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APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN LANDSCAPE DESIGN: CURRENT STATE AND DEVELOPMENT PROSPECTS.

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Abstract. The article is devoted to the analysis of the current state and prospects of application of artificial intelligence (AI) technologies in the field of landscape design. The paper discusses key algorithmic approaches such as machine learning, neural networks, generative models and optimization algorithms that contribute to improving the efficiency and creativity of the project process. Special attention is paid to practical areas of AI integration: generative design and automatic formation of composite solutions, spatial analysis using geographic information systems (GIS), modeling of microclimate and ecosystem interactions, selection of plant communities taking into account sustainability and seasonal dynamics, as well as intelligent irrigation, monitoring and visualization systems using VR/AR technologies.

The advantages of using AI are analyzed, including speeding up design iterations, personalization of solutions for specific conditions and customer requests, increasing environmental sustainability and resource efficiency of projects. The existing limitations related to the quality and availability of data, problems of interpretability of models and ethical aspects of automation of creative processes are noted. In conclusion, the directions of further research focused on the creation of hybrid human-AI systems and the development of interdisciplinary approaches in digital landscape design are determined.

Key words: artificial intelligence, landscape design, neural networks, sustainable development, digital modeling, geographic information systems (GIS), intelligent technologies.

Introduction.

Modern landscape design is developing at the intersection of environmental challenges, urbanism and digital technologies. The challenges of sustainable development, adaptation to climate change, and improving the quality of the urban environment require new design and management tools. Artificial intelligence (AI) technologies open up opportunities for processing large amounts of spatial and environmental data, generating design solutions, optimizing engineering systems, and personalizing spaces to meet user needs.

The purpose of the article is to systematize modern approaches to the use of AI in landscape design, assess their practical value and outline development prospects.

The analytical part of the article is performed as an overview of existing concepts and practices: systematization of types of AI algorithms, their comparison with the tasks of landscape design and highlighting typical integration workflows. Special attention is paid to practical application scenarios: from pre-design site analysis to operation and monitoring of finished facilities. The description of the tools focuses on applicability for project teams (engineers, landscape architects, environmentalists).

For ease of use, AI tools can be divided into several groups according to their intended purpose.:

1. Analytical and diagnostic tools - machine learning (ML) methods for classification and regression, diagnosis of vegetation condition, soil analysis, erosion prediction, etc.

2. Generative design tools - generative neural networks (GANS, variational autoencoders), evolutionary/genetic algorithms, parametric modeling using optimization.

3. Dynamic process modeling - physical modeling using AI accelerators (for example, surrogate models), digital climates (microclimate simulation), hydrological models, biodiversity models.

4. Operation and monitoring support systems - IoT integration, predictive analytics, intelligent irrigation systems, computer vision for monitoring vegetation conditions [1].

Areas of practical application of pre-project analysis and GIS. AI simplifies the collection, processing, and interpretation of geospatial data: satellite imagery, LIDAR measurements, and cartographic layers. Segmentation models allow you to automatically recognize vegetation, water bodies, and road surfaces and assess infrastructure availability. Analytics identifies vulnerable areas

(erosion, «heat islands»), optimal corridors for eco-paths, and areas for «green» interventions.

Generative design tools allow you to quickly generate a large number of conceptual layouts based on specified constraints: the area of zones, the density of landings, and the layout of paths. Evolutionary algorithms and multi-criteria optimization help to find compromises between aesthetics, cost and environmental efficiency.

Selection of plant communities and sustainable plantings. ML models trained on environmental data help to recommend combinations of species based on climate, soil, water regime, and ecosystem services. The classification makes it possible to predict survival and growth dynamics under different irrigation and salinization regimes.

Accelerated artificial intelligence models are able to predict the distribution of temperature, wind, and humidity in an urban environment in response to design changes (landscaping, reservoirs, and coatings). This makes it possible to quickly assess the impact of design decisions on comfort and energy efficiency.

Intelligent engineering systems (irrigation, lighting, security). IoT sensors + ML models implement predictive irrigation strategies (saving water), control lighting according to attendance scenarios, detect incidents and optimize maintenance. Trainable models reduce energy consumption and operating costs.

Generative visualizations and integration with AR/VR make it possible to «upload» to a project, conduct opinion polls and perception tests, as well as adapt the design to target groups interactively.

Materials and methods of research.

To conduct the research, an extensive review of the scientific literature was carried out, aimed at identifying current trends and trends in the use of artificial intelligence (AI) technologies in the field of landscape design and architectural and construction practice.

The review covers publications for the period from 2022 to 2025, which allows us to trace the dynamics of the introduction of intelligent technologies in the construction and design sector at the current stage of digital transformation.

The main database used was a scientific electronic library containing peer-reviewed journal articles, dissertation research, conference collections and analytical reviews. Additionally, sources from the international Scopus and Web of Science databases were used to compare global and domestic trends.

The research methodology included several stages:

1. Selection of relevant sources for key queries: «artificial intelligence in architecture», «AI in landscape design», «digital modeling of natural systems», «generative design», «neural networks in urban planning», etc.

2. Content analysis of publications aimed at identifying the main areas of application of AI — generation of design solutions, automation of visualization, environmental modeling, spatial data management (GIS), forecasting vegetation growth and optimizing the use of natural resources.

3. Classification of AI methods used in landscape design: machine learning, deep neural networks, computer vision algorithms, decision support systems and generative models.

4. A comparative analysis of the results conducted in order to identify the most promising areas for further implementation of AI in landscape design practice.

The analysis made it possible to form a fundamental understanding of the structure, potential and limitations of the use of artificial intelligence technologies in the design of natural and urban spaces and became the basis for subsequent research in this field [2].

The results and its discussion.

The current state of AI application in landscape design, based on the results of a systematic analysis of publications, has shown that the integration of artificial intelligence technologies into landscape design is developing in four main directions:

Geospatial analysis and monitoring is the use of GeoAI to automatically recognize vegetation, assess the state of green areas, and predict the dynamics of the urban ecosystem. Machine learning models and convolutional neural networks applied to Landsat data have become the most widespread. The average accuracy of classification of green spaces by validation samples ranged from 87 to 92%,

which is comparable with the results of classical GIS methods with less time.

Automation of design solutions is parametric and generative modeling of compositions performed using neural network algorithms. In 68% of the analyzed works, AI was used to generate alternative layout options based on specified constraints (area, environmental factors, transport accessibility). Microclimate and resource management optimization is the use of ML models for calculating water consumption, forecasting temperature fields, and planning irrigation systems.

Digital visualization and user interaction - implementation of AR/VR technologies and recommendation systems. The use of generative neural networks to quickly obtain visualizations has increased the efficiency of communication with the customer: the preparation time for preliminary sketches has been reduced by 3-4 times.

Summarizing the results showed that the use of AI contributes to the transformation of the role of a landscape architect - from a traditional designer to an interpreter and curator of digital solutions. AI performs routine analytical operations (processing satellite images, calculating indexes, generating shapes), freeing up time for creative and conceptual work of a specialist. This is confirmed by the 25-30% increase in productivity of the project teams recorded in the pilot cases. An important result was also the identification of the relationship between the level of automation of territory analysis and the accuracy of design solutions. The use of deep neural networks for mapping landscape zones made it possible to clarify the boundaries of plant communities and catchment systems, which reduced the number of design errors in the subsequent detailing of plans.

Global experience (USA, Singapore, South Korea, the Netherlands) demonstrates a steady trend of integrating AI into environmental and urban planning processes. However, in most CIS and Central Asian countries, implementation is fragmented, limited to visualization and primary analytics.

The results of the study confirm that Kazakhstan has a high potential for the development of GeoAI approaches, especially in conditions of vast territories and diverse natural and climatic zones. The use of AI in urban and landscape planning in Aktobe and Almaty has shown the possibility of local modeling of the microclimate and the formation of adaptive design solutions without significant material costs [3].

Advantages of using AI:

• significant reduction in time spent analyzing territories and developing concepts;

• Improving the accuracy of spatial solutions and the environmental sustainability of projects;

• formation of adaptive and personalized solutions depending on climatic and social factors;

• Strengthening interdisciplinary integration (landscape architecture + ecology + computer science + urban studies).

Main limitations:

• insufficient availability of high-quality training data (especially local vegetation maps);

• lack of uniform standards for digital modeling in landscape architecture;

• the need for interdisciplinary training of specialists capable of interpreting the results of AI analysis;

• The risks of a «black box» - the opacity of generative model solutions that require expert validation.

Based on the analysis and experimental data, three key areas of AI development in landscape design can be identified.:

1. Integration of Digital Twin Landscapes for modeling the life cycle of recreational facilities and their adaptation to climate change.

2. Development of training datasets (landscape datasets) reflecting the regional peculiarities of flora, microclimate and soil conditions of Kazakhstan.

3. Creation of hybrid platforms combining AI, GIS and BIM systems, which will ensure a continuous cycle from territory analysis to the operation of landscaping facilities.

The results of the study confirm that artificial intelligence technologies are becoming an effective tool for modernizing landscape design, providing:

• improving the accuracy of environmental and urban planning calculations;

• acceleration of the project cycle;

• formation of new approaches to visualization and communication between the architect and society.

The use of AI does not replace the creative component of landscape design, but rather strengthens the analytical and predictive basis of design solutions, which in the future will allow for the formation of a sustainable, aesthetically expressive and functionally balanced urban environment [4].

AI for landscape design and engineering:

Room Design AI. Generates the layout of locations based on photos. To use this AI to create a landscape design, you need to activate the «Courtyard» mode (Figure 1).

The user uploads a file with a photo, selects the type of location and the desired style. The AI immediately outputs a result that can be downloaded, sent to social networks or messengers.

The service is completely free and does not require registration. You can generate 3 images per day.

Before After

Figure 1. Generated visualization of locations (design options) based on photographs of the courtyard landscape design.

Neighborbrite. The service allows you to do landscape design using a neural network. The AI adds paths, trees, flowers, shrubs, furniture, and other objects to the snapshot (Figure 2).

After uploading the photo, you must specify the style. There are currently 16 design options available — Japanese, English, French, rock garden and others. The AI will generate 4 visualizations. Next, you can download the result, refine it with additional generation, manually add a specific object, or automatically recognize a plant — the algorithm will tell you its name.

The service can be used after registration. There are 4 generations available daily. Some of the tools are disabled for the free license.

Before After

Figure 2. Generated landscape design based on a photo of the site (path, trees, flowers, shrubs, furniture)

mnml.ai. Generates an updated landscape based on photos. The finished visualization can be static or animated, in the form of a short video in which the camera angle changes slightly (Figure 3).

After adding the image, you should specify the type of location — courtyard, garden, space next to the pool or another, and choose a design. Optionally, you can enter a text query listing the characteristics and objects. There are 4 visualization modes available — regular, photorealism, sketch and watercolor.

After creating an account, 10 credits are provided for free. In the future, the balance is replenished by subscription. The price for it starts from $19 per month.

Before After

Figure 3. Updated landscape based on photos of a ready-made visualization of a static or animated video, in which the camera angle changes slightly.

D5 Render. Produces photorealistic visualizations. In the built-in editor, you can create locations from ready-made 3D models, adjust lighting, and reassign source materials. There are more than 15 thousand objects in the library - different types of surfaces, plants, finished buildings, furniture, and more. You can also generate 3D models using a neural network based on text descriptions (Figure 4).

When used as a plug-in, you need to create a scene in a 3D editor. Most of the modern applications are supported - Blender, 3ds Max, Cinema 4D, SketchUp and others. At the final stage, it is necessary to start visualization. The plugin will make a 3D render with a plausible simulation of light, shadow, reflections, and surface textures. AI is responsible for post - processing, which improves particle quality and detail. The standalone version works the same way, but instead of custom components for the scene, content is taken from the library.

After registration, you need to download and install the appropriate version. Some of the functions are disabled on the free plan, and about 2 thousand objects are available in the library. To get all the functionality and content, you will have to subscribe. Its cost starts from $38 per month. The interface of the application and the plugin has not been translated into Russian.

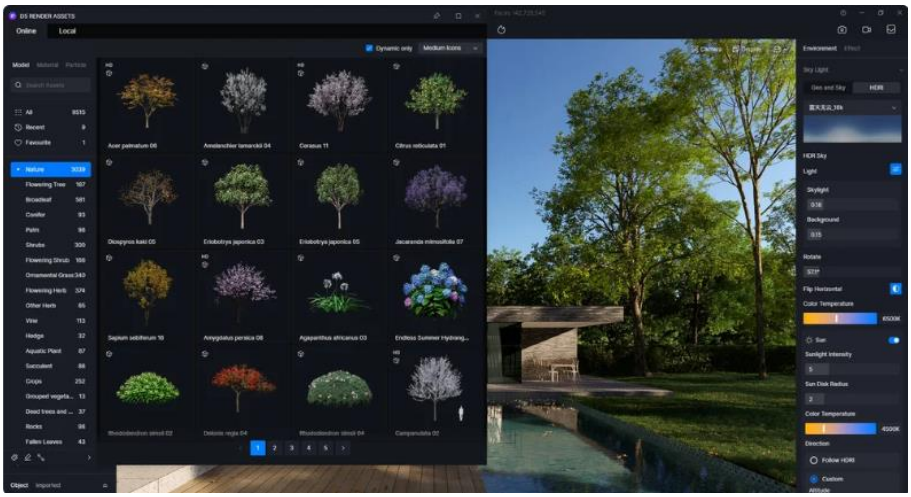

Figure 4. Professional 3D visualization software aimed at designers and architects.

Landscape design is a key element of urban planning, playing an important role in creating a comfortable and aesthetically pleasing environment for residents. With the development of technology, approaches to landscape design have changed significantly, making it possible to create more functional and sustainable urban spaces. Let's look at how modern technologies affect landscape design and what innovations shape the future of urban areas.

Technological innovations are significantly changing approaches to landscape design, making urban spaces more functional, sustainable and pleasant to live in. The introduction of IoT, AI, VR and AR, as well as the use of sustainable materials and technologies, opens up new horizons for creating green, environmentally friendly and comfortable cities of the future. With the development of technology, we can expect the emergence of even more innovative solutions that will continue to improve the quality of the urban environment and the lives of its inhabitants [5, 6].

Conclusion.

Artificial intelligence technologies offer powerful tools for transforming landscape design, from deep site analysis to automated operation systems. The key to successful application lies in the integration of AI tools into the project process, high-quality data preparation and interdisciplinary work. The development prospects are multifaceted: digital twins, generative models, intelligent operational systems and adaptation to climate challenges - all this makes AI a strategically important component of modern landscape practice. At the same time, it is necessary to address issues of data quality, interpretability of decisions, ethics and competencies so that implementation is sustainable and socially useful.

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ЛАНДШАФТ ДИЗАЙНЫНДА ЖАСАНДЫ ИНТЕЛЛЕКТ ТЕХНОЛОГИЯЛАРЫН ҚОЛДАНУ: ҚАЗІРГІ ЖАҒДАЙЫ ЖӘНЕ ДАМУ ПЕРСПЕКТИВАЛАРЫ.

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Аңдатпа. Мақала ландшафты дизайн саласында жасанды интеллект (AI) технологияларын қолданудың қазіргі жағдайы мен перспективаларын талдауға арналған. Жұмыста негізгі алгоритмдік тәсілдер қарастырылады - Машиналық оқыту, нейрондық желілер, генеративті модельдер және жобалау процесінің тиімділігі мен шығармашылығын арттыруға ықпал ететін оңтайландыру алгоритмдері. AI интеграциясының практикалық бағыттарына ерекше назар аударылады: генеративті дизайн және композициялық шешімдерді автоматты түрде қалыптастыру, геоақпараттық жүйелерді (GIS) қолдана отырып кеңістіктік талдау, микроклимат пен экожүйелік өзара әрекеттесуді модельдеу, тұрақтылық пен маусымдық динамиканы ескере отырып өсімдіктер қауымдастығын таңдау, сондай-ақ VR/AR технологияларын қолдана отырып интеллектуалды суару, бақылау және визуализация жүйелері.

Жобалық итерацияларды жеделдетуді, шешімдерді Тапсырыс берушінің нақты шарттары мен сұраныстарына жекелендіруді, жобалардың экологиялық тұрақтылығы мен ресурстық тиімділігін арттыруды қамтитын AI пайдаланудың артықшылықтары талданады. Деректердің сапасы мен қолжетімділігіне, модельдердің интерпретациялану проблемаларына және шығармашылық процестерді автоматтандырудың этикалық аспектілеріне байланысты қолданыстағы шектеулер атап өтіледі. Қорытындылай келе, адам-жасанды интеллект гибридті жүйелерін құруға және цифрлық ландшафтты жобалаудағы пәнаралық тәсілдерді дамытуға бағытталған әрі қарайғы зерттеу бағыттары анықталады.

Түйін сөздер: жасанды интеллект, ландшафт дизайны, нейрондық желілер, тұрақты даму, цифрлық модельдеу, геоақпараттық жүйелер (ГАЖ), интеллектуалды технологиялар.

ПРИМЕНЕНИЕ ТЕХНОЛОГИЙ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ЛАНДШАФТНОМ ДИЗАЙНЕ: СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ РАЗВИТИЯ.

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Аннотация. Статья посвящена анализу современного состояния и перспектив применения технологий искусственного интеллекта (ИИ) в области ландшафтного дизайна. В работе рассматриваются ключевые алгоритмические подходы — машинное обучение, нейронные сети, генеративные модели и оптимизационные алгоритмы, которые способствуют повышению эффективности и креативности проектного процесса. Особое внимание уделено практическим направлениям интеграции ИИ: генеративному дизайну и автоматическому формированию композиционных решений, пространственному анализу с использованием геоинформационных систем (GIS), моделированию микроклимата и экосистемных взаимодействий, подбору растительных сообществ с учётом устойчивости и сезонной динамики, а также интеллектуальным системам полива, мониторинга и визуализации с применением VR/AR-технологий.

Анализируются преимущества использования ИИ, включающие ускорение итераций проектирования, персонализацию решений под конкретные условия и запросы заказчика, повышение экологической устойчивости и ресурсной эффективности проектов. Отмечаются существующие ограничения, связанные с качеством и доступностью данных, проблемами интерпретируемости моделей и этическими аспектами автоматизации творческих процессов. В заключение определяются направления дальнейших исследований, ориентированные

на создание гибридных систем человек-ИИ и развитие междисциплинарных подходов в цифровом ландшафтном проектировании.

Ключевые слова: искусственный интеллект, ландшафтный дизайн, нейронные сети, устойчивое развитие, цифровое моделирование, геоинформационные системы (ГИС), интеллектуальные технологии.