

A Control System of Robot Based on the Kinect Sensor

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Abstract. Design a somatosensory interactive control system for robot based Kinect sensor. The system consists of two aspects, namely the instruction information acquisition part and the instruction execution part. First of all, obtain the human body depth image data through the Kinect, and then use bone tracking technology to extract the human joint points and establish spatial coordinate system. Finally, the joint rotation angle of the human body is calculated by the space vector calculation method to identify the control action and generate control commands. After PC analysis parsing out the corresponding action, we use the wireless module to transmit control commands to the robot to execute the corresponding action. By testing the efficiency of the system action recognition and robot manipulation, experiments show that the control system can control the robot effectively and flexibly.

Keywords: bones tracking, Kinect, robot control system

1 Introduction

With the development of robot control technology, Interaction between human and robot is becoming more and more common. Use body movements to control the robot can replace the complex and cumbersome operating procedures, and we can interact with the robot, issue commands to the robot, and manipulate the robot simply and easily. Body movement recognition based on machine vision is an indispensable key technology which achieve a new generation of human-computer interaction system. As a revolutionary product, Kinect somatosensory device can obtain the color image, depth image and human skeleton image, and it provides a new way of human-computer interaction. It can capture, track body movements, gestures and sounds. According to this, this paper designs a somatosensory interactive control system for robot based Kinect sensor to achieve non-contact interaction interactive control robot through body movements.

Somatosensory interaction control system can be effectively applied in the home environment. Compared with the traditional manipulation, it is simpler and easier to operate, which can accomplish a lot of tasks in the indoor environment. In some extremely complex environments, such as high temperature, severe cold, deep water, etc. In these places that are not suitable for human work, we can help accomplish tasks through somatosensory interaction systems. In the future, somatosensory interaction systems will be used more and more.

This article will be introduced from the following aspects. First introduced the introduction part, and then introduced the overall system structure design and operating principle. Next, the software and hardware design of the system is introduced. Finally, the system is tested and the corresponding conclusions are drawn.

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2 System Overall Structure Design

As shown in Fig. 1, the system consists of two aspects, including the instruction information acquisition part and the instruction execution part. Kinect is used as a tool to collect image information data. Combine Kinect with robot control technology to control the robot by using human motion and gesture.

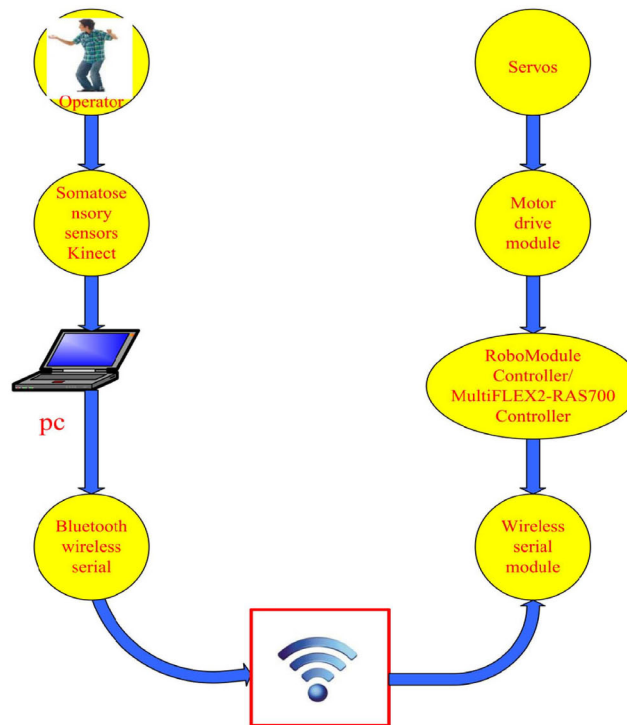


Fig. 1. System structure diagram

The host computer movement instruction acquisition system is mainly used to capture the body language action to identify the human body, which includes the visual sensor, host computer and wireless information transmission module. It can transfer the acquired commands to the slave computer through the transmission system to control the motion of the robot.

In this paper, the action execution system is composed of two robots. Mobile robot with omnidirectional mobile functions and arm robot. The mechanical part of the mobile robot is mainly make up with four-wheel drive chassis and Mecanum round. The mechanical part of the arm robot is mainly composed of a robot arm with a plurality of degrees of freedom and a four wheel drive chassis. Their control system consists of the following parts: MultiFLEX2-RAS700 and RoboModule controller, instruction information transmission module, 24V lithium battery, and driver system. Receive the information through the information collection system to complete the corresponding action instructions.

3 Hardware Design of Somatosensory Interaction Control System

3.1 Body Action Instruction Acquires the Visual Sensor

In this paper, Kinect is used as the body movement instruction to acquire the vision sensor. Kinect somatosensory device was developed by Microsoft Corp. The slogan of Kinect is “you are the controller”. It opens the era of playing games and watching movies with sound and body. Kinect means that the information transfer technology between the new generation of computers and users has been greatly improved. It integrates a lot of cutting-edge technology, integrated mechanical and optoelectronic and other disciplines. It mainly consists of 3 independent motherboards, with nearly 100 main components. After splitting it, there are nearly 1000 small components. It has changed people’s traditional understanding of cameras, and demonstrated the field of human-computer interaction. Kinect has become

a research platform for many research institutes because of its high cost performance and powerful function [1].

This paper uses kinect2.0, compared with the first generation, technical hardware has greatly improved. The identification of the second generation of Kinect becomes more accurate. Kinect has a higher resolution and a better picture. At the same time, it increases the function in depth sensing, which can make people see things smaller and more clear; skeletal tracking has become more stable; the noise floor and the depth of fidelity also has been improved, 3D created a better visual effect. In the field of vision, it becomes more open, which can capture a wider range of vision. Even if the user shortens the distance from the Kinect, it will not change the field of view. In terms of bone tracking, camera fidelity and software are mainly enhanced. Kinect tracking captured posture becomes more stable and accurate. At the same time, a lot of scenes are added, and the interaction becomes simpler. Infrared function, Kinect can capture the user's behavior in the dark, the environmental requirements are reduced, the choice of site becomes wider. In addition to the improvement of the above features, Kinect2.0 also adds more advanced functions such as thumb tracking and finger end tracking. There are more detail elements in somatosensory interaction, which greatly increases the range of development and user's choice [2].

The structure of the sensor is as shown in Fig. 2. Infrared projector is on the left side of Kinect somatosensory device. The model of infrared projector is OG12/0956/D306/JG05A. Compared with the traditional network video capture device, it has a larger lens. It also can auto focus. Infrared projector should be used with infrared camera together. It can independently launch the near-infrared spectrum, the wavelength is 830nm, and the band of infrared light on the human body is harmless. The color camera is installed on the right side of the somatosensory device. The color camera model is VNA38209015CMOS. The infrared camera is in the middle part of the Kinect somatosensory device, and the model is Microsoft/X853750001. The function of Color camera is to collect color data in the field of view and provide color patterns. Infrared camera is a CMOS graphic acquisition and processing device. Its function is to resolve the captured infrared light wave, and finally generate the depth image which forms the target within the visual field acquisition limit. The basic principle of infrared camera's operation is to collect the light signal from projector, and then edit and process the signal to the chip PS1080. PS1080 receives the encoded information and frames the depth image by frame. Finally, the sensor sends the audio stream and depth information to the host via USB, and the host receives the synchronous color deep flow through it [3].

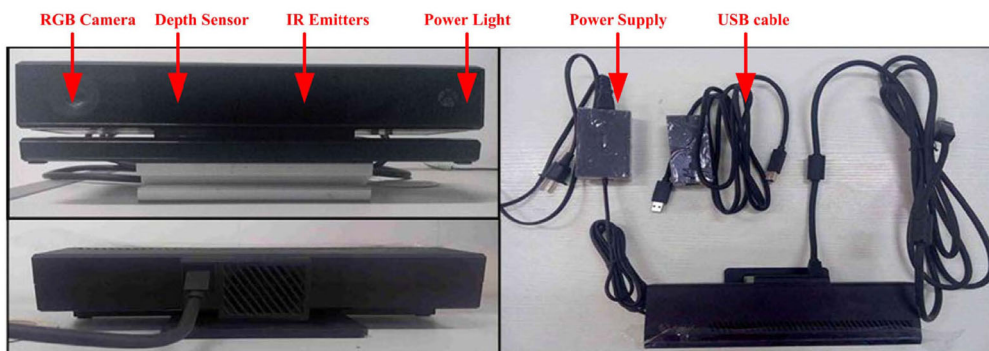


Fig. 2. Sensor structure diagram

Kinect sensors provide 3 kinds of data information for users, which correspond to three processing processes: skeleton tracking, identity recognition, speech recognition [4]. As shown in Fig. 3, the user information captured by the somatosensory device includes the color picture of the human body captured by the camera, the depth map, the infrared map and the joint point of the human body after the background is segmented. This article mainly uses the skeleton tracking part.

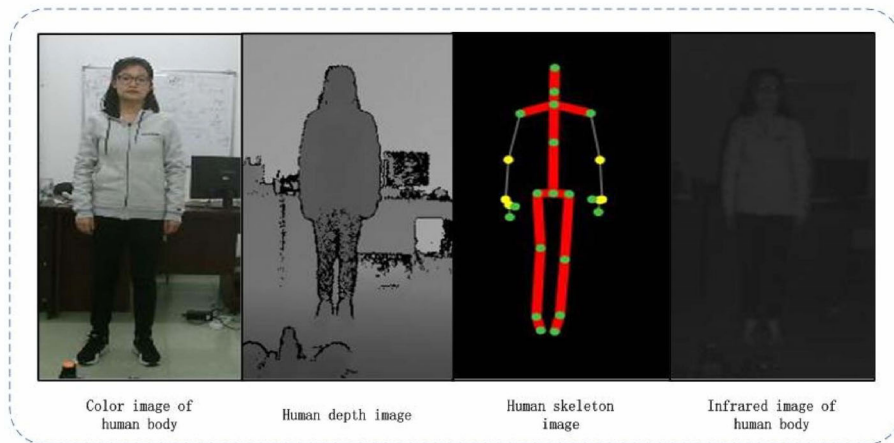


Fig. 3. Human body image information collected by Kinect

3.2 Human Body Skeleton Model

As shown in Fig. 4, it shows the field of vision of the Kinect somatosensory device. The vertical direction is 43 degrees; the horizontal direction is 57 degrees. The shape is pyramid. Bone tracking mode is the basis for the application of somatosensory devices. The somatosensory device projects the optical signal through the projector. In the range of capture of the device, the camera collects the reflected information, resulting in the formation of depth data. Then the system will parse it, similar to the human visual system. The first step is to get a rough outline, and then to go further into the details of the scan. The range of the human body is gradually analyzed in depth data. In the tracking range of Kinect somatosensory devices, Kinect can identify and track two target objects in the active tracking mode. In passive tracking mode, Kinect can identify and track six target objects [5].

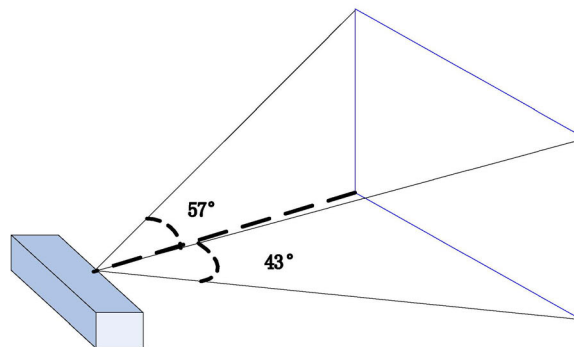


Fig. 4. Kinect somatosensory equipment field of view

After the target object is extracted, the machine vision algorithm is used, and the main position of human body, such as head, thigh and arm, is quickly identified and marked by color. And then the skeleton is extracted. As shown in Fig. 5, the human skeleton point model. As you can see from the diagram, the human body has many skeletal points, and the skeleton is the connection of these skeletal points. Recognition of these skeletal points is the prerequisite for bone tracking, gesture acquisition, and human-computer interaction. Kinect recognition of these skeletal points is based on the principle of the two classification. The first classification is to extract the outline of the object. The second classification is to identify and mark the main parts of the human body. The machine algorithm is used to match the probability. Firstly, the local pixels are analyzed, and then the whole image is detected. From several angles to measure and calculate repeatedly, eliminate the overlap and interlace, identify the skeleton point and connect it, then complete the skeleton construction. Kinect has high precision and compatibility, and it can detect and track both adults and children.

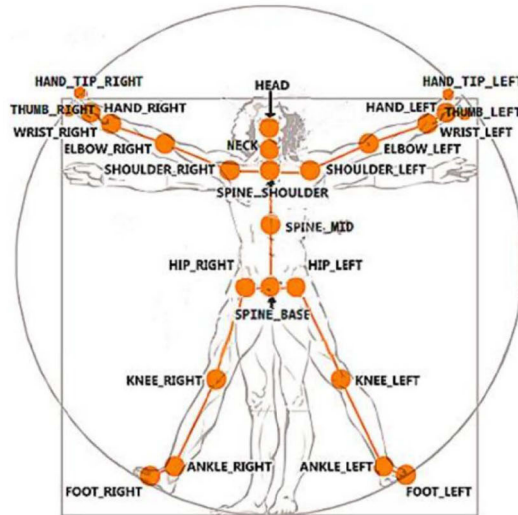


Fig. 5. Human skeleton model

In this paper, the body sense sensor is used to recognize and extract the relevant information of human skeleton points, and the human pose is defined and calculated by calculating the angle between the joints, so as to control the motion of the robot.

3.3 Design and Control Principle of Omnidirectional Mobile Robot

Omnidirectional Mobile Robot is made up with four Mecanum wheel, RM35 chassis DC Gear Motor, Robot Module DC servo motor drive module, aluminum, 24V lithium batteries and other components. Modeling effect and physical map are as shown in Fig. 6.

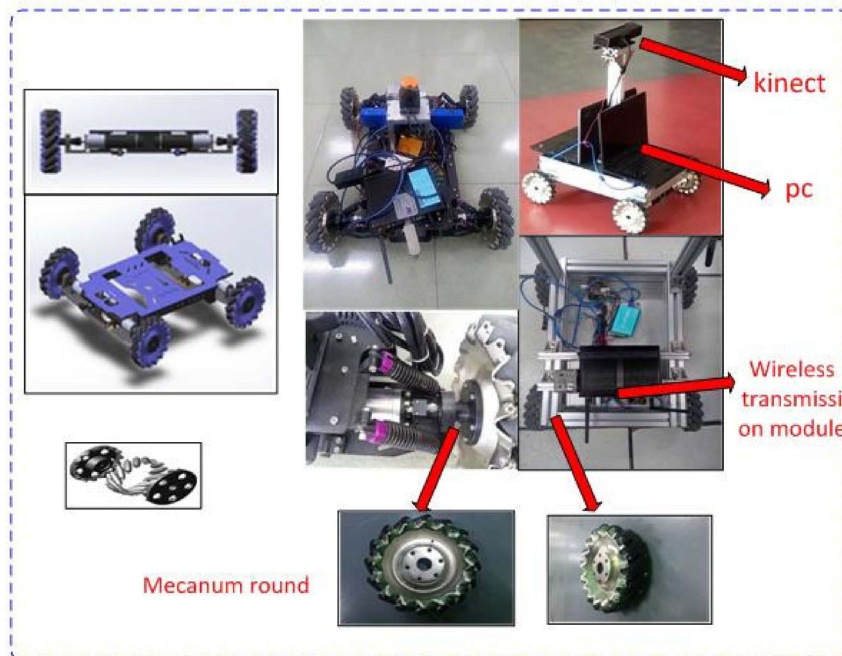


Fig. 6. Mobile robot modeling and physical map

The mobile robot can move all the way because of the Mecanum wheel located at the bottom. The circumference of the main wheel is distributed with a small roller with 45 degree of wheel axis, which makes the main wheel has two degrees of freedom, including rotation of wheel shaft and the roller axis motion along the vertical direction. This is the basic principle why Mecanum wheel can omni-directional motion.

The bottom part of the wheel mobile robot is the Mecanum wheel. Compared with other wheels, it is more flexible. It can rotate clockwise and anticlockwise in zero radiuses, and move in any direction. Especially in complex and narrow environment, it can realize unconventional operation such as S shape and inclined line, which achieve precise positioning function. As shown in Fig. 7, Ordinary wheel passes through a rectangular time needs to reserve space, Mecanum wheel passing process is not limited by the environment.

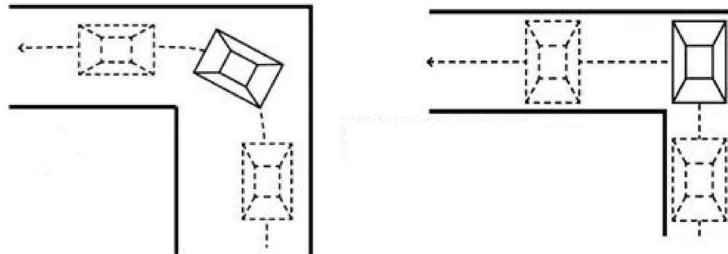


Fig. 7. Mecanum wheel through the right angle

Mecanum wheel is used in aviation Aluminum Alloy level material. Its weight is very light, deformation is very small. Driven wheel is the use of polyurethane, so its hardness and wear resistance is high, which can meet the requirements of the vast majority of terrain. Driven wheel bearings are rolling, so it will be more quiet and reliable, the friction will be smaller. The design and material makes Mecanum wheel has very high service life, which can deal with all kinds of complex terrain and achieve high accuracy in positioning and tracking.

Mecanum wheel is constructed of two parts. Some of them are rims, and the others are rollers. There are a lot of roller numbers; it is uniformly distributed in the outside of the Mecanum wheel. Each roller has an axis. It itself can move along the axis, and its motion does not provide driving force. The schematic diagram of the structure is as shown in Fig. 8.

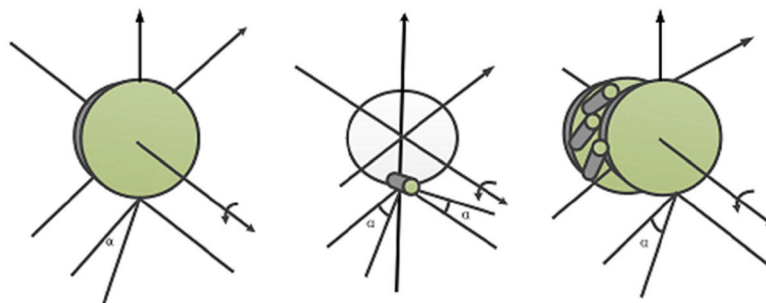


Fig. 8. Mecanum wheel structure principle diagram

The principle of Mecanum wheel to the full range of mobile is the axis each roller will maintain a point axis and the Mecanum wheel rim at installation time. So when the motor drives the Mecanum wheel rim rotates, the surface of the roller is also in rotation, because it does not provide driving force, its rotation relies on ground friction. This round of the whole is equivalent to the collection of the two degrees of freedom. Mecanum wheel can move in the direction of the two revolving forces, which has the ability of the full range of mobile.

A single Mecanum wheel cannot allow the robot to move all round. A mobile robot requires at least four Mecanum wheels that can move freely omnidirectional. As shown in Fig. 9. In the center of the mobile robot platform as the origin o , establish o_{xy} coordinate system. In this paper, the mobile robot has three degrees of freedom, including speed in the x -axis direction, speed in the y -axis direction, own angular velocity v_x, v_y, ω_z . ω_i is the center of the wheel to the axle as the angular velocity of rotation, o_i is the speed of the wheel center, v_{gi} is the rotating speed of the roller [6].

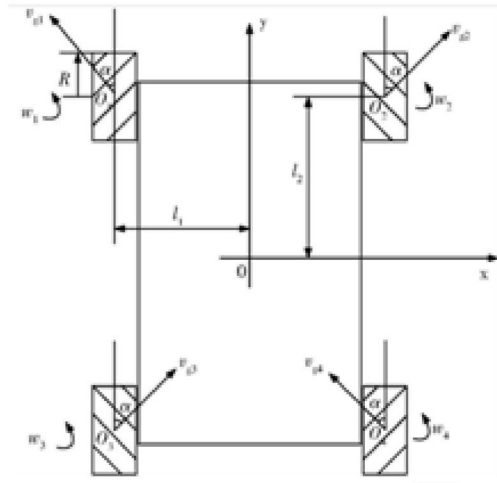


Fig. 9. Chassis motion structure analysis

When the robot moves, the motor drives the wheel to rotate. At this time the wheels have two sports, one is that the wheel is driven by the motor to parallel movement in the horizontal direction; another is that the friction of the ground makes unpowered roller rotates itself. Take the lower right wheel o_4 as an example. Wheel center in the coordinate system of the velocity v_4 is:

$$v_4 = \begin{bmatrix} 0 & -\sin \alpha \\ R & \cos \alpha \end{bmatrix} \begin{bmatrix} \omega_4 \\ v_{g4} \end{bmatrix}. \tag{1}$$

Because the wheels directly fixed on the mobile platform, so the overall speed of the mobile platform can be drawn:

$$v_4 = \begin{bmatrix} 1 & 0 & l_2 \\ 0 & 1 & l_1 \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}. \tag{2}$$

So, it can be drawn from the above:

$$\begin{bmatrix} 0 & -\sin \alpha \\ R & \cos \alpha \end{bmatrix} \begin{bmatrix} \omega_4 \\ v_{g4} \end{bmatrix} = v_4 = \begin{bmatrix} 1 & 0 & l_2 \\ 0 & 1 & l_1 \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}. \tag{3}$$

The same can be analyzed $o_1 o_2 o_3$ can be drawn:

$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = \begin{bmatrix} \frac{1}{R \tan \alpha} & \frac{1}{R} & \frac{-(l_2 \tan \alpha + l_2)}{R \tan \alpha} \\ -\frac{1}{R \tan \alpha} & \frac{1}{R} & \frac{l_2 \tan \alpha + l_2}{R \tan \alpha} \\ \frac{1}{R \tan \alpha} & \frac{1}{R} & \frac{-(l_2 \tan \alpha + l_2)}{R \tan \alpha} \\ -\frac{1}{R \tan \alpha} & \frac{1}{R} & \frac{l_2 \tan \alpha + l_2}{R \tan \alpha} \end{bmatrix} = \begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix} = \begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}. \tag{4}$$

Formula J is the Jacobian matrix of the system. According to kinematics of the mobile robot can be drawn that Jacobian matrix J reflects the relationship between the moving speed of the mobile robot four Mecanum wheel rotation angular velocity and the center and the platform for Mecanum omni wheel mobile systems [7].

The movement direction of the mobile platform is as shown in Fig. 10.

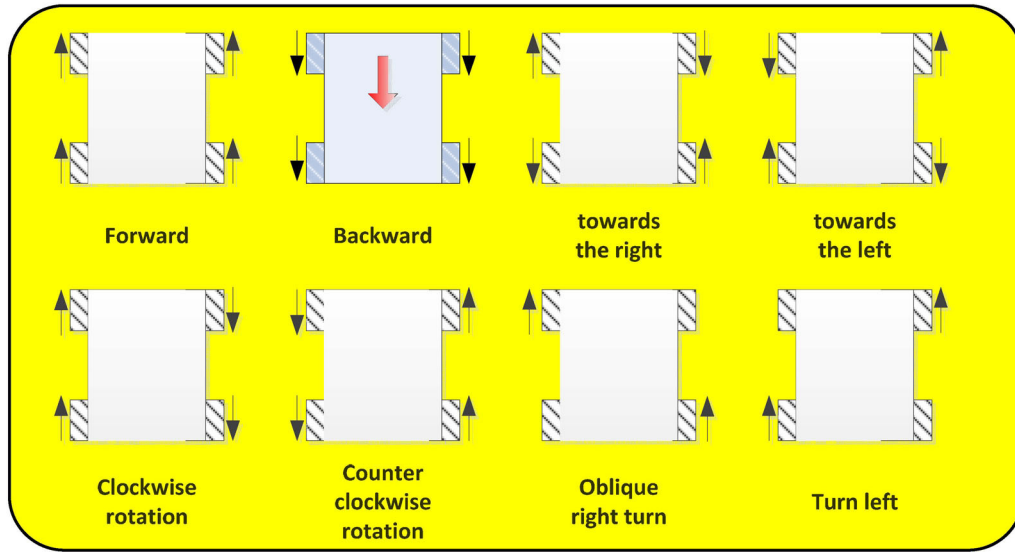


Fig. 10. Schematic diagram of omnidirectional mobile robot

System chooses Robomaster Company RM35 chassis dc gear motor. As shown in Fig. 11. RM35 chassis is a motor for 5 kg to 20 kg tailored wheeled robot chassis power motors. RM35 has the characteristics of high efficiency, high reliability, low noise, which can provide plenty of chassis power. Motor itself with supporting the reducer.

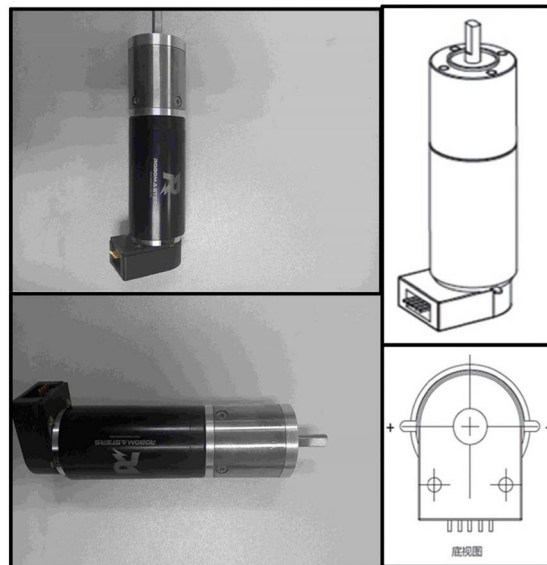


Fig. 11. RM35 motor physical map

The experiment was selected with the motor supporting ROBOMASTERS brand DC servo motor drives RoboModule. As shown in Fig. 12. ROBOMODULE drives are for finished product module. Internal firmware has integrated mode of open loop, current loop, speed loop and position loop mode and uses the CAN bus to control, which most can support 15 cascade uses the same drives. Operating parameters can be modified via the commissioning software. Communication is the CAN bus or TTL serial port. Robot Module provides STM32F103 and STM32F405 version of the interface control code, which can call the appropriate interface function to control without re-programming [8].



Fig. 12. RoboModule Dc servo motor drive

Drive has several operating modes as follows. PWM mode, when open loop control motor rotation, the faster the PWM duty ratio, the greater the rotation. Current loop mode, when given the current, the greater the drive to the constant torque output is larger. Speed loop mode, it can control the rotational speed of motor accurately. Position loop model, which can control the motor, rotates at a specified rotational speed to a specified location. Motor parameter setting mode, namely the three closed loop PID parameters can be set motor, motor rotation direction, is the direction of the encoder feedback. Drive number set mode, which can set the drive on the CAN bus ID number corresponding to the various functions.

ROBOTMODULE has the following interfaces: the power interface, the CAN communication interface, the incremental encoder data acquisition interface, electrical interface, TTL serial communication interface, SWD debugging interface. Configuration position is as shown in Fig. 13.

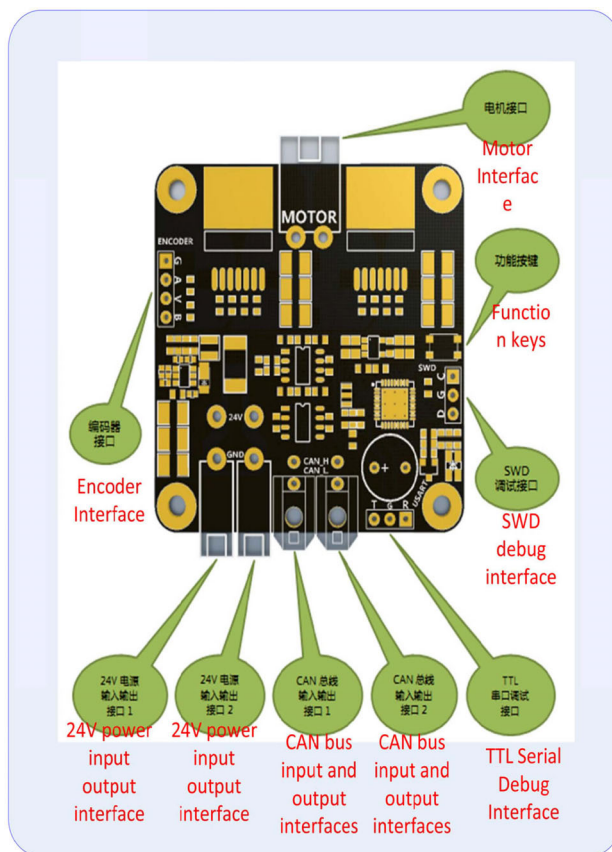


Fig. 13. Drive interface configuration

24V lithium battery. The system uses 24V lithium battery-powered which has a long life and other advantages.

3.4 Design of Arm Robot

The chassis of the arm robot used in this paper is wheeled, which can move back and forth and rotate clockwise and counterclockwise in place. As shown in Fig. 14.

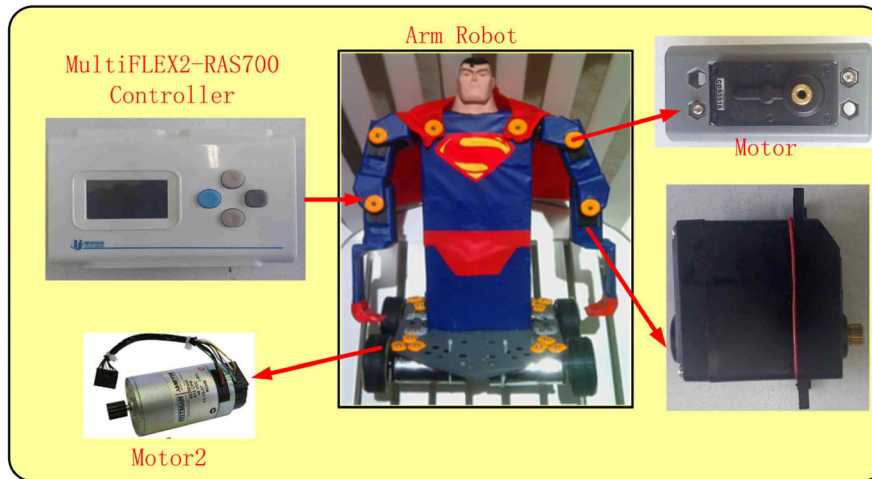


Fig. 14. Arm robot physical map

According to the requirements of the experiment, the design parameters of arm robot in this paper are as follows: the weight is 3 kilograms; The length of the arm part is 250 mm; the height is 350 millimeters. The head of the robot can rotate. The shoulder can be realized forward, back, outreach, adduction. Elbows can stretch. The robot arm has very good flexibility, which is easy to manipulate by limb movements.

This system uses the CDS5516 and 2342L012 digital steering engine. Using TTL/RS-485 serial bus, address + data packet control mode, CDS5516 digital steering gear has the advantages of high control precision and fast response. Robot motor control system uses MultiFLEX2-RAS700 controller. It can control DC motor, the steering gear with various signals, and adjust the speed, position control and torque control of the robot.

Compared with omnidirectional mobile robot, the advantage of arm robot is that it can simulate the upper limb movements of human body in real time, so as to complete some arm work. Sensors can collect and identify people's body language information in real time. By extracting the data of the skeleton points, the angle between the corresponding skeleton lines is calculated. The computer sends out instructions after making judgments. After receiving instructions, the robot will make corresponding actions through the information transmission module.

4 Software Design of the System

4.1 Recognition of Human Body Motion Information

At present, the most commonly used algorithms in the field of human body posture recognition are neural network algorithm and DTW algorithm. But the two algorithms need to consider a lot of factors and parameters, the implementation is very complex, and the requirements for the program are very high. In view of the above situation, this paper uses the space vector method to identify human posture. The advantage of this algorithm is that its parameters and the amount of calculation are relatively less, and the program design requirements are relatively simple. On the other hand, it can define static pose and dynamic pose at the same time, without having to proceed separately.

The core idea of this method to identify actions is the angle between computational vectors. The human body is composed of bones and muscles, and the body can exercise because the muscles drive the

skeleton to move. We can regard the skeleton of human body as rigid body, and the skeleton system of human body can be divided into many skeleton points, and skeleton is the connection between skeleton points. The way the limbs move is the interaction between the wires of the different skeletal sites. For example, the bending of the arm can be seen as the change in the angle between the two skeletons. So if you can calculate the angle, when the angle is within a certain range, you can define the arm bending posture. This is the principle of space vector method to recognize human posture. Angle calculation is a geometrical problem. The difficulty is the consideration of boundary conditions. When calculating the angle, it will encounter a variety of complex situations, such as overlap, vertical and so on, which brings a lot of difficulties to the programming algorithm. Using space vector method can be very simple and effective to deal with the above problems.

Application of bone tracking technology Kinect can track the user’s body 20 points. In this paper, we use the data of 9 points of hands and other points to recognize the user’s action. Recognition of human body control action is mainly to identify the changes in the angle of joint movement. Coordinates are as follows: the midpoint of shoulder is set as coordinate origin point O . The straight point of shoulders is set as X coordinate axis. The straight line of the human spine joint point is set as Y coordinate axis. As shown in Fig. 15(a), take the left arm as an example, “ a, b, c, d, e ” respectively correspond mid-point of the shoulder joint were human, point of shoulder, elbow point, the wrist joints, hand joints. α_1 is the angle between bc and plane xoz . α_2 is the angle between bc and X axis. β is the angle between bc and line cd . γ is the angle between de and line cd . The calculation method used in this paper is space vector method. Taking α_1 and β as an example. To calculate the Angle α_1 and β , for example, as shown in Fig. 15(b), the coordinates of the point b is (x_1, y_1, z_1) . The coordinate of the point c is (x_2, y_2, z_2) .

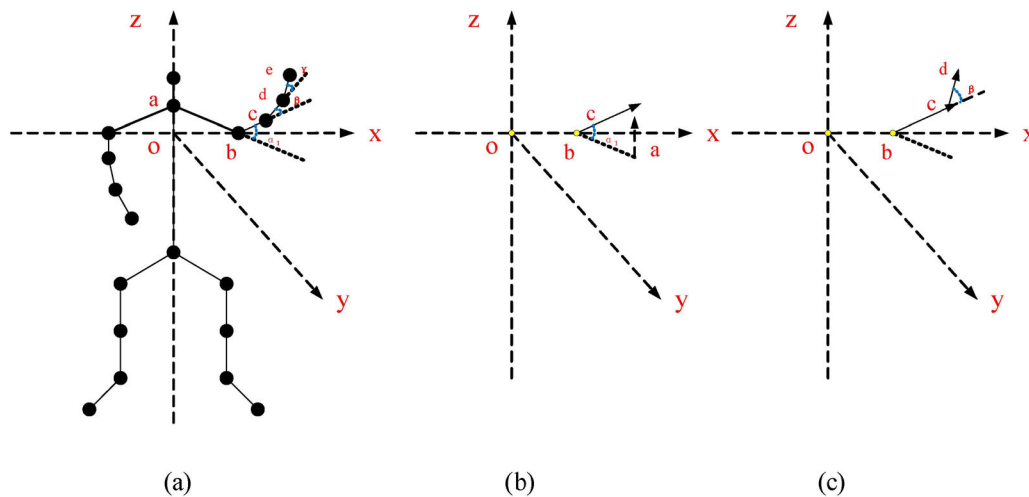


Fig. 15. Joint angle schematic

$$bc = (x_2 - x_1, y_2 - y_1, z_2 - z_1). \tag{5}$$

xoz plane normal vector is a .

$$a = (0, 0, 1). \tag{6}$$

$$\sin \alpha_1 = (bc \cdot a) / (|bc| \cdot |a|). \tag{7}$$

As shown in Fig. 15(c), the coordinates of the d is (x_3, y_3, z_3) .

$$cd = (x_3 - x_2, y_3 - y_2, z_3 - z_2). \tag{8}$$

$$\sin \beta = (bc \cdot cd) / (|bc| \cdot |cd|). \tag{9}$$

By analogy we can be obtained values of the trigonometric angle, after the inverse trigonometric function operation can obtain the rotation angle of each joint. According to the joint angle, the

appropriate threshold is set. In the threshold range, it is believed that the human body has made the corresponding limb movements, so as to complete the purpose of identifying limb instructions. The calculated angles should be satisfied with the following conditions.

$$Angle = \{\theta_1, \theta_2\}. \tag{10}$$

Angle is the joint point angle; θ_1 is the lower limit of the angle, θ_2 is the upper limit of angle. According to the way of robot movement and the habit of human movement in daily life, in order to make the recognition of human body natural and harmonious, after repeated experiments, determine the threshold of each action, as shown in Table 1.

Table 1. Human action threshold range.

Body posture	θ_1	θ_2
Right elbow bend	30	90
Left elbow bend	30	90
Right arm lift	60	120
Left arm lift	60	120
Right knee bent	30	90
Left knee bent	30	90
Right leg stretch	30	90
Left leg stretch	30	90

The results of human posture recognition are shown in Fig. 16.

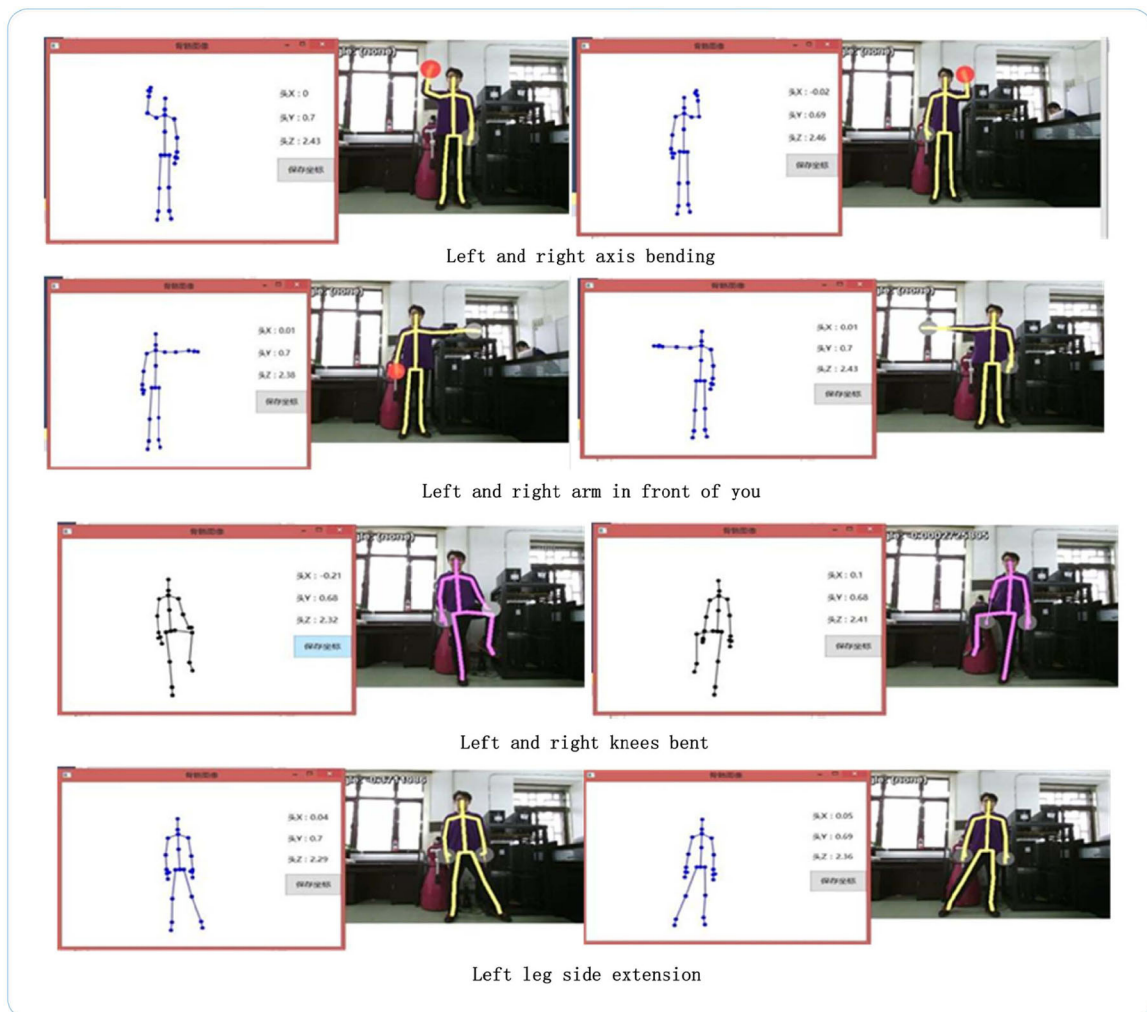


Fig. 16. Human body attitude recognition results

4.2 Software Control System of Omnidirectional Mobile Robot

As shown in Fig. 17. Connect battery, motor, driver board and PC. After confirming that the installation is correct, open RoboModule servo motor driver debugging software to select speed ring mode.

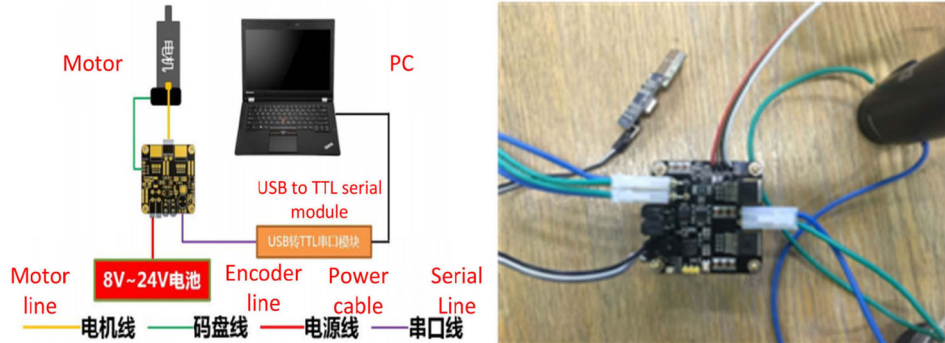


Fig. 17. Drive control system connection diagram

As shown in Fig. 18. The system uses the speed loop mode. Speed loop mode based on the PWM mode. After the PWM value to a positive number, the number must be positive encoder feedback value. Give negative PWM value, the encoder feedback value must be negative. Send command consists of two parts. The first part is to limit the maximum number of PWM. If you worry about burning motor stall occurs during operation, the PWM duty cycle can be limited to a small value. If you need to respond quickly to a given speed value, limiting fill larger PWM duty cycle value in the text box, such as the maximum value of 5000. The second part is a given speed value. The speed value meaning is that within 1ms, the encoder is driven around the line number. The maximum speed of each motor has a limit. If the given speed value beyond the limit, then it will be able to achieve the maximum speed of operation.



Fig. 18. RobotModule mode selection

The system uses the CAN bus to control the drive. The system uses CAN to control the robot's four motor drives. Only one CAN will be able to connect all the drives up. Control board receives control amount calculated by the matrix operation speed in the control process. It is converted to electrical power output by the formula $C_i = \frac{W_i}{m_i \cdot W_{i_{max}}}$ (C_i is the i -th power of the motor, W_i is calculated for the i -th motor speed, $W_{i_{max}}$ is motor speed to set the maximum output power of divination under the same voltage, 4 mi is to maintain maximum motor speed measured parameters). And then through the PWM signal output to the motor drive module to generate corresponding power and complete the chassis drive. In this paper, Images transmitted by Kinect will be judged by the operator's vision and sense to form a closed-loop system and feedback regulation. Finally complete the accurate control of Omni-directional motion.

According to the movement of mobile robot in this paper, there are eight basic motion patterns of

mobile robot, so there are eight kinds of human posture recognition. So it's necessary to calculate the angle of the eight joints. According to the design requirements, we selected several joints required to calculate the angle in the 25 joints of the human body. The calculation is divided into upper limb and lower limb, and each part has four sets of movements. Table 2 shows the joint angles that need to be calculated, and the motion pattern of the robot corresponding to each action.

Table 2. Robot movement mode corresponding to human action.

Body parts	Robot motion mode	Human action	Angle of calculation
Upper limb	Forward	Right elbow bend	Human right elbow joint angle
	Back	Left elbow bend	Human left elbow joint angle
	Left rampage	Left arm lift	Angle of left shoulder joint
	Right rampage	Right arm lift	Angle of l right shoulder joint
Lower limb	Left rotation	Left knee bent	Human left knee joint angle
	Right rotation	Right knee bent	Human right knee joint angle
	Left 45 degrees of inclined forward	Left leg stretch	Left hip angle of human body
	Right 45 degrees of inclined forward	Right leg stretch	Right hip angle of human body

4.3 Software Control System of Omnidirectional

As shown in Fig. 19. Before using this system, the robot's joint angle should be calibrated to keep it in the middle position.

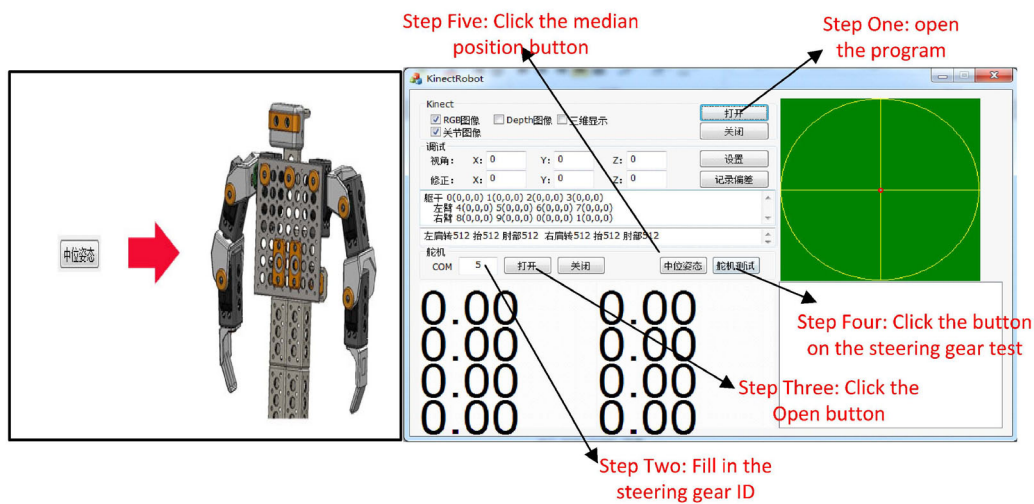


Fig. 19. The median posture and calibration procedure of robot

Specific calibration steps are as following: Start the kinectrobot program and make out the “COM” item of steering engine. Next, click “open” button until the system prompt ports of steering gear. If it fails, confirm the power status of the controller and the Bluetooth setup information. Then we need to check the connection state. The last step is clicking on the KinectRobot program interface “in the middle” button and information list shows the six steering gear commands sent. The RecNum count displayed on the controller will increase.

When the body moves before Kinect, the robot will imitate human movements in real time after receiving the information. Test case is as shown in Fig. 20.

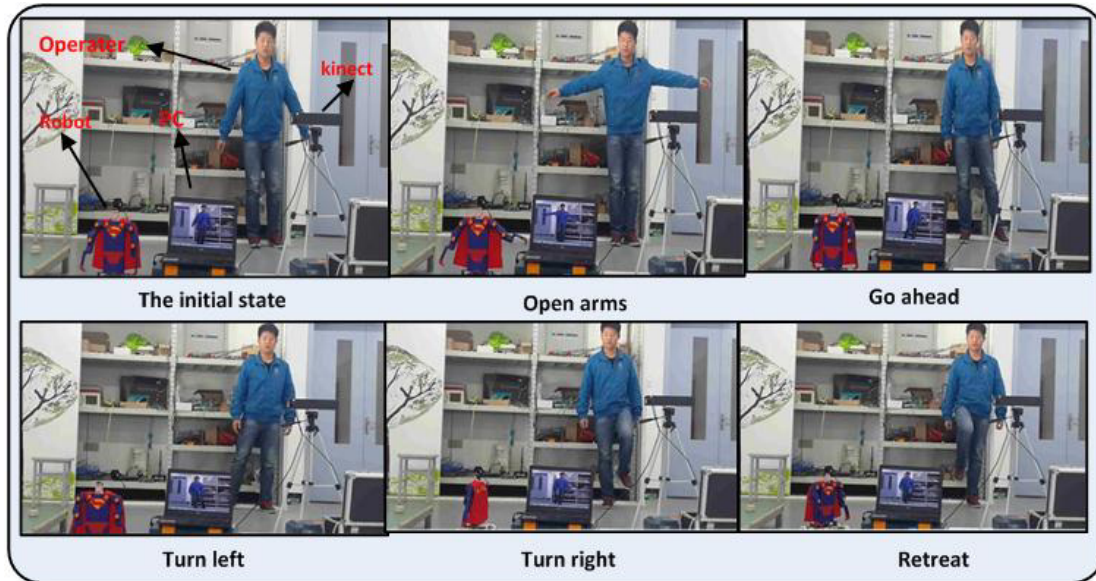


Fig. 20. Real-time manipulation of the robot

4.4 System Flow Chart

Software design uses modular processing method. Each module runs autonomously and does not interfere with other parts. The upper computer is responsible for collecting the data information of human skeleton points. Then it judges the information and generates action instructions. Finally, the instructions are passed to the robot through the transmission module. Development tool is Kinect Software Development Kit (SDK) v1.8. Development environment is Visual Studio 2013. Programming language is c#. The robot is the executor of the instructions. It can do the corresponding action according to the instructions. The flow chart of the system is as shown in Fig. 21.

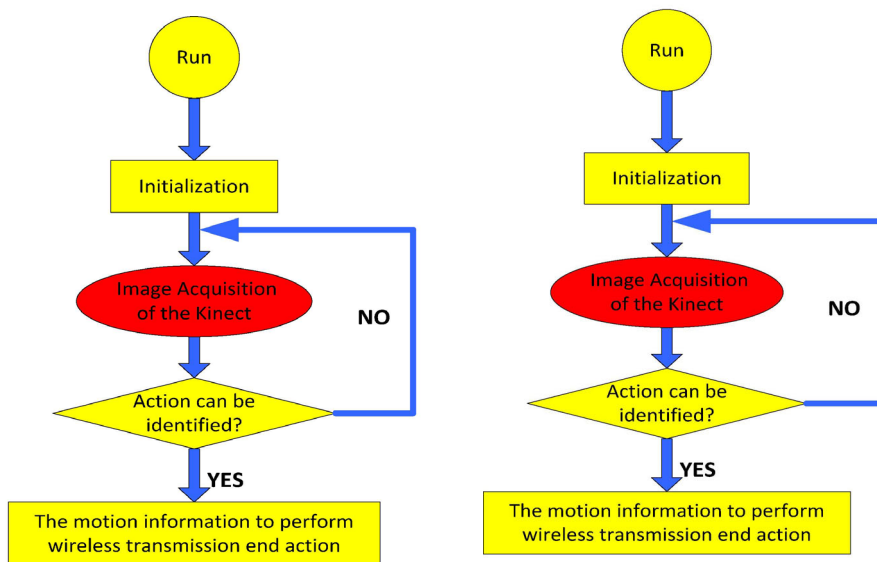


Fig. 21. Program flow chart of system

5 Experimental and Test

In order to test the performance of the human-computer interaction system, we experimented with the arm robot and the omni-directional mobile robot respectively to verify the effect of controlling the robot through the limb movement.

5.1 Experiment of Turning on Light for Arm Robot

The operator will control the arm robot to turn on the light. As shown in Fig. 22. The experiment chooses the common switch as the operation object. The size of the board is 150*270cm. The height of the switch is 30cm. The experimental steps are as follows: The initial part, the operator gives instructions through his limbs. Arm robot will receive instructions and move in the direction of the lamp. Next is the attitude adjustment stage, after the arm robot gets close to the light, we have to adjust the posture of robot in time and find the right position to turn off the lights. Finally, when the robot finds the appropriate position, the instructions are issued, the robot arm touches the switch, and the lamp is turned on.

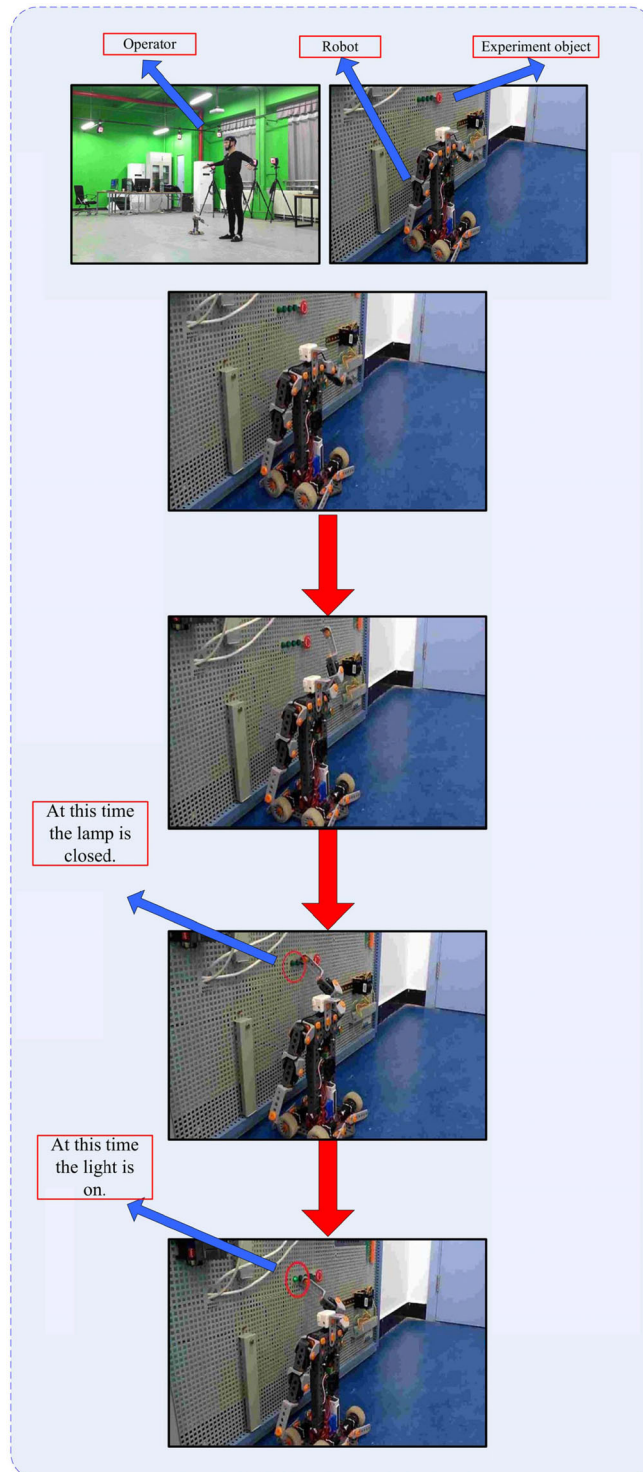


Fig. 22. Arm robot turn on test

In this experiment, because of the delay of the system and the error of the human body operation, the movements of the robot are not very flexible, but in general, it can achieve the expected purpose of the test.

5.2 Human Body Attitude Recognition Test

In this paper, eight kinds of human postures can be identified by visual sensors. These eight gestures are right elbow bending, left elbow bending, right arm lift, left arm lift, right knee bent, left knee bent, right leg stretch, left leg stretch. In order to verify the recognition efficiency of the robot vision system to the defined human posture, five experimenters were tested in this paper. In the experiment, the five subjects were different in gender, height, age and weight. The reason for this setting is to detect whether the robot vision system is universal for human posture recognition. The experiment required each experimenter to do an action repeated 20 times, so each defined action was repeated 100 times at the end of the experiment. As shown in Fig. 23. The human pose recognition test was performed by five experimenters. The experiment was divided into two parts, the upper part of the action recognition test and the lower part of the action recognition test.



Fig. 23. Human action recognition test

It can be seen from the diagram that the five body movements of the tester can be captured very clearly by the visual system. The sex, height, weight and other physical signs of these testers are not the same, but the skeleton system can be identified and plotted. It shows that the system has universality. Table 3 shows the experimental results of human pose recognition test.

Table 3. Attitude recognition test results

	Body movements	Number of experiments	Number of successful tests	Number of test failures	Recognition rate	Overall recognition rate
Upper limb movement	Left elbow bend	100	98	2	98%	96%
	Right elbow bend	100	97	3	97%	
	Left arm lift	100	94	6	94%	
	Right arm lift	100	95	5	95%	
Lower limb movement	Left knee bent	100	92	8	92%	87.5%
	Right knee bent	100	90	10	90%	
	Left leg stretch	100	83	17	83%	
	Right leg stretch	100	85	15	85%	

As shown in Fig. 24. From the data in the table, we can see that the overall recognition rate is 91.75%, at a high level. It shows that the effect of human gesture recognition is ideal. The robot vision system is not affected by the factors such as the height of the experimenter. At the same time, the overall efficiency of the upper limb was 96%, 8.5 percentage points higher than 87.5% of the lower limb. This shows that the system is easier to identify the upper limb. The main reason for the high recognition rate of upper limb motion is that the upper limb is relatively flexible and the threshold range is reasonable. At the same time, the difference between upper limb postures is large, the discrimination is high, the posture is set naturally, the experimenter makes the movement more easily, and the error is small. When the number of repetitions of the lower limb movement is more, the movements are not in place and the errors are more.

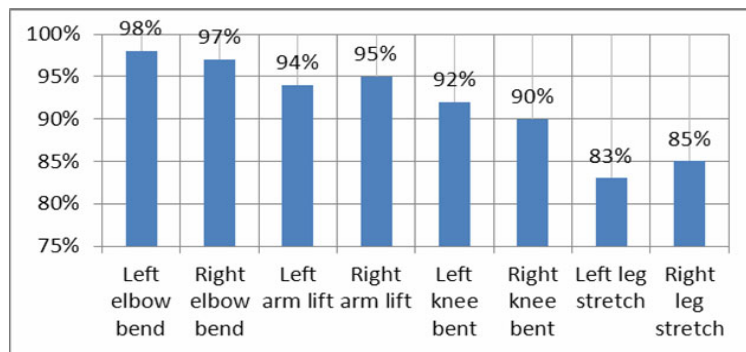


Fig. 24. Recognition rate distribution map

5.3 Mobile Robot Manipulation Test

After testing the performance of the mobile robot’s visual system to identify the human posture, the next step is to test the maneuverability of the mobile robot. In this paper, the mobile robot software and hardware system is ultimately to achieve the effect of robot motion control through human body posture. In order to detect this effect, the mobile robot control experiment is set up.

The experimental area of the mobile robot is shown in Fig. 25. It is a square in the room. Side length is 3.2m. The vision sensor is located in the middle of the left side of the experimental area. The starting position of the mobile robot is in the center of the region. The operator is located in the middle of the right side of the area. The mobile robot in this paper has 8 kinds of motion modes, respectively forward, backward, left, right, oblique right shift, oblique left shift, clockwise rotation, counterclockwise rotation. The vision system of mobile robot can recognize and determine eight postures of human body. These eight gestures correspond to the movement of the robot. The operator is required to manipulate the robot in the experimental area using its own attitude.

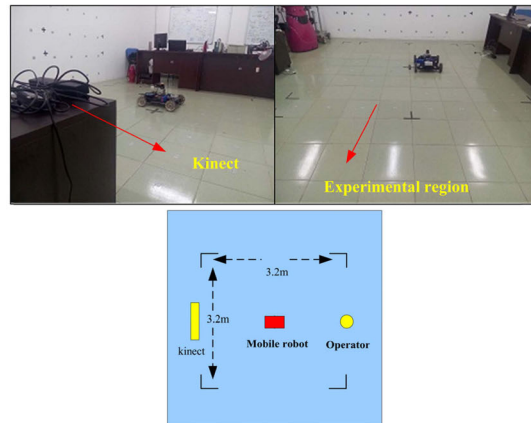


Fig. 25. Mobile robot experimental area

As shown in Fig. 26. The operator manipulates the robot through upper limb movements and lower limb movements. In the experimental area, the robot completed the task of moving around the site. The robot can reach any position in the field according to the operator's requirements. In the process of experiment, the mobile robot is sensitive and maneuverable, and it can recognize the human movement and execute the corresponding instructions. Experiments show that the system performance meets the design requirements.

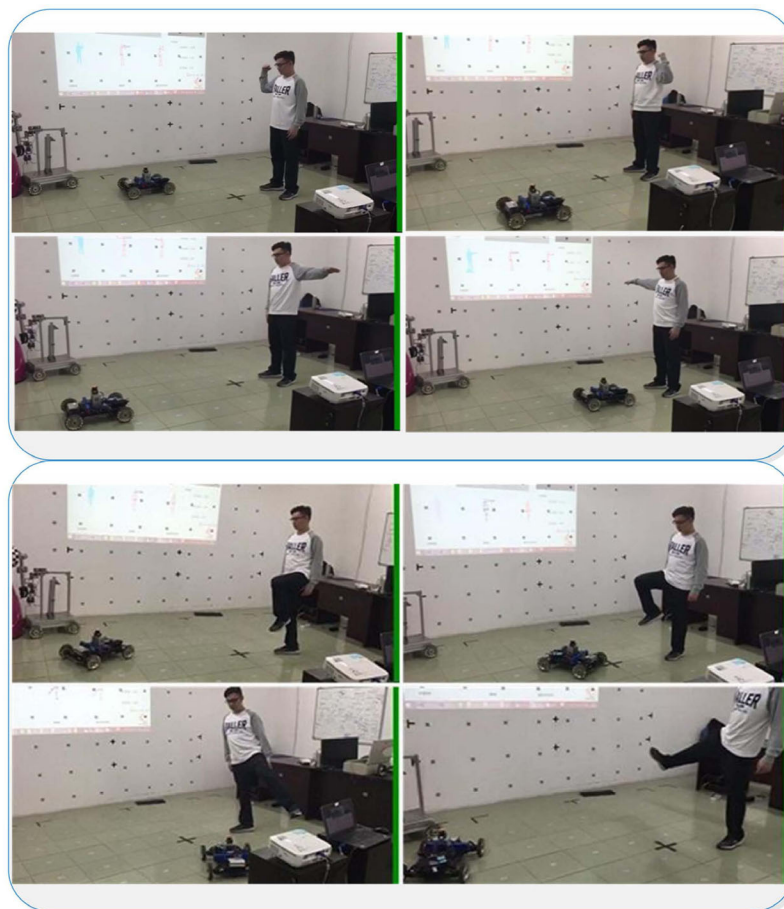


Fig. 26. The operator controls the robot movement

6 Conclusion

In this paper, propose a somatosensory interactive control system for robot based Kinect sensor. Through the test of arm robot and mobile robot, the system meets the requirements of the design. Experiments show that the system has a high recognition rate of human body posture. The part that needs to be improved is the action setting of the lower limb. The definition of human posture needs to be more natural and convenient for operators to implement. The robot operation test shows that the system has high sensitivity and can act effectively according to human instructions.

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