-yilda EBA ta'lim tarmog'ini ishga tushirgan. EBA platformasi COVID-19 pandemiyasi davrida o'zining hayotiy ahamiyatini to'liq namoyon etdi, xususan **2020-2021 o'quv yilida platformadan 7,38 million o'quvchi va 1,03 million o'qituvchi muntazam foydalangan** va shu davrda EBA orqali 5,95 millionta jonli onlayn dars o'tkazilgan. 2020-yil oktabr oyida EBA veb-sayti dunyoda ta'lim yo'nalishida foydalanuvchilar soni va internet trafik hajmi bo'yicha 1-o'rinni egalladi.

Platformada 186 xil elektron kitoblar, 270 ta video modul, minglab interfaol testlar va boshqa ta'lim resurslari to'plangan. Shuningdek, Akademik qo'llab-quvvatlash (**"EBA Academic Support"**) nomli maxsus modul orqali o'quvchilarga imtihonlarga tayyorgarlik ko'rishda ko'mak beriladi. Ushbu moduldan 1,17 mln o'quvchi va 189 ming o'qituvchi foydalangan. Turkiya tajribasi davlat darajasida ishlab chiqilgan markazlashgan platforma qisqa muddatda millionlab foydalanuvchilarni qamrab olishi va ta'lim sifatiga ijobiy ta'sir ko'rsatishini isbotlaydi.

Xitoy – Smart Education of China: 2022-yilda ishga tushgan SmartEdu portali 2025-yil apreliga kelib 164 milliondan ortiq foydalanuvchi to'plagan. Platforma bazasida 110 mingdan ziyod boshlang'ich va o'rta maktab o'quv resurslari, 11 300 dan ortiq kasb-hunar kurslari, 31 000 dan ortiq oliy ta'lim kurslari va 2 000 dan ortiq umrbod ta'lim (Life-long learning) kurslari jamlangan. Boshqa funksiyalar safida milliy imtihonlarga tayyorlov va ish bilan ta'minlash bo'limlari ham bor. Eng muhimi, SmartEdu sun'iy intellekt bilan integratsiyalashgan: foydalanuvchilarga individual o'qishni rejalashtiruvchi va savollarga javob beruvchi AI-chatbot xizmatlari mavjud.

SmartEdu tarkibida ta'limning barcha bosqichlarini qamrab oluvchi 8 ta asosiy kategoriya bo'yicha 51 xil turdagi xizmat mavjud bo'lib, jumladan milliy imtihonlarga tayyorgarlik va ishga joylashish bo'yicha ham alohida bo'limlari bor. SmartEdu portaliga sun'iy intellekt modellarining integratsiyasi alohida e'tiborga loyiqdir. Bu integratsiya foydalanuvchilarga virtual yordamchi (AI chatbot) xizmatini taqdim etadi. Mazkur xizmat shaxsiy yondashuvga asoslangan holda o'quv materiallarini tavsiya qiladi va foydalanuvchilarning savollariga javob beradi.

Hindiston – DIKSHA (Digital Infrastructure for Knowledge Sharing): 2017-yilda "bir makon – bir platforma" tamoyili bilan yo'lga qo'yilgan DIKSHA 36 ta hind milliy tili va til aksenti uchun 19 698 dan ortiq elektron kursni taklif qiladi, 182 milliondan ziyod kursga yozilish qayd etilgan. Platformada milliy o'quv dasturiga muvofiq elektron darsliklar, videodarslar, testlar va o'qituvchilar uchun malaka oshirish kurslari jamlangan. DIKSHA portalida QR-kodli darsliklar orqali o'quvchilar dars materialidan to'g'ridan-to'g'ri qo'shimcha videomateriallar, mashqlar va interfaol testlarga o'tadi.

O'zbekiston ham xuddi shunday, bir platformaga o'zbek tilidagi kontent bilan birga qolaversa qoraqalpoq, rus va ingliz tillaridagi qo'shimcha resurslarni jamlashi mumkin. Shuningdek, DIKSHA kabi O'zbekistonda ham raqamli platformani nafaqat umumta'lim, balki o'qituvchilarning malaka oshirishi uchun ham maydoncha sifatida ishlatish katta samara berishi kutiladi.

Qozog'iston – TopIQ platformasi: Yuqorida tilga olingan TopIQ raqamli ta'lim platformasi Qozog'istonda 2020-yildan boshlab joriy qilinib, "AlmatyKitap" nashriyoti tomonidan ishlab chiqilgan. TopIQ raqamli kutubxonasida barcha elektron darsliklar multimedia formatida interfaol tarzda taqdim etilgan bo'lib, platforma mobil va veb interfeysga ega – ya'ni har qanday smartfonda ham ishlay oladi. 2023-yilga kelib TopIQ mamlakatdagi maktablarning 30% faoliyatini raqamlashtirishda muvaffaqiyatli qo'llanilgani va minglab o'qituvchi hamda o'quvchilardan ijobiy fikr olgani e'lon qilingan.

O'zbekiston uchun ahamiyati, TopIQ misolida nodavlat nashriyot ham raqamli maktab resursini yaratishi va davlat ta'lim tizimiga integratsiya qilinishi mumkinligini ko'rsatadi. O'zbekistonda ham darsliklar nashriyotlari yoki xususiy IT kompaniyalar bilan hamkorlikda kontentni multimedia va interfaol formatga o'tkazish hamda yagona tizimga ulash tajribasini qo'llash maqsadga muvofiq.

Yuqorida ko'rib chiqilgan xalqaro tajribalar O'zbekiston uchun bir qator muhim tajribalarni belgilab beradi. Masalan, Turkiyaning EBA modeli qisqa vaqt ichida millionlab foydalanuvchilarni qamrab olish imkoniyatini ko'rsatdi. Xitoyning SmartEdu platformasi esa sun'iy intellekt va turli xizmatlarni integratsiyalash orqali ta'lim sifatini oshirish usullarini namoyish etdi. Hindistonning DIKSHA tizimi turli tillar va mahalliy kontentlar bilan ishlashni o'rganish uchun qimmatli manba hisoblanadi. O'zbekistonda ham Yagona raqamli ta'lim portali konsepsiyasi asosida shu kabi ishlarni amalga oshirish mumkin. Jumladan, SCORM/xAPI standartlariga mos interfaol elektron darsliklar, o'qituvchilar hamjamiyati, masofaviy ta'lim va sun'iy intellektga asoslangan yordamchi kabi funksiyalarni birlashtirish maqsadga muvofiq bo'ladi. Maqsad o'quvchilarga teng va yuqori sifatli ta'lim olish imkoniyatlarini yaratish, shu bilan birga pedagoglarning raqamli savodxonligini oshirib borishdan iborat.

XULOSA VA TAKLIFLAR

Tadqiqotlar shuni ko'rsatmoqdaki, zamonaviy axborot-kommunikatsiya texnologiyalari O'zbekiston ta'lim sohasida raqamli ekotizimning ajralmas qismiga aylanib bormoqda. Shu

bilan birga, xalqaro miqyosda keng qo'llaniladigan SCORM, xAPI hamda cmi5 kabi standartlar hozircha mamlakatimiz ta'lim amaliyotida to'liq joriy etilmagan bo'lsa-da, ularning qo'llanilishi ta'lim jarayonini raqamli muhitga samarali moslashtirish, o'quv jarayonini esa yanada moslashuvchan va ma'lumotlarga asoslangan tarzda boshqarish imkonini berishi kutilmoqda. Shu bilan birga, raqamli ta'lim resurslari va interfaol xizmatlarning yagona tizim asosida integratsiyalashuvi ta'lim samaradorligini oshirish, sifat ko'rsatkichlarini yaxshilash va barcha o'quvchilar uchun adolatli hamda barqaror ta'lim imkoniyatlarini ta'minlashga xizmat qiladi.

O'zbekiston o'zining raqamli ta'lim tizimini yaratish yo'lida allaqachon muhim qadamlar tashlagan. Jumladan, eMaktab va maktab.uz kabi platformalar ishga tushirilgan bo'lib, endi ushbu platformalarni o'zida mujassamlashtirgan Yagona raqamli ta'lim portali mazkur tizimda muhim ahamiyat kasb etmoqda.

Eng muhim xulosalardan biri shundaki, raqamli transformatsiya nafaqat texnologik yechim, balki ijtimoiy loyiha hisoblanadi. Bu har bir o'qituvchidan o'zini innovatsion jarayonning ajralmas qismi sifatida anglashni va mahoratini uzluksiz oshirib borishni talab etadi. Shu bilan birga, har bir o'quvchi texnologiyalar orqali yangi imkoniyatlar ochilayotganini his qilishi lozim. Bundan tashqari, bu ulkan maqsadga barcha manfaatdor tomonlar - hukumat vakillari, maktablar, o'qituvchilar, o'quvchilar va ota-onalarning hamkorligida erishish mumkin. Raqamli texnologiyalar shunchaki zamonaviylik belgisi emas, balki ta'lim sifatini yuksaltirish, tenglikni ta'minlash va kelajak avlodning raqobatbardoshligini oshirishning muhim vositasidir.

Raqamli ta'lim tizimining muvaffaqiyati ko'p jihatdan o'qituvchilarning yangi texnologiyalardan foydalana olish qobiliyatiga bog'liq. Shu bois, o'qituvchilarning raqamli ko'nikmalarini uzluksiz ravishda oshirishga qaratilgan dasturlarni ishlab chiqish muhim ahamiyat kasb etadi. O'qituvchilarga xalqaro va milliy standartlar asosida raqamli ko'nikmalarini bosqichma-bosqich rivojlantirish imkoniyati yaratilishi lozim.

Yangi yaratilayotgan barcha raqamli kontent va platforma elementlari xalqaro standartlarga muvofiq bo'lishi kerak. Jumladan, mahalliy ishlab chiqilayotgan elektron darslik va kurslar SCORM yoki xAPI formatida paketlanishi, ta'lim portal va LMSlar esa ushbu standartarni qo'llab-quvvatlashi zarur. Bu nafaqat tizim ichidagi muvofiqlikni saqlaydi, balki kelgusida xorijiy platformalar bilan kontent almashishni ham osonlashtiradi.

Portaldan va LMSlardan olingan katta hajmdagi ma'lumotlar (big data) ta'lim siyosatini takomillashtirish imkonini beradi. Buning uchun EMIS kabi ta'lim axborot tizimini yagona portal va LMS bilan integratsiya qilib, har bir maktab va hududdagi raqamli faollik ko'rsatkichlarini uzluksiz kuzatib borish lozim. UNESCO tomonidan O'zbekistonda joriy etilgan Ta'lim axborot tizimi monitoringi vositasi (EMIS PATT) bu borada muhim vosita bo'lib, mamlakatimiz Markaziy Osiyoda birinchi bo'lib ushbu tizimni tatbiq etdi. Ushbu baholash vositasi ta'lim ma'lumotlari tizimida qaysi sohalar kuchli va zaif ekanini aniqlashga yordam beradi. Masalan, onlayn darslarga ulanish pasaygan hududda internet sifati yoki o'qituvchilar malakasini tekshirib, muammolarni bartaraf etish choralarini ko'rish mumkin.

Raqamli ta'lim tizimi barqaror ishlashi uchun uning axborot xavfsizligi yuqori darajada bo'lishi kerak. Portal va LMS ma'lumotlari, shaxsiy profillar va baholar kabi ma'lumotlarni shifrlangan holda saqlash, shuningdek, ishonchli autentifikatsiya tizimlari va foydalanuvchi rollarini joriy etish nihoyatda muhimdir. Xavfsizlik zaifliklari, DDoS-hujumlar va xakerlik hujumlaridan himoyalanish uchun zamonaviy protokollardan foydalanish majburiydir. Har bir foydalanuvchi nosozliklar yuz berganda tizimni zaxiralash va tiklash rejalarini ishlab chiqishi shart. Shuningdek, o'qituvchilar va o'quvchilarni kiberxavfsizlik bo'yicha muntazam o'qitib borish (masalan, parol xavfsizligi, shubhali havolalardan chetlashish haqida ma'lumot berish) muhim ahamiyatga ega.

Shuni ta'kidlash lozimki, yuqorida keltirilgan tavsiyalarni amalga oshirish orqali O'zbekiston ta'lim tizimining raqamli ekotizimi yanada mustahkamlanadi. Texnologiyalar va standartlar jarayonni tezlashtiradi hamda uning sifatini oshiradi, biroq ulardan eng samarali foydalanish uchun inson omili, ya'ni o'qituvchilar, o'quvchilar va ota-onalarning tashabbuskorligi va hamkorligi muhim ahamiyat kasb etadi. Raqamli ekotizimning yutuqlari shunda namoyon bo'ladiki, har bir o'qituvchi o'zini innovatsion jarayonning ajralmas qismi deb his qiladi, har bir o'quvchi esa texnologiyalar unga yangi imkoniyatlar eshigini ochayotganini chuqur anglab yetadi.

Ta'lim jarayoniga integratsiya qilingan raqamli yechimlar ta'lim sifatini yuksaltiradi, teng imkoniyatlar yaratadi va kelajak avlodning jahon miqyosida raqobatbardoshligini oshiradi. Shu sababli, ulardan to'liq va samarali foydalanish kelajagimizga qo'yilayotgan muhim sarmoya hisoblanadi.

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RAQAMLI IQTISODIYOT KONTEKSTIDA OLIY TA’LIM TIZIMIDA XIZMAT KO‘RSATISH MUASSASALARINING IQTISODIY SAMARADORLIGINI OSHIRISH

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***Annotatsiya* — Ushbu maqolada raqamli iqtisodiyot sharoitida oliy ta'lim tizimida xizmat ko'rsatuvchi muassasalarning iqtisodiy faoliyat samaradorligini oshirish masalalari ko'rib chiqiladi. Oliy ta’lim muassasalarining innovatsion va investitsion faoliyatini rivojlantirish, interaktiv davlat xizmatlari tizimi orqali kadrlar bandligi va talabni baholashning zamonaviy modellarini yaratish muhokama qilinadi. Raqamli texnologiyalarni joriy etish orqali ta'lim sifatini va xodimlarning faoliyat samaradorligini oshirish imkoniyatlari tahlil qilinadi. Tadqiqot natijalari asosida oliy ta'lim tizimini barqaror rivojlantirish va xalqaro raqobatbardoshligini oshirish uchun amaliy tavsiyalar ishlab chiqiladi. (*Annotatsiya*)**

Kalit so‘lar — Oliy ta’lim, raqamli iqtisodiyot, xizmat ko’rsatish samaradorligi, interaktiv davlat xizmatlari, kadrlar bandligi, innovatsiya, investitsiya, iqtisodiy samaradorlik. (*kalit so‘zlar****)***

CLXVIII. KIRISH

GLOBAL IQTISODIYOT VA IJTIMOIY SOHALAR RAQAMLI TEXNOLOGIYALAR ASOSIDA TEZ SUR’ATLARDA RIVOJLANAYOTGANI BUGUNGI KUNDA OLIY TA’LIM TIZIMI FAOLIYATINING SAMARADORLIGINI OSHIRISH MUHIMLIGINI TA’KIDLAYDI. OLIY TA’LIMDA XIZMAT KO‘RSATUVCHI MUASSASALARNING IQTISODIY SAMARADORLIGI NAFAQAT TA’LIM SIFATINI OSHIRISH, BALKI MAMLAKAT IQTISODIYOTINING RAQOBATBARDOSHLIGINI TA’MINLASH UCHUN ASOSIY MEZONLARDAN BIRIDIR. KO‘PLAB DAVLATLARDA OLIY TA’LIM TIZIMINING MOLIYALASHTIRILISHI DAVLAT TOMONIDAN TA’MINLANADI, AMMO SAMARADORLIKNI OSHIRISH VA RAQAMLI IQTISODIYOT SHAROITIDA RAQOBATBARDOSH BO‘LISH UCHUN INNOVATSION YONDASHUVLAR ZARUR. SHU BOIS, RAQAMLI TEXNOLOGIYALAR YORDAMIDA XODIMLARNING FAOLIYATI VA KADRLAR BANDLIGINI BAHOLASH TIZIMLARI ISHLAB CHIQISH, TA’LIM SIFATINI VA XIZMAT KO‘RSATISH SIFATINI OPTIMALLASHTIRISH DOLZARB VAZIFALARDAN BIRIDIR.

O‘zbekistonda oliy ta’lim tizimini rivojlantirish va uning xalqaro standartlarga mosligini ta’minlash maqsadida davlat tomonidan ko‘plab strategik hujjatlar qabul qilingan. Jumladan, “Raqamli O‘zbekiston-2030” strategiyasi, "Ta’lim to‘g‘risida"gi qonun va boshqa normativ hujjatlar oliy ta’lim tizimini modernizatsiya qilish, raqamli xizmatlarni rivojlantirish va kadrlar tayyorlash sifatini oshirishga qaratilgan. Bugungi kunda oliy ta’lim muassasalari u chun o‘zining iqtisodiy salohiyati va ilmiy-pedagogik kadrlar tarkibini yanada takomillashtirish muhim ahamiyat kasb etmoqda.

Ushbu maqolada yuqorida ta’kidlangan kontekst asosida oliy ta’lim tizimida xizmat ko‘rsatuvchi muassasalarning iqtisodiy samaradorligini oshirish, xodimlarning faoliyatini raqamli texnologiyalar yordamida baholash vakolatlari, kadrlar bandligini modellashtirish hamda raqobatbardoshlikni kuchaytirish masalalari ilmiy yondashuvlar va amaliy tajriba ko‘rsatmalari orqali tahlil qilinadi.

A. Tadqiqot metodologiyasi

Tadqiqot jarayonida kompleks metodologik yondashuv qo‘llanildi va quyidagi ilmiy tadqiqot usullari ishlatildi:

- Natijalarni aniqlik bilan baholash uchun iqtisodiy-statistik tahlillar, korrelyatsion-regression tahlil, statistik guruhlash va prognozlash usullari qo‘llanildi;
- Tizimli tahlil orqali oliy ta’lim tizimida inson resurslari, moliyaviy va texnologik resurslarning o‘zaro ta’siri o‘rganildi;
- Analiz va sintez usullari yordamida oliy ta’lim tizimida xizmat ko‘rsatuvchi muassasalarning iqtisodiy faoliyati samaradorligini oshirishga qaratilgan nazariy-analitik materiallar ishlab chiqildi;
- Ekspert baholari va amaliy yorliqlardan foydalangan holda oliy ta’lim tizimining raqobatbardoshligini oshirish bo‘yicha ilmiy-tadqiqotlar yakunlandi.

B. Adabiyot sharhi

Oliy ta’lim tizimining raqamli iqtisodiyotda samaradorligini oshirish mavzusida xalqaro va mahalliy olimlar tomonidan keng qamrovli tadqiqotlar olib borilgan. Misol uchun, O.Graumann, P.Senge va Itel de-Sol Pul kabi olimlar oliy ta’lim tizimini boshqarish samaradorligini oshirishda uzluksiz ta’lim va boshqaruv strategiyalarini

o'rganishgan. MDH mamlakatlaridan E.Y.Ignatev va boshqalar ta'lim menejmentining zamonaviy usullarini tahlil qilgan bo'lsa, O'zbekistondagi olimlar, jumladan R.X.Jo'rayev va N.N.Azizxo'jayev, o'zaro bog'liqlik va boshqaruv tizimlarini takomillashtirish yo'llarini ilgari surishgan.

Shuningdek, E.Wagner va J.M. Ferreira oliy ta'lim muassasalarining raqobatbardoshligini strategik boshqarish nuqtai nazaridan o'rganib, xalqaro miqyosda barqaror raqobat ustunligini yaratishning omillarini izohlashgan. Bunda jahon bozoridagi integratsiya, texnologik yangiliklar va marketing strategiyalari asosiy omillar sifatida ko'rsatildi. Xorijiy tajribalar orqali O'zbekiston oliy ta'lim tizimining zamonaviylashtirilishi, raqamli platformalar, big data va sun'iy intellektni qo'llash yo'nalishlari o'rganildi.

O'zbekistonda esa M.Rosenberg va Q.S.Raxmanovning tadqiqotlari raqamli ta'limning ta'sirini va davlat boshqaruvini raqamlashtirishdagi mavjud muammolarni batafsil ko'rib chiqadi. Milliy kontekstda esa personalni rivojlantirish va raqamli texnologiyalar orqali xodimlarning malakasini oshirishga katta e'tibor qaratilmoqda. Xalqaro tajribadagi Yaponiyaning yuqori samarali kadrlar tayyorlash modeli, Fransiyaning malaka oshirish qonunchilik mexanizmi kabi yondashuvlar O'zbekistonga moslashtirilmoqda.

Bundan tashqari, Kaplan va Norton tomonidan ishlab chiqilgan Balanced Scorecard usuli va Robert Campning Benchmarking yondashuvi oliy ta'lim muassasalari faoliyatini kompleks baholashda keng qo'llanilmoqda. Bu usullar moliyaviy natijalar, mijozlar qoniqishi, ichki jarayonlar samaradorligi va innovatsion rivojlanishni bir vaqtning o'zida baholash imkonini beradi.

CLXIX. TADQIQOT NATIJASI

Tadqiqot natijalariga ko'ra, oliy ta'lim tizimida xizmat ko'rsatuvchi muassasalarning raqobatbardoshligini oshirish quyidagi asosiy yo'nalishlarda amalga oshirilmoqda:

- Texnologik infratuzilmani va ilmiy-texnik dasturlarni kengaytirish, bu 2019 yildan 2024 yilgacha texnik dasturlar ko'lamining 72% dan 82% ga oshganligi bilan namoyon bo'ladi.
- Ilmiy-pedagogik xodimlar soni ham sezilarli oshib, 65% dan 78% gacha yetgan.
- Raqamli texnologiyalardan keng foydalanish orqali ta'lim sifatini yaxshilash va avtomatlashtirish tizimlari joriy qilingan, dasturlardan foydalanish samaradorligi esa 70% dan 83% gacha oshgan.

Ushbu ko'rsatkichlar O'zbekistonning 2030 yilga qadar raqamli iqtisodiyotga o'tish va ta'lim infratuzilmasini rivojlantirish strategiyasiga to'liq mos keladi.

2-jadval. Respublika bo'yicha oliy ta'lim tizimiga xizmat ko'rsatuvchi muassasalar sonining o'sish dinamikasi (2014-2023)[55]

Yil	Oliy ta'lim tashkilotlar soni
2014/2015	68
2015/2016	69
2016/2017	70
2017/2018	72
2018/2019	98
2019/2020	119
2020/2021	127
2021/2022	154
2022/2023	191

Bu raqamlar 2014-2023 yillar oralig'ida oliy ta'lim muassasalari soni 2,8 barobar o'sishini ko'rsatadi. Xorijiy oliy ta'lim tashkilotlari filiallari soni esa 7 tadan 26 taga oshgan, bu esa xalqaro hamkorlikning rivojlanganini tasdiqlaydi.

2-jadval. Hududlar bo'yicha oliy ta'lim muassasalari va talabalar soni

Hududlar	Muassasalar soni (2024)	Talabalar soni (2023)
Toshkent shahri	90	370,253
Andijon	12	58,247
Buxoro	13	55,418
Samarqand	17	88,345
Surxondaryo	8	55,367
Qashqadaryo	11	54,211
Farg'ona	13	82,167
Navoiy	5	28,236

Bu o'sish raqamli transformatsiyani jadallashtirish, ta'lim sohasida axborot-kommunikatsiya texnologiyalarini keng joriy etish, ta'lim sifatini oshirish va ilm-fanni rivojlantirishga yo'naltirilgan "Raqamli O'zbekiston—2030" strategiyasi doirasida amalga oshirilmoqda. Strategiya doirasida ta'lim infratuzilmasini kengaytirish, raqamli xizmatlar va yangi ta'lim platformalarini joriy etish ustuvor vazifalar sifatida ko'rilgan.

Mazkur strategik yo'nalishlar mamlakatda ta'lim tizimini modernizatsiya qilish, xalqaro hamkorlikni

kengaytirish, kadrlarning raqobatbardoshligini oshirish va o'quv jarayonlarini raqamlashtirishni ta'minlaydi.[56]

Shu bilan birga, oliy ta'lim muassasalari sonining oshishi va hududlarda taqsimlash ta'lim sohasida raqamli iqtisodiyotga o'tish jarayonining muhim qismidir, bu esa O'zbekistonning iqtisodiy va ijtimoiy rivojlanishini yangi bosqichga ko'tarishga xizmat qiladi.

Oliy ta'lim tizimida xizmat ko'rsatuvchi muassasalar iqtisodiy faoliyatining samaradorligini oshirish zamonaviy sharoitda muhim ahamiyat kasb etadi. Jahon iqtisodiyotining raqamli transformatsiyasi va sun'iy intellekt texnologiyalari rivojlanishi holatida, oliy ta'lim tizimi, jumladan unda xizmat ko'rsatuvchi muassasalar faoliyatini optimallashtirish zarurati yuzaga kelmoqda. Bu jarayonda, xodimlarning mehnat unumdorligini baholash va optimallashtirish uchun raqamli texnologiyalar muhim vositadir.

Mamlakatimizda ta'lim sifatini oshirish va raqobatbardoshlikni ta'minlash uchun xizmat ko'rsatuvchi muassasalar faoliyati zamonaviy boshqaruv tizimlari va dasturiy majmualar orqali avtomatlashtirilmoqda. Ushbu usullar mehnat resurslaridan foydalanishni samarali tashkil etish hamda sifatli xizmat ko'rsatish imkonini beradi. Oliy ta'lim tizimiga xizmat ko'rsatuvchi muassasalarda raqobatbardoshlikni oshirish strategiyalari ta'lim sifati, xodimlar malakasi va innovatsion yechimlarga asoslangan.

Bundan tashqari, mamlakatda ta'lim tizimini rivojlantirish, xorijiy va mahalliy hamkorlikni kengaytirish, ta'lim xizmatlari bozorini shakllantirish kabi vazifalar hamda sohadagi raqamlashtirish jarayonlari amalga oshirilmoqda. Bu esa nafaqat xizmat ko'rsatish hajmini oshirish, balki oliy ta'lim tizimining global raqobatbardoshligini ta'minlashga xizmat qiladi.

Xodimlarni boshqarish tizimlari mehnat bozoridagi talab va ta'lim muassasalari imkoniyatlarini muvofiqlashtirishga yordam beradi. Zamonaviy axborot-kommunikatsiya texnologiyalari yordamida ta'lim jarayonini raqamlashtirish, ilmiy-tadqiqot faoliyatini yanada samarali boshqarish imkonini yaratadi. Ta'lim infratuzilmasining kengayishi va ilg'or texnologiyalarni joriy qilish strategiyasi davlat tomonidan ustuvor yo'nalish sifatida qo'llab-quvvatlanmoqda.

Bu jarayonda yuqori malakali kadrlarni tayyorlash, ilmiy tadqiqotlarni rivojlantirish, shuningdek, xodimlarning faoliyatini tahlil qilish va optimallashtirishga xizmat qiluvchi raqamli dasturiy komplekslar ishlab chiqish muhim ahamiyatga ega. Shunday qilib, xizmat ko'rsatuvchi muassasalar faoliyati iqtisodiy va ijtimoiy sohalarda samaradorlikni oshirishda katta rol o'ynaydi.

O'zbekiston oliy ta'lim tizimida so'nggi yillarda sezilarli va tizimli o'zgarishlar amalga oshirildi. Misol uchun, 2014/2015 yilda mamlakatda 68 ta oliy ta'lim muassasasi faoliyat ko'rsatgan bo'lsa, 2023/2024 o'quv yilida bu ko'rsatkich 213 taga yetdi. Buning natijasida oliy ta'lim muassasalarida tahsil olayotgan talabalar soni 1,3 millionga yetdi, bu esa mamlakat yoshlarining oliy ta'lim bilan qamrab olinish darajasini 2016 yildagi atigi 9 foizdan bugungi kunda taxminan 42 foizga oshishini ta'minladi. Uzoq tarixda kuzatilmagan bu o'sish raqamli iqtisodiyotga o'tish va ta'lim infratuzilmasini kengaytirish strategiyasining samarasi sifatida ko'riladi.

Mazkur kengayish natijasida hududlarda ham ta'lim muassasalari sonining ko'payishi kuzatilmoqda. Toshkent shahrida bugungi kunda 90 ta oliy ta'lim muassasasi faoliyat yuritmoqda, unda tahsil olayotgan talabalar soni 370 mingdan oshadi. Samarqand va Farg'ona kabi yirik hududlarda 17 va 13 ta muassasa mavjud bo'lib, talabalarning soni keskin oshgan (mos ravishda 88 ming va 82 ming kishi). Bu esa ta'lim xizmatlarining hududlardagi teng taqsimlanishiga, yoshlar o'rtasida ta'lim olish imkoniyatlarining kengayishiga xizmat qilmoqda.

Oliy ta'lim sohasida raqamli transformatsiya jadal sur'atlar bilan amalga oshmoqda. 2019 yildan boshlab barcha oliy ta'lim muassasalari kredit-modul tizimiga (European Credit Transfer and Accumulation System) bosqichma-bosqich o'tmoqda. Bu esa ta'lim dasturlarining moslashuvchanligini oshirib, talabalar uchun fanlarni tanlash imkoniyatini kengaytirmoqda. Shu bilan birga, qo'sh diplom dasturlari (Double Degree) joriy etilib, talabalarga xorijiy universitetlar bilan aloqada ta'lim olish imkoniyati yaratilmoqda. Mazkur integratsion jarayonlar O'zbekiston oliy ta'limining xalqaro maydondagi raqobatbardoshligini oshirishga yo'naltirilgan muhim strategik qadamdir.

Yana bir muhim yo'nalish ta'lim tizimining moddiy-texnika bazasini mustahkamlashdir. 2016 yilda oliy ta'lim muassasalari binosining quvvati 274 ming kishini tashkil qilgan bo'lsa, 2023 yilda bu ko'rsatkich 395 mingga yetkazildi. Yotoqxonalarda yashash istagini bildirgan talabalar qamrovi 2019 yildagi 28 foizdan 2023 yilda 52 foizga oshdi. Davlat-xususiy sheriklik loyihalari orqali yangi yotoqxona qurilishi va ta'lim muassasalarining infratuzilmasini yaxshilash borasida katta ishlar bajarilmoqda.

Shuningdek, oliy ta'limda sifatni oshirishga qaratilgan ilmiy va metodologik islohotlar ham amalga oshirilmoqda. Bakalavriat va magistratura ta'lim yo'nalishlari optimallashtirilib, xalqaro akkreditatsiyadan o'tgan dasturlar soni ortmoqda. Bu esa ta'lim sifatining xalqaro standartlarga mos kelishini ta'minlashga xizmat qilmoqda.

Tahlil shuni ko'rsatadiki, so'nggi yillarda O'zbekiston oliy ta'lim tizimida nafaqat muassasalar soni va talaba qamrovi ortdi, balki sifatni yaxshilash, ta'lim dasturlarini takomillashtirish, ilmiy tadqiqotlarni rivojlantirish va ta'limning raqamlashtirilishi bo'yicha ham katta yutuqlarga erishildi. Bu esa mamlakatning raqamli iqtisodiyotga o'tish strategiyasi bilan uyg'unlashgan holda, iqtisodiyotning turli tarmoqlarini yuqori malakali kadrlar bilan ta'minlash imkonini yaratadi. Shu bilan birga, yuqori malakali kadrlar tayyorlash, innovatsion faoliyatni rivojlantirish va xalqaro standartlarga moslashish oliy ta'lim sohasining yetakchi vazifalaridan biri hisoblanadi.

Bularning barchasi mamlakat ta'lim tizimining barqaror rivojlanishini ta'minlab, yosh avlodning zamonaviy bilimlar bilan qurollanishi va iqtisodiy o'sishdagi raqobatbardoshlikni oshirishga xizmat qiladi.

O'zbekiston oliy ta'lim tizimi so'nggi yillarda jadal rivojlanish, kengayish va sifat jihatidan sezilarli o'zgarishlarni boshdan kechirmoqda. 2014/2015 yildan

boshlab 2023/2024 o‘quv yiliga qadar oliy ta’lim muassasalari soni 68 tadan 213 taga yetib, uch barobarga yaqin o‘sish kuzatildi. Bu o‘z navbatida talabalarning oliy ta’lim bilan qamrab olinishi darajasining ham oshishiga olib keldi. 2016 yilda oliy ta’lim qamrovi atigi 9 foizni tashkil qilgan bo‘lsa, hozirgi vaqtda bu ko‘rsatkich 42 foizga yetdi. Bunday o‘sish mamlakatda yoshlar uchun ta’lim olish imkoniyatlari kengayganidan, ta’lim tizimining hududlarga teng taqsimlanganidan va sifatli ta’lim standartlari joriy etilayotgani natijasidir.

Hududlar bo‘yicha ta’lim infrastrukturasi kengaymoqda, Toshkent shahri 90 ta oliy ta’lim muassasasi va 370 mingdan oshiq talaba bilan yetakchilik qilmoqda. Samarqand va Farg‘ona kabi yirik shaharlar ham so‘nggi yillarda oliy ta’lim muassasalarining soni ortib, talaba qamrovi „barqaror“ tarzda oshmoqda. Shu bilan birga, Navoiy kabi hududlarda talabalar va muassasalar soni boshqa hududlarga nisbatan past bo‘lsa-da, mintaqaviy rivojlanish istiqbollari mavjud.

Ta’lim tizimining sifat va zamonaviylik darajasini oshirish maqsadida 2019 yildan boshlab kredit-modul tizimiga bosqichma-bosqich joriy etish boshlandi, shu bilan birga qo‘sh diplom dasturlari kengaytirilmoqda. Bu talabalar uchun turli imkoniyatlarni yaratib, ularni xalqaro ta’lim maydoniga chiqishiga xizmat qilmoqda. Ilmiy tadqiqotlar va innovatsion faoliyatni integratsiyalash „Universitet 3.0“ konsepsiyasi doirasida amalga oshiriladi, bu esa ilmiy salohiyatni oshirib, intellektual mulkni tijoratlashtirishga zamin yaratmoqda.

3-rasm. O‘zbekiston oliy ta’lim tizimining ayrim asosiy ko‘rsatkichlarini 2014/2015 yildan 2023/2024 yilgacha

Yil	OTM soni	Talabar soni(ming)	Bakalavr bitiruvchilar soni	Magistr bitiruvchilar soni
2014/15	68	264	Noma’lum	Noma’lum
2017/18	72	360	Noma’lum	Noma’lum
2019/20	119	570	65,400	9,362
2021/22	154	912	Noma’lum	Noma’lum
2023/24	213	1,300	197,319	4,943

Infratuzilma va moddiy-texnika bazasining rivojlanishi ham diqqat markazida. Mamlakat bo‘ylab oliy ta’lim muassasalari binosining o‘quv quvvati sezilarli o‘sdi, yotoqxonalarda talabalar qamrovi 28 foizdan 52 foizgacha ko‘tarildi va yangi yotoqxona loyihalari amalga oshirilmoqda.

Davlat tomonidan iqtidorli yoshlarni qo‘llab-quvvatlash uchun grantlar soni oshirilib, davlat va xususiy sektordan moliyaviy yordam bilan ta’minlash mexanizmlari joriy etildi. Bu esa yoshlar orasida ta’limga bo‘lgan motivatsiyalarni kuchaytirib, ta’lim sifat va samaradorligini oshirishga yordam beradi.

O‘zbekiston oliy ta’lim tizimidagi so‘nggi yillardagi islohotlar nafaqat muassasalar soni va talaba qamrovining o‘sishiga, balki ta’lim sifatini yaxshilashga, ilmiy-innovatsion salohiyatni oshirishga va ta’lim infratuzilmasini zamonaviylashtirishga qaratilgan. Bu o‘zgarishlar mamlakat iqtisodiyotining iqtisodiy va ijtimoiy rivojlanishiga xizmat qiladi, yoshlarni raqobatbardosh mutaxassislar sifatida tayyorlash imkonini yaratadi. Shuningdek, ta’lim tizimi raqamli iqtisodiyotga moslashish va xalqaro ta’lim makonida o‘z o‘rnini mustahkamlashga intilmoqda. Bularning barchasi O‘zbekistonning kelajakdagi taraqqiyoti uchun mustahkam poydevor bo‘lib xizmat qiladi.

CLXX. XULOSA

O‘zbekiston oliy ta'lim tizimida xizmat ko'rsatuvchi muassasalarning iqtisodiy samaradorligini oshirishga qaratilgan tadqiqot natijalari, raqamli texnologiyalarni joriy etish, ilmiy salohiyatni rivojlantirish va zamonaviy boshqaruv tizimlarini shakllantirish bilan bog‘liq ekanligi tasdiqlandi. Bu esa ta’lim sifatini yaxshilash va muassasalar raqobatbardoshligini oshirish imkonini beradi. Toshkent axborot texnologiyalari universiteti misolida olib borilgan ekonometrik tahlil esa iqtisodiy ko‘rsatkichlar va kadrlar siyosatining samaradorligini ko‘rsatmoqda.

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