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Research on Automated Building Construction Robot Technology based on BIM Technology

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Abstract

To promote the innovation and upgrading of China's construction industry, a cutting-edge automated building robot system has been designed. This system deeply integrates Building Information Modeling technology to precisely construct a comprehensive housing information model from multiple perspectives. By using the advanced You Only Look Once object detection algorithm, it accurately identifies the building blocks needed for construction and commands the robots to carry out construction tasks. Equipped with multi-jaw mechanical claws, it can flexibly grasp various building materials and achieve efficient construction from multiple angles, contributing to the continuous development of the construction industry.

Keywords

Building Robot; Multi-Fixture; Mechanical Claw; Building Information Modeling Techology; Object Detection Algorithm.

1. Introduction

This project aims to design an automated building robot to reduce labor costs and enhance construction safety. The robot can monitor the construction site in real time, grasp the required building blocks, automatically plan the driving route, and transport the blocks to the designated location to ensure precise construction, leading the construction industry towards intelligence and efficiency.

2. Design of the Mechanical Structure System for Building Robots

(1) Overall Structure of the Building Robot

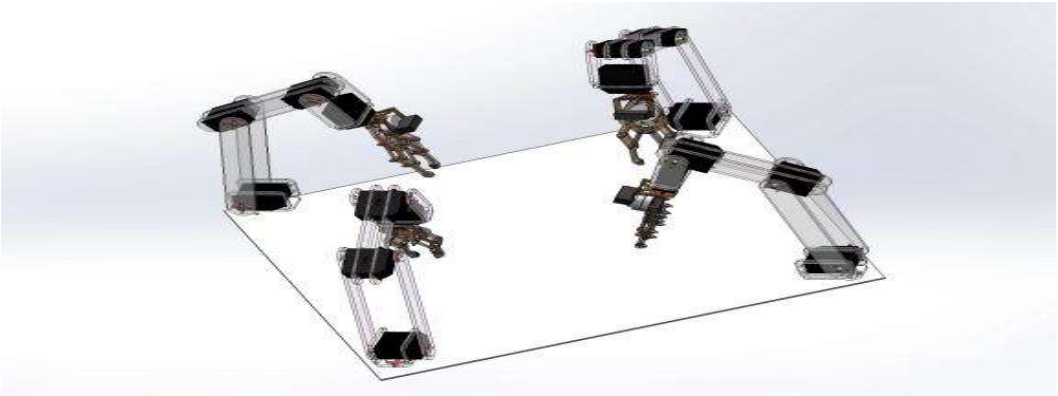

Fig. 1 The overall structure of the robot arm for automated building construction

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The overall structure of the robotic arm is shown in Fig. 1, including key components such as the base, waist, arm, wrist, and end effector. Its design is inspired by the movement patterns of the human arm, enabling flexible operation in three-dimensional space. Through a precise gear transmission mechanism, the accurate meshing of large and small gears not only transmits power but also regulates the speed and direction of movement, ensuring that the building robot can precisely execute the predetermined tasks and demonstrate outstanding performance.[1]

(2) Construction Robot Mechanical Gripper Structure

Using the SolidWorks software, we have meticulously designed a new type of multi-finger mechanical gripper for the construction robot. This mechanical gripper is a clamping device used to grasp or adsorb the objects being transported. Compared to traditional mechanical grippers, this mechanical gripper's left and right swinging is driven by an electric motor. With the cooperation of contact-type universal limit switches, the electric push rod can adjust the swing range of the mechanical gripper in real time to meet the requirements of the change in the grasping range of the mechanical gripper. The axial and circumferential free movement of the mechanical gripper is supported. At the same time, this mechanical gripper can also adjust the force and flexibility by itself to avoid damage and waste to the objects being grasped, and it is also equipped with multi-turn encoders and advanced control systems to ensure a precision of up to millimeters or even finer, perfectly capable of performing high-precision assembly of small objects. The outer layer is made of high-quality materials, ensuring stable operation in harsh environments. Through the work protocol, the staff can monitor the status of the mechanical gripper in real time and promptly obtain fault alerts. This greatly improves the efficiency of construction work. Fig. 2 shows the innovative design of the multi-finger mechanical gripper.[2]

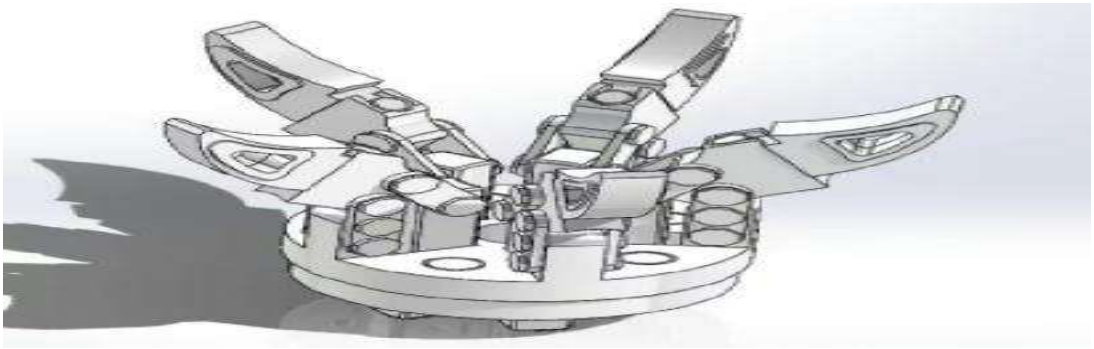

Fig. 2 Building robot multi-fixture mechanical claw entity

two Hardware Design of Building Robot Control System

The core of the hardware design for the building robot is the PLC control system, which is supplemented by detection modules to form an efficient control method, enabling comprehensive management of the building system.

The overall structure of the building robot control system

The automated building construction robot adopts a semi-closed-loop control system. This system integrates PLC as the core and ingeniously combines closed-loop and open-loop control to form a unified and efficient overall control scheme. [3]

(3) Building system control

The detection module mainly includes target recognition, displacement detection, and obstacle avoidance detection.[4]

The target recognition technology is responsible for precisely locating the position and range of the object to be grabbed, ensuring the accuracy of the grasping area. This process relies on advanced target detection technology. Displacement monitoring then monitors the actual range of the object to

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be taken, precisely regulating the movement boundary of the mechanical arm. Obstacle avoidance detection uses a visual obstacle avoidance system, using cameras to capture on-site images, combined with image processing and machine learning algorithms to identify various obstacles and perform real-time path planning to ensure a smooth and unobstructed building construction process.

(4) Building Construction Control Module

The building construction control system integrates two major modules: the building mechanical arm and the grasping and cleaning module. The former precisely controls the start and stop, amplitude, direction, speed and displacement of the mechanical arm. The latter manages the grasping, placement position, cleaning range and height of the objects. The system continuously monitors the external environment. Once it detects any adverse factors such as fire or smoke, it immediately triggers an alarm and automatically stops the operation to ensure the safety of building construction.[5]

3. Software Design of the Building Construction Robot System

In the system software composition of the building construction robot, we have included important components such as the precise software for 3D space model design and the advanced software for target detection. The following text will elaborate in detail on these two crucial software designs.

(1) 3D Space Model Design

In the 3D space model building scene constructed based on BIM technology, the collaborative management platform is endowed with powerful functions through two core technologies - viewing technology and management technology, and it can also support various functions such as the exchange of geographic information. Thus, the BIM collaborative management platform can be successfully completed. Given the large number of participating units in the project, the BIM collaborative management platform adopts an architecture design that separates the data layer from the operation layer. In the data layer, the platform is dedicated to collecting engineering design information, uniformly storing and integrating it, and also strengthening the controllability and security of the data; while in the operation layer, the platform implements refined control of users' access through three control means - user level, object level, and function level.

(2) Creation and Coordination of 3D Space Model

The BIM technology has excellent information sharing capabilities, enabling the construction and maintenance teams to easily obtain project data. Its 2D and 3D simulation functions can realistically present and accurately reflect the entire building. The house drawings provided by BIM support multi-angle observation, allowing staff to intuitively grasp the details of the building. Subsequently, these information is transmitted to the building construction robot, whose target recognition module quickly determines the target position and grasping range; the displacement sensor precisely measures the movement angle and direction; the lifting displacement sensor monitors the position of the mechanical arm, ensuring the precise driver is responsible for the lifting operation, and the pressure point ceramic driver precisely controls its lateral movement and angle rotation, working together to complete the operation efficiently.[6]

(3) Target Detection Design

As shown in Fig. 3, after starting the target detection camera, it is placed at the preset position. The target detection module immediately starts and continuously reads the current image, accurately identifying the category of the target object and the target box. At the same time, it accurately records and displays the coordinates of the upper left corner and the lower right corner of the target box, saves it to the designated file, and this process continues until the end instruction is received.

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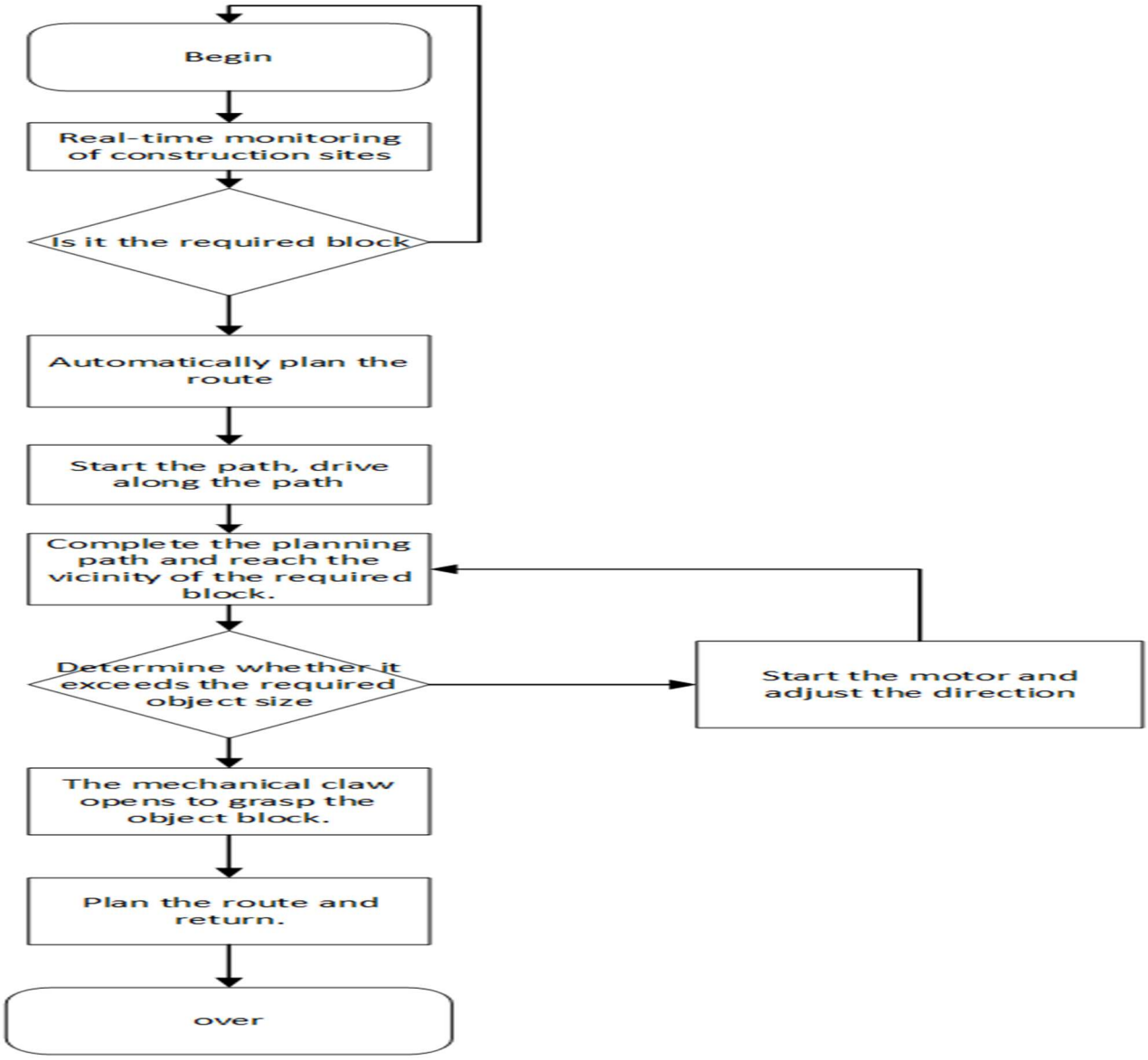

Fig. 3 Object detection flow chart

4. Summary

This project is dedicated to developing an automated building construction robot. While ensuring the safety of workers and improving work efficiency, it is designed with multiple fixture mechanical claws. At the same time, BIM technology is adopted to provide detailed house drawings and convey precise construction information, laying a solid foundation for subsequent construction and effectively guaranteeing the smooth progress of the project. We innovatively integrated target detection technology and developed a new method for automatically identifying required components. This new type of building construction robot will significantly enhance construction safety and efficiency, effectively reduce labor costs, and make a significant contribution to promoting the intelligent, digital, and green development of the construction industry.

Acknowledgments

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