Design of Motion Control System for Fire Fighting Robot

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Abstract—This paper introduces a kind of motion control system of fire fighting robot. The main framework of the action of fire fighting robot is wireless remote control, including the head action to control the motion direction of fire fighting robot water gun. The data of head motion is collected by MPU6050 gyroscope. The camera on the water gun feeds the image back to the operator's VR glasses to realize the synchronization of vision. The water gun can realize the rotation of yaw angle and pitch angle, and the driving method adopts a stepping motor. The four way navigation key module controls the action of the water gun. The two axis rocker sensor module controls the working state of the robot's driving motor, and the robot uses the track driving method. The control system can be applied to most of the fire fighting robots used by remote control.

1. Introduction

With the development of society towards automation and intelligence, the status of special robots is also increasing, among which the fire fighting robots are more prominent. Fire fighting robots can replace firefighters to enter some extremely dangerous areas to a certain extent. For example, the confined space of underground buildings is smaller than that of above ground buildings. If there is a fire, the temperature and smoke concentration of underground buildings will rise rapidly, which will also have an adverse impact on the rescue of firefighters [1]. With the continuous occurrence of fire accidents, the life safety of firefighters is also threatened. As an effective tool for fire rescue, intelligent fire-fighting robot can replace firefighters to enter dangerous places for rescue and reduce the casualty rate of firefighters [2]. The personal safety of firefighters has become increasingly serious due to the complex fire scene [3]. Therefore, the relevant departments of various countries have also actively studied this issue. Foreign research on consumer robots is earlier, technology accumulation is deeper, and domestic development speed is relatively fast. Fire fighting robots have developed from the second generation with sensing function to the third generation of intelligent humanoid robots. The robot has more flexible limbs and can imitate the actions of firefighters in the rescue process. As a "special soldier" in the robot, the fire fighting robot has a variety of skills [4], Robotics; New Robotics Findings from China University of Mining and Technology Reported (Intelligent Fire Monitor for Fire Robot Based On Infrared Image Feedback Control) [5].
In this paper, gyroscope is used to detect the related movement of human head to control the relevant action of water gun of fire fighting robot. The four way navigation key module cooperatively controls the relevant action of water gun. The dual axis rocker sensor module controls the working state of the robot drive motor through certain logic. It can provide a convenient control mode. According to the needs of the system, the module is divided into data processing sending module and data processing receiving module.

2. Data Processing And Sending Module

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The main idea is to send and receive an array, which is composed of 10 numbers, FS [10] = {0}; FS [0] FS [9]; it is a command frame, and the receiver judges whether the first bit is the specified signal. FS [1] is the rotation of the water gun; 1 is down, 2 is up, 3 is turning left, and 4 is turning right. FS [2] FS [3] is the rotational speed of the motor controlled by the rocker; FS [4] FS [5] FS [6] FS [7] is the yaw angle and pitch angle of the gyroscope, FS [8] is the 01 switch to control the use of external equipment switch.

The transmitter receives the signals of gyroscope, four-way navigation button and rocker, processes the collected information, sorts it into a specified array, and sends it to the receiver through the wireless module. The receiver makes the specified action according to the received relevant data. The system block diagram is shown in Figure 1.

![System block diagram](image)

2.1. Control Object

The controlled object is shown in Figure 2. The main control objects are two driving motors at the track of the fire-fighting robot and two stepping motors of the rotating part of the water gun above the fire fighting robot. One step motor drives the water gun to rotate around the y-axis in the figure, and the other drives the water gun to rotate around the x-axis in the figure. A camera is installed on the water gun, and the camera feeds back the image to the glasses and controls it through the head movement. The action of water gun realizes the synchronization of vision. The main control chip of MCU is stm32c8t6. Considering the economy and reliability, the wireless module selected is Lora wireless serial communication module WH-1108-p, which sends and receives data through serial port. The main control is that the gyroscope installed on the head controls the rotation direction and speed of the water gun stepper motor, and the data collected by the gyroscope are the speed and direction around the x-axis and the y-axis. The four-way navigation key module cooperatively controls the relevant actions of the water gun. The dual axis rocker sensor module controls the working state of the robot drive motor through certain logic, and realizes the actions of robot forward, backward, left, right, acceleration and deceleration.
2.2. Motion Detection Part
The 6-axis MPU6050 module is used to detect the acceleration of x, y and z axes and the angular acceleration of three axes. In this system, only the angular velocity and angle of yaw angle and pitch angle are used. The module supports I2C interface and communicates with MCU through I2C.

When the device is started up, the gyroscope will start to read the acceleration of the three axes Gx, Gy and Gz after initialization. When it is stationary, the resultant acceleration is the direction of gravity acceleration g (the direction is perpendicular to the ground and downward at this time).

\[ G = \sqrt{G_x^2 + G_y^2 + G_z^2} \]  
(1)

The angles with the coordinate axis of the datum coordinate system are as follows:

\[ \theta_x = \arcsin\left( G_y / \sqrt{G_x^2 + G_z^2} \right) \]  
(2)

\[ \theta_y = \arcsin\left( G_z / \sqrt{G_x^2 + G_y^2} \right) \]  
(3)

\[ \theta_z = \arcsin\left( G_x / \sqrt{G_y^2 + G_z^2} \right) \]  
(4)

When the action, the combined acceleration of the three-axis acceleration is the current actual acceleration. Considering the error reason, the combined acceleration is taken as the average value of the two times, and the appropriate weight is selected. Finally, the corresponding angle is calculated by integral calculation.

The obtained data is sent to the execution end through the wireless module to realize the follow-up of head action and water gun action. The rotation direction is judged by the positive and negative speed, and the rotation speed is judged by the size of the speed.

2.3. Four Way Navigation Key Control Part
When the key in a certain direction is pressed, the corresponding interface outputs high level, and MCU assigns values to FS [1] according to the input high level of different ports. Interface 1 inputs high level, FS [1] = 1, interface 2 inputs high level, FS [1] = 2, interface 3 inputs high level, FS [1] = 3, when interface 1 inputs high level, FS [4] = 4, receiver performs corresponding actions according to FS [1], 1 is down, 2 is up, 3 is left turn, 4 is Turn right.

2.4. Dual Axis Rocker Sensor Module Control Part
The dual axis rocker sensor module outputs two voltage values, which are the voltage values of x-axis and y-axis. Stm32c8t6 single chip microcomputer supports AD conversion. By reading the corresponding voltage value, it can control the motor movement at the track. The default position of remote sensing is the center of the circle as shown in figure 3. When the input voltage of remote sensing is 2.8V, the voltage value X of the circle center in Figure 3 is 1.4V and Y is 1.4. In order to facilitate the programming, the voltage value read is directly multiplied by 10, as shown in the figure, which is the voltage value multiplied by 10 for each part of remote sensing. The remote control area is divided into five parts, and each part corresponds to the operation mode of each part. After reading the
voltage value, the rotation of the motor is controlled by four PWM outputs. Out1 and out2 control one side motor, out3 and out4 control the other side motor.

X, Y (14,14) is the default position of the rocker. At this time, the output is zero and the robot does not move. The speed at the four vertices is defined as, X, Y (14, 0) is full speed left turn, that is, left track full speed reverse, right track full belt forward rotation, at X, Y (14,14), left and right side motor does not move, when X, Y (28,14), left and right motor full speed forward rotation, when X, Y (14,28), left motor full speed forward, right motor full speed reverse, turn right, When X, Y (0, 14), the left and right motor reverses at full speed, which is a backward action. Other points are calculated according to table I. Out1 and out2 are a group, out3 and out4 are a group. The program calculates according to the data in the table I.

3. Verification
After downloading the program to the single chip microcomputer, the data obtained is sent to the upper computer through the serial port, and the corresponding values are read by the software of the upper computer, as shown in Figure 4.

![Remote sensing voltage change diagram](image)

Figure 3. Remote sensing voltage change diagram

| TABLE I. Control logic |
|------------------------|
| Range      | OUT1    | OUT2    | OUT3    | OUT4    |
| Y0-7&&X>4   | (7-Y)+7 | 0       | \sqrt{(Y-14)^2+(X-14)^2+14} | 0       |
| Y7-14&&X>14 | 0       | (Y-7)+7 | \sqrt{(Y-14)^2+(X-14)^2+14} | 0       |
| Y14-21&&X>14| 0       | \sqrt{(Y-14)^2+(X-14)^2+14} | (21-Y)+7 | 0       |
| Y21-28&&X>14| 0       | \sqrt{(Y-14)^2+(X-14)^2+14} | 0       | (Y-21)+7 |
| X<14       | (14-X)+14 | 0     | 0       | (14-X)+14 |
| X=14&&Y=14 | 0       | 0       | 0       | 0       |
4. Conclusion
Fire fighting robot can reduce the number of times firefighters enter the dangerous area, enter the high-risk fire-fighting and rescue scene of toxic, thick smoke, high temperature, hypoxia, improve the firefighting efficiency and obtain the relevant information on the scene. With the continuous improvement of industrial level, the working environment faced by firefighters is relatively dangerous. The emergence of fire-fighting robot can reduce the number of related personnel entering the dangerous area, and effectively protect the life safety of relevant personnel. The system can work more conveniently and improve the efficiency to a certain extent.

Acknowledgment
This work was supported by the project of 2019 provincial innovation and entrepreneurship training program for College Students "Intelligent fire locomotive" (No. S201913857014).

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