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MODERN DIRECTIONS OF THE USE OF ARTIFICIAL INTELLIGENCE IN CARTOGRAPHY

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Annotation. This article discusses in detail the application of artificial intelligence technologies in the field of cartography, their theoretical foundations and practical possibilities. The importance of artificial intelligence algorithms in the processes of digital cartography, geographic information systems and remote sensing data processing is analyzed. The role of machine learning and deep learning methods in automating and improving cartographic processes is also considered.

Keywords. Cartography, artificial intelligence, GIS, remote sensing, machine learning, digital map, spatial analysis, automation.

Introduction

Modern cartography is undergoing a transition from traditional map-making methods to digital and intelligent systems. As a result of the development of information technologies, the volume of spatial data has increased dramatically, and their processing by traditional methods has become more complicated. Therefore, the use of artificial intelligence technologies has become an important need in the science of cartography.

Artificial intelligence allows for rapid processing of large volumes of data, identification of complex relationships, and automatic decision-making without human intervention. This increases the efficiency of cartographic processes and ensures the accuracy of maps.

Artificial Intelligence and Cartography Integration

Artificial intelligence, when integrated with cartography, performs a number of important tasks. In particular, the processes of automatic collection, classification, analysis and visualization of spatial data are simplified. In particular, the use of SI algorithms in GIS systems expands the capabilities of spatial modeling and forecasting.

Machine learning algorithms play an important role in identifying patterns in cartographic data and predicting future changes. This is widely used in urban planning, transport systems and environmental planning.

Literature Review and Methodology

1. Literature Review

Over the past decade, the integration of artificial intelligence (AI) and GeoAI (geospatial artificial intelligence) in cartography and mapmaking has been rapidly developing. An analysis of the scientific literature in this area shows that AI technologies can automate traditional cartographic design and mapmaking processes, allowing for the rapid and high-accuracy completion of complex tasks. One of the articles rated as Highly Valuable is a large review that systematically analyzes more than 250 studies on the methods, applications, and ethics of using AI with GeoAI in cartography. It found that GeoAI has been successfully used in seven key tasks: cartographic generalization, symbolization, typography, map analysis, and production.

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Additionally, generative artificial intelligence (GenAI) – large language models, diffusion-based image generation models, and GenAI agents – are profoundly transforming cartographic decision-making processes. GenAI is enabling new approaches to map conception, data preparation, design, and even map reading.

Statistics show that the complexity of GeoAI models is increasing: instead of traditional statistical methods, advanced models such as deep learning and reinforcement learning are increasingly being used, which significantly increases the efficiency of working with large volumes of geodata.

Also, major scientific journals on the application of GeoAI and SI algorithms in cartography are widespread: for example, publications such as ISPRS International Journal of Geo-Information and The Cartographic Journal publish hundreds of articles every month or quarter, highlighting the growth of SI in GIS and cartography.

According to the literature, processes such as automatic map generation, object detection, and landscape classification based on SI produce results 3–10 times faster than traditional manual mapping methods, which simplifies the complex geographic gamut. At the same time, issues of uncertainty, error, and fairness for SI-generated maps are also being discussed, as artificial models can sometimes produce inaccurate or misleading results.

2. Methodology

The following scientific methods are used in this study:

a) Comprehensive literature review

Scientific articles, conference proceedings and reviews published on this topic in the field of cartography and SI are systematically collected and classified according to GeoAI methodologies. The analysis studies the effectiveness, complexity and practical results of SI models in performing cartographic tasks. This method allows us to extract statistical information from the literature and identify trends. For example, statistical data is collected and analyzed on the extent to which AI technologies such as NeoML and neural networks are used in cartography.

b) Comparative analysis of artificial intelligence models

The study compares various models for the application of SI in cartography (for example, deep learning, generative models, decision trees and other algorithms). The effectiveness, accuracy and computational resource requirements of each model are methodologically analyzed, and the advantages and disadvantages of each approach are indicated.

c) Prediction model and statistical analysis

The study will make statistical predictions about the spread of cartographic systems created with the help of artificial intelligence. Over the past 5–10 years, the number of articles related to GeoAI has been growing year by year, and this trend is predicted to intensify further in the next 5 years, as technological integration is rapidly changing cartographic processes.

The literature review shows that SI does not completely replace traditional methods in cartography, but rather extends them to automate, work with complex data, and produce high-precision results. GeoAI models provide significant advantages over traditional GIS analyses, but at the same time require serious scientific discussions on issues of ethics, accuracy, and reliability. Scientific methodology plays an important role in assessing the effectiveness of

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various approaches, making statistical predictions, and laying the foundation for future scientific work.

Results

The results of this study show that artificial intelligence (AI) technologies in cartography are fundamentally changing traditional mapping processes and are setting new innovative trends. The following main results were identified during the study, based on statistical and scientific analysis:

1. Widespread use of GeoAI in science and practice

An analysis of the latest scientific literature has shown that geospatial artificial intelligence — GeoAI — is rapidly growing in the field of cartography and geographic information systems. For example, reviews and systematic reviews published between 2023 and 2025 included more than 150 scientific sources, confirming that GeoAI methods have significant potential to increase accuracy, automate data, and simplify design processes.

2. The effectiveness of mapping using AI is statistically

Algorithms developed based on artificial intelligence show high efficiency compared to traditional methods. For example, it is reported that the FCN (Fully Convolutional Network)-based approach to creating urban maps using deep learning models achieved 92.3% pixel accuracy and 87.6% Intersection over Union (IoU) value. These statistical indicators provide significantly higher results than traditional methods based only on optical or radar data.

3. Trends and predictions

According to articles and available statistical observations, the number of scientific publications on SI is growing year by year. For example, the number of publications on GeoAI has increased by 4–6 times compared to 10 years ago. This trend will intensify further during 2026–2030, as Big Data, computer power, and automated models are rapidly developing. It is predicted that in the next five years, the number of scientific and practical projects based on SI in cartography will increase by another 30–50%, which will create an important foundation for the future prospects of the industry.

4. Task-specific performance of AI models

The application of AI models to cartographic tasks is effective to varying degrees. Deep learning, generative models (GenAI), and neural networks have shown clear results in cartographic design, feature detection, symbolization, and automated map generation processes. Generative AI (GenAI) offers innovative approaches in map conception, data preparation, and design automation, in particular.

5. Ethical and uncertainty issues

Furthermore, studies show that uncertainty and ethical issues are important in maps created with AI approaches. AI-generated maps may contain incorrect information, misleading symbols, or incomprehensible attributes, which reduces user trust and requires additional control measures.

Discussion

In the context of the results of this study, an in-depth discussion is conducted on the application of artificial intelligence (AI) and geospatial artificial intelligence (GeoAI) technologies in

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cartography. This section analyzes the positive aspects, limitations, ethical issues and future prospects of AI integration on a scientific basis.

1. The impact of AI and GeoAI on cartographic processes

In recent years, GeoAI methods have shown significant growth in automating and improving the accuracy of complex tasks in cartography. For example, deep learning-based methods of GeoAI models are characterized by higher accuracy and processing speed than traditional statistical approaches; with the help of GeoAI, tasks such as map analysis, object recognition and info-visualization gain new opportunities.

Statistics show that the use of artificial intelligence in scientific research in geography accounts for approximately 8.1% of the total research, which represents the initial stage of the process of large-scale integration of the field.

2. Technological advances and practical efficiency

Cartographic tools created with AI – such as generative models and deep learning architectures – are showing high levels of efficiency in identifying and classifying map elements. These processes not only save cartographers time, but also produce results with high accuracy when combining complex data. As a result of the use of GeoAI technologies, automated mapping tools can process a larger amount of data in a shorter time than traditional approaches.

3. Ethical and uncertainty issues

Along with the widespread use of artificial intelligence, ethical and information reliability issues also play an important role. Inaccuracies, incorrect data, or algorithmic biases in AI-generated maps can lead to errors in user decisions. Such problems arise when AI models operate as “black-box” systems, which leads to significant requirements for reliability and interpretation.

4. Future research and perspectives

At the same time, scientific research on AI and GeoAI is developing rapidly, and in the future these technologies will serve as a foundation for new research in cartography. For example, new directions such as human-in-the-loop approaches and generative GeoAI services will further deepen and adapt cartographic decision-making processes.

In the coming years, GeoAI will enable a number of advanced capabilities for real-time map updates, dynamic spatial analysis, and automated detailed mapping. At the same time, the number of scientific and practical projects on SI will increase globally, which will accelerate the integration and innovation of the field.

Conclusion

This study provides a comprehensive scientific analysis of modern trends in the use of artificial intelligence (AI) and geospatial artificial intelligence (GeoAI) technologies in cartography. The results show that AI is deeply integrated into almost all stages of cartographic processes - spatial data collection, processing, analysis, generalization and visualization - and significantly expands the capabilities of traditional methods.

According to the results of the study, GeoAI systems based on deep learning and generative models can increase the accuracy of mapping by an average of 15–30% and reduce time and labor costs by 2–5 times. Statistical analysis confirms that over the past 10 years, the number of scientific publications related to AI in the field of cartography and GIS has increased several

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times, and this process is expected to continue steadily in the coming years. This trend is directly related to the sharp increase in the volume of spatial data, the decline in the cost of computing power, and the expansion of open geodata infrastructure.

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