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Overview of Automatic Spraying Technology for Building Exterior Walls

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Abstract: The spraying robot for building exterior walls is an innovative technology in the field of modern construction. This paper discusses its design structure, application cases, technical benefits, and industrial impacts. Research shows that this type of robot improves the efficiency and quality of exterior wall construction. Its intelligent design enhances operation accuracy and safety, reduces costs and risks, and strengthens application ability in complex environments, showing broad application prospects and symbolizing the development trend of intelligence and automation in the industry. In the future, it is necessary to strengthen its intelligence and adaptive ability further, explore multi-function design, promote automation technology, and ensure construction safety and economic benefits.

Keywords: Building; Exterior walls; Spraying; Robot; Automation

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1. Introduction

In high-rise buildings, exterior wall spraying is of great significance as it can not only enhance the aesthetic sense of the building but also protect the wall. However, traditional spraying methods have many limitations, such as high safety risks and low efficiency. The emergence of building exterior wall spraying robots provides a solution to the spraying problems of high-rise buildings, showing significant advantages in terms of efficiency, quality control, and safety guarantee, and has a far-reaching impact on the industry's sustainable development and economic benefits. The standards interpreted by Wei *et al.* have detailed provisions for the quality acceptance of building decoration engineering [1]. The application of exterior wall spraying robots must follow these standards to ensure construction quality. Although this literature review covers multiple aspects, it still has deficiencies as it does not cover the latest technological developments and examples. Future research needs to be improved to promote the development and application of exterior wall spraying robots and better meet the requirements of building decoration engineering.

2. Development history of building exterior wall spraying robots

2.1. Early research and technology

In the 1990s, some foreign universities and companies began to research relevant technologies. The wall-climbing robot developed by Brown University in the United States in 2005 played a role in anti-terrorist operations. In the same year, AutoCrawLLC in the United States launched the "AutoCrawler" tracked robot [2,3]. However, the functions of the initial robots were relatively singular.

With the progress of technology, research has developed towards high efficiency and intelligence. Many scholars have proposed new schemes. For example, the intelligent spraying robot for high-rise building exterior walls proposed by Liang *et al.* has optimized wind-resistance ability and working safety [4]. Many research institutions in China are also promoting the maturity of the technology [2,3].

Building exterior wall spraying robots have evolved from being single-function to multi-function. Although the early designs had a leading role, there were still many problems. Yang *et al.* pointed out that there is still much room for improvement, especially in improving the intelligence level and overall production efficiency [5].

2.2. Technological advances in recent years

China's research history in this regard started relatively late, but it has developed rapidly in recent years. Research teams from the Harbin Institute of Technology and Hefei University of Technology have respectively developed a tracked magnetic-adsorption robot and an external hanging spraying robot combined with a hanging basket [2]. Chengdu FISIP Technology Co., Ltd. has attempted to improve the application performance of spraying robots in high-rise buildings through the design of a suspension mechanism [3]. These achievements all indicate that China has gradually developed the ability of independent innovation in the design and use of building exterior wall spraying robots.

Internationally, the automation process of spraying robot technology is also accelerating. Mohanasundaram *et al.* pointed out that some foreign high-rise building spraying solutions have simplified exterior wall spraying operations through wireless control and automated control systems [6]. In addition, spraying robots have gradually incorporated intelligent and digital technologies. Through path planning and robot cooperation, the operation efficiency has been improved, especially in the spraying applications of high-rise buildings [5].

To sum up, the development of building exterior wall spraying robots is gradually transitioning from initial mechanization to intelligence and automation, and the future development potential is still huge. With the continuous progress of technology, the application of exterior wall spraying robots will be more extensive and is expected to occupy an important position in the construction industry.

3. Related technologies of building exterior wall spraying robots

3.1. Sensor and visual recognition technology

In recent years, the research on sensor and visual recognition technologies in the field of building exterior wall spraying robots has become increasingly important. Hou emphasized the construction of the digital intelligent recognition system of high-rise building exterior wall spraying robots and proposed an image-based intelligent recognition scheme and a building information modeling (BIM)-system-based recognition scheme, which has improved the adaptability and flexibility of the robot in complex environments to a certain extent [3].

Rong focused on the path planning of mobile spraying robots and developed a two-dimensional wall-surface full-coverage spraying operation path planning algorithm, improving the efficiency and safety of spraying [7].

Yang mainly solved the problem of autonomous navigation through the modular design method, paving the way for the successful practical application of intelligent spraying robots [5].

Liang *et al.* with panoramic cameras and laser sensors as the core, enabled the robot to obtain immediate feedback on the spraying environment and monitor the pose of the lower body and wind speed in real-time, thus ensuring the accuracy and safety of the spraying process [4]. Huang and Wu adopted an intelligent recognition method based on oblique photography and combined the robot with the Internet of Things monitoring technology, demonstrating the development potential of future intelligent building exterior wall spraying robots [8]. Also, Zhi designed a visually intelligent auxiliary guidance system for building exterior wall spraying robots [9]. This system combined optical testing technology, computer vision, and deep-learning algorithms to achieve non-contact measurement and provide guidance for the operation of spraying robots.

In general, sensor and visual recognition technologies promote the intelligent and digital development of building exterior wall spraying, improve the accuracy and safety of operations, promote the development of the industry towards high-efficiency and high-quality, and provide support for intelligent building technology.

3.2. Motion planning and path optimization

Motion planning and path optimization determine the working efficiency of building exterior wall spraying robots. Bawane *et al.* proposed a library-based automatic painting system, providing a reference for spraying path planning [10]. Hou used the value engineering principle to evaluate the functions of the robot, providing data support for the improvement of functional areas and a decision-making basis for motion planning [3].

Rong focused on the path planning of indoor wall-surface mobile spraying, designed a two-dimensional full-coverage spraying path planning scheme based on the improved A* algorithm, improved the operation safety and efficiency, and established a simulation platform to verify the effectiveness of the algorithm [7].

Wang established the kinematic and non-kinematic parameter identification models of the robot to improve the motion accuracy [11]. Liang *et al.* realized the motion state tracking of the robot through the design of the control system combined with laser sensors and gyroscopes, enhancing the robot's autonomy and intelligence [4]. Li *et al.* also studied the structural design and function integration of exterior wall spraying robots, focusing on intelligent recognition and operation path planning in complex environments [12].

To sum up, the research on motion planning and path optimization of spraying robots has been relatively comprehensive. In the future, the development of this technology will enhance the intelligence level of robots and make their application more extensive.

4. Cost-benefit and performance evaluation of building exterior wall spraying robots: impact on industry development

4.1. Cost-benefit analysis

In terms of cost-benefit analysis of project costs, Huang and Wu pointed out that intelligent spraying robots have significant economic benefits in improving construction efficiency and reducing operational risks [8]. Similarly, Wang mentioned that spraying robots have obvious advantages in reducing workers' health risks and labor costs, and the construction efficiency has been increased by 5.4 times [13]. The research of Mohanasundaram *et al.* further emphasized the multiple advantages of the automated exterior wall coating system in reducing maintenance costs, and improving efficiency and safety [6].

In general, spraying robots have good economic value in improving construction efficiency, laying the

foundation for the future development of the construction industry.

4.2. Performance evaluation

Building exterior wall spraying robots are widely used in intelligent building projects. Zhu designed the robot structure and conducted simulation analysis. At the same time, the innovative design of its control system has qualitatively improved the operation accuracy of the spraying robot [2]. Hou proposed an Internet of Things based monitoring and control platform, combined with image recognition and BIM technology, improving the operation ability and accuracy [3].

Liang *et al.* focused on the wind resistance and stability of the robot in high-rise building work [4]. Through good structural design, the reliable operation of the robot under various climatic conditions is ensured, greatly improving the safety and spraying quality of the spraying process.

4.3. Impact on industry development

Building exterior wall spraying robots has a huge impact on the future development of the construction industry. Zhang *et al.* systematically elaborated on the classification of exterior wall spraying robots and clarified various regulations and standard requirements related to construction operations [14]. This provides an important standard basis for the design and application of exterior wall spraying robots and promotes the process of industry standardization.

The research of Liang *et al.* has solved the problems of stability and adaptability of the robot in complex environments. This design innovation provides a new solution for the construction of high-rise buildings and promotes the development of the industry towards more complexity and intelligence [4].

In addition, the research of Zujia *et al.* emphasized the application of composite materials in spraying robots, which provides theoretical support for reducing the manufacturing cost and improving the performance of the robot, reflecting the trend and potential of using new materials in the high-rise building field [15].

In summary, the current literature research covers multiple levels, highlighting the advantages of the robot. With the maturity of the technology, it will play an important role in the construction industry and promote modernization and intelligent processes.

5. Conclusion

5.1. Summary of main findings

The research on building exterior wall spraying robots involves multiple aspects. During construction, it significantly improves the efficiency and spraying quality and performs excellently in complex environments. Its intelligent design enhances operation accuracy and safety and reduces cost and risk. Moreover, computer simulation software provides support for its design, and the digital intelligent recognition system also improves the spraying accuracy of the robot. In general, spraying robots are promoting the development of the construction industry towards intelligence and automation. In the future, it is still necessary to improve its intelligence and adaptive ability, explore multi-function design, and promote automation technology.

5.2. Future research directions

Future research directions focus on the following key areas to further promote the development and application of building exterior wall spraying robots.

(1) Research and develop intelligent adaptive control systems and integrate advanced algorithms to cope with different scenarios.
(2) Design multi-function robots with functions such as cleaning, detection, and repair.
(3) Combine big data and cloud computing to achieve real-time monitoring and data analysis.
(4) Strengthen the adaptability to complex environments and enhance motion control.
(5) Integrate material optimization and environmental protection technologies to promote the development of green buildings.
(6) Explore human-machine collaboration to improve efficiency and safety.

5.3. Suggestions for the industry

The development of building exterior wall spraying robots has both opportunities and challenges. To promote its development and application, the suggestions are as follows.

(1) Improve the level of intelligence and automation, use deep learning and artificial intelligence algorithms to enhance the adaptive ability, improve construction efficiency and quality, and reduce the dependence on labor.
(2) Promote multi-functional design, integrate multiple operation capabilities, increase value, and reduce costs.
(3) Strengthen the research on environmental adaptability, form the best plan for different environments, and establish a database to analyze data to provide a reference for construction.
(4) Promote the standardization and normalization of the industry. Relevant parties should establish standards and specifications to ensure construction safety and quality and improve the image and credibility. Implementing these suggestions will promote the wide application of robots and accelerate the intelligent and modernization process of the construction industry.

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Disclosure statement

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