Structure and System Design of Stacking Robot Based on Oil Field Pipe Products

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Abstract. Stacking robot is one of the core equipment of automated warehouse, and it is also the main cargo access equipment. Stacking robot consists of three main parts: control system, measurement and servo system and mechanical system. With the development of computer control technology and logistics storage technology, stacker is widely used and its technical performance is getting better and better. At the same time, in order to meet the requirements of large-scale three-dimensional warehouse, its overall height keeps climbing. Automatic storage has become one of the symbols of enterprise modernization, and stable, reliable and practical stacking robot is the key. The stacking robot is the carrier to realize the flow of materials. It runs back and forth in the high-rise shelf roadway to store or take out the goods, so as to realize the flow of materials. The advantages of automated warehouse must be fully reflected by the stacker. As the most important handling equipment in the three-dimensional warehouse, the stacker requires fast, stable, safe, reliable and accurate operation. In this paper, the structure and system of the stacking robot for oilfield pipe products are analyzed.

Keywords: Stacking Robot, Three-Dimensional Warehouse, Automation

1. Introduction

Automatic three-dimensional warehouse belongs to the category of automatic three-dimensional warehouse, which is a new concept of modern logistics warehousing. Through the equipment of three-dimensional warehouse, the high-level warehouse can be more reasonable, and it is convenient, quick and easy to operate the equipment when accessing goods. Stacking robot is a professional lifting equipment rising along with automated warehouse. It is one of the core equipment of automated warehouse and the main cargo access equipment [1]. Stacking robot consists of three main parts: control system, measurement and servo system and mechanical system. The control system includes an industrial control computer and a memory, which are used to control the input-output interface device for interlocking the robot and peripheral equipment, control the network communication and control the servo system of the robot [2]. The measurement and servo system includes motion...
controller, servo amplifier driver and AC servo motor with position and speed feedback. The mechanical system of the robot includes the stacking robot and the transmission mechanism which converts the rotary motion of the servo motor into the required motion. The advantages of automated warehouse must be fully reflected by the stacker. As the most important handling equipment in the warehouse, the stacker requires fast and stable operation, safety and reliability, and accuracy [3].

With the development of computer control technology and logistics storage technology, the application of stacker is more and more widely, and the technical performance is getting better and better. At the same time, in order to meet the requirements of large-scale three-dimensional warehouse, its overall height keeps climbing. Based on special product storage, the mechanism design of stacking robot needs to be improved in some aspects [4]. The stacking robot is the carrier to realize the flow of materials. It runs back and forth in the high-rise shelf roadway to store or take out the goods, so as to realize the flow of materials. The traditional warehouse only plays the role of storage place for goods, and the only function is static storage of goods [5]. The automatic stereoscopic warehouse adopts supporting handling equipment, which can not only automatically store and store goods in the warehouse according to needs, but also organically connect the production links outside the warehouse. Through computer system management and intelligent handling equipment, the warehouse has become an important link in enterprise storage. As a complex multi degree of freedom system, robot needs to effectively use its own multi-sensor information to perceive the external environment and its own state changes, and adjust its motion actuator, so its control system needs to have high reliability and real-time [6]. Automated three-dimensional storage has become one of the symbols of enterprise modernization, and stable, reliable and practical stacking robot is the key. In this paper, the structure and system of the stacking robot for oilfield pipe products are analyzed.

2. Motion mechanism and sensor system

Automated warehouse plays an important role in modern logistics, which can automatically store and take out materials without direct operation [7]. Automated warehouse and its supporting equipment are the technological products of the development of modern industrial technology, which are of great significance for improving production productivity and reducing capital cost. Stacking robot is generally composed of metal horizontal walking mechanism, lifting mechanism, rotating mechanism, telescopic arm mechanism, grasping mechanism and electrical control cabinet [8]. The control system is based on an industrial control computer, which stores the control program in the memory. This program is fixed. It commands the computer to execute the instructions and control functions of various stacking robots. The information transmission between the operators and the control system is realized through the control panel, programmer and function keys. The industrial control computer regularly detects and scans the control situation. The metal mechanism of stacking robot is the main bearing part of stacking robot, which is mainly carried by double columns, upper beams, two lower beams and rotary table. The industrial control computer supervises and controls the working process and the input and output signals between the control systems. For example, if the required movement is on a certain axis, it will send a command to the axis device. The wrist of the stacking robot is driven by an AC servo motor fixed at the end of the arm, which can change its speed and torque. In actual network transmission, with the change of effective distance between receiver and transmitter, the interaction weight of communication topology often changes dynamically. Adding a new connection edge and changing its topological structure will not affect the rigidity of the graph. Behavior-based controller consists of a series of behaviors, that is, simple basic actions.

The output of each robot is sent to its actuator to control the distributed control of the robot. Because of its particularity, multi-robot vision positioning must be able to transmit information anytime and anywhere. Data acquisition, visual positioning and data receiving modules transmit data through interfaces. The data format is shown in Table 1.
Table 1. Data format

| Name            | Length |
|-----------------|--------|
| Start flag      | 5      |
| Data length     | 9      |
| command word    | 11     |
| Data part       | 16     |
| Termination code| 12     |

For agent individuals, the best path to find is along the negative gradient direction of artificial potential field, that is, the direction in which the function declines fastest. The main controller first receives various sensor data obtained from the co-controller and the moving position information obtained from the positioning computer. The controller processes the information and gives instructions. Automation can greatly improve production efficiency and work efficiency, save energy and reduce consumption of raw materials, improve working conditions and narrow the difference between mental and manual labor. In the static state, the cross-section stress of the frame column of stacker is small. However, because the frame column is in a plane parallel to the track, there is no lateral constraint in the middle of the two column limbs except that there are cross bars at the top and bottom, so the calculated length of the column limbs in this plane is too large [9]. Considering that wireless communication is affected by multipath depletion, shadowing, distance change between transmitter and receiver, it is different from the traditional topological graph model with fixed connection weights. When the number of agents increases, a single camera can't cover the robot's motion space. Aiming at the medium access constraint of wireless communication network, the agent node scheduling protocol is designed by using binary sequence.

By virtual structure method, the distribution of stacking robots is regarded as a virtual rigid structure, and each agent is regarded as a fixed point on the rigid structure. When multiple obstacles are superimposed on each other and the robot performs distributed control, it is necessary to regard the superimposed obstacles as a large virtual obstacle. As shown in Figure 1.

![Figure 1](image-url)

**Figure 1.** Distributed control trajectory of the robot when obstacles are superimposed

With the different actual working conditions, the stacking robot can adopt various control modes. From simple programming automation, small computer control to microprocessor control, etc., the structure of robot control system can also be quite different. In the automated warehouse system, the storage equipment uses high-rise shelves to store goods, and the access equipment is mainly roadway stacking cranes, combined with the supporting equipment for warehousing and outbound operations. In reality, it is often necessary for multiple mobile units to move from the initial position to a specified target position or roam in a specified area in an environment with obstacles. In the intelligent group, there is relative distributed control between individuals, and there is macro distributed control as a human service tool in the cluster relative to the external environment.

3. **Design of control system for stacking robot**

3.1. **Requirements for control system of stacking robot**
A new type of stacker is designed by improving the structure of the common stacker, which realizes that the stacker can automatically complete the outbound and warehousing operations of tubing products with different diameters in the automatic three-dimensional storage of tubing. After the computer is applied to the industrial robot controller, the computer becomes the core of the controller. The computer realizes the control algorithm, receives and processes various signals, and forms and sends out the required control instructions. In the multi-agent location experimental system, the operation of the controller module is to receive the information of agent location and environment, make information decisions and issue control instructions. The main controller first receives various sensor data obtained from the co-controller and the moving position information obtained from the positioning computer. Trajectory planning, interpolation calculation and coordinate transformation are carried out according to the operator's command and the requirements of action program statement [10]. After calculating the position set value sequence of each axis motor, the position update value corresponding to the set point is transmitted to the lower joint position servo system once, so as to realize the coordination and control of the joint movement.

When the stacking robot has a large reduction ratio and works in PTP point control, each joint of the stacking robot can be controlled by local decoupling PID. The control system structure of stacking robot can be divided into centralized control, hierarchical control and distributed control. In order to improve the stability, real-time and develop ability of the stacking robot, the processor of the control unit is required to have high processing speed [11]. Stacking robot is a highly nonlinear multi-variable and time-varying multi-input multi-output system. If the accurate model of the joint is integrated with the optimal control according to strict constraints and initial conditions to track the predetermined trajectory, there is no way to get an acceptable solution. When all the set values transmitted at one time are servo-finished, report to the main control computer and turn to execute the end point servo program. End point servo is to save the set value of this point after the position servo completes the servo calculation of the last point, and perform subsequent servo actions with this value.

### 3.2. Path planning of stacking robot

Stacking robot is a complex system, and the conventional working environment is full of sudden obstacles, so it is difficult for the system to achieve stable movement. To realize the dynamic walking of stacking robot, it is necessary to design dynamic modeling, gait control and stability control algorithm. The degree of conformity between the analysis model of the special-shaped stacking robot and the mechanical characteristics of the actual engineering structure directly affects the reliability of the finite element analysis results. In order to ensure the accuracy of finite element analysis results, it is important to establish an effective and correct finite element model based on actual mechanical mechanism. While completing the overall mechanical structure of the special-shaped parts stacking robot, it is necessary to preliminarily calculate the important parameters of the stacking robot. For an agent individual, the best path to find is along the negative gradient direction of the artificial potential field, which is the direction in which the function declines fastest [12]. By introducing the receiving probability, a new communication topology model with interactive weights is established, which makes the connection weights change with the distance between agent nodes.

In the working process of stacking robot, the stress situation in the acceleration process when it is fully loaded is complicated. Excessive load and unstable stress situation may cause deformation of the frame structure of stacking robot, which will affect the speed-up and positioning accuracy of stacking robot in severe cases. Because the geometric model of the object and the actual loading mode are complex, only a few simple equations and geometric boundaries with quite regular conditions can be explained by classical elastic and plastic mechanics methods. Under the condition of not being affected by blocking obstacles, the intelligent agent will distribute control in the direction of the target point under the guidance of the target point. Selecting the repulsion potential function between agent and obstacle:
The potential field function between agents can be defined as:

$$w_j = \frac{1}{\sum_{j=1}^{k} (EP_{LR}^{j})^2}, j \in (1, k)$$

Therefore, the agent is controlled by the potential field:

$$V_{id} = wV_{id} + c_1r_1(P_{id} - X_{id}) + c_2r_2(P_{gd} - X_{id})$$

The main controller makes comprehensive analysis according to position information, sensors and other information, and sends the control speed and angular velocity information of movement to the distributed control system. In structural disorganization, the accuracy of finite element analysis can be directly affected by the thickness of mesh division and the number of nodes. The finer the grid, the more nodes there are, and the greater the computational complexity of the computer. Too fine the grid directly affects the analysis efficiency, so proper grid division can not only improve the analysis efficiency but also meet the analysis accuracy. Considering the uncertainty of the network and the relationship between the topological connection weights and the distance between agent nodes, the traditional topological graph with fixed connection weights obviously cannot truly reflect the communication quality. Figure 2 shows the consistent distributed control state of agents.

**Figure 2.** Consistency distributed control state of agents

Generally, a single agent in behavior-based method only needs the information of neighboring agents, which is essentially a distributed control method and will not be affected by the scale of agents. When there is no obstacle in the distributed control path of the agent, the agent directly performs distributed control to the target position [13]. Assuming that the adjacency graph corresponding to the group is connected, all individuals in the group will avoid the environmental obstacles and reach the destination, and finally form a stable cluster distributed control. If there is a big gap between the actual working environment and the preset working environment, the adaptive neural network adjusts the parameters of the fuzzy controller online to ensure the stability of the system.

4. Conclusion

The deformation position and amount of the main components of the tubing stacking robot under the action of heavy load in the extreme position provide an effective theoretical basis for the actual prototype manufacturing, and at the same time improve the data basis for the later loading experiment.
debugging of the stacking robot. In this paper, the mechanical analysis of the special-shaped stacking robot is carried out, and the structure of the new stacking robot designed for the automatic storage of oilfield pipe products is demonstrated. To realize the dynamic walking of stacking robot, it is necessary to design dynamic modeling, gait control and stability control algorithm. The degree of conformity between the analysis model of the special-shaped stacking robot and the mechanical characteristics of the actual engineering structure directly affects the reliability of the finite element analysis results. For the stable walking of stacking robot, the main control system based on real-time operating system is indispensable. In order to ensure the stability and real-time performance of the stacking robot, as few functions as possible should be realized under the real-time kernel module. Therefore, the master control system based on the time-sharing system is also indispensable. With the increase of task complexity and the improvement of intelligence and cooperation required to complete tasks, robots must evolve from the original industrial manipulator to intelligent robot, and a single robot needs to develop into a multi-robot system.

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