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# Application of Artificial Intelligence in the Management of Robotic Systems

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## Abstract

*The article addresses the essence, features, advantages, associated challenges, and prospects of using artificial intelligence (AI) in managing robotic systems. The relevance of this topic is substantiated by the rapid development of technologies that drive the automation of processes in industries such as manufacturing, medicine, logistics, and other key sectors. The aim of the study is to analyze existing approaches to integrating AI in robotic systems, identify positive effects, systematize the most apparent drawbacks, contradictions, and challenges, and formulate the author's perspective on future developments in this domain. Discrepancies identified in the scientific literature include variations in assessing AI's impact on the labor market, insufficient standardization of approaches to developing management mechanisms, and the complexity of implementing ethical and legal standards in practical applications. The conclusion emphasizes that the successful development of robotic systems requires the synergy of technical, social, and legal solutions. The author has contributed to structuring knowledge on the subject, with a focus on an interdisciplinary approach. The article describes the development of a model for the robot's motion trajectories.The presented materials will be useful to specialists in robotics, developers of intelligent systems, and researchers studying the societal and economic aspects of digitalization and automation.*

**Keywords:** *Automation, Artificial Intelligence, Robotic Systems, Robotics, Social Aspects, Management.*

## INTRODUCTION

Modern technological advancements underscore the rapidly growing role of artificial intelligence (AI) in automating various processes. One of its key areas of application is the management of robotic systems, which are utilized in industries such as manufacturing, medicine, agriculture, logistics, and other fields.

The issue lies in the need to develop intelligent approaches that ensure the adaptability, autonomy, and high performance of these systems, particularly under conditions of uncertainty and environmental instability.

The origins of robotics as a scientific field date back to the mid-20th century, when the first automated machines began to emerge. One of the earliest successful projects was the creation of the autonomous robot Shakey in the 1960s. Shakey could navigate a predefined environment and make basic decisions based on sensor data.

The advent of high-performance computers in the 1980s initiated extensive research into management systems based on deterministic algorithms. These systems were capable of performing only those tasks explicitly defined by programmers.

A turning point came with the development of machine learning and artificial intelligence. The integration of AI into robotics began in the 2000s, enabling robots to adapt to environmental changes and perform tasks beyond pre-defined scenarios. Modern approaches involve the use of deep neural networks, allowing robots to learn from experience and data, thereby expanding their functionality.

Robotic solutions have traditionally relied on algorithms limited by predefined scenarios. However, such algorithms often lack the flexibility required for complex, dynamically changing tasks. The introduction of AI opens entirely new possibilities. In this context, researchers focus on analyzing methods and approaches to applying AI in robot management, highlighting advantages, challenges, and prospects.

## MATERIALS AND METHODS

The literature addressing the topic encompasses a wide range of issues and nuances, including technical developments, as well as social, cultural, legal, and ethical aspects.

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For example, the challenges of designing and applying AI for robotic management are thoroughly examined in the works of Yu. Zhu, K. Zhang [10], and Y. Cao et al. [2]. These studies characterize current approaches to integrating AI in industrial robotics, including features of algorithm development aimed at improving system performance and reliability.

The application of artificial intelligence in specific fields is analyzed in the article by Sh. Gupta and colleagues [4], discuss robots operating in the hospitality sector and their contributions to enhancing the customer experience.

The societal response to the introduction of AI in robotics is studied in publications by J.M. Stibel, H.C. Barrett [6], and K.Ch. Yam et al. [9]. These researchers focus on how cultural perceptions of robots shape attitudes toward AI, influencing its acceptance and dissemination. It is noted that the specificity of this acceptance varies significantly depending on the sociocultural context.

Mass perceptions of AI are described in the work of L. Xu and colleagues [8], who demonstrate how everyday beliefs impact expectations of robotic systems and their applications.

Ethical and legal issues are actively discussed in the works of A.G. Gurinovich, M.A. Lapina [5], and L. Velázquez [7]. These authors focus on legal aspects, such as the need to develop international standards for regulating AI usage and address challenges posed by the development of AI and robotics, including transhumanism and social equity concerns.

F. Bordot [1] analyzes the impact of AI-powered robots on the labor market in OECD countries, highlighting the risks associated with automation. The data presented by the author are complemented by information from a report on the global AI robotics market [3], which examines the sector's growth prospects and economic significance.

The review of scientific publications reveals that, despite the broad scope of research, there are discrepancies in evaluating AI's impact on society. For instance, some authors emphasize only the positive aspects of automation, while others focus on potential threats. Issues of standardization and unification of approaches to the development of AI-powered robotic systems remain insufficiently addressed to date.

The methods employed in preparing this article include comparative and content analysis, statistical data processing, systematization, and generalization. For further progress, it is crucial to pay greater attention to the development of ethical standards.

## RESULTS AND DISCUSSION

In 2024, the global market for robotics with artificial intelligence exceeded USD 19 billion, representing an increase of nearly 30% compared to 2023. By the end of the decade, in 2030, it is expected to surpass USD 36 billion (Fig. 1). This reflects a significant growth rate, with the market value increasing by almost 20% annually [3].

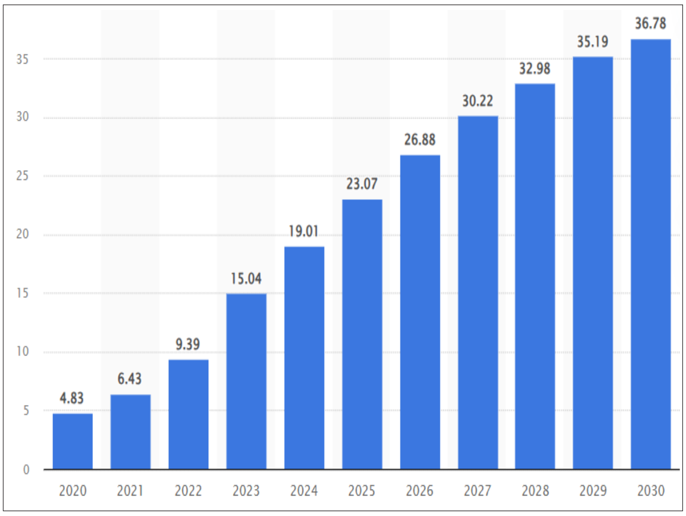


**Fig. 1.** Dynamics and projected values of the global market volume of robotics with artificial intelligence, billion US dollars [3]

The management of robotic systems is based on the interaction of hardware and software components, which enable the execution of various specific tasks. At the core of this structure lie control systems, comprising the following elements (Fig. 2):

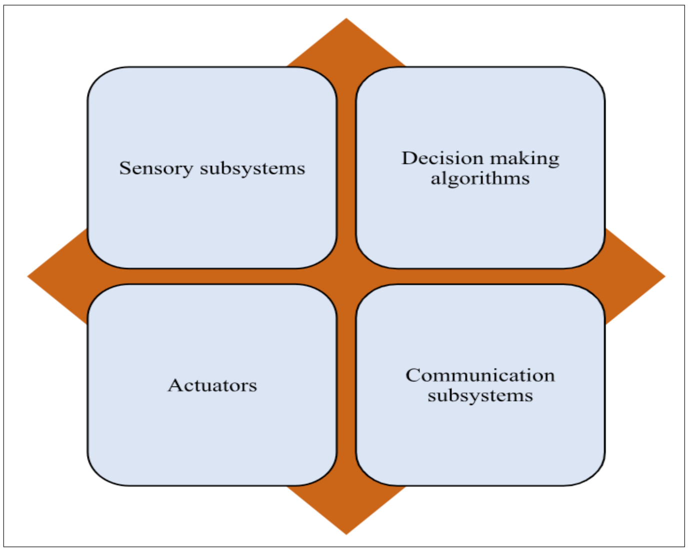


**Fig. 2.** Elements of control systems (compiled by the author on the basis of [1, 4-6, 9])

Commenting on the above diagram, it is pertinent to note that sensory subsystems provide environmental perception. Through appropriate modules, data are collected from cameras, LIDAR sensors, ultrasonic detectors, and other devices, with the information interpreted for subsequent decision-making.

Based on the collected data, algorithms determine optimal actions to ensure task execution. In the context of AI, this is represented by:

- neural networks;
- Bayesian models;
- optimization methods, among others.

In turn, actuators ensure the physical implementation of decisions. These primarily include motors, manipulators, grippers, and other devices that convert computational commands into motion.

The functioning of communication subsystems facilitates interaction between components and ensures connectivity with external systems.

Attention should now be directed to the characterization of the main directions for applying artificial intelligence (Fig. 3).

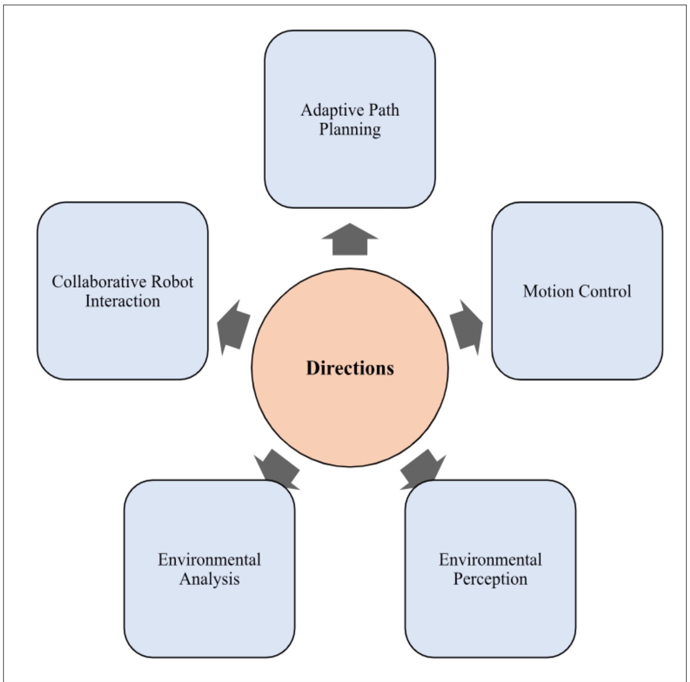


**Fig. 3.** Systematization of the main directions of using artificial intelligence in the management of robotic systems (compiled by the author on the basis of [2, 5, 7, 9, 10])

One of the most critical aspects in the field under consideration is trajectory planning, particularly in complex and unknown environments. Traditional algorithms are limited in terms of scalability and adaptability. In contrast, deep learning methods, including convolutional neural networks (CNNs) and recurrent neural networks (RNNs), enable robots to dynamically respond to environmental changes. For instance, the application of Deep Reinforcement Learning (DRL) optimizes movement by considering multiple factors:

- obstacles;
- energy constraints;
- time limitations.

Computer vision and sensory perception serve as key components that allow robots to interpret the surrounding environment. Modern algorithms based on transformers and Generative Adversarial Networks (GANs) enable high-precision processing of visual information, including object segmentation, texture recognition, and depth estimation. The integration of LIDAR sensors with deep learning models facilitates the creation of three-dimensional maps of the environment and the identification of the safest navigation paths.

Additionally, multi-agent interaction systems based on AI ensure the coordination of groups of robots for executing complex tasks. For example, distributed learning algorithms enable data sharing and collaborative adaptation to changing conditions. The implementation of such technologies in logistics and warehouse systems enhances process efficiency.

Thus, the integration of AI into robotics provides several advantages, as summarized in Figure 4.

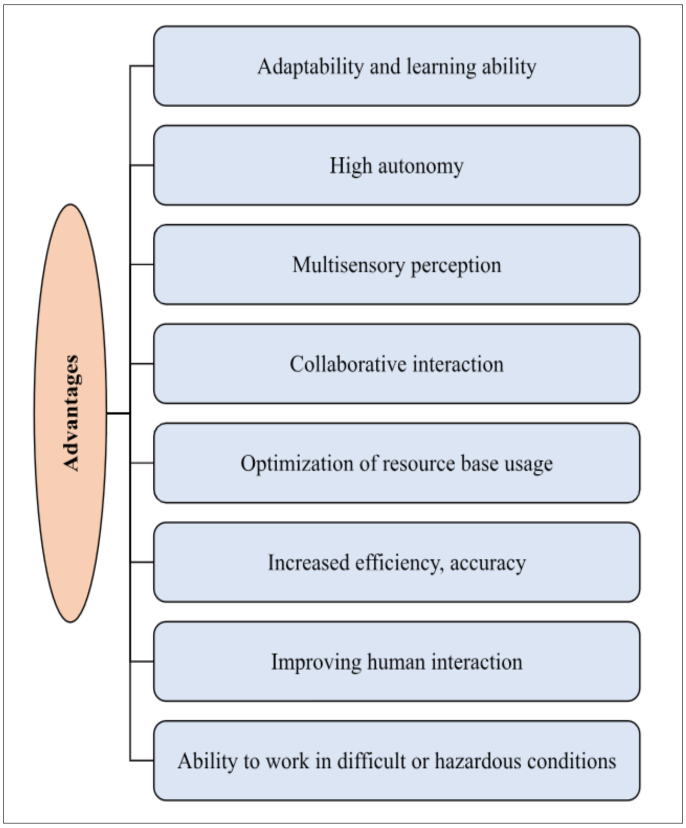


**Fig. 4.** Systematization of the advantages of using artificial intelligence in the management of robotic systems (compiled by the author on the basis of [1, 2, 6])

First and foremost, in the context of beneficial effects, it is worth noting the significant increase in system autonomy. Robots equipped with intelligent algorithms are capable not only of executing predefined instructions but also of independently adapting to new conditions and adjusting to them. Additionally, the application of AI helps optimize resource usage and reduce time and energy costs. Another highly significant aspect is the improvement of human-robot interaction. Speech interfaces enable robots to communicate effectively with users, which is particularly important in medical and educational applications.

Despite significant advancements, the use of AI in the management of robotic systems is associated with numerous challenges (Fig. 5).

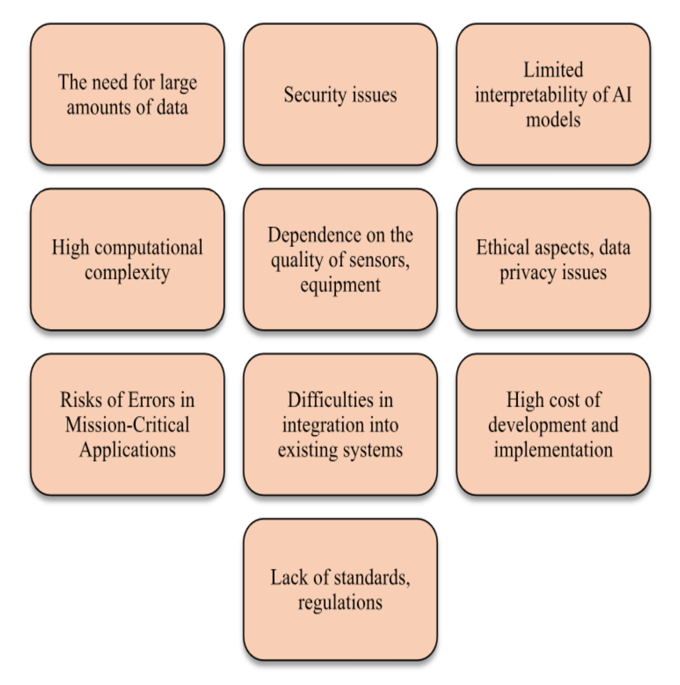


**Fig. 5.** The variety of problems of using artificial intelligence in the management of robotic systems (compiled by the author on the basis of [1, 2, 5, 6, 8])

One of the most apparent barriers is the need for large volumes of data to train models. Complex scenarios require diverse information, which is often difficult to access or incurs significant costs for data collection and annotation.

In addition, security issues remain relevant. Errors in AI algorithm performance inevitably lead to serious consequences, especially in critical applications, such as surgical robots or autonomous vehicle control systems.

Ethical aspects also require careful consideration. Data privacy, which is essential for training, is a particularly significant issue in this context.

For an in-depth investigation of the robot's trajectory dynamics, a mathematical model based on classical kinematic equations was developed:

$dx/dt = v \cdot \cos(\theta)$,

$dy/dt = v \cdot \sin(\theta)$,

$d\theta/dt = \omega$,

where "v" - is the linear velocity, "θ" - is the orientation angle, and "ω" - is the angular velocity.

A key innovation was the integration of an artificial intelligence module that analyzes sensor data in real time and adjusts the motion parameters, adapting to changes in the surrounding environment. Numerical computation of the trajectories was performed using the fourth-order Runge–Kutta method. In the experiment, the AI module, trained on historical data, predicted optimal corrective commands, which reduced the mean squared error (MSE) to 0.05 m with a time step of 0.1 s. Furthermore, a modified gradient descent algorithm with neural network approximation achieved a 30% reduction in the objective function compared to the traditional model, demonstrating the effectiveness of AI-based approaches. Overall, the results show that integrating artificial intelligence into the trajectory planning process significantly enhances the adaptability and accuracy of robotic system control. The application of AI enables the system not only to follow predefined algorithms but also to autonomously adjust its trajectory, effectively responding to dynamic changes in the external environment.

## CONCLUSION

The application of artificial intelligence in the management of robotic systems opens numerous additional opportunities for solving complex tasks across various industries. However, realizing the full potential of these technologies requires overcoming numerous challenges related to training, security, and ethics.

Nevertheless, the integration of AI into this field continues to advance rapidly, forming a kind of «foundation» for future innovations and improving the quality of human life.

The prospects for using AI in the management of these systems appear promising and are linked to the integration of cutting-edge developments, such as quantum computing and bioinspired algorithms. These directions offer the potential to significantly increase computational power and enhance the effectiveness of solutions.

Another future-oriented approach involves the development of hybrid systems that combine elements of classical algorithmic management and AI. This approach can leverage the strengths of both methods, ensuring stability and adaptability. An essential vector of development remains the improvement of human-machine interaction. Creating intuitive interfaces and training robots for emotional perception will allow for their integration into everyday human life.

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