Analysis of Key Technologies and Application Cases of Industrial Robots in Intelligent Manufacturing

Hao Zhang

Gansu Forestry Vocational Technical College, Tianshui, 741020, China

Abstract: Industrial robots play a crucial role in intelligent manufacturing, and the analysis of their key technologies and application cases is vital for advancing the development of intelligent manufacturing. This paper focuses on industrial robots, delving into their key technologies and application cases in intelligent manufacturing. First, by reviewing the development history of industrial robots, it outlines their status and role in intelligent manufacturing. Second, it analyzes the current state of development of key technologies for industrial robots, including innovations in perception, decision-making, and execution. Following this, through case studies, it explores the application of industrial robots in intelligent manufacturing, demonstrating their advantages and potential in enhancing production efficiency, reducing costs, and improving product quality. Finally, the paper summarizes the key technologies and application cases of industrial robots in intelligent manufacturing and looks forward to future development trends and challenges.

1. Introduction

With the rapid development of technologies such as artificial intelligence, big data, and the Internet of Things, intelligent manufacturing is becoming an important direction for the development of the manufacturing industry. As an essential component of intelligent manufacturing, the analysis of key technologies and application cases of industrial robots is of significant importance for enhancing the level of intelligence in the manufacturing industry. However, in practical applications, industrial robots face many challenges, such as insufficient perception capabilities and low decision-making accuracy. Therefore, in-depth research on the key technologies and application cases of industrial robots in intelligent manufacturing is crucial for addressing these challenges and advancing the development of intelligent manufacturing.

2. Current State of Key Technologies in Industrial Robots

2.1. Perception Technology

Perception technology is one of the foundations for the realization of intelligence in industrial robots. It enables robots to acquire information about their surrounding environment and react accordingly. The perception technology of industrial robots has made significant advancements,

mainly reflected in the following aspects:

Firstly, the progress in visual perception technology provides strong support for the application of industrial robots. With high-resolution cameras and advanced image processing algorithms, industrial robots can monitor and identify their working environment in real time, enabling more precise operations. For example, on assembly lines, robots can accurately identify the position and orientation of components, achieving automatic grabbing and assembly, which improves production efficiency and product quality.[1]

Secondly, the application of sensor technologies such as LiDAR has brought new breakthroughs to the perception capabilities of industrial robots. LiDAR can quickly obtain three-dimensional information about the environment, including distance and shape, providing reliable data support for robot positioning and obstacle avoidance. In automated warehousing systems, industrial robots use LiDAR to quickly locate and stack goods, greatly improving storage efficiency and space utilization.

Moreover, the development of tactile perception technology is ongoing. By equipping robot arms with pressure sensors and force feedback devices, robots can simulate human tactile perception, achieving delicate manipulation and force control of objects. This technology is significant in assembly and processing tasks, effectively preventing collisions and damage, and ensuring production safety and product quality.

In summary, the perception technology of industrial robots is continuously innovating and improving, providing a solid foundation for the development of intelligent manufacturing.

2.2. Decision-making Technology

Decision-making technology in industrial robots refers to their ability to make reasonable decisions and plans based on perceived information during task execution. With the continuous development of artificial intelligence and machine learning technologies, decision-making technology in industrial robots has become more mature and intelligent, mainly reflected in the following aspects:

Firstly, rule-based decision algorithms provide an efficient and reliable decision-making method for industrial robots. These algorithms enable robots to act based on pre-set rules and logic according to the perceived environmental information. For instance, on automated assembly lines, robots can automatically select the appropriate tools and actions based on the pre-set assembly process and technical requirements, completing the assembly tasks of components.

Secondly, decision-making technology based on machine learning is gradually becoming a new trend for industrial robots. By training on large datasets, robots can automatically learn and optimize their decision models, achieving more intelligent and flexible operations. For example, using deep reinforcement learning algorithms, robots can learn the optimal action strategy through continuous trial and error, improving the efficiency and success rate of task execution.

Moreover, the application of integrated decision systems provides a new solution for the decision-making capability of industrial robots. By integrating and optimizing decision algorithms and models from different fields, robots can achieve complex task planning and execution across domains. For instance, in intelligent logistics systems, robots can consider factors such as the priority of goods, path planning, and obstacle avoidance simultaneously, achieving efficient logistics operations and collaborative work.

In summary, the decision-making technology of industrial robots is continuously innovating and exploring, providing new development opportunities for their application in intelligent manufacturing.

2.3. Execution Technology

Execution technology in industrial robots refers to their ability to perform tasks, including

technologies related to mechanical structures, motion control, and actuators. The development of execution technology directly affects the work efficiency and precision of industrial robots, hence it is of great significance. Currently, the execution technology of industrial robots is mainly reflected in the following aspects:

Firstly, the optimization of mechanical structures is key to improving the execution efficiency of industrial robots. Modern industrial robots use lightweight and high-rigidity mechanical structures, achieving high movement speed and precision. For example, robot arms made of carbon fiber materials have lower inertia and higher stiffness, enabling faster response and more accurate positioning.[2]

Secondly, advanced motion control technology provides strong support for the execution capability of industrial robots. With high-performance servo systems and motion control algorithms, industrial robots can achieve precise trajectory control and rapid acceleration and deceleration responses. For example, using PID controllers and high-speed data transmission technology, robots can achieve stable movement and accurate positioning in complex environments.

Moreover, innovations in actuator technology provide new development opportunities for the execution capability of industrial robots. Using efficient and energy-saving electric actuators and pneumatic actuators, robots can perform fast and flexible movements, meeting the demands of different tasks. For example, air-driven flexible grippers can achieve stable grabbing and handling of irregularly shaped objects.

In summary, the execution technology of industrial robots is continuously innovating and improving, providing a solid foundation for their application in intelligent manufacturing.

3. Application Case Analysis of Industrial Robots in Intelligent Manufacturing

3.1. Application of Industrial Robots in Flexible Manufacturing Systems

3.1.1. Overview of Flexible Manufacturing Systems

Flexible Manufacturing Systems (FMS) are highly intelligent production systems that integrate various equipment and technologies to quickly adjust production lines according to demand, achieving a production mode of multiple varieties, small batches, and rapid switching. FMS typically consist of automated equipment, computer control systems, and industrial robots, characterized by flexibility, efficiency, and automation, providing significant support for the development of the manufacturing industry.

3.1.2. Role of Industrial Robots in Flexible Manufacturing Systems

Industrial robots play a crucial role in flexible manufacturing systems. Their highly flexible operation capabilities and intelligent control systems make them a key component in achieving rapid conversion and production of various types. Robots can flexibly adjust their posture and actions according to different product requirements, achieving automated assembly, processing, and handling. Through coordination with other automated equipment and computer control systems, industrial robots realize the intelligent and automated production process.

3.1.3. Application Cases of Industrial Robots in Flexible Manufacturing Systems

In the automotive manufacturing industry, the application of flexible manufacturing systems is widespread. For example, in the car body welding segment, industrial robots can achieve precise welding of various car body parts through automated welding technology, ensuring welding quality and stability. In the painting segment, robots use high-precision painting devices to achieve automated

painting of car bodies, ensuring uniformity and coating quality. In the assembly segment, industrial robots can flexibly adjust their working posture and path planning according to the requirements of different car models, achieving automated assembly of car body parts, greatly improving production efficiency and the flexibility of the production line.

Additionally, in the electronic product manufacturing field, flexible manufacturing systems are also widely applied. For example, in the PCB board assembly segment, industrial robots can achieve high-precision assembly of electronic components through automated operations, ensuring the quality and efficiency of product assembly. In the component testing segment, robots can perform automated testing of components through an intelligent control system, improving the quality controllability of products and the stability of the production line.

In summary, the application of industrial robots in flexible manufacturing systems is of great significance, not only improving production efficiency and product quality but also promoting the intelligent and automated development of the manufacturing industry. With continuous technological advancements and application expansion, the application prospects of industrial robots in flexible manufacturing systems will become even broader.[3]

3.2. Application of Industrial Robots in Intelligent Logistics

3.2.1. Introduction to Intelligent Logistics Systems

Intelligent logistics systems are efficient, intelligent logistics management systems that utilize IoT, sensor technology, and intelligent control algorithms. By real-time monitoring and analyzing logistics information, intelligent logistics systems can automate the sorting, handling, and storage of goods, improving logistics transportation efficiency and management level.

3.2.2. Role of Industrial Robots in Intelligent Logistics Systems

Industrial robots play a key role in intelligent logistics systems. Their efficient handling capabilities and intelligent path planning abilities make them a critical technology for automating logistics. Robots can intelligently plan the optimal path based on warehouse layout and goods requirements, achieving fast and accurate handling operations. Integrated with intelligent logistics systems, industrial robots automate goods processing, enhancing the efficiency and accuracy of logistics transportation.

3.2.3. Application Cases of Industrial Robots in Intelligent Logistics Systems

In the e-commerce warehousing industry, the application of intelligent logistics systems has achieved significant results. By integrating industrial robots and automatic navigation technology, goods are automatically sorted and packaged, greatly improving storage efficiency and order processing speed. Industrial robots can intelligently plan handling paths based on order information and goods attributes, quickly retrieving and sorting packages from the warehouse, enabling rapid order processing and accurate delivery.

In the raw material warehouses of the manufacturing industry, industrial robots also play a crucial role. Through laser navigation and intelligent path planning technology, robots automate the handling and storage of raw materials. Based on production plans and raw material requirements, robots intelligently plan transport routes, quickly moving raw materials from warehouses to production lines, reducing labor costs and handling time, and increasing production efficiency and raw material utilization.

In summary, the application of industrial robots in intelligent logistics systems brings tremendous convenience and benefits to the logistics industry, promoting improvements in logistics management

levels and transportation efficiency. With ongoing technological progress and application expansion, industrial robots have an increasingly broad application prospect in intelligent logistics.

3.3. Application of Industrial Robots in Intelligent Assembly

3.3.1. Introduction to Intelligent Assembly Systems

Intelligent assembly systems are efficient production systems integrating automated assembly equipment and intelligent control systems, designed to automate the assembly and inspection of components. By integrating advanced assembly equipment and intelligent control systems, intelligent assembly systems improve assembly efficiency, reduce costs, and ensure the stability of product assembly quality.

3.3.2. Role of Industrial Robots in Intelligent Assembly Systems

Industrial robots play an essential role in intelligent assembly systems, where their high-precision positioning and flexible operation capabilities make them key tools for product assembly and inspection. Robots can intelligently adjust their working posture and force to accurately fit and secure components. Integrated with intelligent assembly systems, industrial robots achieve efficient production line operations, enhancing assembly efficiency and product quality.

3.3.3. Application Cases of Industrial Robots in Intelligent Assembly Systems

In the electronic product assembly industry, intelligent assembly systems integrate industrial robots and vision inspection systems to automate the assembly and quality inspection of electronic parts. Robots can automatically pick and assemble components based on assembly drawings, while the vision system checks the quality of product assembly, automating and ensuring the accuracy of product assembly. For example, in the assembly process of smartphones, industrial robots can accurately assemble various components together and use vision systems to check the position and quality of each component, ensuring the quality and functionality of the final product.

In the automotive manufacturing industry, intelligent assembly systems are widely applied in the assembly and inspection of vehicle components. Industrial robots automate the efficient assembly and quality control of complex components. For example, in the assembly process of car engines, robots precisely install each component and monitor assembly force and position in real time via sensors, ensuring the correct installation and reliability of each component. These application cases demonstrate the significant role of industrial robots in intelligent assembly systems, providing efficient, precise solutions for manufacturing, and advancing the intelligent and automated development of the industry.

4. Future Outlook for Industrial Robots in Intelligent Manufacturing

4.1. Technology Development Trends

4.1.1. Artificial Intelligence and Machine Learning

In the future, the development of industrial robots will focus more on the application of artificial intelligence and machine learning technologies. Through algorithms such as deep learning and reinforcement learning, robots can learn from vast amounts of data, continuously optimizing their decision-making and execution abilities to achieve more intelligent production operations. With advances in data collection and processing technologies, robots will better understand and adapt to

complex production environments, achieving more flexible and efficient operations.[4]

4.1.2. Breakthroughs in Perception Technology

As sensor technology continues to develop and costs decrease, the perceptual abilities of industrial robots will be further enhanced. High-resolution cameras, LiDAR, and other sensors will be widely applied in industrial robots, achieving more accurate and comprehensive perception of the environment. Additionally, the introduction of new types of sensor technologies, such as sonar and infrared, will provide robots with more diverse perceptual abilities and expand their application fields.

4.1.3. Adaptive Control Technology

Industrial robots will focus more on the application of adaptive control technology to rapidly respond and adjust to different working conditions. Adaptive control algorithms can adjust the robots' motion planning and force control in real-time based on environmental changes and task requirements, enhancing their flexibility and adaptability. With the development of intelligent sensors and actuators, robots will precisely sense and control forces, achieving more accurate operations and a higher level of adaptability.

4.2. Application Prospects

4.2.1. Drivers of Intelligent Manufacturing

As an integral part of intelligent manufacturing, industrial robots will become a significant force in driving the transformation and upgrading of the manufacturing industry. Their efficient, precise operational abilities and intelligent control systems will significantly enhance the manufacturing industry's production efficiency and product quality. As the concept of intelligent manufacturing becomes more ingrained, the application scope of industrial robots will expand further, injecting new vitality into the development of the manufacturing industry.

4.2.2. Implementers of Customization

With the continuous diversification of consumer demands, personalized customization will become a development trend in the manufacturing industry. Industrial robots, with their flexible operational abilities and rapid conversion capabilities, can achieve personalized customization production for different products, meeting the market's diverse demands. The application of industrial robots enables manufacturing enterprises to achieve flexible production layouts and rapid product updates, enhancing market competitiveness.

4.2.3. Key Components of Manufacturing Intelligence

The application of industrial robots in intelligent manufacturing will continue to expand and deepen, becoming an essential part of the intelligent transformation of the manufacturing industry. Through deep integration with artificial intelligence, big data, and other technologies, industrial robots will achieve more intelligent and flexible production methods, driving the manufacturing industry towards digitization and intelligence. In the future, industrial robots will become core elements of smart factories, bringing more flexible and efficient production modes to the manufacturing industry.

4.3. Challenges and Strategies

4.3.1. Technical Integration Challenges

The widespread application of industrial robots in intelligent manufacturing will face challenges in technical integration. Compatibility and standardization issues among robots and automation equipment produced by different manufacturers will become significant factors restricting the application of industrial robots. Addressing this issue requires strengthening international standardization efforts to establish unified technical specifications and communication protocols. Additionally, inter-company cooperation and open innovation are effective ways to solve technical integration challenges. Establishing joint research and development platforms and technology sharing mechanisms can promote technical exchange and collaboration, advancing the integration and application of industrial robot technologies.[5]

4.3.2. Safety Risk Challenges

As industrial robots become more widespread and their application scope expands, safety risk issues will also become a significant factor restricting their application. Potential safety hazards in robots' operation, such as collisions, damage, and personnel injuries, need attention. Addressing this issue requires enhancing the research and application of robot safety technologies, establishing comprehensive safety management systems, and emergency plans. Moreover, by applying intelligent perception technology and intelligent control algorithms, the safety protection capabilities of robots can be improved, reducing the occurrence of safety risks.

4.3.3. Human-Robot Collaboration Challenges

The deep integration of industrial robots with human work environments will become an important trend in intelligent manufacturing. However, technical challenges exist in the collaboration model between robots and humans, such as safety assurance and work coordination. Addressing this challenge requires strengthening the research and application of human-robot collaboration technologies to achieve safe and efficient cooperation between robots and humans in work scenarios. Developing intelligent perception technologies and human-machine interfaces can enable real-time communication and collaborative work between robots and humans, improving production efficiency and work quality.[6]

5. Conclusion

As a crucial component of intelligent manufacturing, the continuous innovation in key technologies and accumulation of application cases of industrial robots will drive the development of intelligent manufacturing. However, many challenges still exist, such as enhancing perception abilities and improving decision-making precision. In the future, further research on the key technologies of industrial robots is needed, continuously optimizing their application in intelligent manufacturing to achieve the intelligence, flexibility, and efficiency of the manufacturing industry.

References

[1] Shen Jianjun. Research on Industrial Robot Technology Based on Intelligent Manufacturing. Journal of Electromechanical Product Development and Innovation. 2023, 36(04): 96-98.
[2] Sun Luqi. Application of Industrial Robot Technology in the Field of Intelligent Manufacturing. Paper Equipment and Materials. 2023, 52(09): 29-31.
[3] Zhang Huajin. Application of Industrial Robots in Intelligent Manufacturing. Application of Integrated Circuits. 2023,

40(11): 322-323.

[4] Qu Minmin. Analysis of the Effective Application of Robots in Intelligent Manufacturing. Electronic World. 2021(17): 9-10.

[5] Wang Zan. Application and Development of Electromechanical Integration Technology under the Background of Intelligent Manufacturing. Southern Agricultural Machinery. 2023, 54(15): 141-143+158.

[6] Wang Yaonan. Industrial Internet Promotes the Development of Collaborative Intelligent Manufacturing with Robots. Robot Technology and Applications. 2023(05): 8-11.