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Development analysis of intelligent robots in manufacturing industry

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Abstract. With the continuous development of the manufacturing industry, the application of intelligent robots is becoming more and more extensive. Many emerging technologies can be applied to intelligent robots. Typical intelligent robots still have room for further improvement in terms of automatic control and adaptation to the surrounding environment. And independent learning of production tasks and realization of human-computer interaction is the future development direction of industrial robots. In view of these deficiencies, the development of intelligent robots is particularly important. This paper introduces the application fields, key technologies and needs of intelligent robots, and explains the important position of intelligent robots in the future manufacturing industry. The functions of intelligent robot control, perception and human-computer interaction based on artificial intelligence technology are studied. Possible future challenges, limitations and problems will be presented at the end of this paper.

Keywords: intelligent robots, manufacturing, stationary robotics, mobile robotics, artificial intelligence technology.

1. Introduction

With the continuous development of the manufacturing industry in the direction of intelligence and informatization, industrial robots have also undergone tremendous changes. An industrial robot is defined in ISO 8373:2012 as: "an autonomous, reprogrammable, multipurpose manipulator that can be programmed in three or more axes that can be fixed in place or moved for industrial automation applications". In the third industrial revolution, industrial robots are an important part. Because of the use of industrial robots, the efficiency of many factories and production floors has been greatly improved. However, it also has some drawbacks. For example, it cannot adapt to the changing environment and cannot learn production and processing tasks on its own. Specific operations can only be carried out according to specific requirements [1]. In the context of industrial manufacturing 4.0, industrial robots have turned to intelligent robots, bringing more intelligent and flexible production methods to the manufacturing industry. The biggest feature of Industrial Manufacturing 4.0 is the integration of digitalization, networking, intelligence, and automation. Using advanced digital technology and automation technology, the manufacturing industry can complete the production process more efficiently, so as to achieve the comprehensive upgrading and optimization of the industrial environment. Intelligent robots have the characteristics of high self-learning and adaptability, which also have the ability to self-diagnosis and fault repair. Multi-sensor information fusion technology supports intelligent robots for self-diagnosis and fault rest [2]. It can take signals from multiple sensors as input to a one-dimensional convolutional neural network (CNN) and implement a fault classification method through improved CNNs. Then realize the self-diagnosis and repair function of intelligent robot. Intelligent robots are used in manufacturing production lines, and can autonomously perceive the production environment through technologies such as sensors and vision, and make decisions and control autonomously. This autonomous and intelligent robot will greatly improve production efficiency and quality, while having a more flexible production model.

Mobile robots have also become an important development direction for intelligent robots. Mobile robots are divided into wheeled, legged, hybrid, and walking. It uses laser, sonar, vision, and other technologies for autonomous navigation, and can operate and collaborate in any location required by the plant [3]. Mobile robots can not only assist manual completion of repetitive and cumbersome tasks, but also realize assembly line processing, logistics and distribution on the production line, thereby improving the efficiency of the entire manufacturing process. Stationary robots mainly play the role of automated production in manufacturing and smart factories. It can complete some repetitive, high-intensity, high-precision, and hazardous environments. It can not only improve the efficiency of manufacturing production, reduce the risk of manual participation in the processing process, but also improve the quality of products produced by the factory. This paper will analyse and discuss the application and development of the above two types of intelligent robots in the era of industrial manufacturing 4.0, and outline the key technologies. The author expects to provide effective reference and suggestions for the manufacturing industry and to provide readers with inspiration about intelligent robots in the manufacturing field.

2. Characteristic analysis of intelligent robots in manufacturing industry

2.1. Intelligent robot definition

An intelligent robot is a robot capable of perception, decision-making, execution, and learning. Its internal structure integrates modules such as sensors, controllers, actuators, data storage and processing, autonomous learning and decision-making. It can interact with the environment and complete tasks in production and manufacturing autonomously. It has good adaptive ability to identify and deal with complex situations. At the same time, intelligent robots are also robots that integrate many artificial intelligence technologies. It can be said that artificial intelligence technology is the core of intelligent robots, including machine learning, deep learning, and computer vision. In addition, artificial intelligence technology can also facilitate real-time information sharing, knowledge discovery, and informed decision-making among robots [4]. Compared with traditional industrial robots, intelligent robots have wider applicable scenarios and higher efficiency. Combined with the characteristics of the manufacturing industry, intelligent robots can be divided into stationary robots and mobile robots according to their mobile forms.

In the production process of the manufacturing industry, the classification, transportation, and assembly of materials are common links, which usually need to be completed manually. However, as the manufacturing industry tends to be intelligent and automated, intelligent robots have gradually become the main force to replace manual operations. Among them, intelligent robots in the form of mobile have great advantages in material classification. First, the assembly line is the main form of the manufacturing production line, and the materials in each production link need to be transported and converted in an orderly manner on the assembly line. Traditional static classification methods often cannot adapt to the changes and flexibility requirements of the production process. The intelligent robot can flexibly move between the assembly lines in the mobile form, complete the classification and transfer tasks of materials, and improve production efficiency and quality. Secondly, the output of raw materials and products also needs to be sorted and sorted for subsequent assembly and transportation. Traditional manual sorting has problems such as low efficiency and poor quality, while intelligent robots can accurately classify and sort materials according to programs and algorithms in mobile form, avoiding errors and instability of manual operations. Finally, intelligent robots are versatile and versatile,

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which can adapt to different processes and production modes. At the same time, intelligent robots can also adapt to different material classification and transfer requirements by adjusting algorithms and programs, improving their intelligence and adaptive capabilities, and further improving production efficiency and quality. Therefore, the classification and transfer of materials by intelligent robots in the form of mobile is a necessary trend for the intelligent transformation of the manufacturing industry, which has many advantages such as improving efficiency, reducing costs, and optimizing resource utilization.

Stationary robots are a special type of industrial robot that are usually fixed on a workstation and perform the same operations, such as assembly, welding, or inspection. Stationary robots have advantages over other types of robots. First, since a stationary robot is fixed on a work site, its stability is very high and it can perform the same task without moving or repositioning. Second, since stationary robots can perform the same tasks continuously for long periods of time, their productivity is very high, improving the efficiency of the entire manufacturing system. Finally, stationary robots typically perform tasks using pre-programmed programs that are precise enough to allow high-precision manipulation. But stationary robots also have some drawbacks and limitations. On the one hand, stationary robots usually cannot adapt to changes in the production line, so they are not suitable for production lines with frequent changes. At the same time, stationary robots require a relatively cumbersome installation and commissioning process, which may increase costs and time for manufacturers. In addition, since the stationary robot is fixed, the difficulty of maintenance and repair will also increase. The cost of stationary robots is relatively high, which may limit their use for some manufacturers. Combining the analysis of the above characteristics, for some tasks that require precision and stability, stationary robots have great advantages, but for some manufacturing environments that need to flexibly respond to changes, its shortcomings and limitations will also be more obvious.

2.2. Characteristic analysis of mobile robot

As an important part of intelligent manufacturing, mobile robots have the following characteristics and characteristics. First, mobile robots are highly flexible, and thus can move and operate in an adaptable manner in different scenarios. It enables rapid autonomous planning and routing when needed, and brings greater flexibility and adaptability to manufacturing lines. Second, the production cost of mobile robots is low, so that they can be adapted and integrated into the production line without large-scale transformation and investment. It can more flexibly meet different production needs and reduce the cost burden caused by equipment and system updates in the manufacturing industry. Third, mobile robots have stronger human-computer interaction and can better adapt to the rapidly changing needs of the modern manufacturing field. Fourth, the efficiency of mobile robots improves rapidly. It can choose paths and tasks independently and operate more flexibly. It can complete the task in a short time and greatly improve the production efficiency of the manufacturing industry. Fifth, mobile robots are characterized by high safety. It can move through autonomous planning, and can choose its own path and interact with the environment based on real-time perception, avoiding increasingly complex security risks. This will improve the safety of the manufacturing industry and the quality of the production environment for the staff.

Combining the analysis of the above characteristics, mobile robots have the characteristics and characteristics of strong adaptability, low cost, good human-machine cooperation, fast efficiency improvement, and high safety. Therefore, it can bring more intelligent production methods to the manufacturing industry, allowing the manufacturing industry to better adapt to changing market and production environment needs.

As an important part of the manufacturing line, mobile robots have the following advantages and limitations. In terms of advantages. first, it has good flexibility and adaptability. Mobile robots can select paths and tasks based on real-time data, adapt to production needs in different scenarios, and enhance the flexibility and adaptability of the production line. Second, mobile robots can independently select paths and tasks and then quickly complete various tasks, which can improve production efficiency. Third, the interaction performance between mobile robots and operators is very good, which can achieve better collaboration effects. Make the division of labour between humans and robots more coordinated. Fourth, compared with traditional stationary robots, mobile robots have advantages in production performance and efficiency.

In terms of limitations. First, compared with traditional robots, mobile robots have limited functions and processing capabilities, so they may not be able to meet the needs well in some special production processes. Second, the mobile robot contains many hardware modules and needs strong technical support. Therefore, a certain technical team support is required.

To sum up, mobile robots have the advantages of strong production adaptability and improved production efficiency, but their functions and processing capabilities may be limited, and the operating technology requirements are relatively high. At the same time, the line is dependent on its movement and has certain safety hazards.

2.3. Characteristic analysis of stationary robot

A typical stationary robot mainly includes the following structures, and can be applied to a variety of complex scenarios according to its structural characteristics, which shown in Table 1.

Table 1. Some typical stationary robot structures.

Robot type	Characteristic
Gantry robot [5]	Composed of two parallel beams and longitudinal support columns, the structure is similar to a gantry crane.
Cartesian robot [6]	It is composed of three or more linear axes, and the workpiece can be operated through the movements of the linear axes such as lifting, telescoping, and moving back and forth.
SCARA robot [7]	It consists of two rotary joints and one linear joint that moves along the Z axis, and has good positioning accuracy and progressiveness.
Cantilevered robot [8]	The structure of the cantilever robot arm consists of a rotary joint equipped with a servo motor and a reducer, and a lifting and rotating hanging arm, which can be applied in the fields of aviation manufacturing and 3D printing.
Delta robot [9]	Composed of three or more degrees of freedom, a large range of motion of the robotic arm is achieved by controlling the length and angle of the moving link.

Stationary robot is a kind of important automation equipment, which is widely used in manufacturing industry. It has many advantages. First, the predetermined program and control system of the stationary robot can make it operate with high precision. Second, stationary robots are fast and reliable, and can greatly increase productivity for many repetitive operations. Third, the robot can quickly repeat the operation over a long period of time, and maintain the same quality and output. Fourth, stationary robots can replace different tools and perform different tasks as needed.

But it also has certain disadvantages and limitations. First, purchasing and installing a stationary robot requires a substantial investment. Second, compared to human labour, stationary robots lack the responsiveness and adaptability to handle non-standard or uncommon tasks. Third, the development cycle and the input of manpower, material resources and time for stationary robots are relatively long. Fourth, stationary robots may malfunction during work, such as improper operation, program errors, etc.

To sum up, stationary robot is an important automation equipment, which can improve production efficiency and strengthen the standardization and standardization of production links. However, it also has a lot of room for improvement in some aspects.

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3. Stationary robotics

3.1. Object awareness technology numbering

Stationary robots need to have good perception and vision capabilities so that they can perceive their surroundings and make correct decisions during operations. Using sensors and vision systems, robots can identify and locate workpieces, sense obstacles, and avoid collisions, enabling precise positioning and assembly. In the current manufacturing industry, stationary robots still occupy the main part of the production system. Traditional stationary robots are mainly controlled by fixed programming logic. But this method not only wastes time, but also the program is inflexible, requiring professional personnel to maintain it regularly. In the context of industrial manufacturing 4.0, it is required that it should be able to realize the detection and recognition functions of objects during work, and understand the 3D structure of the working environment. This allows parts of different shapes to be identified, handled, and assembled. Therefore, stationary robots also need the ability to process and interpret sensor data to reflect the situation of objects and working environments and meet production needs. At the same time, this function can also realize the detection and behavior evaluation of staff. On the one hand, it can ensure the safety of nearby workers, and on the other hand, it can also correct the trajectory of the stationary robot online to avoid dangerous actions. Laser distance sensors or stereo cameras are often used in stationary robotic systems to reconstruct the surrounding work environment [10].

3.2. Motion control

Motion control of stationary robots plays an important role in manufacturing. The control method of the stationary robot provides flexibility and programmability, making it adaptable to different production requirements and different parts. At the same time, the motion control of stationary robots requires high precision and repeatability. By precisely controlling the path and motion of the robot, consistency and accuracy can be ensured every time the same production task is performed. In addition, the control of stationary robots can realize automatic production, reducing the need for manual operation. Reasonable control of stationary robots can greatly improve production efficiency and product quality, and reduce production costs. In general, motion control methods for stationary robots usually require a combination of sensor technology and vision systems. Intelligent control is realized through sensor feedback and visual guidance, which is very important in the era of industrial manufacturing 4.0. Traditional programming control methods are no longer suitable for the current industrial environment of intelligent manufacturing. Today, modular robot control frameworks are mainstream application frameworks. It can convert the motion control commands of advanced robots into skills and decompose them into combinations of various processing programs, thereby enabling rapid control of the robot. At the same time, the framework can be applied to robotic tasks in various industrial settings [11]. In industrial manufacturing, gesture control of robots is becoming common. This control method is mainly for the control of the fixed mechanical arm. Gestures are used to define the approximate pose of the robotic arm, which can be further defined by the robot's motion control. Gesture control is mainly used to manipulate the robot to make specific motion estimates or change directions, and this process needs to be further integrated into the control program. On the other hand, voice control can also be used as a control interface for stationary robots. This enables a semantic approach to multimodal interaction between workers and robots. And then enhance the reliability and naturalness of collaboration between them in a specific environment [12].

3.3. Human-robot interaction

In the context of Smart Manufacturing 4.0, stationary robots have become an indispensable part of the manufacturing industry. Compared with traditional machines, stationary robots have a higher level of autonomy and intelligence, and can automate heavy, repetitive, and dangerous tasks. However, to better meet production demands, effective human-robot interaction with stationary robots becomes crucial. In the context of intelligent manufacturing, different human-computer interaction methods and technologies have been widely used. For example, touchscreen interfaces, voice control, gesture

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recognition, virtual reality, and wearable devices all provide operators with diverse options for interacting with stationary robots. Through these methods, the operator can intuitively operate, guide, and monitor the work of the robot, making the production process more flexible, intelligent, and humanized. Human-robot interaction with fixed-base robots has been a focus in recent years. Two conditions in which two kinds of humans and robots are co-located in one environment can be considered. The first is that the robot must have a full understanding of the existence and environment of the staff. The second is to manage the safety of the shared space to ensure that the stationary robot will not hurt the staff during the movement [13]. Based on such demands, a new form of human-computer interaction—teleoperation—has emerged in factories. But teleoperation can be challenging with latency, especially when communicating over long distances or with unstable network connections. After the operator sends a command, due to the time of signal transmission and processing, it may take a certain delay to generate a response on the target object. This delay affects the operator's real-time feedback and precise control, especially in high-precision operations or hazardous environments. Combining with specific algorithms, such as the DCNN regression algorithm, can improve the calculation speed and noise robustness Can realize the motion control precision and accuracy of human-computer interaction robots based on teleoperation [14]. At the same time, visual support is also important for the success of teleoperation. An additional "hand-held camera" arm can be used to provide a clear field of vision for the worker to control the working arm. While workers use teleoperation to control stationary robots, the "handy camera" arm can be servoed in real time to provide sufficient visual range. It can avoid mutual occlusion with the operating robot, thereby providing specific surrounding environment information and a detailed view. At the same time, action prediction is utilized to emphasize the next action of the worker. This approach features a robotic arm with a camera that can be servoed in real time, always providing workers with a sufficient range of view. And the robotic arm with the "handheld camera" can move autonomously, so workers only need to operate the robotic arm that needs to be operated. This allows the staff to focus on operations and improve work efficiency [15].

4. Mobile robotics

4.1. Robot mobile technology

Mobile robots can move in a variety of ways, including wheeled, tracked, legged, and hybrid in the manufacturing industry. The first is wheeled mobility. This is the most common and simple way of moving. Mobile robots are usually equipped with wheels, motors and axles, and the motors control the rotation of the wheels to move. The advantage of wheeled movement is that it is simple, the movement speed is fast, and it is suitable for stable ground. The disadvantage is that the ability to cross complex environments and obstacles is limited. The second is crawler movement. The bottom of the mobile robot uses a track similar to that of a tank. The motor controls the track to move forward and backward. It can move on uneven ground and gradient areas, and has a good ability to cross obstacles, but the disadvantage is that the movement speed is slow. The third is leg movement. The bottom of the mobile robot is equipped with some mechanical legs and joints, and the movement of each joint is controlled by a motor to achieve movement. The advantage of legged movement is that it can travel on complex terrain and obstacles, and has excellent maneuverability and adaptability, but the disadvantages are complex structure, high cost, and slow-moving speed. The fourth is the mixed movement of wheels and legs. The mobile robot integrates the advantages of wheeled movement and legged movement. It can not only move forward quickly on flat ground, but also cross uneven ground and obstacles of a certain height.

4.2. Environmental awareness technology

The information perception of the surrounding environment of a mobile robot is one of the important technical guarantees for its autonomous decision-making and task execution. Only the safety management of the working space of the staff and the robot can ensure that the mobile robot will not hurt the staff during the movement. Different kinds of sensors can be added in mobile robots to track people or obstacles in the workspace. The most common method is to obtain a complete 3D model of the environment. Vision sensors are the most commonly used perception units and are often used to inspect workspaces, allowing mobile robots to detect the presence of objects while ensuring safety. Vision sensors such as stereo cameras, RGB-D cameras, proximity sensors or laser scanners. These can make the mobile robot have the function of creating a three-dimensional environment model, and at the same time calculate the distance between itself and obstacles or workers [13]. Avoiding collisions is another way for mobile robots to perceive their environment. The mobile robot should not collide with obstacles or staff during the movement, which will cause injury to the staff, as well as damage to the robot itself or the transported goods. Here you can use a depth camera or a lidar sensor to perceive whether there are obstacles or staff near the mobile robot. Obstacles can also be detected using a simple RGB camera, and algorithms can be used to enable mobile robotic systems with intelligent perception capabilities, such as visual recognition and adaptive reasoning. That is, mobile robots can avoid collisions and perform online path planning in a dynamically changing environment in real time. A low-cost RGB camera is enough to form a robot's visual recognition system [16].

4.3. Navigation path planning technology

Mobile robot navigation path planning technology refers to the use of algorithms and technical planning in different environments to make the robot reach the target point according to the appropriate travel route. This technology is of great significance for autonomous navigation, obstacle avoidance and path optimization of mobile robots. First, the navigation path planning technology of mobile robots can greatly improve the robot's autonomous navigation performance. For different environments and difficulties, robots can make autonomous decisions and perform mobile tasks through path planning technology without human intervention. This not only increases the autonomy and flexibility of the robot, but also reduces operating costs and increases the work efficiency of the mobile robot. Secondly, the mobile robot navigation path planning technology can effectively solve the problem of robot obstacle avoidance. The robot may encounter various obstacles during its travel, such as instruments, materials and other robots in the factory, and these obstacles may affect the trajectory and speed of the robot. By applying navigation path planning technology, the robot can more accurately find the location of obstacles and avoidance strategies, so as to avoid problems such as collisions and losses. Finally, the mobile robot navigation path planning technology can also optimize the robot's travel path and improve energy efficiency and working time. The navigation path of the robot can be optimized through the optimization algorithm and the site model to select the shortest path, reduce energy consumption, and time waste, and improve the sustainability and autonomy of the mobile robot. Therefore, mobile robot navigation path planning technology is very important in a variety of application scenarios, it can improve the autonomy, flexibility, and work efficiency of the robot, reduce costs, and improve the work efficiency of the robot [17].

The path planning and navigation technology of mobile robots can be roughly divided into classical and reactive approaches. Classical approaches are based on pre-built maps and planning algorithms for path planning and navigation. This approach usually employs techniques based on graph search, shortest path algorithms. The starting position and target position of the robot are taken as input, and the algorithm calculates the path that the robot should follow. These methods typically use a global map during planning and navigation and consider static environments and obstacle-avoiding paths. Classical methods are often used for path planning and navigation of mobile robots in known environments. However, in terms of real-time navigation, the classical method has great limitations compared to the reactive method, its computational cost is high and it cannot make timely actions for sudden uncertainties in the environment. Moreover, it often generates wrong paths due to inaccurate environmental information and lack of precise real-time navigation perception mechanism. Therefore, this method is not suitable for real-time path planning and navigation. Most of the current mobile robots use reactive approaches for path planning, such as cell decomposition method (CD), road map method (RA), artificial potential field method (APF), etc. The reactive approach pays more attention to the mobile robot's real-time perception of the current environment and immediate response to the strategy.

This method emphasizes the real-time decision-making ability of the robot, and directly generates navigation behaviours based on the perception information and sensor data of the current environment. Reactive approaches, usually based on techniques such as rule bases, state machines, or behaviour trees, link the robot's behaviour with environmental perception for fast path planning and navigation. The advantages of the reaction method are as follows. First, using the reaction method to plan the navigation path of the mobile robot has a good ability to deal with the uncertainty in the environment, and then realize real-time planning. Second, this approach enables mobile robots to work in dynamic and complex environments, where the newly developed algorithms have a wide range of applications. Finally, the reaction methods can be fused with each other, which has great flexibility, and then improves the performance of the algorithm. However, the reaction method also has disadvantages such as long calculation time, complex algorithm design and high hardware requirements. To sum up, combined with the actual scene, different algorithms can be selected to improve the autonomous navigation ability of the robot.

4.4. Human-robot interaction

Human-robot interaction is a new production mode that was born under the background of industrial manufacturing 4.0. It integrates the perception of robots, people, and products, and then makes decisions on the planning and control of the entire system. In the past, the way of human-computer interaction was mainly to operate the robot alone. This has now shifted to human-to-robot access. In the future, the field of human-computer interaction will pay more attention to how to conduct close human-computer interaction. There are many ways of human-computer interaction, such as voice commands, touch interfaces, gesture recognition, mobile applications and virtual or augmented reality [18]. But the main problem of human-computer interaction now is that reliable interactive actions cannot be realized in some environments. The main reasons are unreliable sensors or lack of efficient and accurate data fusion. Robots need sensor data to implement a series of actions, such as reactive planning, motion control, visual recognition, servo control, and fault diagnosis. In order to achieve human-computer interaction with mobile robots, it is necessary to add a multifunctional sensor system, including vision, temperature, distance, and depth perception. Only in this way can the reliability and security of human-computer interaction be guaranteed. Among the key technologies for human-robot interaction with mobile robots is natural language processing (NPL). It is an artificial intelligence technology designed to enable computers to understand and process human natural language. When interacting with mobile robots, NLP technology can convert human users' voice commands or text input into commands that machines can understand and execute. Through technologies such as semantic understanding, syntactic analysis, and contextual reasoning, NLP can achieve more advanced dialogue and communication, and enhance the interactive experience between humans and computers. NPL technology can further enable the machine to understand and process the user's natural language, and make reasonable feedback and execution actions for specific interactive tasks. The ultimate goal of NPL is to make talking between humans and machines as easy as talking between humans. Natural language is very promising in robotics. Using NPL, mobile robots can interact with operators remotely throughout the plant without requiring workers to follow the movement of the mobile robot [19]. By introducing human-robot interaction, the flexibility of automated production can be further improved. At the same time, intuitive control design and task distribution between the worker and the mobile robot are also key factors for the success of human-robot interaction.

5. Discussion

The application of intelligent robots in manufacturing helps to improve production efficiency and product quality. Intelligent robots can complete complex manufacturing tasks through precise, efficient, and programmable actions, reducing manual operations and errors, thereby improving production efficiency. In addition, intelligent robots are characterized by automation and flexibility, and can quickly adapt to different production environments and product requirements. Therefore, the application of

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intelligent robots can improve product quality, reduce human factors in production, and improve overall production efficiency.

This paper divides intelligent robots into stationary robots and mobile robots and classifies them respectively, and outlines the key technologies among them. Stationary robots need to sense and recognize targets, surrounding environments and workers. This allows precise handling of workpieces and avoids injury to workers. The motion control method of the traditional stationary robot is accomplished through a certain programming logic. In the context of industrial manufacturing 4.0, the motion control of stationary robots has also become more intelligent. Including gesture control, voice control, etc. At the same time, modular robot control frameworks are becoming mainstream. It can decompose the abstract control instruction program into a combination of various program instructions to achieve fast real-time control. Human-robot interaction with stationary robots is also a hot topic in recent years. Among them, teleoperation can realize the staff to control the robot in another relatively safe and comfortable environment. The challenge was to provide the staff with specific information about their surroundings and the widest possible view. In the mobile robot part, it is classified according to the way of movement. The technical focus of mobile robots lies in environmental perception and autonomous navigation path planning. Mobile robots need to sense workers or obstacles in their surroundings. Usually, a complete set of sensor systems and algorithms are required to process sensor data. Autonomous navigation path planning for mobile robots is an important technology. At the same time, it needs to be supported by powerful and fast algorithms. Researchers need to analyze which algorithm needs to be used to endow mobile robots with flexible and fast path planning and navigation capabilities according to specific application conditions and environments. Interaction with mobile robots is also an important aspect. It focuses on the application of natural language processing technology in this field.

However, intelligent robots face some challenges in manufacturing. Although intelligent robots have made remarkable progress in some fields, in complex and changing manufacturing environments, robots need to have more powerful perception, decision-making and execution capabilities. In the part of the stationary robot, how to control it accurately and quickly still has a lot of room for improvement. It requires a combination of powerful control algorithms and machine learning techniques. At the same time, in the human-computer interaction part with the stationary robot, the response speed and accuracy of the operation are still a difficult problem. In addition, it also needs to incorporate environmental awareness technology to provide workers with surrounding environment information and operational views. In terms of mobile robots, the autonomous navigation path planning of mobile robots is a key part of their mission execution. It needs to be combined with environmental awareness technology to achieve directional movement in the factory and avoid workers and obstacles. The difficulty now is how to adapt mobile robots to dynamic environments. Most of the studies are carried out for specific environments and fixed obstacles. Technology and research in this area need to be deepened. In addition, the deployment and maintenance of intelligent robots also require professional technicians and equipment support. This means that we need to further develop and improve the related technologies of intelligent robots to cope with changing manufacturing needs.

6. Conclusion

The development of intelligent robots in the manufacturing industry is a topic that has attracted much attention. This paper analyzes its current situation, challenges, and future development trends through a comprehensive analysis of existing literature and practical cases. Through the research and analysis of relevant literature and practical cases, the application and future development potential of intelligent robots in manufacturing are demonstrated. The main research conclusions of this paper are as follows:

First, the application of intelligent robots in manufacturing is gradually becoming a trend. With the advancement of technology and the transformation and upgrading of the manufacturing industry, the efficiency of traditional manual labor is gradually limited, and the emergence of intelligent robots has solved this problem. Intelligent robots have the characteristics of precision, efficiency, and flexibility, and can complete complex operations and production tasks in the manufacturing industry, improving production efficiency and product quality.

Secondly, intelligent robots face some challenges in the manufacturing industry, including problems in robot perception, decision-making, control, and human-computer interaction. Although intelligent robots have made remarkable progress in some areas, difficulties remain in more complex environments. For example, traditional stationary robots execute fixed control programs in an environment that does not change much to achieve assembly line production work. But in the era of intelligent manufacturing, the working environment of stationary robots is dynamically changing, and specific workpieces need to be processed. This requires it to have a certain degree of flexibility and learning characteristics for production tasks. Mobile robots only need to move along a fixed path in a traditional factory to achieve some functions. However, in the context of intelligent manufacturing, it needs to have certain autonomous navigation path planning capabilities to cope with changing environments and different manufacturing tasks. Human-robot interaction is a key technical part in both stationary and mobile robots, but the technical focus is different. The same point is that both require precise control and real-time fast response.

Finally, intelligent robots hold great promise in manufacturing. With the rapid development of technologies such as artificial intelligence, the performance, and capabilities of intelligent robots will continue to improve. In the future, intelligent robots are expected to be applied in a wider range of manufacturing environments. Intelligent robots can also interact with staff to improve the overall production efficiency of the manufacturing industry.

To sum up, the development prospects of intelligent robots in the manufacturing industry are broad, but they also face a series of challenges. Only by continuously promoting technological development and strengthening collaboration can peoples realize the widespread application of intelligent robots in the manufacturing industry and further accelerate the arrival of the era of intelligent manufacturing 4.0.

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