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APPLICATION OF MATHEMATICAL ALGORITHMS BASED ON ARTIFICIAL INTELLIGENCE IN PRODUCTION

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Abstract: This article examines the theoretical and practical aspects of the integration of artificial intelligence (AI) and mathematical modeling for the production sector. Also, in the context of modern Industry 4.0, the processes of machine learning and predicting failures using mathematical algorithms based on large volumes of IoT data in real time, virtual simulation and optimization of processes using digital twins technology are analyzed.

Keywords: Mathematical modeling, artificial intelligence, mathematical algorithms, digital twins technology, neural networks, Predictive Maintenance methodology

Аннотация: В данной статье рассматриваются теоретические и практические аспекты интеграции искусственного интеллекта (ИИ) и математического моделирования для производственной сферы. Также в контексте современной Индустрии 4.0 проанализированы процессы машинного обучения и прогнозирования сбоев с использованием математических алгоритмов на основе больших объемов данных IoT в режиме реального времени, виртуальное моделирование и оптимизация процессов с использованием технологии цифровых близнецов.

Ключевые слова: Математическое моделирование, искусственный интеллект, математические алгоритмы, технология цифровых близнецов, нейронные сети, методология Прогностического обслуживания

Annotatsiya: Mazkur maqolada sun’iy intellekt (AI) va matematik modellashtirish integratsiyasining ishlab chiqarish sohasi uchun nazariy va amaliy jihatlari o‘rganib chiqildi. Shuningdek, zamonaviy sanoat 4.0 sharoitida real-vaqt rejimidagi katta hajmdagi IoT ma’lumotlari asosida mashina o‘rganish va matematik algoritmlar yordamida nosozliklarni oldindan bashorat qilish, digital twins texnologiyasi orqali jarayonlarni virtual simulyatsiya qilish va optimallashtirish jarayonlari tahlil qilinadi.

Kalit so‘zlar: Matematik modellashtirish, sun’iy intellekt, matematik algoritmlar, digital twins texnologiyasi, neyron tarmoqlar, Predictive Maintenance metodologiyasi

INTRODUCTION

In recent years, as a result of the rapid development of science and technology, mathematical modeling and artificial intelligence (AI) have become an integral part of our daily lives.

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Mathematical modeling is one of the important scientific approaches used to understand, analyze, and predict complex processes in the real world. Artificial intelligence allows the creation of intelligent systems capable of making decisions similar to human thinking. Today, the mutual integration of these two areas serves to increase efficiency in various fields and the development of new innovative approaches. Moreover, in the era of modern industry 4.0, production processes are becoming increasingly complex, and to ensure their effectiveness, a huge amount of real-time data is being created - IoT sensors, monitoring systems, dynamic changes in production parameters - for analysis and management. Traditional engineering and economic theories cannot adequately process this complex flow of information. Therefore, approaches prepared for mathematical algorithms based on artificial intelligence are emerging as an important tool for optimizing production processes, predicting failures, and making real-time decisions. [1]

At present, with the help of mathematical algorithms and modeling, it is possible to deeply study existing problems in such areas as natural sciences, economics, engineering, ecology, biomedical science, and determine the dynamics of their development. For example, mathematical models are widely used in economics to predict market trends, in ecology to monitor climate change, or in medicine to analyze the spread of diseases. Artificial intelligence, in turn, creates the possibility of processing, classifying, and forecasting large amounts of data. Thanks to AI technologies, such as machine learning, in-depth learning, and neural networks, it is possible to automatically analyze medical images, develop automated control systems in industrial robotics, and create intelligent navigation systems in the transport sector.

Currently, mathematical algorithms based on artificial intelligence are widely used in the following areas: Finance (FinTech), Healthcare (Healthcare & Pharma), Manufacturing (Manufacturing & Advanced Manufacturing), Energy and Alternative Energy (Energy), Logistics and Transport (Transportation & Logistics), Agriculture (Agriculture). [2]

In particular, in the financial sector, services such as fraud detection, risk management, algorithmic trading, chatbots, and robo-advisors have been automated using AI. In the field of healthcare, AI is used in diagnostics, disease prediction, personalized medicine, and particle models. In these areas, physiological and drug testing models are built using statistical models, ML regression, genetic algorithms, and GAN/ANN networks. In agriculture, AI models for precision farming, drone imagery analysis, disease prediction, and livestock monitoring are widely used. Regression, time-series analysis, classification, and clustering algorithms play a key role in these.

MAIN PART

Indeed, today the integration of artificial intelligence (AI) and mathematical modeling - that is, the transformation of industrial processes into a digital model through machine learning algorithms, optimization methods, physics-informed neural networks (PINN) - significantly increases production efficiency. For example, the predictive maintenance approach identifies equipment malfunctions by analyzing sensor data and predicting maintenance times, while digital twins technology allows simulating and optimizing processes by creating a virtual copy of the real network [3].

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If inaccurate or low-quality data is used in the modeling or machine learning process, the results may also be inaccurate. This can affect the results of economic forecasts, medical diagnostics, and environmental analyses. Efficiency of computational resources and algorithms. Artificial intelligence and mathematical modeling processes require large computing power. Especially for the operation of deep learning models, there is a need for high-level GPU or quantum computer technologies. This creates financial and technological constraints for small and medium research centers and enterprises. Ethical and Legal Issues The use of artificial intelligence creates problems such as the confidentiality of personal data, the adoption of incorrect decisions by AI systems, and the impact on jobs. Especially in the fields of medicine and safety, incorrect decisions can have a serious impact on human life. Therefore, it is important to clearly define ethical and legal norms in the development of artificial intelligence.

A mathematical algorithm is a strictly defined, precise, and repetitive sequence of operations for solving a specific problem. Basic mathematical algorithms and their applications: Genetic algorithms (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) [4]

These metaheuristic optimization approaches are used to solve complex combinatorial problems such as production scheduling, resource allocation, and energy consumption reduction. Their application leads to scalability, efficient planning, and time reduction.

Reinforcement learning (RL) - for the development of automatic control systems based on real-time feedback, AI agents make decisions using RL and optimize the system. [5]

In Predictive Maintenance, real-time data is collected through Sed or IoT sensors, then the equipment's failure propensity is predicted using ML models (for example, optimized with Random Forest, XGBoost, Deep Learning, SVM GA). As a result, downtime during production time is reduced by 20-50%, and costs are significantly reduced.

DISCUSSION AND RESULTS

The Predictive Maintenance methodology provides effective results in enterprises. Based on the conducted research, unexpected technical downtime is reduced by 30-50%, service costs are reduced by 20-40%, and the equipment's service life is extended by 20-30%. [6]

There is a significant shortage of qualified specialists in the necessary AI/analysis at enterprises and resistance of employees to new technologies. There is a need for retraining and the formation of an innovative culture so that systems are ready for the necessary loading.

AI systems increase risks associated with cybersecurity threats, data privacy, and legal norms.

AI-based mathematical algorithms have great potential in optimizing investments, increasing operational efficiency, and ensuring the stability of production systems**.** Real examples and empirical results provide real economic benefits in important functions such as technical condition forecasting, quality control, and planning based on AI. At the same time, when implementing the technology, serious attention should be paid to financial, personnel, data, and regulatory issues. Through proper planning and sustainable integration, AI-optimization approaches ensure long-term and sustainable production.

CONCLUSION

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In conclusion, mathematical algorithms based on artificial intelligence (AI), in particular predictive maintenance, optimization, and virtual simulation tools, raise production processes to a new level. AI is used to predict malfunctions and provide scheduled maintenance. This approach reduces unplanned downtime by 20-50%. As a result, operational efficiency and production quality increase, and product delivery prospects improve.

Various scenarios are tested using mathematical algorithms - GA, PSO, ACO, RL, and PINN - and the most optimal option is selected. This approach allows one to act confidently when scientifically substantiating the long-term development strategy of the enterprise. Indeed, mathematical algorithms based on artificial intelligence are becoming a central tool for predicting malfunctions in the production sphere, saving costs, efficient use of resources, quality control, and creating a stable production system. They create a solid scientific and practical basis for resource optimization, automation of production processes, and strategic development of enterprise management.

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