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Overview of the Application Research on Robots Controlled by Artificial Intelligence

Xiaoyu Liu

School of Future Science and Engineering, Soochow University, Suzhou, China
a13920669890@163.com

Abstract. With the continuous development of robot technology, robots based on artificial intelligence technology have gradually emerged in the public eye and played a crucial role in various fields. The development of robot technology is advancing rapidly with each passing day. It has gradually become an important indicator of a country's innovation capability and industrial competitiveness, and it is also a field of competition among most countries globally. This article focuses on the roles played by robots in industry, the service industry, and special fields, as well as the technologies utilized. It selects representative robot technologies in the industrial, service, and specialized fields for analysis. By delving deeply into the development history of robot technology and comparing it to the robot technologies currently in use, this article provides a summary and conclusion. Robot technology has now reached a considerable scale, encompassing fields such as algorithms, mechanical structures, and so on. Robot technology will also maintain a trend of rapid development in the future.

Keywords: robot, artificial intelligence, technology

1. Introduction

Robot technology has now entered a period of rapid development. Several countries have announced strategic initiatives related to robot development, such as the Winning the Race: America's Artificial Action Plan in the United States, the "Japan’s Robot Strategy" in Japan, the Fourth Basic Plan for Intelligent Robots in South Korea and The High-Tech Strategy 2025 Progress Report, HTS 2025 in Germany. In the Opinions of the State Council on Further Implementing the “Artificial Intelligence+” Initiative, China clearly states that it will focus on strengthening the research and development of "artificial intelligence+" science and technology and promoting the industrial development of "artificial intelligence+" [1]. The integration of robots and artificial intelligence has become a general trend nowadays.

In addition, industrial robot technology is constantly upgrading, the intelligence level of service robots is continuously improving, and specialized robots are also playing an indispensable role in special fields such as disaster relief, search and detection. Robot technology has gradually expanded from simple human-robot interaction to various fields [2]. The era we are in now is no longer one where robots merely resemble humans, but rather one where the focus is on how to make robots think like humans.

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In the face of the rapid growth of the market and the continuous transformation of robot technology, this article summarizes typical robot technologies currently being applied in industry, service industry, and special fields, aiming to promote more intelligent, miniaturized and integrated Chinese robot technology.

2. Industry

2.1. The current development status of industrial robots

Industrial robotics is a highly intelligent and integrated technology in automated production. Since the 1980s, under the guidance of relevant policies, China has invested a lot of manpower, material resources, and financial resources to develop industrial robotics technology. Up to now, China has established many industrial robotics industrial bases and has a very mature industrial production chain, which enables it to produce self-developed industrial robots [3].

Artificial intelligence technology has also been greatly utilized in the field of industrial robots. For example, deep learning algorithm technology enables industrial robots to adaptively complete tasks such as path planning, grasping, and recognition based on the perception of their own sensors during work [4].

2.2. Technical application of industrial robots

2.2.1. Intelligent perception and recognition technology

With the comprehensive upgrade of artificial intelligence algorithms, the intelligent perception and recognition system of industrial robots has entered the era of artificial intelligence. The intelligent perception system acquires surrounding environmental information through sensors and ultimately makes decisions. Any action completed on the production line can be accurately captured by the system, even the movement of personnel. Moreover, it can continuously optimize itself through deep learning. Industrial robots not only complete work according to preset programs but also can complete the "perception-decision-control" process when facing complex working environments. This enables them to adjust path planning and pose adjustment in a timely manner according to different production needs. This technology greatly improves the learning ability of robots [4,5].

2.2.2. Adaptive control and optimization technology

Artificial intelligence systems play an irreplaceable role in industrial robots. Leveraging their powerful machine learning and deep learning algorithms to perceive changes in the surrounding environment, industrial robots can manage any step in the production process, including product quality inspection and timing nodes. Everything on the production line can be accurately perceived by the artificial intelligence system, which controls the industrial robots to make corresponding decisions and adjustments. This ensures product quality, improves product quality, and reduces the rate of defective products. The artificial intelligence system can also perceive the working habits of workers, and provide timely feedback to the robot based on the worker's pose, hand trajectory, and even gaze during assembly, thereby changing the robot's working mode to match the worker's working habits, improving work efficiency, enhancing adaptability to different production needs, and adjusting timing [5].

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2.2.3. Multi-modal large model technology

Relying on single-modality industrial robots can no longer meet the growing market demand. For example, relying solely on vision will lead to a significant decrease in the success rate of grasping when the sensor is obstructed, while relying solely on force sensing will result in an inability to instantly perceive minor changes in force during work. Therefore, multi-modal large model technology has emerged. It no longer relies on the function of a single modality, but instead improves the robot's environmental perception and decision-making capabilities through the collaborative operation of multiple modalities such as vision, touch, and language. The voice module can be used for work instruction input. The vision module can provide real-time data of the work scene. The two work together to form the robot's data perception and processing system, which completes functions such as path planning for the robot [6].

2.2.4. Multi-robot collaboration and flexible control

Robot work is suitable for processing large components of multiple models and small batches, which requires multi-robot collaborative work without interference. The end-effector paths of multiple robots need to satisfy the constraints of time and space brought by different process requirements. At any time and any location, singularities and interference with other robots should be avoided. This can be addressed by analyzing the kinematic constraints of multi-robot motion during the writing process. When the robot end-effector establishes rigid contact with the workpiece to be processed, minor deviations in the end-effector may amplify the contact force between the effector and the workpiece, potentially leading to irreversible damage to both the end-effector and the workpiece. Therefore, when performing contact tasks, it becomes essential to integrate a force control unit into the robot control system. This integration enhances the accuracy of the force exerted by the end-effector during contact, thereby realizing compliant control [7].

3. Service industry

3.1. The current development status of service robots

Since 2014, with the gradual commercialization of 4G networks, network communication speeds have significantly increased, ushering in the rapid development of service robots. More and more manufacturers have begun to develop and produce service robots, enhancing production processes, and their production costs are becoming lower and lower. Service robots are gradually becoming more affordable, intelligent, and lightweight [8]. Currently, service robots can be divided into household service robots and public service robots. The former involves fields such as housekeeping, elderly care, and education, while the latter involves fields such as catering, entertainment, and healthcare. Nowadays, service robots are closely related to people's livelihood in China.

3.2. Technical application of service robots

Service robots face a complex and ever-changing environment, primarily encountering intricate road information and obstacle data. To fulfill the need for path planning in complex road conditions, the A* algorithm can identify the optimal path. The A* algorithm is a type of heuristic search algorithm that seeks the path with the lowest cost through multiple nodes on a graphical plane [9].

The evaluation function of the A* algorithm is:

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$$F(n)=G(n)+H(n) \tag{1}$$

In the formula, n represents the position of the current node, F(n) denotes the evaluation of each possible probe point, G(n) signifies the cost from the starting search point to the current point, and H(n) indicates the evaluation from the current node to the target node.

However, the traditional A* algorithm has high computational complexity and slow computation speed. Therefore, based on this, the A* algorithm is improved by adding a coefficient W before H(n), thereby changing the weight of H(n). The modified evaluation function is:

$$F(n)=G(n)+W*H(n) \tag{2}$$

The value of the coefficient W should be matched with actual road conditions, such as the number of obstacles and search time. The above methods can significantly reduce computation time [10].

3.3. DWA algorithms

The Dynamic Window Approach (DWA) is a classic local path planning method specifically designed for obstacle avoidance in mobile robots. Given the robot's starting and ending points, the robot calculates the most appropriate linear and angular velocities to complete the path and avoid obstacles.

The evaluation function of the dynamic window method is:

$$Cost(v,\phi)=\alpha Dist(v,\phi)+\lambda Head(v,\phi)+\eta Vel(v,\phi) \tag{3}$$

$Cost(v,\phi)$ is used to evaluate the satisfaction level of the current trajectory, $Dist(v,\phi)$ to evaluate the degree of contact between the trajectory and obstacles, $Head(v,\phi)$ to evaluate the closeness of the trajectory to the global path, and $Vel(v,\phi)$ to evaluate the quality of the current speed. α , λ , and η are the weighting coefficients of the corresponding cost functions.

However, the traditional dynamic window method treats the robot as a point mass for path planning, ignoring its physical volume. This leads to a failure to slow down in time during obstacle avoidance, posing a collision risk. Therefore, a safety factor is introduced to increase the safety range around the robot, reduce the collision risk between the robot and obstacles, and enhance safety [9].

3.4. YOLO algorithms

The YOLO algorithm is a real-time object detection algorithm. However, when service robots face complex scenes with multiple obstructions, the features of the target objects are not clearly identifiable, affecting the accuracy of target recognition. Therefore, the improved YOLOv7 network model emerges as the times require, which includes a backbone network, a neck network, and a head network. Through the depthwish over-parameterized module (Figure 1), a deep over-parameterized efficient aggregation network is constructed.

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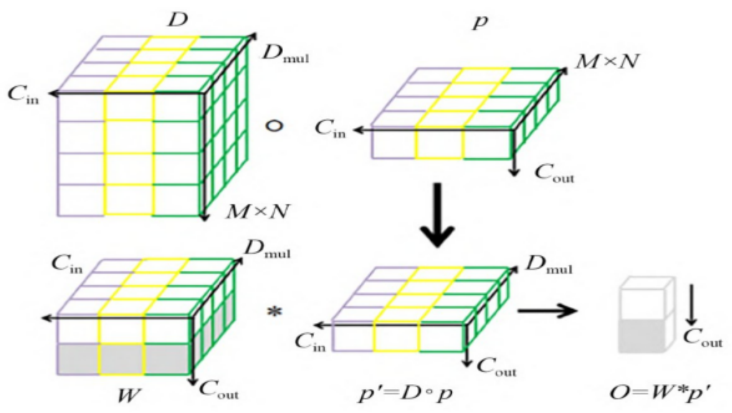

Figure 1. Depthwish over-parameterized mould [11]

The output result is:

$$O=W^*(D\circ p) \tag{4}$$

p denotes the input feature, D represents the depthwise convolution kernel, ∘ signifies the depthwise over-parameterized operation, M and N indicate the spatial dimensions of the input vector. Cin and Cout represent the number of input and output vector channels, respectively, and * denotes the conventional convolution operator.

By collecting a large amount of data and inputting it into the YOLOv7 network model, we continuously train the model through deep learning, update the network parameters, and save the final model [11].

The YOLOv7 algorithm constructed based on this has significantly improved the accuracy of object recognition under occlusion conditions, enhancing its adaptability.

4. Specialized field

4.1. The current development status of the specialized robots

Compared to ordinary robots, specialized robots operate in harsher environments and under more adverse conditions. Currently, the maturity of specialized robot technology is gradually increasing, leading to the emergence of various types of special robots, such as firefighting robots, explosive ordnance disposal robots, search and rescue robots, autonomous underwater vehicles and space robots. The consumer market for specialized robots is gradually expanding, and the industrial chain is becoming more mature.

4.2. Technical application of specialized robots

4.2.1. Search and rescue robot

With the frequent occurrence of natural disasters in recent years, search and rescue robots have played a crucial role in rescuing the lives of disaster victims. Nowadays, search and rescue robots utilize autonomous exploration algorithms. This algorithm extracts feature points through laser radar and finds the correlation between these points. It matches feature points from frame to frame to estimate the pose of the laser radar. After obtaining the poses of multiple adjacent frames, it matches

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them with the global map to ultimately construct a three-dimensional laser radar map. Based on this, the map is segmented, obstacles are identified, and finally, the algorithm is used to solve. Based on this autonomous exploration algorithm, unknown areas can be gradually explored and a disaster area map can be constructed [12]. The continuous updating and iteration of search and rescue robots in recent years have given people more hope for survival in the face of disasters, greatly improved the efficiency and success rate of search and rescue personnel, and ensured the safety of people's lives.

4.2.2. Space robot

Space has now become a field that countries are vying to dominate, and the development of space robots will undoubtedly greatly enhance China's competitiveness in space. In the complex environment of space, visual perception and positioning are particularly crucial. Compared to region-based image matching algorithms, feature-based image matching algorithms can perform image matching on the feature points of the target, thereby greatly reducing the computational load, but the matching accuracy is more susceptible to external interference. When robots are working, they cannot make completely autonomous decisions and require human intervention through teleoperation. Teleoperation technology has been widely applied in robots across various countries, such as Germany's SSRMS and China's CSSRMS.he master-slave force feedback teleoperation mode can feed back the interaction forces between the robot and the environment to the operator, who can adjust the robot's working state based on this, thus improving the intuitive operation, enhancing the timeliness of information interaction, and enhancing the stability of control [13].

4.2.3. Autonomous Underwater Vehicle (AUV)

The ocean covers 70% of the Earth's surface and is rich in resources. With technological advancements, marine resources are gradually being utilized, and underwater exploration robots have become essential tools for marine operations. AUVs primarily perform path planning through three methods: path following, trajectory tracking, and stabilization control. Path following is a static tracking method that can be used to avoid obstacles, trajectory tracking is a dynamic tracking method that can be used for target following, and stabilization control can maintain a steady state for hovering at a fixed point. AUVs can also enhance their perception and decision-making capabilities through deep learning algorithms. Neural networks, which are the basic components of deep learning, can update virtual control signals online based on estimates of model parameter uncertainties and external disturbances. The sliding mode variable structure algorithm improves the anti-disturbance capability of AUVs [14]. AUVs integrate multiple algorithms to ensure efficient and accurate completion of predetermined tasks.

5. Future development trends of robots

5.1. Intelligent

Although robots today, aided by artificial intelligence algorithms, can complete most tasks, human intervention is still required. Therefore, robots in the future need to become more intelligent. Firstly, enhance the perception ability to analyze the surrounding environment more precisely. Secondly, improve the decision-making ability to make autonomous decisions in complex work environments.

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5.2. Miniaturized

Currently, robots employed in certain applications suffer from the drawback of being excessively large, particularly in specific domains such as military and healthcare. Robots applied in these fields should be further miniaturized.

5.3. Luster operation

A swarm robot consists of multiple individual robots. To enhance efficiency, these robots can facilitate the exchange of information among themselves, fostering behavioral coordination and better adapting to complex tasks in industrial manufacturing environments. Intelligent robots can more effectively accomplish large-scale equipment manufacturing and processing tasks, thereby reducing costs and increasing efficiency [7].

5.4. Explainable artificial intelligence

With the continuous advancement of artificial intelligence technology, the demand for interpretability in AI is also on the rise. Robots are not only expected to be executors but also decision-makers, capable of executing tasks while incorporating reasonable explanations and feedback from users. This enables executors to make timely adjustments to the robot's working status [5].

6. Conclusion

As one of the most crucial products in today's digital economy, robots have become an integral part of people's daily lives. Cooperation and competition among countries in the field of robotics are intensifying. The gradual maturity of robotics technology and the high degree of self-sufficiency in industrial lines have become important pillars driving national economic development, promoting industrial upgrading, and safeguarding national security. With strong policy support from China, many robotics companies have been established, such as DeepSeek, Unitree Robotics, and Deep Robotics. Chinese education is also emphasizing the cultivation of innovative and composite talents for the research and development of new robots and artificial intelligence algorithms. In the future, China's robotics technology will become more mature, leading the world in the field of robotics, and will have a more mature and expansive market.

Nowadays, artificial intelligence algorithms are highly integrated with robots, with deep learning, neural networks, and visual perception being representative technologies. Industrial robots can complete multi-cluster collaborative work and multi-modal collaborative work through artificial intelligence algorithms. Service robots can complete path planning and environmental perception through artificial intelligence algorithms. Special robots can complete visual recognition, detection, and search through artificial intelligence algorithms. However, with the continuous development of technology, the types of robots and artificial intelligence algorithms are rapidly evolving, and their categories are diverse. This article has certain limitations. In the future, further summarization and induction will be conducted in the face of continuously emerging new robots and new algorithms.

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