# Design of Remote Three-axis Motion Control Device

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*Keywords:*   PLC, three-axis, remote control, motion control.

*Abstract:*   In view of the defects of the current three-axis motion devices that they could only be applied to on-site operation, operated complicate and has low data visualization, a three-axis motion device, whose main control part is PLC (Programmable Logic Controller), that can be remotely operated and monitored was designed. In order to solve the problem that the operator is unable to operate in the field, the remote control of the device based on the web-sending function of the Siemens PLC was implemented. Secondly, a friendly human-computer interaction interface for the flaw of the complicated operation was designed, which enabled the operator to read and adjust the relevant parameters quickly. Finally, a physical prototype was built according to the design, thereafter the device, through a quantity of tests, was proved to have advantages of reliable structure, simple and convenient on-site control, and stable and safe remote control.

## 1.  Introduction

The development level of numerical control technology represents the development level of national industry. The three-axis motion device is a kind of CNC machining or auxiliary device that is relatively mature in the industry at the present stage [1,2], and is suitable for various control systems such as robot arms, placement machines, engraving machines and three-dimensional warehouses. For these three-axis motion devices, there are currently four more reliable motion control schemes: general motion control using a single-chip system; repetitive motion control using a professional motion control PLC [3,4]; Precision motion control; using PC + motion controller to achieve complex motion control. The current motion control devices, whether open or closed, generally use only one of the control schemes, mainly to achieve certain motor control and multi-axis coordinated operation control. Under normal circumstances, only on-site control is used, and remote read/write data and remote real-time monitoring cannot be performed; and the problems of complicated operation, single function, and poor scalability are common. In response to the above problems, this paper designs a remotely controllable motion control device (hereinafter referred to as "the device") based on the Web transmission function of Siemens PLC, which allows the operator to use HMI (Human Machine Interface) in the field. The touch screen controls the movement of the three-axis slide table, the opening and closing of the mechanical claws, and the function of automatically recognizing the object gripping; and in the networked state, the operator can read and write the motion control process parameters through the remote end webpage, control

the slide table and the mechanical claws. Exercise and monitor the actual health through a webcam[5].

## 2. The Overall System Design

The three-axis motion control device designed in this paper consists of main control module, human-computer interaction module, data transmission module, communication module, actuator and so on. The main control module is the CPU 1214c of Siemens s7-1200 PLC, which is responsible for processing data and sending control instructions; the human-computer interaction module includes the field touch screen, field router, remote router and remote client, which is responsible for human-computer interaction; the data transmission module includes the sensor group, control button and openmv, which is responsible for transmitting field data to the CPU; the communication module is responsible for the field equipment and Communication with remote equipment; the actuator consists of three-axis screw slide and mechanical claw, which is responsible for the execution of operation instructions.

The specific movement of the device needs to be realized by a three-axis screw slide. The control pulse is output to the drive module through the PLC, and the rotation direction of the stepper motor is controlled by the drive module. And the speed, in order to achieve the purpose of controlling the sliding of the screw slide slider [6]. After testing, this paper selects two-phase hybrid stepping motor (model: 42HBS48BL4-TR0) as the driving device, its rated step angle is 1.8 °, under the premise of limited PWM wave frequency, can change the subdivision number of the driver Change the step angle to increase the motor speed [7, 8]. Using a stepper motor driver to control the stepper motor only needs to control the frequency and direction signals of the output PWM wave. It is relatively easy for the ladder programming of the PLC, so this article uses the stepper motor driver (model: ZD-2HD318) to drive The corresponding stepper motor.Organization of the text.According to the above, each time the controller PLC sends a pulse signal, the actual step angle of the stepping motor is:

$$\theta = \frac{\theta_0}{m}$$

(1)

Where: $\theta$ is the actual step angle, $\theta_0$ is the rated step angle, and m is the subdivision number. Therefore, the number of pulses required for the motor to rotate one revolution is:

$$L = \frac{N}{n} \times L_1$$

(2)

In the formula, L is the set displacement value; N is the single-pass total pulse number; n is the single-turn pulse number; L1 is the displacement value of the ball screw of one rotation of the motor.Through the formula (2), the stepping motor stroke can be programmed to realize the positioning control by using the encoder count feedback [9].

$$x = \frac{f \times t}{n} \times L_1$$

(3)

Where: f is the number of pulses per millisecond (taking into account the execution capability of the motor, the PWM wave pulse is 20 kHz), t is the PWM wave on time, n is the number of single-turn pulses, and L1 is the single-turn displacement value.For the control of the mechanical claw, the

steering angle of the steering gear is actually controlled. The servo type selected for the device is MG996R, and the control principle of the mechanical claw can be simplified as shown in Figure. 3. By controlling the duty cycle of the PLC output pulse (20Hz) to control the rotation angle of the steering gear to control the opening and closing of the claw; because the PWM amplitude of the PLC output is 24V, and the maximum pulse amplitude that the servo can bear is 5V, Therefore, it is necessary to use a drive module to reduce the pulse outputted by the PLC to drive the servo.

## 3.    Mechanical Structure Design

According to the above overall scheme, the mechanical structure of the three-axis motion device shown in Figure. 1 is designed, and the structure mainly comprises four parts: a platform base, a moving device mounted on the upper side of the base frame, and a whole frame mounted on the base. Monitoring devices for each part and independent control devices.
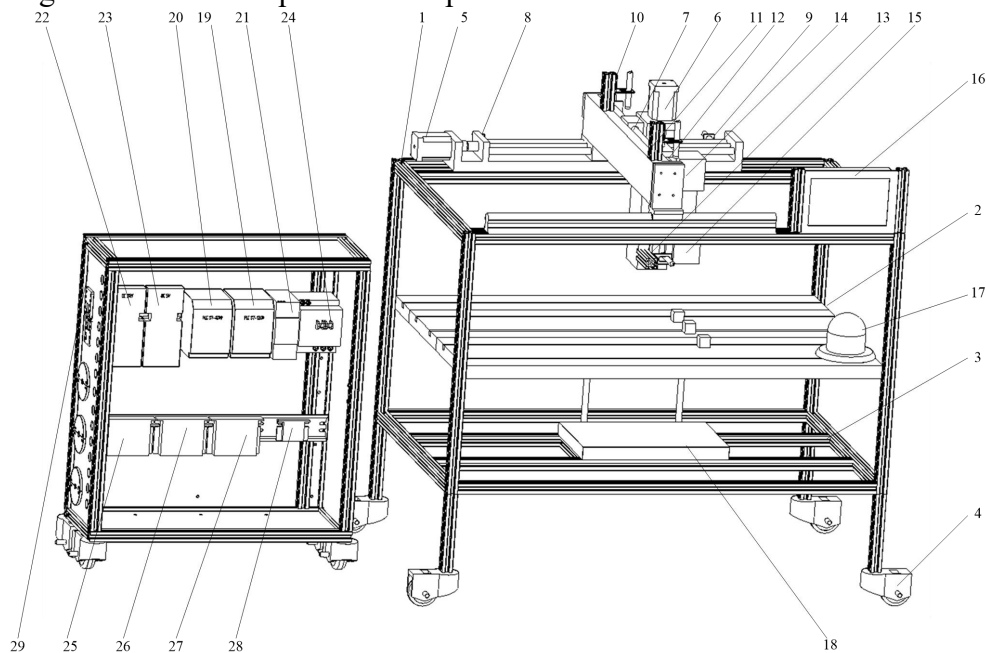


Figure 1: Detailed drawing of the mechanical structure.

1. Aluminum profile rectangular frame; 2. Operating platform; 3. "H" type fixed structure; 4. Universal wheel; 5. X-axis screw slide; 6. Y-axis screw slide; 7. Z-axis screw Slide table; 8. X-axis limit sensor 1; 9. X-axis limit sensor 2; 10. Y-axis limit sensor 1; 11. Y-axis limit sensor 2; 12. Z-axis limit sensor 1; Z-axis limit sensor 2; 14. OpenMV module; 15. mechanical claw; 16. HMI touch screen; 17. web camera; 18. field router; 19. PLC CPU; 20. PLC communication module; 21. PLC line splitter; 22.DC24V power supply; 23.DC5V power supply; 24.Air switch; 25.X-axis stepper motor driver; 26.Y-axis stepper motor driver; 27. Z-axis stepper motor driver; 28.Steering drive module; .control box.

The motion device is the "four limbs" of the device, and is also the actuator of the device. The three screw slides are mounted on the upper side of the aluminum profile box frame in an inverted three-dimensional coordinate system; six photoelectric switches are used as limit sensors in turn. Installed on the limit position of the effective stroke on each side of the X-axis, Y-axis, and Z-axis screw slides, the range of motion is limited in a non-contact manner; the mechanical claws are mounted on the slider of the Z-axis screw slide, following the slider Moving in three-dimensional space for gripping objects; the OpenMV module is mounted on the bottom of the clamping jaws,

moves synchronously with the mechanical jaws, identifies the color and shape of the objects on the operating platform, and provides a signal for automatic gripping of the mechanical jaws.

## 4. Field Control Design

The basic function that the device first needs to implement is to make corresponding movements in the field through the HMI touch screen control device, that is, on-site control. Field control includes manual control and automatic control. After the system is powered on, the system defaults to manual control mode. The manual control process is shown in Figure 2. Press "X Left" on the control panel, the X-axis motor rotates forward, the X-axis guide slider moves to the left, click to move 0.1mm, long press to move continuously until it moves to the X-axis limit switch 1 position. Stop moving. Press "X Right", the X-axis motor reverses, the X-axis guide slider moves to the right, click to move 0.1mm, long press to move continuously until it moves to the X-axis limit switch 2 position, stop moving. Similarly, the Y-axis and Z-axis control processes are the same as the X-axis. To control the three-axis movement, move the mechanical claw on the Z-axis screw slide slider to the appropriate position, press "Stretch" or "Fold" to control the opening or closing of the mechanical claw to release or grab the object. "Automatic" can switch the control system to automatic control mode. Under automatic control, the OpenMV module uses mechanical jaws to scan according to the partition at a distance (150 mm) above the operating platform. If the partition number is specified in advance, the robotic claw will move directly to the corresponding area for scanning.
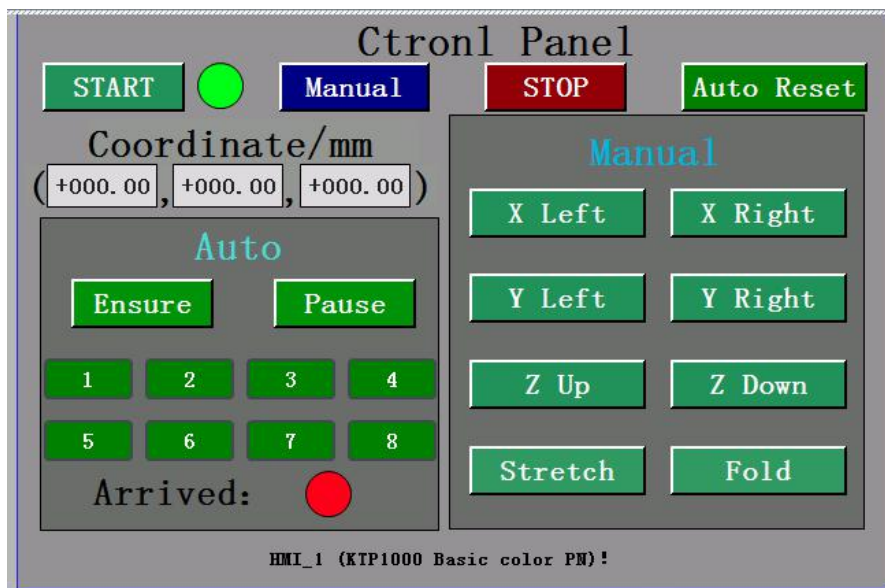


Figure 2: HMI control interface.

This paper uses the Web sending function of Siemens S7-1200PLC to transmit the IP address of the PLC CPU through the on-site router for intranet penetration and port mapping, send it to a fixed address, and then use the remote router to set up a VPN channel with the on-site router to access the network. The operator can log in to the account on the remote operation terminal (computer or mobile phone) to realize remote monitoring and control. Building a VPN tunnel can connect remote devices and field devices, which is the basis of remote control. The model for establishing a VPN tunnel for remote user connections is shown in Figure 3.
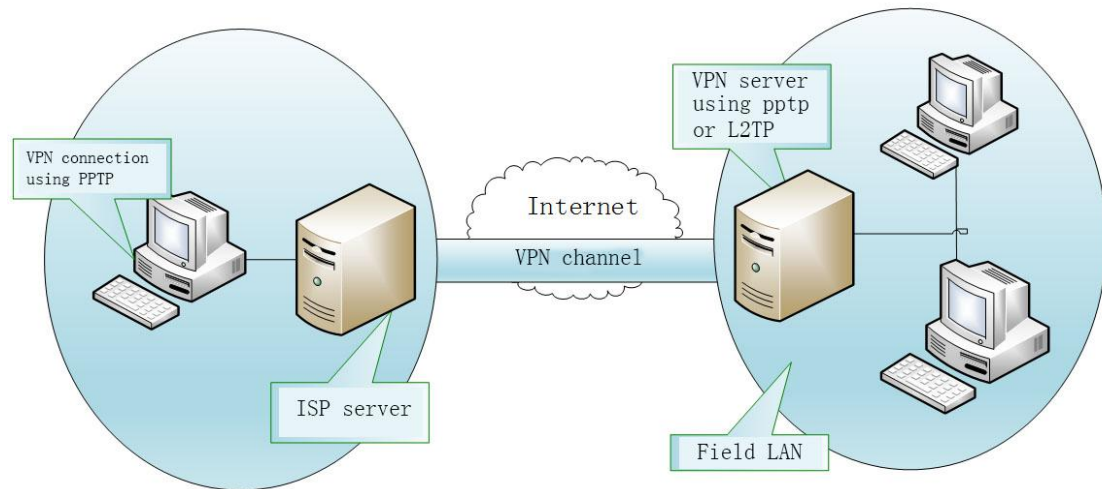
Figure 3: LAN VPN channel model.

Following the control interface of Figure 2, this article uses Adobe Dreamweaver CS6 software to design a remote control interface. The button control function is the same as the on-site control HMI touch screen interface. It can be manually controlled and automatically controlled through the web page button remotely, and the device can be read in real time. The parameters of the webcam are obtained and the remote monitoring requirements are met. The webcam monitoring can observe the actual running effect of the device in real time and assist remote operation. When designing the remote control interface, the function of the button is realized by changing the value of the PLC variable, so it needs to be done using the <form> form tag. The properties of the form mainly include Action, Method, and Target. The Action is used to process the format of the submitted form, the program that executes the form processing, the Method property is used to indicate the method for submitting the form, and the Target property is used to specify the target window or target frame, and specify the location where the submitted result document is displayed. This article uses the form submission function to design control buttons that display the results of the submission on the page to ensure continuous operation.

## 5. Experimental Test

Based on the above scheme and design content, this paper builds the physical device and tests the design requirements. The test method is as follows: the object to be detected is placed in different positions on the operating platform, the field router and the remote router are networked and logged into the remote control interface, and the control system is started, and the on-site manual control, on-site automatic control, remote manual control and remote automatic control are sequentially performed. The test results are shown in Table 1 (the success rate listed in the table includes 50 test results). It can be seen from Table 1 that the device can realize the basic button operation, and can successfully realize on-site and remote control, the average success rate is above 85%, and the control success rate can be further improved by the late optimization compensation.

Table 1: Test results.

| Test items | On-site manual control | On-site automatic control | Remote manual control | Remote automatic control |
|---|---|---|---|---|
| Test content | 1. HMI button function<br>2. Coordinate display<br>3. Robot manual control | 1. HMI button function<br>2. Automatic control logic correctness<br>3. OpenMV recognition ability | 1. Remote end and field communication test<br>2. Webcam monitoring<br>3. Web page manual button function | 1.PLC Web launch function<br>2.Remote monitoring test<br>3. Remote automatic control |
| Test Results | 1.Content 1 success rate 90%<br>2.Content 2 success rate 88%<br>3.Content 3 success rate 76% | 1.Content 1 success rate 85%<br>2.Content 2 success rate 83%<br>3.Content 3 success rate 78% | 1. Content 1 success rate 92%<br>2. Content 2 success rate 87%<br>3. Content 3 success rate 90% | 1. Content 1 success rate 91%<br>2. Content 2 success rate 88%<br>3. Content 3 success rate 92% |
| Problem | There is an error of 1-2 mm between the display coordinates and the actual travel distance, but does not affect the identification and gripping. | At normal operating speeds (12.5mm/s), OpenMV can be recognized normally, and there is a delay under fast scanning. | The communication speed is limited by the network speed, and there is a delay in the transmission of the webcam picture; the remote control is normal, but there is a delay in the control command. | There is a delay in the webcam screen and remote automatic control commands, and the delay phenomenon is more serious than manual control. |

## 6. Conclusions

In order to solve the problem that the general three-axis motion device only allows on-site operation, complicated operation and low data visualization, a remote motion control device based on Siemens PLC is designed. The device runs stably and reliably, reduces integration and operation difficulty, and enhances the degree of data visualization. At the same time, it allows the operator to remotely monitor the actual running status of the device and perform necessary remote operations in real time, which greatly improves safety. In addition, the device integrates knowledge of machinery, electronic circuits, and automatic control to help strengthen the operator's knowledge and flexibility in these aspects. The operation process of the device is safe and stable, and is suitable for teaching experiment display and equipment expansion in various directions. In addition to the inspection

control method, through further development, functions such as writing, engraving and stacking can be realized, and the promotion prospect is better.

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