The Multi-Purpose Robot Controlled via VR

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Abstract. There are still many high-risk industries in society, so it is very important for robots to replace humans to complete these tasks. However, existing robotics are often unable to perform simple operations, limiting their widespread use in society. This study proposes a robot control method based on VR (Virtual Reality) technology, which provides new ideas for solving the difficulties of robot operation through remote control. The production process of this method is mainly divided into two parts: programming and mechanical structure design. In terms of mechanical structure, the project is divided into the body of the robot and the part of the operator. Through this design, the operator can operate the robot remotely. In the end, the project has been verified and achieved good results. By using VR technology to realize remote control of robots, the difficulty of operation is greatly reduced and the application of robots in high-risk industries has been improved. This research provides new ideas and solutions for the application of robotics in high-risk industries.

Keywords: Virtual Reality, MEMS, Electronic gloves.

1. Introduction

With the progress of society and the development of science and technology, high-risk industries play an important role in the safety and survival of human beings. However, due to the limitations of traditional robots in performing complex tasks, the wide application of robots in these industries has been restricted [1-3]. Traditional robots often need to be pre-programmed or follow fixed instruction patterns, and cannot respond flexibly to unknown, uncertain or changing environments. This limitation makes robots unable to work in some high-risk industries, thus bringing greater safety risks to human beings.

However, today's virtual reality (VR) technology provides a new way to solve this problem. By combining virtual reality with robot technology, people can interact and operate with robots by wearing VR helmets and entering the virtual environment [4-5]. This robot operation method based on VR technology can provide a more intuitive and immersive control experience, enabling people to control the movements and behaviors of robots more accurately and flexibly. Moreover, with the help of VR technology, people can also remotely control robots to perform unattended tasks, so as to keep people away from high-risk environments and ensure their safety [6].

By realizing the simple control of the robot based on VR technology, people can better control the robot to complete vaintenance in high-risk environments. At the same time, this technology can also provide experts or rerious complex tasks, such as dangerous goods dismantling, remote rescue and investigation and mascuers who can't often appear at the work site with the ability to remotely operate robots, ensuring the timeliness and efficiency of work. Therefore, this paper will explore the method of simple control of robots based on VR technology, and explore its greatest application prospects in high-risk industries. Through these explorations, we can foresee that the trend of robots replacing human beings in high-risk industries will gradually strengthen, thus creating a safer and more sustainable working environment for human beings.

2. Research and implementation

This product is based on VR technology and robot control module, which is mainly divided into robot module and control module.

The robot module includes VR part, arm part and mobile platform, which is used to realize the interaction between the user and the virtual environment, control the robot to complete various tasks

through gestures and instructions, and has mobile functions. The control module includes the VR receiving part and the operation detection part. It is responsible for receiving user instructions and transmitting them to the robot module to ensure the accurate execution of user instructions. Through this VR-based robot control mode, users can intuitively operate the robot in a virtual environment, enabling it to perform high-risk tasks instead of human beings and improve the safety and sustainability of work. The next part explains the specific implementation of each part in detail.

2.1. Remote control terminal design

The remote-control terminal is designed to recognize the movement state of the operator's arms and fingers, and remotely transmit it to the robot through the Internet to complete the corresponding following movements.

2.1.1 Arm movement status detection

Arm movement status detection is a key difficulty of this project. According to research, there are the following methods on the market (Fig.1):

1. Binocular vision recognition: use the binocular camera to obtain the three-dimensional movement information of the human arm, and identify and track through computer vision algorithms, which has certain advantages in real-time and accuracy.

2. Electronic skin: The electronic skin patch with sensing function is used to obtain the movement status of the arm in real time by sensing the touch and pressure changes of the arm. This method is suitable for close operations, but there may be some challenges to the recognition of complex gestures.

3. MEMS gyroscope angle sensor: The gyroscope angle sensor developed by micro-electromechanical system (MEMS) technology can accurately measure the angle change of the arm. This sensor has the advantages of low cost, low power consumption and easy to wear, and is widely used in the field of tracking and identification of moving targets.

Based on the research and investigation of the above scheme, this project adopts the method of MEMS gyroscope angle sensor to detect the movement status of the arm. The design framework will fully consider real-time, accuracy and feasibility to provide reliable remote control and realize the following motion of the robot.

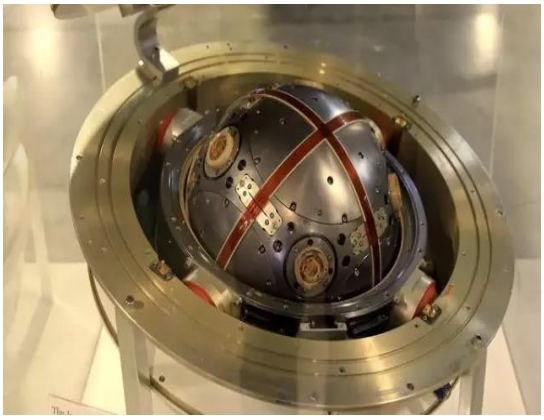


Fig. 1. Air-floating gyroscope of U.S. "militia" intercontinental ballistic missile

In order to accurately identify the movement state of the arm, you can consider installing multiple gyroscopes in different positions of the arm. However, due to the large size and high cost, the traditional gyroscope is not suitable for the needs of this project. Therefore, we can choose to use the cheap and compact JY901 nine-axis MEMS sensor to replace the traditional mechanical gyroscope (Fig.2).



Fig. 2. JY901 nine-axis MEMS sensor

2.1.2 MEMS gyroscope acceleration sensor detection arm attitude scheme realized

According to the design, we will install three sensors in different positions of the arm, namely, the sensor at the shoulder (sensor No. 1: P1), the sensor in the middle of the upper arm (sensor 2: P2), and the sensor in the middle of the lower arm (sensor 3: P3). As shown in the Fig.3:

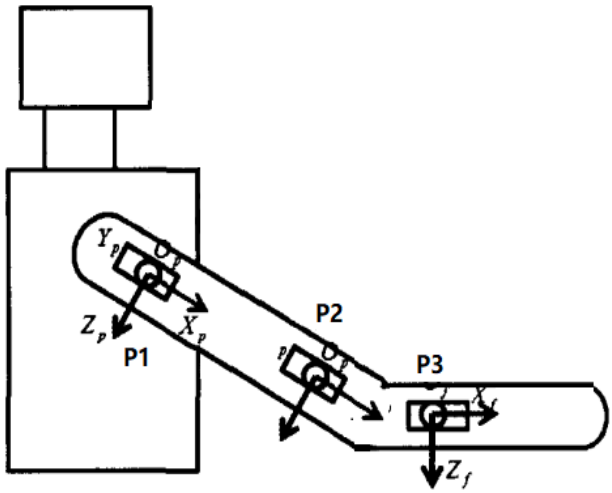


Fig. 3. Human body installation diagram of arm motion detection sensor

These three sensors will measure the angle and acceleration changes of the arm in space in real time. By analyzing these data, we can obtain the posture information of the arm, including the rotation angle, direction and motion state, etc.

2.1.3 Implementation of inclination accelerometer in this project

In this project, complex arm movement and detection can be simplified to the motion detection and control of the upper and lower arms. By analyzing the output data of the sensors P1, P2 and P3, the angle offset information of the arm relative to the three axes of X, Y and Z can be obtained.

For the movement of the upper arm, it can be divided into front and rear swing arm and tension movement. We can use the X-axis data of the sensor P1 to represent the degree of tension of the arm, and the Y-axis data to represent the degree of offset of the front and rear swing arm of the arm relative to the vertical downward [7].

A similar method can be used for the movement of the lower arm. The X-axis data of the sensor P2 is used to represent the tension of the arm, and the Y-axis data is used to represent the degree of offset of the front and rear swing arm of the arm relative to the vertical downward.

Then the arm opens outward: X arm = Xp1

Degree of opening of the upper arm forward and backward: Y upper arm = Yp1

For the movement of the small arm, it can be simplified to the tension degree of the small arm relative to the upper arm. For this reason, we only need to take out the X data of P2 X p2 and the X data Xp3 of P3, then the relative opening degree of the small arm X the small arm = X p2 - Xp3.

2.1.4 Finger movement status detection

In order to detect the movement state of the fingers, this project uses an electronic glove made of a resistive bending sensor. The working principle of the sensor is that when the finger is bent, the metal surface of the sensor will deform, resulting in a change in the resistance value.

Installing these sensors at the finger joints can monitor the curvature of the fingers in real time. When the finger is bent, the sensor will detect a change in the resistance value and transmit this information through the circuit to the control system for processing and analysis. In this way, we can obtain the curvature data of each finger and further analyze the movement state of the finger. This provides the basis for precise finger control and gesture recognition [8]. The electronic gloves made of resistive bending sensor have high sensitivity and accuracy in finger motion state detection. Its production is relatively simple, and the cost is relatively low for large-scale applications. Therefore, this scheme is a feasible and effective method for detecting finger movement status.

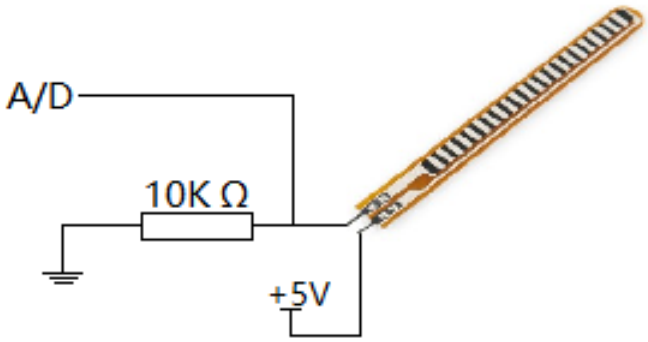


Fig. 4. Bending Sensor and Circuit diagram

The schematic diagram of the circuit is shown in Fig. 4. The sensor and 10K resistance form a simple voltage-parting circuit. The bending or straightening of the sensor is that the resistance will constantly change, and the voltage division above the 10K resistance will change accordingly. The curvature of the finger can be obtained through A/D collection (Fig.5).

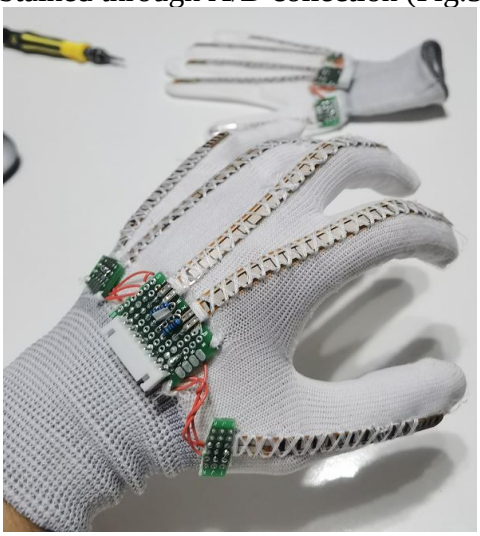


Fig. 5. Electronic gloves composed of 5 sets of sensors

2.1.5 Data collection and transmission

The above discusses the specific scheme of arm and finger movement status detection. Next, let's talk about the collection and transmission of these data.

In this paper, the Arduino single-chip microcomputer control board is used for data acquisition and transmission control, and the programming language adopts C voice. Arduino uses Arduino Nano. As shown in the following Fig.6.

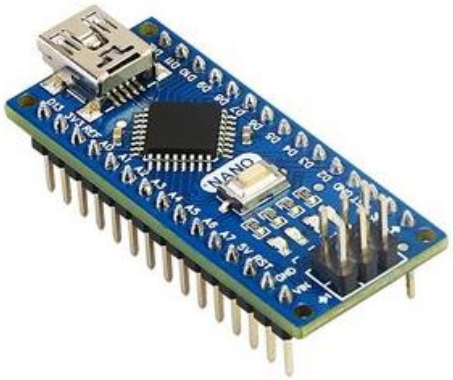


Fig. 6. Arduino Nano

We will use Arduino Nano's five A/D acquisition I/O, I2C serial buses and standard serial ports. The circuit schematic diagram is as Fig.7:

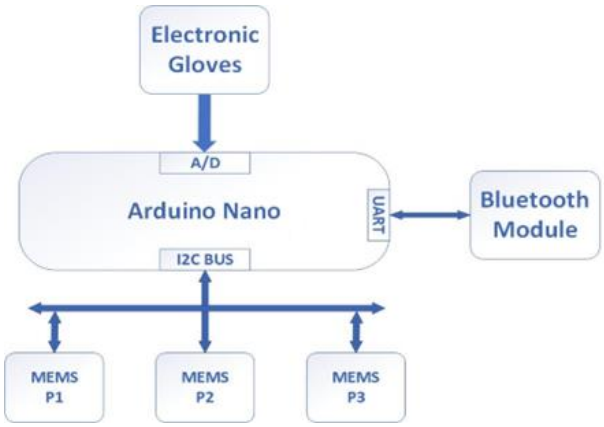


Fig. 7. Circuit block diagram

A/D collection is used to convert the curvature of the finger of the electronic glove into a number from 0 to 512. The smaller the number, the more curved it is. The I2C serial bus is used to read the X and Y data of the three sensors in the arm. The standard serial port is used to communicate with the Bluetooth module, sending the arm and finger status data to the Bluetooth module, and then transmitted by the Bluetooth module to the remote controller to control the robot (Fig.8).

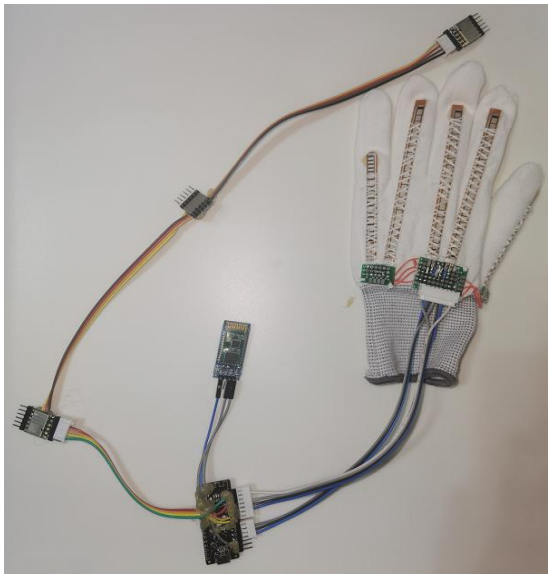


Fig. 8. Electronic gloves + Arduino Nano + Mems Sensors + Bluetooth

2.2. Robot design

This article has made a certain simplification according to the functional requirements of the project, that is, replacing the legs of the robot with a small track car that can control the movement. The focus of this article is on the control of the upper limbs [7,8]. After this simplification, the functional requirements raised above can still be completed. Robot upper limb control can be divided into: upper arm control, forearm control, finger control

2.2.1 Upper limb mechanical design

upper arm mechanical design

The robot can realize the up/down (first X-axis direction) and front and back (defined as Y-axis direction) movement of the large arm. Two servo motors can be placed on the shoulder joint. We use a 60kg large torque servo motor. As shown in the Fig.9.

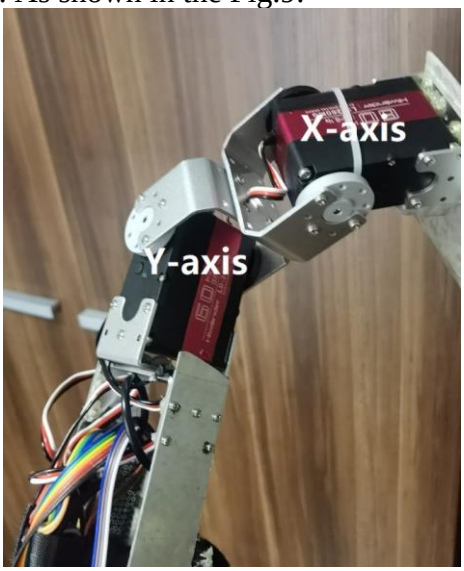


Fig. 9. Upper arm control

Forearm arm mechanical design

The small arm movement can be equivalent to the tension movement of the relatively large arm. For this reason, we only need to put a 20 kg torque servo motor in the elbow joint to control the tension and closing of the small arm to achieve the small arm movement (Fig.10).



Fig. 10. Forearm control

Bionic finger mechanical design

The design of bionic fingers requires the same number of knuckles as solid fingers, flexible and smooth bending and straightening, and flexible catching objects.

This article is designed through Zhongwang 3D design software, and uses 3D printers to make bionic fingers. Each finger has an internal thread, and pull the upper and lower thread of each finger, which can realize the opening and closing of the fingers [9]. Each palm of the control part needs to be equipped with 5 small servo motors to control 5 fingers respectively. The assembly set of upper limbs is shown in Fig. 11-12:

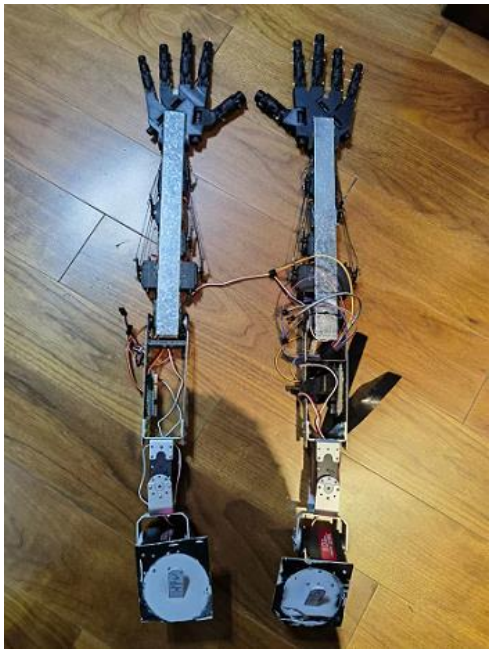


Fig. 11. Assembly diagram of the upper limb

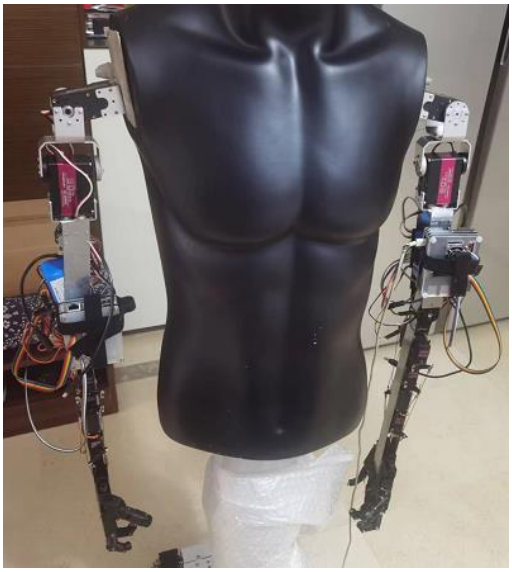


Fig. 12. Robotic arms attached to the body

2.2.2 Upper limb movement control

The control of upper limb movement is realized through the control of the servo motor of the upper limb's upper arm, forearm and fingers. The controller uses Raspberry Pi 4B (Fig.13).

Introduction to Raspberry Pi:

Raspberry Pi is a microcomputer with only the size of a credit card, and its system is based on Linux. It has rich interfaces such as video, network, Wifi, Bluetooth, USB, etc. Theoretically, what a personal computer can do, Raspberry Pi can basically do it. However, Raspberry also has an external pin with 40 pins, which can use extended I/O to control peripheral hardware devices.

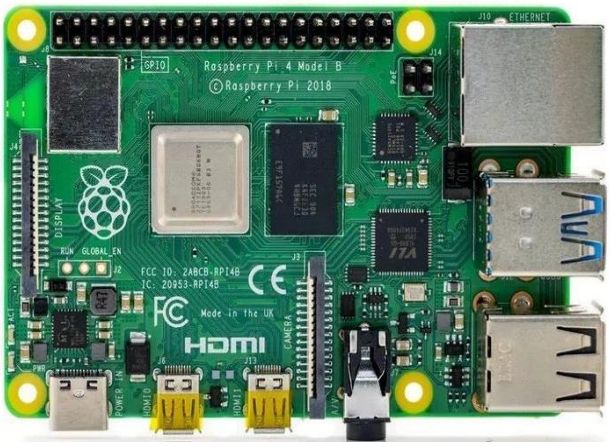


Fig. 13. Raspberry Pi 4B

PWM control servo motor

We use these I/O interfaces to complete the control of 8 servo motors of the upper limbs (2 upper arms + 1 small arm + 5 fingers). Programming uses an easy-to-use Python language.

The servo motor control is achieved by outputting PWM (pulse width modulation control) signal through the Raspberry Pi I/O pin. The servo motor changes the rotation angle according to the pulse width of the PWM waveform.

The PWM signal used here is a control signal with a cycle of 50Hz. The minimum pulse width in each cycle is 0.5ms, which corresponds to the rotation of the servo motor of 0 degrees, 1.5ms corresponds to the rotation of the servo motor of 90 degrees, and 2.5ms is the maximum width. At this time, the steering wheel rotates 180 degrees. As shown in the fig.14

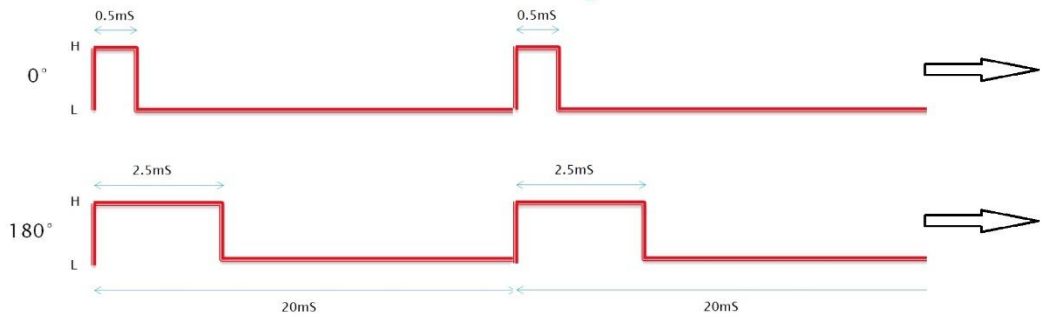


Fig. 14. Adjust the servo angle by controlling the pulse width of PWM

By controlling the pulse width of the PWM waveform, the rotation angle of each servo motor can be adjusted in real time to complete the control of the robotic arm [10].

Remote data reception and decoding

In the previous chapter 2.3.1, we have realized the posture recognition of the upper limbs of the human body. The data completed by attitude recognition will be packaged by the Arduino controller, and then continuously output through WIFI or Bluetooth wireless transmission.

Stream data is a data stream with a specific tag. Each moving state has a special start tag and end tag. The following is a intercepted data stream:

X1:-45.96#X2:-177.91! X3:-50.87@Y3:7.53|f1:163&f2:160<f3:171+f4:187>f5:175_X1:-45.96#X2:-177.91! X3:-50.87@Y3:7.53|f1:163&f2:164<f3:172+f4:184>f5:176_X1:-45.96#X2:-177.91! X3:-50.87@Y3:7.53|f1:165&f2:171<f3:177+f4:181>f5:172_

For example, in the data stream:

X1: Indicates the starting label of the attitude data of the small arm P3 sensor, # is the end label

The -45.96 data in the middle indicates that it is offset by -45 degrees relative to the initial position.

X2: The starting label for the attitude data of the arm P2 sensor,! Label for the end

The -177.91 data in the middle indicates that it is offset by -177 degrees relative to the initial position.

F1, f2, f3, f4, f5 is the starting position of finger movement.

After these data are sent by WIFI or Bluetooth, they will be received by the Raspberry Pi on the robot side, and the data will be decoded through the corresponding program to count the location data in advance.

2.2.3 VR control

VR control is also divided into two parts: human body control side and remote robot side (Fig.15).

The VR binocular camera is placed on the robot side, and the human body control side will wear a VR BOX and a motion status sensor mentioned in 2.1.

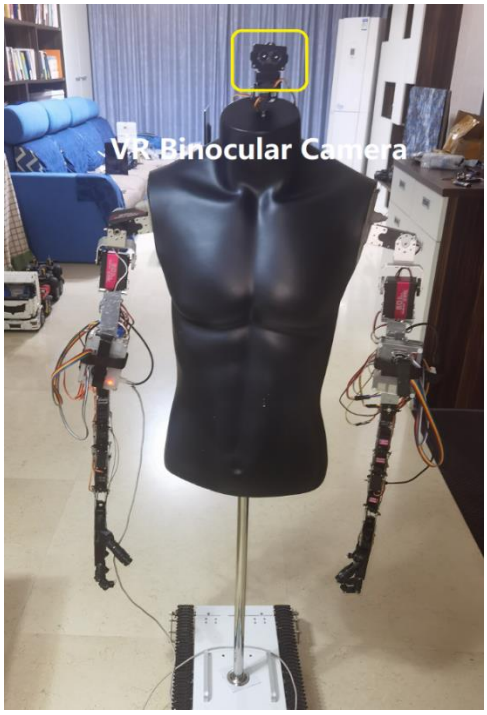


Fig. 15. Remote robot side VR control diagram

3. Experimental test

In order to verify the feasibility and functional realization of the above scheme, we conducted a series of experimental tests.

First of all, we carried out the arm posture detection test. By installing the MEMS gyroscope accelerometer sensor in different positions of the arm and collecting sensor data, we can obtain the attitude information of the arm in real time. In the test, we performed arm posture tests at different angles and in motion states and compared them with the expected results. The results show that the scheme can accurately detect the movement posture of the arm and achieve relatively flexible arm remote control.

Secondly, we tested the finger bending test. With electronic gloves made of resistive bending sensor, we can monitor the curvature of our fingers in real time. In the experiment, we tested the curvature of different fingers and compared them with the actual curvature of fingers. The test results show that the scheme can accurately detect the curvature of the finger and realize the dexterity of the finger to grasp the object.

Finally, in order to evaluate the feasibility of the scheme, a verification experiment of hand grasping function and robot movement function was carried out. In the experiment, a stable workbench was first built, and a robot and a water cup were prepared as test materials. Under the design of the remote controller, the programming sets a series of actions, including the action of the manipulator grasping the water cup, lifting the water cup and placing the water cup (Fig.16). Through the operation of the remote controller, observe whether the robot successfully grabs the water cup

according to the set action, and pay attention to the stability and accuracy of the grasping process. Subsequently, after the robot successfully grabbed the water cup, it controlled the robot to move through the remote controller to observe whether the robot could move smoothly and successfully complete the transfer of the water cup. During the experiment, the movement of the robot, the stability of the grasp, the safety of the water cup and the movement effect of the robot are observed and recorded in detail. The experimental conclusion shows that the robot successfully grabbed the water cup and transferred it. At the same time, it was able to move smoothly, verifying the feasibility of the scheme. These experimental data provide valuable references for further optimizing and improving products.

During the experimental test, we also noticed some shortcomings. For example, there may be some errors in the gyroscope sensor, which leads to problems in robot operation. In addition, the accuracy of the servo motor may be limited and cannot be micro-operated. These problems need to be further improved and optimized in practical application.

In summary, through experimental tests, we have verified the feasibility and functional realization of the scheme, and found some problems that can be improved. This provides valuable guidance for further improving the product and improving the user experience.



Fig. 16. Pictures of a paper cup gripped by a robot

4. Conclusion

In this study, we propose a robot control method based on virtual reality (VR) technology, which aims to solve the difficulties of robot operation through remote control and verify its feasibility. The research process mainly includes two parts: programming and mechanical structure design.

In terms of mechanical structure, we divide the project into the part of the robot body and the operator. Through the clever design of the mechanical structure, the operator can operate the robot remotely. This design provides new ideas for robot operation, so that the operator can directly participate in the movement and grasping tasks of the robot.

In the experiment, we built a stable workbench and prepared robots and water cups as test materials. A series of actions are set through remote control programming, and observe whether the robot successfully grabs the water cup according to the set action and can move smoothly. By observing and recording the experimental data in detail, we verified the feasibility of the robot's hand grasping function and moving function.

The experimental results show that the robot successfully completed the preset action, grabbed the water cup steadily, and was able to move smoothly. This provides an effective solution to solve the difficulties of robot operation. Through remote control, the operator can safely participate in the operation of the robot, thus improving the flexibility and accuracy of the operation.

In summary, the robot control method based on VR technology proposed in this study has achieved good results in the experiment and verified its feasibility. However, there is still some room for improvement, such as further optimizing the grasping algorithm of the robot and improving the real-time of the operation. In the future, this method can be applied to a wider range of robot operation scenarios, and further research and development can be carried out in combination with other technologies.

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