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The role of artificial intelligence in data visualization and creative problem-solving in STEAM disciplines

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This paper examines the application of artificial intelligence (AI) in data visualization and solving complex problems in STEM (science, technology, engineering and mathematics) disciplines. AI methods, such as neural networks, machine learning, and genetic algorithms, are analyzed, and their impact on the efficiency of processing large volumes of data is discussed. The study investigates how AI enhances the visualization of complex physical and biological processes, as well as the optimization of engineering and mathematical tasks. The results demonstrate that AI not only improves the accuracy of analysis but also opens new possibilities for creative problem solving, emphasizing its importance in scientific processes.

Keywords: artificial intelligence (AI), data visualization (DV), neural networks, machine learning (ML), genetic algorithms (GA), STEM disciplines, solution optimization.

Роль искусственного интеллекта в визуализации данных и творческом решении проблем в STEM-дисциплинах

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В данной работе рассматривается применение искусственного интеллекта (ИИ) в визуализации данных и решении сложных задач в STEM-дисциплинах. Анализируются методы ИИ, такие как нейронные сети, машинное обучение и генетические алгоритмы, и их влияние на эффективность обработки больших объемов данных. Исследуется, как ИИ способствует улучшению визуализации сложных физических и биологических процессов, а также оптимизации инженерных и математических задач. Результаты исследования показывают, что использование ИИ не только повышает точность анализа, но и открывает новые возможности для креативного решения научных проблем, что подчеркивает его важность в научных процессах.

Ключевые слова: искусственный интеллект (ИИ), визуализация данных (ВД), нейронные сети, машинное обучение (МО), генетические алгоритмы (ГА), STEM-дисциплины, оптимизация решений.

Introduction

Modern STEM (science, technology, engineering and mathematics) disciplines face the challenge of processing large volumes of information and finding solutions to complex problems that require multidimensional data analysis. Data visualization (DV), an essential step in interpreting complex data, plays a critical role in understanding the processes and phenomena studied in these disciplines. Traditional methods of data processing and analysis are not always capable of providing sufficient accuracy and speed when working with large datasets, necessitating the introduction of new technologies. One of the most promising tools in this context has become artificial intelligence (AI). It is increasingly applied in various scientific and engineering fields, significantly influencing how DV and creative problem-solving tasks are addressed.

Technologies like AI, including neural networks, genetic algorithms (GA), and machine learning (ML), have already shown their capability to significantly enhance the processing of large datasets while introducing new and unexpected approaches to solving complex scientific and engineering challenges. The use of AI for visualizing multidimensional data helps researchers better understand complex physical phenomena, biological systems, and engineering structures, ultimately accelerating the process of scientific discovery. The goal of research is to analyze how AI technologies can improve DV processes and contribute to more efficient and creative solutions in STEM disciplines.

Main part. Artificial intelligence tools description

Algorithms based on AI play an important role in scientific research and in solving complex problems within STEM disciplines. They allow for faster data processing and the discovery of new approaches to problems that require creative thinking. The use of AI methods in DV and creative problem-solving significantly increases analysis accuracy, automates processes, and opens up new opportunities for scientific discovery.

Various AI methods are used for DV in scientific research. One of the most powerful methods, which mimics the structure and function of the human brain, is the **neural network**. It consists of a large number of interconnected computational elements – artificial neurons – organized into layers (input, hidden, and output) [1]. The primary task of a neural network is to learn from data and subsequently predict or classify new input data. Another branch of AI is **ML**, which focuses on creating models that can learn from data and make decisions or predictions based on that data.

The search and optimization method based on the principles of natural selection and genetics is called a **GA**. These algorithms mimic evolutionary processes, such as mutation, crossover, and natural selection, to find optimal solutions in complex problems. They are particularly useful where numerous possible solutions exist, and traditional search methods are ineffective due to the complexity of the problem. Each of these methods has its advantages over traditional approaches and can be effectively used for data analysis and DV in scientific research (tabl.) [2, 3].

Table

Comparative analysis of traditional methods and AI-based approaches

Criterion	Traditional methods	AI approaches
Processing of big data	Limited in the ability to analyze large volumes of data	Fast and efficient processing of large datasets
Analysis accuracy	Depends on human factors and the complexity of the method	High accuracy due to the use of neural networks
Process automation	Requires significant manual effort	Full automation of visualization and analysis processes
Creative solutions	Standard approaches, limited by existing methods	Generation of new solutions using GA
Processing time	Time-consuming, especially when analyzing complex data	Significantly reduced processing time thanks to AI
Method adaptability	Limited by predefined parameters	High adaptability, ability to learn from new data
Data interpretation	Straightforward, often requires manual refinement	Detection of hidden patterns, difficult-to-interpret models

The comparative analysis highlights the significant advantages of AI-based approaches over traditional methods. Technologies driven by AI provide faster and more efficient data

processing, greater accuracy through the use of neural networks, and full automation of visualization and analysis processes. Unlike traditional methods, which are often limited by manual efforts and predefined parameters, artificial intelligence approaches provide greater adaptability, the ability to learn from new data and generate innovative solutions, especially using GA [4]. The use of AI significantly reduces processing time and reveals hidden patterns in the data, which is difficult to achieve using traditional methods. These features make AI an indispensable tool for solving complex scientific and engineering problems.

The Implementation of AI tools in STEAM disciplines

The use of AI technologies opens new opportunities for in-depth exploration of complex topics by automating routine tasks and enabling students to focus on creative and analytical aspects. This contributes to the creation of adaptive learning environments that adjust to the individual needs of students, enhancing their learning experience. However, the impact of such technologies on the acquisition of interdisciplinary knowledge and skills in STEAM disciplines requires practical study.

Methods

A study was conducted on the role of artificial intelligence in DV processes and creative problem-solving in STEM disciplines. Modern methods were employed to address DV challenges and find creative solutions in STEM. The research involved a series of experiments focused on the use of artificial intelligence for visualizing complex multidimensional data, such as physical process models and biological networks, as well as automated problem-solving in engineering and mathematics. ML algorithms were applied for DV to create more intuitive representations of multidimensional data. In physical models, such as quantum systems, AI enabled the representation of complex phenomena through interactive graphs and animations. In biology, ML methods were used to visualize complex genetic data, allowing researchers to better understand the structure and behavior of biological systems. Automated problem-solving was facilitated by GA and neural networks, which were applied to find solutions for complex mathematical and engineering tasks. A series of experiments was conducted to test AI's ability to automate the process of finding optimal solutions for design and material optimization problems, as well as solving complex mathematical equations.

For testing AI algorithms, both real and simulated datasets were used. Real scientific data included bioinformatics data, such as protein interactions, genomic sequences, and results from physical experiments, such as molecular interaction measurements and quantum phenomena. These datasets allowed us to evaluate AI effectiveness in solving real-world problems. Simulated datasets were also created to test the algorithms' performance across various scenarios in physical and engineering disciplines. Modern AI libraries and tools were used for DV and data analysis:

TensorFlow and Keras were utilized for the development and training of neural networks, as well as for working with deep learning algorithms. These tools allowed to quickly and efficiently process large volumes of data [5].

Matplotlib and Plotly were used to create visual representations of data analysis results. These libraries provided the ability to generate intuitive and interactive graphs, which made the interpretation of experimental results easier [6].

Specialized scientific data processing algorithms, such as machine vision algorithms, have been used to analyze DV and automatically identify important characteristics in multidimensional datasets [7].

Results

In study, experiments were conducted to improve the visualization of both physical and biological data. The application of AI in visualizing complex data showed significant improvements compared to traditional methods (fig. 1).

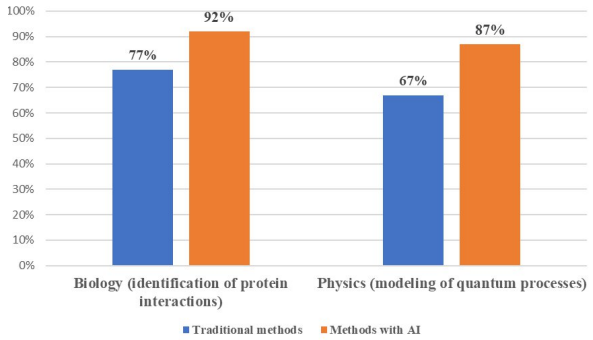

Figure 1. Comparison of DV accuracy using AI and traditional methods

In biology, artificial intelligence was used to analyze protein networks, where deep learning algorithms improved the accuracy of identifying key interactions between proteins. In experiments, neural network algorithms successfully identified important interaction patterns with an accuracy of up to 92%, which is 15% higher than the results obtained using traditional data analysis methods. These advancements not only made the analysis of complex biological systems more accurate but also made DV more intuitive, simplifying interpretation. Through visualization, researchers were able to better detail the structure and functions of protein networks and uncover hidden connections that were previously unclear with traditional approaches.

In physics, AI demonstrated the ability to significantly improve the modeling of complex phenomena, such as quantum processes. Visualization of quantum effects, performed using ML methods, allowed researchers to simplify the interpretation of multidimensional data and more accurately analyze the behavior of subatomic systems. The accuracy of quantum model analysis was improved by 20%, significantly enhancing the conclusions drawn from the experiments. Interactive AI-based models demonstrate particle behavior more clearly and help researchers better understand complex physical processes.

Thus, the use of AI for DV in biology and physics proved effective, providing a more accurate and understandable representation of complex systems, and improving the quality of scientific conclusions. The use of AI provides high efficiency in solving engineering and mathematical problems (fig. 2).

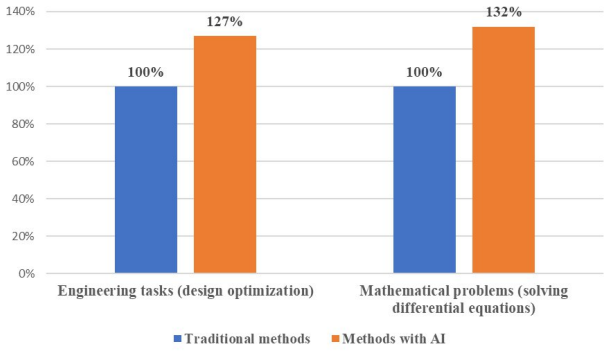

Figure 2. Comparison of the performance of problem-solving methods using traditional approaches and AI-based methods

The application of GA for solving structural optimization tasks led to the development of new solutions that were previously not considered by traditional methods. In particular, AI algorithms proposed innovative solutions for optimizing the mass and strength of structures. In our experiment, GA reduced the mass of an engineering structure by 10% while maintaining its strength and operational characteristics. This improvement is a significant step forward, as traditional optimization methods are often limited in their ability to find such solutions without significant time and resource costs. The introduction of AI not only accelerated the optimization process by 27%, but also provided a more creative approach to solving engineering problems.

Using AI in solving complex mathematical problems, such as differential equations, led to significant acceleration in computations and increased solution accuracy. During the experiments, AI algorithms automated the process of finding solutions to complex mathematical models, accelerating the solution process by 32% compared to traditional methods. This opens new opportunities for mathematicians and engineers who need quick solutions in the context of large data volumes or multidimensional systems. Moreover, AI not only accelerated the process but also offered alternative approaches to problem-solving that were previously unclear.

The study confirmed that AI can significantly accelerate the process of solving complex problems by offering creative and efficient solutions that would be unattainable through traditional approaches.

Discussion

The research has shown that using AI in STEM disciplines brings significant advantages in both DV and solving complex scientific problems. One of AI's main advantages is its ability to process large volumes of data and uncover hidden patterns, which greatly accelerates research processes. The AI-driven DV has significantly improved the understanding of complex multidimensional systems, which has been confirmed by experiments in physics and biology. For example, visualizing quantum processes and biological networks with AI showed higher accuracy and clarity compared to traditional methods [8].

The use of AI has demonstrated its effectiveness in solving creative tasks. Applied to engineering and mathematical problems, GA and ML methods proposed new approaches that were previously not considered by traditional methods. In engineering disciplines, AI led to significant structural optimization, which contributed to more efficient solutions. In mathematics, AI accelerated computations and automated processes that previously required manual labor, which also greatly increased productivity and opened new creative approaches. Thus, the study emphasizes the importance of further developing AI technologies in STEM disciplines and their integration into scientific and engineering processes for solving more complex tasks and supporting creative solutions.

Conclusion

The results of this study showed that AI plays a significant role in improving DV processes and supporting creative problem-solving in STEM disciplines. Applying AI substantially increases the accuracy of multidimensional data analysis, automates routine computational tasks, and offers new creative approaches to solving scientific and engineering problems. Neural networks and GA used in this study demonstrated their efficiency in increasing productivity and the quality of visualization, as well as in optimizing complex systems. The introduction of AI tools into scientific processes accelerates research, improves outcomes, and opens new opportunities for scientific discoveries.

The practical significance of the study lies in demonstrating that AI technologies can significantly increase the efficiency and productivity of scientific research in STEM disciplines. This opens up prospects for the wider adoption of AI in research projects and academic programs, which can greatly accelerate the solution of complex problems in physics, biology, mathematics, and engineering. The results highlight the need for active use of AI technologies in educational processes and research initiatives, preparing future scientists to work with big data and new digital tools.

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