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Research on the Application of Construction Robots in the Context of Construction Industrialization

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Abstract: Based on the original construction technology, construction robots are realized by integrating industrial information technology, and construction robots are used to replace manual labor in completing construction projects. China's research on construction robots is still in its early stages. Research efforts need to be increased in order to promote better applications of construction robots. To this end, by analyzing the application of modern construction robots, we conduct a comprehensive study on the development of construction robots to ensure that construction robots can be widely used in the future.

Keywords: Construction engineering; Robot; Intelligence; Construction technology

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1. Introduction

Upgrading the intelligent construction industry is one of the effective ways to solve many problems in the construction industry. In the broad sense, construction robots include all robotic equipment related to the entire life cycle of a building. In the narrow sense, construction robots specifically refer to robotic equipment closely related to the construction operations, usually one that performs specific construction tasks such as masonry, cutting, welding, etc., in building prefabrication or construction processes. The output value of China's construction industry continues to expand, which also provides sufficient space for development for the construction robot industry. It is estimated that by 2023, the application scale of China's construction robot industry will reach 22.4 billion yuan [1]. Although China's patented construction robots are currently growing rapidly, most of them are still in the research and development stage, and have not entered the commercial field or achieved large-scale mass production, and the penetration rate of downstream application is less than 1%. By implementing and using construction robots, the construction industry has saved some labor costs, improved construction efficiency and construction quality, and effectively solved problems existing in construction projects. Since modern construction robots are still in the early stages of research and application, large-scale production and utilization have not yet been achieved. Construction robots have only been applied to actual construction with the reform and development of the construction industry in recent years [2]. The professional content and construction scope involved in the research of construction robots are relatively wide, including construction survey, maintenance, demolition, etc. However, in order to ensure the quality of construction, the development of construction robots needs to be further clarified to achieve intelligent and high-precision standards [3].

2. Characteristics of industrial robots

2.1. Programming

The development of production automation lies in flexible startup. Industrial robots can change based on changes in the working environment. Therefore, it plays an important role in flexible production with batch consumption, variety, and high efficiency, which is the key to flexible manufacturing.

2.2. Personification

Industrial robots have legs, arms, claws, and other parts similar to humans in terms of mechanized structure, and are controlled by computers [4]. Therefore, intelligent industrial robots have biosensors related to humans. For example, skin type, power type, vision, speaker, language, and other sensors. Sensor applications improve the ability of industrial robots to adapt to the surrounding environment.

2.3. Universality

General industrial robots also have versatility when performing different tasks. Different operating tasks can be performed by replacing the hand-operated end operator.

2.4. Industrial machine technology involves a wide range of disciplines

The combination of machinery and microelectronics creates mechatronics technology. With the emergence of the third generation of intelligent robots, it can acquire sensors for external environment information, as well as the memory function, language understanding ability, image recognition ability, and reasoning and judgment ability of normal artificial intelligence (AI). These are all part of the application of microelectronic technology, especially the application of the closely related computer technology. Therefore, the development of robotics can promote the development of other related technologies, and the development and application level of robotics can also verify a country's scientific and technological level as well as industrialization level.

3. Applications of construction robots

Labor shortages in the construction industry are growing, with increasingly fewer young people planning to join the construction industry. At the same time, construction is also accompanied by serious safety issues. According to rough statistics, about 30% of occupational accidents occur in the construction industry, and the risk of fatal accidents in the construction industry is four times that of other industries [5]. At the same time, labor productivity and cost-effectiveness issues are also key issues in construction.

Robots can solve health and safety issues on construction sites, complete the handling of large and heavy loads, and replace workers in working in polluted areas. In addition, robots can complete complex and repetitive processing tasks and perform dangerous tasks. Through automated construction methods, the shortage of labor and skilled workers in the industry can be solved, and young people can also be attracted to join the construction field. From a cost-benefit perspective, taking the use of concrete materials as an example, compared with traditional construction methods, three-dimensional (3D) concrete printing can save 30–60% construction materials and 50–80% labor costs, and shorten the construction period by 50–70%, thereby significantly reducing the production costs in construction.

3.1. Ground construction robot

In 2014, members of the Singapore Future City Experiment collaborated with personnel from ETH Zurich and developed a floor-tiling robot, as shown in **Figure 1**. The structure of the floor-tiling robot mainly consists of two parts.

(1) Manipulator: The end of the manipulator is equipped with concrete sprayers and suction cups. Sensors are installed at both ends of the equipment to identify and locate the space of the floor tiles, and effectively identify the boundary of the floor tiles. With the application of computer programs, calculations are used to ensure the accuracy of floor tile paving.

(2) Autonomous mobile robot navigation platform: The platform mainly controls the moving speed and range of the robot. It has navigation and control functions, which can promote the flexible movement of the floor-tiling robot, and can be used in the floor tile laying construction of large and small buildings.

The core component of the floor-tiling robot is the robot positioning system, and laser sensors are installed inside the robot. Generally, there are about four laser sensors. If too many laser sensors are installed, it will have a certain impact on the operating accuracy of the positioning system, and even cause errors in positioning data information. In the manufacturing of robots, it is necessary to accurately control the number of laser sensors to ensure the positioning accuracy of the robot. However, there are still many shortcomings in the actual application of floor-tiling robots, which need to be improved and optimized.

Figure 1. Floor-tiling robot

3.2. Demolition/removal robot

Construction projects involve earth excavation, waste disassembly and renovation, earth removal, and other construction contents, which increase the difficulty and danger of construction. Moreover, the process of earthwork will produce a large amount of dust, causing air pollution to the surrounding environment. Building demolition relies heavily on manual control of machines, and the risk of demolition is relatively high. It is easy to make disassembly errors, which poses a life safety threat to on-site construction technicians, consumes a large amount of human and physical resources, and contradicts China’s green, environmentally friendly, and energy-saving construction concept [6]. In order to effectively solve this construction problem, relevant departments have developed a demolition robot through the effective use of modern information technology, thereby changing the traditional mode of manually driving the demolition equipment and realizing an operation mode of impact crushing using robot. When the robot is carrying out impact crushing operations, it mainly uses a rocker to automatically and effectively control the robot, thus keeping construction workers away from the demolition site, and ensuring construction safety at the demolition site. In addition, the demolition robot is small and flexible, and can be used indoors or in demolition work of small building. However, demolition robots are widely used in rescue work.

3.3. 3D printing construction robot

There are relatively many control systems involved in 3D printing construction robots, including three-dimensional computer-aided design systems, robot control systems, engineering material management systems, etc. 3D printing construction robots can build solid models of three-dimensional building by using 3D printer based on existing three-dimensional model. With the effective use of 3D printing construction robots, the construction process can be simplified, thereby saving construction time and improving construction efficiency. For example, the AIBuild startup company in London, UK, has realized a 3D printed AI robot with modern information technology. The robot has 3D printing functions, AI algorithm functions, and industrial robot control functions. In actual use, the robot is visually controlled through AI algorithms. Technology can avoid blindly executing computer instructions, and with the effective use of this technology, an information feedback loop can be realized, and problems existing in the robot’s self-test printing process can be promptly adjusted, which will play a role in improving the efficiency of architectural 3D printing.

3.4. Floor grinding robot

In cement floor grinding, although the use of ground grinders can reduce labor consumption and improve grinding efficiency, the dust treatment effect is relatively low. It is inconvenient to adjust the tie rod during the operation of the grinder, and this situation often occurs during transportation. The bottom of the device collides with the ground, causing damage to the ground [7]. To this end, by utilizing industrial information technology, a floor grinding robot is realized. The robot changes the rotation angle of the tie rod by activating the device knob and then pushing the knob to move in the first chute. In addition, during the operation of the floor grinding robot, the brush at the bottom of the casing will automatically clean the polished dust, and a vacuum will be used to collect the dust in the channel. The dust generated after polishing will cause harm to the human respiratory system.

3.5. Spraying robot

Spraying robots are also called spray painting robots. They can complete automatic painting or automatic spraying during operation. This technology is mainly based on a robot, which combines computer information technology and control systems, including mailboxes and electrodes. Driven by hydraulic equipment, it can automatically complete the painting work in construction projects. Spraying robots are environmentally friendly and efficient. They meet the current painting needs and can also replace manual spraying work.

3.6. Vision-guided robot

With the continuous development of science and technology, intelligent technology and automation technology have been widely used in industrial production, which include robot vision. However, there are still problems in the application of robot vision. When there is loud noise in the industrial production workshop, the machine vision system will be affected, thus reducing the equipment sensitivity and damaging the performance of the equipment.

In the industrial production process, the application of machine vision systems has also attracted much attention. Some industrial production sites have relatively high temperatures, while some have low temperatures. At this time, the machine equipment must have anti-interference capabilities and strong stability. When collecting images, it is affected by the intensity of light. When the light is relatively low, it will affect the extraction, recognition, and analysis of the target image, causing the increase in the rate of defective products and affecting its production efficiency and accuracy. The current focus lies in how to solve these problems, improve machine performance, recognize images, and efficiently apply machine vision technology in industrial production. Firstly, efficient image processing software and hardware should be developed. The speed of image acquisition is partly affected by the speed of the hardware. High-quality hardware can reduce the burden on the host and has a direct impact on its system resolution, acquisition efficiency, image processing speed, and processing and analysis efficiency. High-quality software is also critical, which can significantly increase the speed of machine command execution [8]. Secondly, intelligent algorithms with strong adaptability, good stability, and high efficiency should be developed. Intelligent, stable, and efficient intelligent algorithms can increase system analysis and processing speed, improve the system's anti-interference ability in complex environments, and make the system more stable.

4. Key technologies for the development of construction robots

4.1. Structural design

At this stage, the structural volume of China's construction robots is relatively large, and the robot's own gravity is relatively high, which has a certain impact on the movement of the robot. For this reason, in the future development of construction robots, it is necessary to simplify the robot structure and adopt lightweight materials, mainly micron-level micro-motion materials, which can improve the motion resolution of the robot. By using composite materials instead of aluminum alloy materials for robots, it can not only reduce the manufacturing cost of the robot, but also reduce the gravity of the robot, and ensure the structural strength and hardness of the robot.

4.2. Sensor technology

In the future development of construction robots, sensor technology will be fully applied to meet the robot's functional requirements in information transmission [9]. Voice-activated sensors or visual sensors can be installed in the robot structure to accurately control the operation of the robot. This enables construction robots to operate effectively in positional work environments. For example, applying a pressure sensor based on process, voltage, and temperature (PVT) phase characteristics to the structure of a construction robot can effectively improve the pressure of the construction robot. The maximum pressure can exceed 100 MPa. Alternatively, image restoration technology can be used to realize a visual sensor. In construction robots, they can be used as the robot's "eyes" to effectively detect the surrounding environment. Humans can also be used to speak to the machine control system to implement voice-activated sensors, which can be used in construction robots to recognize language and make correct operational judgments.

4.3. Navigation and positioning technology

In the future development of construction robots, genetic algorithms or ant algorithms should be implemented based on the movement of construction robots to effectively assist robot sensors, control safe movement positions, avoid surrounding obstacles in a timely manner, and achieve accurate positioning. For example, the ultrasonic indoor navigation and positioning system can be used to calculate the ultrasonic reception time difference after emitting ultrasonic waves, so as to grasp the mobile position of the robot. During the test, the positioning accuracy of the robot was controlled. The laser navigation system of the construction robot can also be optimized and modified, a fusion encoder or an unscented Kalman filter (UKF) sensor can be added to the robot structure to comprehensively improve the navigation and positioning accuracy of the construction robot [10].

5. Conclusion

In summary, the realization of construction robots has laid a good foundation for further development in the construction field, and it is also an important new topic currently being studied in the construction field. There are relatively many types of construction robots. To effectively leverage the advantages of construction robots, comprehensive research on construction robots needs to be conducted to achieve high-precision, lightweight, and intelligent construction robots.

Disclosure statement

The author declares no conflict of interest.

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