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Automatic Control Method of Climbing Speed of Wall-Climbing Robot Based on Multi-Vision

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In order to achieve better automatic control of the climbing speed of wall-climbing robots with multi vision, this research designed two robot motion controllers, namely the incremental PID sliding mode fuzzy kinematic controller and the sliding mode fuzzy adaptive kinematic controller based on the backstepping method. Simulation and analysis were conducted for each controller to determine their stability. Also, the multi-vision system is used to guide the robot movements. The images captured by the global camera outside the hand and by the local camera on the hand of the robot are combined to locate the target accurately, so that the robot can complete various operations flexibly and intelligently and cope better with more complex scenes. The results of this research have a have implications for the automatic control of the climbing speed of the wall-climbing robot based on multi-vision.

Keywords: multi-vision; wall-climbing robot; climbing speed; automatic control.

1. INTRODUCTION

A wall-climbing robot has the characteristics of simple structure, strong adsorption force and good adaptability to the wall surface. It is widely used in the nuclear, construction, and shipbuilding industries, to name a few, and its climbing speed directly affects the progress of the project [1]. In terms of the design principles of wall-climbing robots, some scholars have proposed designs based on bionic reconstruction, gait control and electronic integration. It has also been suggested that the wall-climbing robot should be equipped with a special probe-holding device, combined with magnetic properties, so that the robot can detect ferromagnetic industrial structures [2]. In these traditional designs, the wall-climbing robot has a serious problem in terms of adapting to the wall-climbing angle, which makes its crawling speed slow and difficult to control well. The crawling speed and the ability to control the speed are very important for the wall-climbing robot.

To solve these problems, this paper proposes an automatic climbing speed control method for wall-climbing robot based on multi-vision. According to the multi-vision principle, the matching method based on central axis is used to construct the three-dimensional coordinates of the climbing path from different perspectives. The 3D modeling technology is used to reconstruct the 3D model of the climbing path, and the values of the climbing coordinates and moving speed of the climbing robot are obtained. The sensing system and control system of the wall-climbing robot are optimized to better deal with the external information and the robot's own crawling parameters. To achieve the automatic control of the crawling speed, the control structure of the wall-climbing robot is improved, and the control instructions are issued in combination with software programming [3]. The simulation results show that the proposed method improves the robot's climbing efficiency, provides better accuracy in terms of speed control, and can meet the application requirements better than the traditional method.

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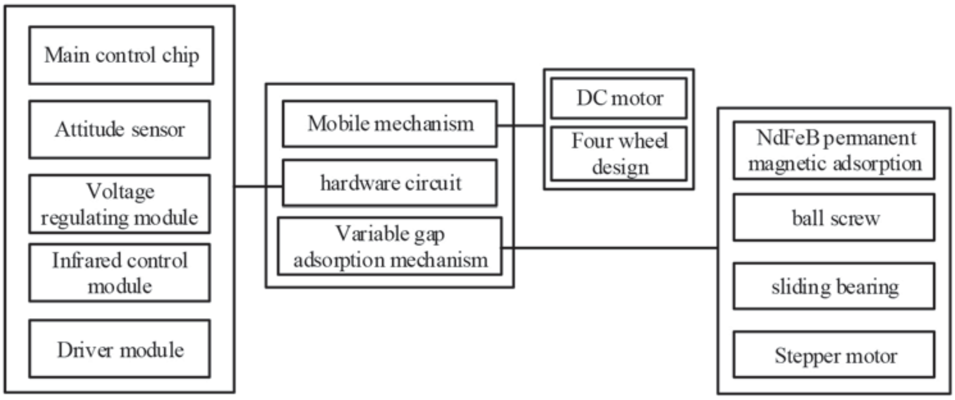

Figure 1 Overall design scheme.

2. OVERALL SCHEME AND STRUCTURE DESIGN OF WALL-CLIMBING ROBOT

2.1 Overall Scheme Design of Wall-Climbing Robot

The overall design of wall-climbing robot comprises a moving mechanism, an adsorption mechanism and a control circuit, as shown in Figure 1. The design requirements of the wall-climbing robot are as follows: the maximum speed is 0.3 m/s, the body weight is not more than 5kg, and the volume is less than 500mm * 400mm * 500mm. However, different adsorption methods and moving modes will affect the weight, speed and size of the robot. This section briefly compares several common adsorption motion modes of wall-climbing robots to determine the design scheme.

2.1.1 Scheme of Adsorption Mechanism

At present, the commonly-used adsorption methods of wall-climbing robots include magnetic adsorption, negative pressure adsorption and bionic adsorption. Negative pressure adsorption is either single suction cup or multi suction cup, which is the earliest and the most mature technology in this area. However, this method requires walls to be very smooth [4]. The magnetic adsorption method includes permanent magnetic adsorption and electromagnetic adsorption. Electromagnetic adsorption often needs a load cable, so its application range is very limited. Bionic adsorption technology requires the highest technical specifications, and its development potential is also high. A brief comparison of the above adsorption methods is shown in Table 1.

Given the description above, the permanent magnet adsorption method has the advantages of low energy consumption, strong adsorption capacity, light weight, mature technical means, and can adapt to rough wall surface [5–6].

2.1.2 Mobile Mechanism Scheme

At present, the main mobility modes of wall-climbing robots are wheel type, crawler type, foot type, wheel foot mixed type, etc. [7]. For comparison, Table 2 summarizes these common movement modes.

It can be seen from the above table that the wheel-type wall-climbing robot has better mobility than the crawler type. Compared with the foot type, the wheel type has stronger mechanical stability, simpler control and lower cost.

2.1.3 Overall Hardware Design of Control System Scheme

The intelligent wall-climbing robot control system has hardware two parts: the upper computer hardware and the lower computer hardware [8]. The hardware architecture of the wall-climbing robot control system is shown in Figure 2.

The hardware modules of the lower computer consist of: a power supply module, S3C2440 minimum system, serial ZigBee wireless communication module, PAL format analog camera, 5.8G analog video signal picture transmission module transmitter, video decoding module, pneumatic valve opening control circuit, high pressure water and vacuum pressure data conversion circuit, high pressure water and vacuum valve switch control circuit, wall-climbing robot posture detection measuring circuit, etc.

The upper computer comprises: a power module, S3C2440 minimum system, serial ZigBee wireless communication module, 5.8G analog video signal picture transmission module receiving end, video signal decoding module, rocker and rocker driving circuit, LCD touch screen, etc.

Both the upper computer and the lower computer have the minimum system of S3C2440 as the control core. The minimum system comprises a S3C2440 chip as the main control chip and the necessary peripheral circuit to ensure the normal operation of S3C2440.

S3c2440 is an ARM9 architecture chip produced by Samsung, with arm 920t as the core. Arm architecture is a CPU architecture created by the ARM company, founded in Cambridge, UK in 1991 [9]. ARM is a leading supplier of semiconductor in the world, and is a major developer of digital electronic products. The Arm32-bit processor is a RISC (reduced instruction set) microprocessor.

The S3C2440 minimum module of the upper computer and the lower computer controls the peripheral circuit to complete the intelligent control task of the wall-climbing robot. The minimum system of S3C2440 is a circuit module essential for the normal operation of the S3C2440 chip. The basic system

Table 1 Comparison of several common adsorption methods.

Adsorption mode	Adsorption principle	Advantage	Shortcoming
Permanent magnetic adsorption	Permanent magnet materials produce magnetic adsorption force on ferromagnetic wall.	No power supply is needed to maintain the adsorption force, and it is relatively reliable.	The force required for the separation between the magnet and the wall is large, and the wall is required to be made of magnetic material.
Electromagnetic adsorption	By electrifying the inner coil, the magnetic field is generated, and the adsorption force on the ferromagnetic wall is produced.	Strong adsorption force, easy to control the strength of the adsorption force, easy to separate the robot and the wall.	Cables are usually required and it is heavy.
Optimal control method of wall-climbing robot based on steel wall			
Vacuum negative pressure adsorption	A motor is used to drive the centrifugal blade, and negative pressure is generated in the adsorption cavity to make the robot adhere to the wall	The adsorption capacity is good, the sealing is good.	After power failure, the robot will lose its adsorption capacity. The surface is required to be smooth.
Thrust adsorption	The high-velocity airflow creates thrust, which holds the robot to the wall.	No leakage problem, no rigid requirements for the shape and material of the wall, and strong obstacle crossing ability	Complex control, noisy, bulky, low efficiency and high energy consumption.
Dry adhesive adsorption	A new bionic composite material is used to produce adsorption force on the wall.	Light weight, can adapt to all kinds of wall surface, no noise, no energy consumption.	The adsorption capacity is poor and the technology is not mature.

Table 2 Comparison of several common mobile modes.

Mobility mode	Description	Advantage	Shortcoming
Wheeled type	Driven by multiple drive wheels	The steering speed is fast, the roll moment is small, the structure is relatively simple, and the mechanical stability is high.	The contact area with the wall is small, the adsorption stability is poor, and the obstacle-crossing ability is general.
Foot type	It has bionic structure, and can avoid obstacles.	The ability of crossing obstacles is strong, and it can adapt to many kinds of wall surfaces.	The structure is complex, the speed is slow, the control is relatively complex and the cost is high.
Wheel foot mixed type	The wheel type is used for the smooth wall surface, and the foot type is used for obstacle avoidance.	It has strong adaptability and excellent obstacle- avoidance ability.	The structure and control are complex, the stability is poor and the cost is high.
Crawler type	The crawler is driven by a motor.	Large contact area, strong adsorption force and large load.	Poor maneuverability, difficult steering and poor wall adaptability.

of S3C2440 consists of a clock circuit, memory chip, NAND flash chip and NOR flash chip.

The clock circuit is the heart of the controller operation and is essential for the S3C2440 to work. The clock is produced by a 12-MHz crystal oscillator. Its main function is to define the working cycle of the microprocessor, define the time meaning inside the chip, and maintain the flow of software. The internal execution of the chip is determined by the "heartbeat" device crystal oscillator. Pins 1 and 2 are connected to xtipl and xtipll pins respectively, and filter capacitors and decoupling resistors are connected [10]. When the clock crystal oscillator signal is connected to the S3C2440, the internal PLL (phase locked loop) circuit will generate the main frequency of s3c2400 400MHz oscillation signal.

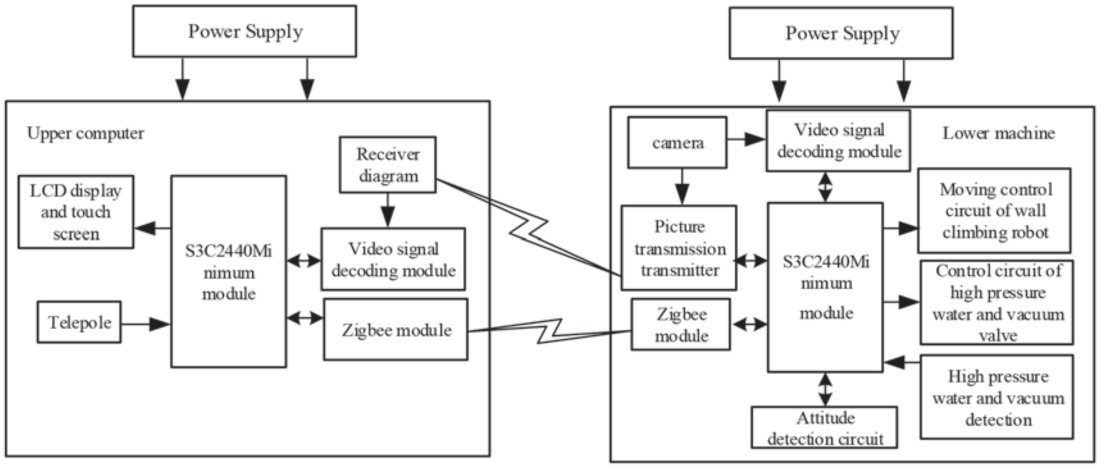

Figure 2 Overall hardware diagram of intelligent wall-climbing robot control system.

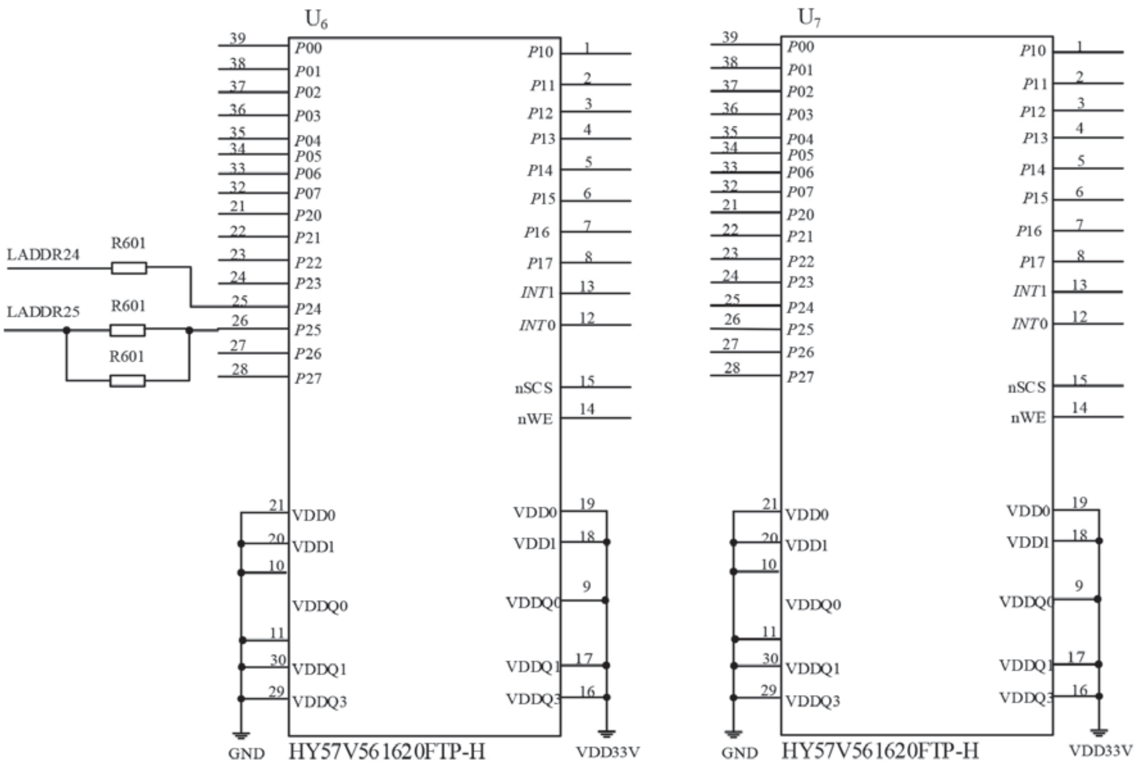

Figure 3 Memory chip circuit.

There is no RAM or ROM in S3C2440, so RAM and ROM chips need to be added externally. The RAM chip is often known as ‘memory’, used to save the relevant code and data. The memory chip used here comprises two hy57v562620 chips in parallel. The chip is a 16bit 64M SDRAM memory chip [11]. Two chips in parallel generate a 32-bit memory circuit, with a total memory of 128M. The memory circuit diagram is shown in Figure 3.

The external ROM of S3C2440 has a NAND flash chip and a NOR flash chip. These two kinds of chips are used for different scenarios. The NOR flash chip not only saves program data, but also runs the S3C2440 program. However, the cost is high. The en29lv160ab chip with 2M memory is NOR flash.

NAND flash is the main ROM of the smallest system. K8f2g08uoa chip is used as NAND flash. The chip size is 256M. The boot program, kernel, file system, driver and application program of Linux operating system are written into NAND flash by NOR flash.

3. TRAJECTORY TRACKING OPTIMIZATION CONTROL OF WALL-CLIMBING ROBOT

The design goal of the trajectory tracking controller of wall-climbing robot is to make the system stable and fast converge to the desired trajectory within a certain error range. In addition, the controller should have good robustness during control system convergence. In the actual control, the closed-loop control of the drive wheel motor is not carried out alone, and there is obvious coupling between each driving wheel motor. This strong coupling phenomenon makes the wall-climbing robot show serious nonlinear characteristics, which makes the dynamic control of the robot difficult. There are two main issues regarding the motion control of the wall-climbing robot. One is how to realize the stability of the closed-loop control error system, so that the actual trajectory error tends to 0 in possible shortest time; The other is how to stably and effectively suppress the external interference so as to reduce the influence of the interference signal on the tracking accuracy within a certain range.

At present,modern control theory methods and intelligent control methods are the main methods used to track the wall-climbing robot. From the perspective of modern control theory, the mature wall-climbing robot motion control technology can be divided into three categories: parameter adaptive control, sliding mode variable structure control and modern robust control. The wall-climbing robot control technology using the intelligent control method can be divided into neural network control, fuzzy control, expert control and cross-control.

3.1 Modern Control Method of Wall-Climbing Robot

(1) Adaptive control

The uncertain dynamic characteristics of the robot can be represented by a linear relationship of unknown parameters, and the adaptive algorithm is used to estimate the unknown parameters online. Model reference adaptive control and self-tuning control are commonly used for robot control. The model reference adaptive controller consists of a proportional differential regulator and a feedforward compensator based on the control system model. The self-tuning regulator uses an online recursive mathematical model identification method and minimum variance control performance to correct the deviation.

(2) Variable structure control

Sliding mode variable structure control (SMC) is a control method whose core technical route is to find a suitable hyperplane in the state space of control system error. If the hyperplane can ensure that all moving points in the hyperplane are close to zero, then the plane is called a ‘sliding mode surface’. One of the main advantages of this type of control is its strong robustness, which is mainly manifested in the invariance of sliding mode motion equation to disturbance [12]. Moreover, as long as the appropriate control signal is selected, the state can reach the sliding surface reliably from any initial state under any disturbance. Because of this advantage, the sliding mode variable structure control method can be used to control the robot. However, the discontinuous switching characteristics of sliding mode variable structure control (SMVSC) can cause chattering of the system and increase the energy consumption. Moreover, the high-frequency unmodeled dynamics in the system can be easily excited, and even cause oscillation or instability of the system and damage the controller components.

(3) Robust control

Robust control design is based on the description parameters of uncertainty and the mathematical model of the nominal system [13]. It can use a controller whose structure and parameters are fixed to ensure that the design requirements can be met even when the uncertainty has the worst impact on the characteristics of the system. Generally speaking, robust control is a conservative control strategy. This is exactly what is expected in the actual field. This control method does not need an adaptive algorithm or a lengthy calculation, and it has fast calculation speed and good real-time performance, which explains the extensive research on robot robust control.

3.2 Intelligent Control Method of Wall-Climbing Robot

There are many kinds of technical methods for intelligent control system design, such as: real-time intelligent control, artificial intelligence control, neural network control, fuzzy control and so on. Intelligent control theory is developed for complex control tasks and purposes. Robotics is one of the important fields where intelligent control is applied. In recent years, more and more scholars have proposed intelligent control methods for robot control [14].

(1) Neural network control

A neural network is a multi-input and multi output nonlinear dynamic system, which is described by a set of state equations and a set of learning equations. The state equation describes the functional relationship between the excitation or inhibition levels of each neuron, its input and the connection strength on the input channel, while the learning equation indicates how the connection strength of the channel should be modified. The input-output relationship of the whole neural network is adjusted by modifying the connection strength. The neural network controller does not need the accurate mathematical model of the controlled object, and it also shows strong adaptability to any changes in the external environment and to system parameters. This makes the neural network particularly suitable for the dynamic control of a robot.

(2) Fuzzy control

Fuzzy control is a computer digital control technology based on fuzzy set theory, fuzzy linguistic variables and fuzzy logic reasoning. The following steps are used to design a fuzzy controller:

1) Fuzzy control parameters. The input quantity of fuzzy controller is selected and transformed into the system recognizable fuzzy quantity [15].

2) The fuzzy rule base is established. Fuzzy rule is a special language of fuzzy algorithm to represent the fuzzy relationship between control variables and controlled variables. Fuzzy rule base contains many control rules, which is a key step in the transition from actual control experience to fuzzy controller.

3) Fuzzy reasoning, according to fuzzy rules to achieve knowledge-based reasoning decision-making.

4) The main function of the fuzzy solution is to convert the control quantity obtained by reasoning into control output.

In the early 1980s, fuzzy control was introduced into robot control for the first time, which showed the application potential of fuzzy control in this regard from the experimental aspect. In addition, the fuzzy system has been widely used and studied in the aspects of robot fuzzy modeling, control, flexible arm control, force / position control, fuzzy compensation control, and the path planning for the mobile robot.

(3) Cross control

In practical application, different control methods are usually combined. This kind of control method, which combines intelligent control with traditional control, is known as the cross-control method. In trajectory tracking control of wall-climbing robot, there are two kinds of cross-control methods, namely fuzzy neural network and fuzzy sliding mode control.

1) Fuzzy neural network control

Fuzzy control and neural network control have been widely used in robot control. Fuzzy control uses the experience of human experts to control, without the precise model of the object. Once the control rules and membership functions are determined, they cannot be changed; therefore, the control cannot make timely response when the environment changes. Neural network control can be designed according to the actual algorithm, so it has the ability of on-line automatic learning, online automatic resource allocation and integration, and adjust the performance of the controller. It can greatly reduce the influence of uncertain factors such as environment change and load change when it is used to control a wall-climbing robot. However, the neural network control needs a lot of prior data and a certain time for off-line learning, and the initial value of its weight is difficult to determine due to the lack of clear physical significance. The combination of neural network and fuzzy control can make up for the defects of the two methods to a certain extent, and the neural network can perform reasoning and induction.

2) Fuzzy sliding mode control

Fuzzy sliding mode control is a type of cross-control. Its core idea is to combine the advantages of fuzzy control and traditional sliding mode control. Fuzzy sliding mode control retains the advantages of conventional fuzzy controller; that is, it can be independent of the system model. However, compared with the conventional fuzzy control, the fuzzy sliding mode control has two important features. One is that the control target changes from the tracking error to the sliding mode function. As long as the sliding surface and switching function are designed reasonably, the value of the sliding mode function can be zero, and the tracking error of the system will reach the switching surface asymptotically, that is, the zero point. The other is that the fuzzy sliding mode control can simplify the fuzzy control system in terms of structural complexity. Fuzzy sliding mode control is widely used for robot control.

3.3 Trajectory Tracking Control of Wall-Climbing Robot Based on Kinematics

Since the system output of the robot is only linear velocity and angular velocity, most of the trajectory tracking controllers based on kinematics follow modern design methods. Therefore, in practice, the kinematic model of the wall-climbing robot is easier to describe accurately than the dynamic model. A backstepping controller with feedback gain and incremental PID sliding mode fuzzy control are designed, and the trajectory tracking algorithm is simulated.

3.3.1 Trajectory Tracking Backstepping Control Method

The backstepping method is used to solve the control problem. The system is split and backstepping is applied to the subsystems whose total number does not exceed the order of the system. Then, different Lyapunov functions are designed for each subsystem according to the system properties, followed by the designing of the auxiliary control variables which can control the whole system. Assume that the controlled object is:

$$\begin{cases} \dot{x}_i = x_2 \\ \dot{x}_2 = f(x,t) + b(x,t)u, b(x,t) \neq 0 \end{cases} \tag{1}$$

The control law of the second-order system shown in equation (1) is divided into two subsystems. Finally, the overall control law is designed by combining the two. The design process of the first subsystem is described below.

The system error is set as follows:

$$z_1 = x_1 - z_d \tag{2}$$

Where z_d is the expected coefficient. By deriving formula equation (2), we can get the following results:

$$\dot{z}_1 = \dot{x}_1 - \dot{z}_d = x_2 - \dot{z}_d \tag{3}$$

The control quantity of the subsystem can be defined as:

$$a_1 = -c_1 z_1 + \dot{z}_a, c_1 > 0 \tag{4}$$

The auxiliary control quantity is defined as:

$$z_2 = x_2 - a_1 \tag{5}$$

According to the principle of backstepping method, the Lyapunov function of the first subsystem is designed as follows:

$$V_1 = \frac{1}{2} z_1^2 \tag{6}$$

By deriving equation (6), we can obtain the following results:

$$\dot{V}_1 = z_1 \dot{z}_1 = z_1(x_2 - \dot{z}_d) = z_1(z_2 + a_1 - \dot{z}_d) \tag{7}$$

By introducing equation (4) into the above equation, we can get the following results:

$$Z_2 = 0 \tag{8}$$

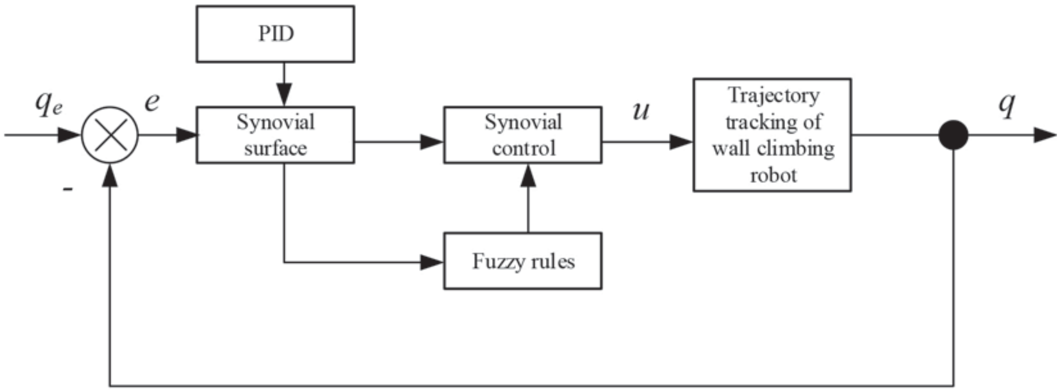

Figure 4 Block diagram of incremental P1D sliding mode fuzzy control.

If $Z_2 = 0$, then $\dot{V}_1 \leq 0$ and $\dot{V}_1$ are semi negative definite. According to Lyapunov stability criterion, the system is asymptotically stable. In the next step, the second subsystem is designed. Let the Lyapunov function of the system be V_1 and the Lyapunov function of the second subsystem be V_2

$$V_0 = V_1 + V_2 = \frac{1}{2} z_1^2 + V_2 \tag{9}$$

Combining equations (1) and (2), we can get the following results:

$$\dot{z}_2 = \dot{x}_2 - \dot{a}_1 = f(x,t) + \mathrm{b}(x,t)u + c_1\dot{z}_1 - \ddot{z}_d \tag{10}$$

By deriving equation (9) and substituting it into equation (10), we can get the following results:

$$\dot{V}_2 = \dot{V}_1 + z_2\dot{z}_2 = -c_1 z_1^2 + z_1 z_2 + z_2[f(x,t) + b(x,t)u + c_1\dot{z}_1 - \ddot{z}_d] \tag{11}$$

In order to make $\dot{V}_1 \leq 0$, the control law U of the system can be designed as follows:

$$u = \frac{1}{b(x,t)}[-f(x,t) - c_2 z_2 - z_1 - c_1\dot{z}_1 + \ddot{z}_d],\ c_2 > 0 \tag{12}$$

From the design process of the above control law, we can see that the backstepping method is reverse-designed. Firstly, the Lyapunov function is designed according to the controlled variables, and then the control law satisfying the stability is deduced according to the Lyapunov function. Because of the backstepping control law, the designed control law must be asymptotically or globally stable.

3.3.2 Trajectory Tracking Incremental PID Sliding Mode Fuzzy Control Method

The combination of the sliding mode variable structure control and the conventional PID control can effectively reduce the chattering of sliding mode control, but there will be a relatively large steady-state error. Therefore, fuzzy control is used for self-tuning the three parameters of PID so as to improve the quality of trajectory tracking control system. By means of if-then rules, a fuzzy controller is constructed to achieve the self-tuning of PID control parameters. When the input error and error change rate change, the fuzzy controller can adjust the PID control parameters in real time. This adjustment of the PID controller makes it more more suitable for the current error and error change rate. The control flow is shown in Figure 4.

The main idea of incremental PID is to discretize the position type PID, and then make $\int_0^t e(t)dt \approx T\sum_{m=0}^{k} e(m)$ integral act on $t \approx kT$, $k = 0, 1, 2 \ldots$, and then make differential $de(t)/dt \approx e(k) - e(k-1)/T$, where T is the sampling period and k is the sampling times. Then, the incremental PID algorithm transformed by position PID algorithm can be obtained as follows:

$$\Delta U_k = k_p \Delta e(k) + k_i e(k) + k_d[\Delta e(k) - \Delta e(k-1)] \tag{13}$$

Namely:

$$\Delta U_k = k_p[e(k) - e(k-1)] + k_i e(k) + k_d[e(k) - 2e(k-1) + e(k-2)] \tag{14}$$

Compared with the position type PID control algorithm, the advantage of the incremental PID control algorithm derived from discretization is that its output is related only to the $K-1$ sampling and $K-2$ sampling of the system deviation $e(T)$. Therefore, in the actual control process, it does not need a lot of calculation in order to achieve better control.

4. THE APPLICATION OF WALL-CLIMBING ROBOT BASED ON MULTI VISION

4.1 Overall Scheme Design of Wall-Climbing Robot System Based on Multi Vision

The wall-climbing robot based on multi-vision combines the global camera outside the hand and the local camera with the lens on the hand to create multi-vision, which gives the industrial robot six degrees of freedom to operate flexibly and intelligently. For the movement of the robot, the global monocular camera carries out the initial positioning of the target, and sends the positioning information to the PC host, and the PC host controls the robot's manipulator. After that, the local binocular camera with lens on the hand is used to accurately locate the target, and then the PC host performs corresponding operations according to the accurate positioning information.

(1) Camera calibration

Based on the premise of machine vision, the corresponding relationship between the actual points in space and the pixels in the image is determined, and the camera internal and external parameters calibration are completed. Zhang Zhengyou's calibration algorithm can be used to capture the images at different angles and heights by moving the chessboard to achieve the simple and accurate calibration of the target.

(2) Hand-eye calibration

The eyes of a global monocular camera are calibrated manually. The position of the robot is fixed on the end of the chessboard and the robot is fixed at the end of the frame.

The lens of the local binocular camera on the hand are calibrated. By installing the camera on the manipulator of the robot, the hand eye calibration algorithm based on constant rotation can be used to obtain the fixed conversion relationship between the camera and the end of the manipulator.

(3) The internal parameter coefficients of each camera are calibrated by the binocular camera, and the translation and rotation parameters of the right camera relative to the left camera are calibrated. The optimal double target determination result is obtained through the double target determination algorithm under OpenCV.

4.2 Global Monocular Vision Target Detection and Positioning Analysis

For the image processing of simple and small volume objects, a surface template-matching localization algorithm can be used to detect and locate objects. However, for large and complex objects, a landmark-based positioning method can be used for image processing, and the target can be identified from the image to realize the spatial positioning of the object.

(1) The target recognition and location based on surf template-matching is processed by monocular camera, and the template matching algorithm based on feature points can accurately identify the position of the target in the image and obtain its three-dimensional information. The process involves: original image filtering processing binarization expansion processing contour detection to determine the candidate region feature matching based on surf target position and angle 3D information in the base coordinate system.

(2) This method is suitable for the location of large and complex objects. It is mainly through the identification and processing of the markers pasted on the surface of the target to obtain the spatial coordinates and spatial position of the markers.

4.3 Three-Dimensional Positioning and Trajectory Planning of Hand Binocular Stereo Vision

(1) Three-dimensional positioning of the multi-camera stereo vision can accurately learn the three-dimensional information of the target through the motion guidance of industrial robot with multi-eye vision, mainly to process the image of left-hand and right-hand views, and then according to the principle of three-dimensional reconstruction of binocular stereo vision, the spatial coordinates of the object in the left camera coordinate system and the spatial position of the robot in the base coordinate system can be obtained. The process involves: left view - image processing - the position and angle of the object in the image; Left and right view - stereo correction - stereo matching - generation of parallax map; Final generation of point cloud image to obtain the three-dimensional coordinates of the target.

Two cameras are used to photograph the same object, and the projection points of the fixed points in the space are mapped to the image projection points under different perspectives, and the disparity map is generated to realize the 3D reconstruction of the object. The commonly used stereo matching algorithms include: region based stereo matching algorithm, feature-based stereo matching algorithm and phase based stereo matching algorithm. Stereo matching is one of the key elements. It searches for matching points in the left and right views according to the matching primitives. It uses epipolar constraints to reduce matching vision and improve matching efficiency. Finally, after stereo matching, the depth information of the target point is obtained, and the three-dimensional reconstruction of the object is completed, and the two-dimensional information of the image is converted into the three-dimensional information of the space.

(2) According to the principle of machine kinematics, the position and pose relationship between the joints of the manipulator and the end of the robot can be known, and the rotation angle and moving distance of each joint of the manipulator can be calculated when the robot contacts the target. In order to control the motion of the manipulator stably and safely, it is necessary to plan the trajectory of the robot. The interpolation method is usually used to plan the trajectory in the joint space of the robot. Based on the spatial position information of the nodes on the robot's motion path, the equation is established and solved, so that the robot can quickly and smoothly complete the movement from the starting point to the end point. Generally speaking, the following three interpolation methods can

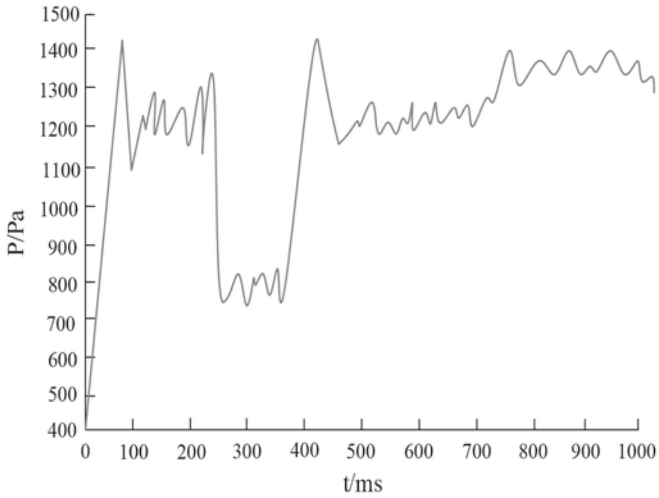

Figure 5 Pressure value sampling results.

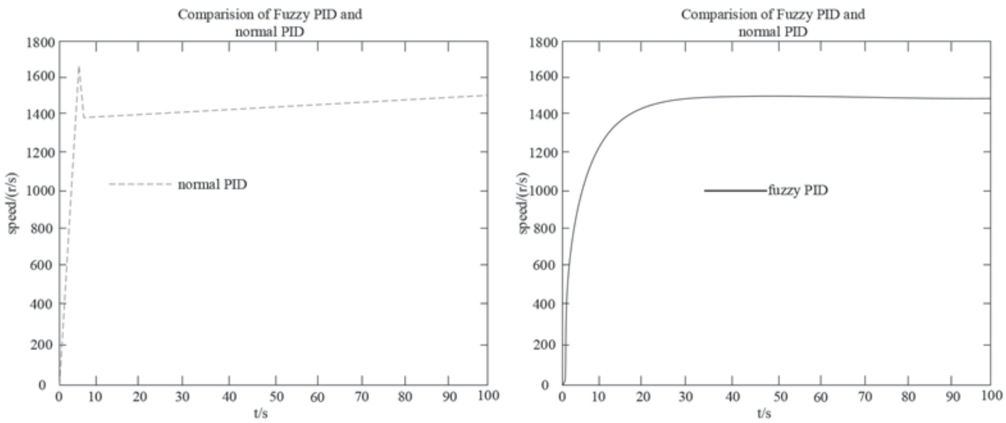

Figure 6 Response output curve of observation system.

be used to interpolate the robot joint space: cubic polynomial interpolation, cubic polynomial interpolation through path points, and higher-order polynomial interpolation.

5. EXPERIMENT

The simulation experiment of the wall-climbing robot is carried out with MATLAB. The experiment content includes tests of the robot's ability to climb walls, move in a straight line and turn. The test content includes the walking stability of the robot on a circular arc surface with a curvature radius of 0.8m, and the robot's wall adsorption ability when the wall gap is greater than 8mm. In addition, the remote control distance and stability of the controller are also tested. AD sampling is carried out in the sealing chamber, and the sampling results are shown in Figure 5.

According to the pressure value sampling results in Figure 5, the incremental P1D sliding mode fuzzy controller is compared with the traditional PID controller, and the response output curve of the observation system is shown in Figure 6.

It can be seen from the simulation results in Figure 6 that compared with the traditional PID algorithm, the incremental P1D sliding mode fuzzy control algorithm has a shorter adjustment time. It has almost no oscillation and overshoot close to zero, also its steady-state error is less than 1R / s. Therefore, it can be concluded that the incremental P1D sliding mode fuzzy controller has better adaptability and robustness than the traditional PID controller, and improves the working speed of the system.

6. CONCLUSION

The trajectory tracking controller of wall-climbing robot is designed and simulated by MATLAB. The research designs a backstepping controller with feedback gain to improve the system convergence speed. In addition, the research proposes a sliding mode and incremental PID sliding mode fuzzy kinematics controller to optimize the controller performance and enhance the robustness. The sliding mode controller will bring chattering problems in use, so it is optimized by adding fuzzy control to the system. Besides,the speed output of the backstepping controller is taken as the input of the dynamic controller, and the sliding mode adaptive controller and the sliding mode fuzzy adaptive torque controller are designed respectively. Both methods estimate the uncertainty factors of the model, and add fuzzy rules to adjust the sliding mode gain, which greatly improves the convergence speed of the system.

Furthermore, the application of wall-climbing robot based on multi vision meets the requirements of intelligence, flexibility, stability and rapidity. It can combine monocular and binocular systems to form a multi vision system, and guide the robot to deal with the operation in different environments reasonably. On the premise of vision and trajectory optimization, the climbing speed of the multi vision wall-climbing robot is automatically controlled.

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