

The Application of Artificial Intelligence in Robotic Control

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Abstract:

The pursuit of automated robotics took shape in the mid-20th century. While industrial robots relied on fixed programs to perform repetitive tasks in structured environments, they faced significant limitations in adaptability and flexibility. By the early 21st century, technological advancements enabled robots to make basic decisions, though complex tasks still required human programming. Following the AI revolution, robots now possess autonomous learning and decision-making capabilities through AI algorithms, transitioning from rule-based to intelligence-driven systems. Current challenges in robotic control primarily involve three aspects: enhancing environmental adaptability in unstructured settings to improve interference resistance, and optimizing real-time coordination efficiency for complex tasks. This paper analyzes the technical principles, practical applications, and countermeasures to address these challenges. It explores how AI can reshape robotic control. Research conclusions indicate that AI holds vast potential in robotic control. Through continuous optimization of technical pathways and resolution of existing issues, comprehensive intelligent upgrades in robotic control are achievable, delivering more efficient and precise automation solutions across industries.

Keywords: AI, Robotic Control, Intelligent Driving, Medical Robots, Drones

1. Introduction

Modern robot control primarily employs three learning approaches: reinforcement learning optimizes decisions through trial-and-error, imitation learning replicates expert behaviors, and large models guide control by leveraging pre-trained knowledge for high-level reasoning. The VIKI-R framework for multi-agent reinforcement learning adopts a two-phase training strategy. Initially, it fine-tunes scene

understanding by leveraging visual-language models. Subsequently, it optimizes collaboration strategies through a multi-level reward mechanism. This framework successfully coordinated multiple robots to complete object assembly, demonstrating the effectiveness of hierarchical reinforcement learning in resolving collaborative conflicts.

The core of using artificial intelligence to control robots lies in generating task strategies and motion trajectories based on perceptual information. It then

translates decisions into motor control signals to achieve precise movements. Additionally, it involves constructing an environment model using sensor data, such as vision, lidar, and tactile information.

AI-controlled robots demonstrate significant advantages. First, in environmental adaptability, traditional control systems rely on precise models that often fail in unstructured environments, whereas AI control can adapt to complex environments through data learning. Second, regarding flexibility, modifying traditional control tasks requires reprogramming, while AI control only needs fine-tuning of strategies for self-adaptation. Additionally, AI control enhances anti-interference capabilities through data-driven approaches, improving system robustness. Finally, AI control reduces development costs, as traditional control requires expert manual programming, while AI control only needs extensive data training.

This paper examines the current applications, technical advantages, challenges, and future development paths of artificial intelligence in robot control. The research aims to reveal how AI is reshaping the paradigms and performance of robotic control systems, providing theoretical support and practical guidance for the intelligent advancement of robotics technology. By driving efficient robot applications across diverse fields, it seeks to enhance production efficiency, improve quality of life, and foster innovation and development in related industries.

2. Artificial Intelligence for Robot Control Applications

2.1 Intelligent Driving

As a typical carrier of the deep integration of artificial intelligence and robot control technology, the intelligent driving system is based on the closed-loop architecture of “perception-decision-control-execution” to realize the autonomous operation of the vehicle, which can be decomposed from the two dimensions of hardware and software. The sensor system serves as the sensory organ of the intelligent driving system, utilizing devices such as LiDAR, millimeter-wave radar, and high-definition cameras to perceive the vehicle’s surroundings. The domain controller acts as the brain of the intelligent driving system, responsible for processing and analyzing the data collected by sensors and making driving decisions. The perception system analyzes sensor data and identifies environmental characteristics around the vehicle. The planning and control system regulates steering and speed, planning optimal driving paths based on perception and positioning information [1].

Taking Tesla’s FSD system as an example, it utilizes a pure vision solution that employs Occupancy Network (ON), an advanced deep learning technology, to perceive the environment. It generates a 3D occupancy grid from multi-angle images, determining whether a cell in the 3D

space is occupied. Depth information is obtained through disparity maps captured by eight cameras around the vehicle, and the occupancy grid method is used to identify drivable space. Finally, a Multi-Layer Perceptron (MLP) processes these features, such as applying nonlinear transformations to spatial characteristics—to produce final control commands [2].

2.2 Medical Robots

As a groundbreaking innovation in modern medical technology, medical robots provide patients with more precise and efficient healthcare services. In recent years, they have been widely adopted across various medical fields, including surgery, rehabilitation, and nursing. Surgical robots, exemplified by the Da Vinci surgical system, are currently the most widely used type of medical robot, particularly prevalent in urology, gynecology, and cardiothoracic surgery. Some medical institutions and elderly care facilities have also begun testing surgical robots and rehabilitation robots.

Traditional medical robots still face limitations despite significant advancements in the field. Regarding precision, while surgical robots can achieve high operational accuracy in complex scenarios, they still struggle to meet clinical demands. Neurosurgery requires exceptionally precise operations due to the brain’s intricate structure and dense vascular and neural networks. Even minor errors in robotic arms or inaccurate positioning during brain surgeries may increase risks. The operational flexibility of conventional surgical robots also needs improvement, as their limited range of motion and degrees of freedom make complex procedures challenging. In dynamic medical environments, these robots demonstrate poor adaptability and struggle to maintain stable performance. Emergency rescue scenarios often involve harsh conditions where traditional robots may malfunction due to vibrations, electromagnetic interference, and other disturbances. Additionally, their interaction with patients lacks real-time physiological and psychological monitoring capabilities. While providing personalized medical services, they struggle to adjust procedures according to individual patient needs. Current legal frameworks for liability determination in AI-assisted medical incidents remain underdeveloped [3].

While medical robots have certain limitations, artificial intelligence (AI) can significantly compensate for these shortcomings, achieving a qualitative leap in intelligence. Both operational precision and environmental adaptability have been substantially enhanced. AI empowers medical robots with superior perceptual and decision-making capabilities, enabling them to analyze vast amounts of medical imaging, surgical data, and patient physiological information through deep learning algorithms. This allows precise understanding and assessment of surgical scenarios and patient conditions. During procedures, medical robots can perform real-time analysis of imaging data from

surgical sites, accurately identify tissue structures, and automatically plan surgical pathways to avoid damaging adjacent vital organs. AI also enables autonomous learning capabilities, continuously optimizing operational strategies based on surgical experience and patient feedback to improve success rates and treatment outcomes, gradually mastering optimal surgical techniques. For precision control, advanced algorithms and sensor technologies ensure accurate motion execution. By utilizing computer vision technology, medical robots determine the positioning and posture of surgical instruments through image recognition and analysis, achieving precise surgical positioning and real-time visualization of surgical sites. In orthopedic surgeries, AI-assisted robotic systems can precisely plan implant placement angles and positions, ensuring surgical accuracy through 3D model analysis of patients' skeletal structures. Domestically developed orthopedic surgical robots demonstrate precision in lower limb alignment, surgical efficiency, and postoperative functional recovery comparable to world-class products in total knee replacement procedures [4]. Artificial intelligence enables medical robots to perceive tissue mechanical properties through force feedback control technology during operations, preventing tissue damage caused by excessive force. For instance, surgical robots performing minimally invasive procedures can precisely control instrument force, achieving gentle manipulation of delicate tissues like blood vessels and nerves through force feedback information. Real-time tissue deformation perception enhances tumor resection accuracy and prevents complications, while deep reinforcement learning-based surgical robot path planning algorithms provide personalized feedback and improvement suggestions to trainees. Artificial intelligence also plays a crucial role in improving medical robots' environmental adaptability. Through machine learning algorithms, medical robots can model and analyze various medical environments, automatically adjusting operational parameters and modes to adapt to complex and changing conditions. In telemedicine scenarios, medical robots can communicate in real-time with remote physicians via networks based on doctors' instructions and patients' real-time status, automatically adjusting surgical procedures and treatment plans. Even under unstable network signals, medical robots can maintain smooth operations through adaptive adjustments powered by AI algorithms. Artificial intelligence can also enable medical robots to detect their faults in time and take corresponding measures to repair them, so as to improve their reliability and stability [5].

2.3 Drones

The emergence of artificial intelligence algorithms has provided new solutions for autonomous drone control, replacing the previous reliance on manually set rules and commands that struggled to adapt to complex environments. By leveraging AI algorithms such as machine learning and deep learning, drones can learn and optimize

their behaviors from massive data, gradually developing more adaptive and autonomous control strategies in challenging environments. Domestic research has primarily applied AI algorithms to drone autonomous navigation, path planning, and collaborative decision-making [6]. For example, the Wing Loong series, developed by the Chengdu Aircraft Industry Group, is a series of medium-to-high altitude, long-endurance Unmanned Aerial Vehicles (UAVs). This series, which includes models such as the Wing Loong-1 and Wing Loong-2, is designed to perform a variety of missions, including reconnaissance, surveillance, and precision strikes. Notably, the Wing Loong-2 features a highly intelligent autonomous identification system that introduced AI algorithms for the first time, enabling self-feedback, friend-or-foe identification, and threat assessment. It also possesses full-autonomous capabilities including wheeled takeoff/landing and cruise flight [7].

With the continuous advancement and widespread application of artificial intelligence technology, there is an increasing demand for natural, precise, and secure human-machine interactions. Human-machine collaboration effectively integrates human cognitive and analytical capabilities with intelligent systems' data processing and decision support capabilities, achieving a "1+1>2" effect. Therefore, it is essential to conduct research on theories related to human-machine intelligent collaboration mechanisms and their principles, tackle key technologies such as dynamic permission allocation, human intent evaluation, and advanced human-machine interaction, thereby realizing hybrid augmented intelligence in human-machine systems.

3. Challenges and Future Directions

While artificial intelligence has made remarkable progress in robot control, it still faces numerous challenges. First, there's the data issue. Robots require vast amounts of data for learning, but acquiring high-quality operational data from the real world is both costly and inefficient. This often results in insufficient or subpar data for model training [8]. Second, there are limitations in hardware architecture. The mechanical structures, sensors, and actuators of robots generally lack the flexibility, durability, and adaptability of biological systems. For instance, performing delicate tasks like threading a needle with precise tactile feedback remains extremely challenging. Third, there's the disconnect between perception and action. Although robots can "see" the world through cameras and LiDARs, there's a gap between visual information and translating it into smooth, accurate movements. It's like someone who can see a ball but struggles to catch it due to uncoordinated limbs. Fourth, there are challenges with real-time performance and reliability. While complex AI models may require extensive computation time, robot control demands millisecond-level responsiveness. Any decision delay could lead to task failure or even safety hazards [9].

Additionally, robots' unpredictable behavior in untrained scenarios raises concerns about safety and ethics.

Facing these challenges, the future development path is clear. In learning and training, simulation technology and "digital twins" will play an increasingly important role. People can create highly realistic virtual environments in computers, allowing robots to undergo massive, risk-free training, thereby significantly reducing reliance on real-world data. This is like providing robots with a "metaverse" training ground where they can repeatedly trial and error. Regarding the "brain" of robots, the vision-language-action model represents a key direction. Researchers are striving to develop a unified model that seamlessly connects visual scenes, understood language commands, and required actions, achieving end-to-end control from perception to decision-making [10]. This means robots can understand complex instructions like "Please pass me the cup on the table" more directly. In design, software-hardware co-design will become a trend. When algorithm engineers and mechanical engineers worked in isolation, future robot development will no longer be "going it alone." Artificial intelligence is poised to play a dual role in the realm of robotics. Not only will it control robots, but it will also be instrumental in optimizing their designs. This will lead to the emergence of new robot structures that are better tailored to specific tasks, a concept referred to as "embodied intelligence." In this context, safety and ethics will permeate all developments. As robots become more deeply integrated into human life, establishing systematic safety standards and ethical guidelines becomes crucial. This includes ensuring robots' behaviors are predictable and interpretable, and that there are clear accountability mechanisms in place to address any issues that may arise.

4. Conclusion

In conclusion, artificial intelligence technology, as a core driving force, has profoundly reshaped the field of robot control, endowing robots with unprecedented perception, decision-making and adaptive capabilities. This paper clearly demonstrates this transformation through the analysis of three typical fields: intelligent driving, medical robots and drones.

In the realm of intelligent driving, deep learning-based algorithms for environmental perception and decision-making empower vehicles to understand complex road conditions in real time. This capability enables safe and efficient autonomous navigation, signaling a fundamental transformation in transportation. In medical robotics, the integration of AI not only enhances the precision and stability of surgical robot operations, reducing human errors, but also propels advancements in precision medicine. AI algorithms enable surgical robots to perform with greater accuracy and reliability, contributing to improved patient outcomes. For drones, AI algorithms bestow robust au-

tonomous flight capabilities, dynamic obstacle avoidance, and swarm coordination. These advancements showcase exceptional efficiency and adaptability in various scenarios, including logistics, surveying, and agriculture. Drones equipped with AI can navigate complex environments, avoid obstacles in real time, and coordinate with other drones in swarms, making them invaluable tools across multiple industries.

While artificial intelligence has achieved groundbreaking advancements, we must remain acutely aware of persistent challenges in data dependency, algorithmic interpretability, real-time security assurance, and cross-scenario generalization capabilities. Future research should not only focus on continuous optimization of algorithm performance but also prioritize establishing ethical frameworks and safety standards for human-machine collaboration. As AI technology continues to evolve, robots are expected to become increasingly intelligent, reliable, and ubiquitous, ultimately seamlessly integrating into all aspects of human production and daily life, thereby creating greater societal value.

References

- [1] Huang, C. (2025). Innovative applications of AI and electronic integration in intelligent driving systems for vehicles. *Internal Combustion Engine & Accessories*, (21), 117-119.
- [2] Tesla. (2025, March 19). Tesla FSD: A detailed breakdown. Zhihu. <https://zhuanlan.zhihu.com/p/31348764856>
- [3] Wang, Y. X., & Tang, Y. M. (2023). Medical artificial intelligence ethics: Issues, causes, and countermeasures. *Journal of Wuhan Institute of Metallurgical Management*, 33(01), 25-28.
- [4] An, H. M., Ping, H. Y., Li, H. F., & Chai, W. (2023). Comparative study on the recent efficacy of domestic "Honghu" orthopedic surgical robot-assisted and traditional manual total knee arthroplasty. *China Journal of Reconstructive Surgery*, 37(04), 404-409.
- [5] Xu, J. (2025). Artificial intelligence empowering medical technology innovation: Transformations and challenges. *Science and Technology Entrepreneurship Monthly*, 38(06), 113-124.
- [6] Zhao, Y. P., Huang, Y., Li, H., & Meng, J. (2023). Artificial intelligence applications and development in military intelligence. *Command, Control and Simulation*, 45(04), 36-43.
- [7] Ma, J., & Li, Y. (2024). Artificial intelligence applications in the drone field. *Radio Engineering*, 54(03), 759-764.
- [8] Song, H., Wang, L., Qiao, X., Chen, Y., Sun, D., & Sun, Z. (2025). Embodied intelligence for robot manipulation: development and challenges. *Vicinagearth*, 2(1), 8.
- [9] Li, L., Li, L., Li, M., & Liang, K. (2025). AI-Driven Robotics: Innovations in Design, Perception, and Decision-Making. *Machines*, 13(7), 615.
- [10] Khan, W., & Ishrat, M. (2025). Embracing the Future: Navigating the Challenges and Solutions in Embodied Artificial Intelligence. In *Building Embodied AI Systems: The Agents, the Architecture Principles, Challenges, and Application Domains* (pp. 281-299). Cham: Springer Nature Switzerland.