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FLAME TRACKING INNOVATIONS: UTILIZING STC89C52 IN THE DEVELOPMENT OF SMART FIRE SAFETY ROBOTS

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Abstract: *Fire robots, a distinct category of robotic technology, serve as formidable substitutes for human firefighters in the midst of perilous fire emergencies marked by high temperatures, thick smoke, and oxygen depletion. These versatile automatons are capable of executing critical missions, including smoke ventilation and cooling, fire suppression, and reconnaissance and rescue operations. The deployment of intelligent fire robots in firefighting and rescue operations significantly enhances efficiency, concurrently safeguarding the well-being of human firefighters to the utmost extent. Among the pivotal components in the realm of fire robot research, flame recognition technology assumes a paramount role. The global landscape of flame recognition and detection technology exhibits a rich tapestry of in-depth exploration, encompassing traditional flame detectors and sensors, alongside innovative digital image recognition techniques underpinned by emerging paradigms like artificial intelligence, pattern recognition, and neural networks. In comparison to the advanced state of international research in this domain, China's endeavors lag slightly behind. Evidently, the majority of flame detectors employed within domestic industries are imported products. Consequently, an in-depth exploration of indigenous flame recognition technology is imbued with practical significance, presenting an avenue for innovation and development.*

Keywords: *Fire robots, Flame recognition technology, Firefighting efficiency, Robotics in fire emergencies, Domestic technology development*

1. Introduction

The As a special type of robot, fire robots can replace firefighters to enter the scene of fire accidents such as high temperature, thick smoke, and oxygen deficiency, undertake tasks such as smoke exhaust and cooling, fire extinguishing, and reconnaissance and rescue. An intelligent fire robot can effectively improve the efficiency of firefighting and rescue, ensuring the safety of firefighters to the greatest extent possible. It is not difficult to see that flame recognition technology plays an important role in the research of fire robots. Currently, there has been in-depth research and progress in flame recognition and detection technology both domestically and internationally, such as traditional flame detectors and sensors, and digital image recognition based on new theories such as artificial intelligence, pattern recognition, neural networks, etc. Compared to the development level of foreign countries, China's research in this field is slightly backward. From the articles published in various journals and literature, it can be seen that the vast majority of detectors

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used in factories are produced abroad. Therefore, studying the innovative development of domestic flame recognition technology has practical significance.

In response to the needs of the intelligent firefighting robots mentioned above, this article designs and develops a flame automatic recognition and tracking system that can be conveniently installed on firefighting robots. Based on the changes in smoke, temperature, and infrared light at the scene of the fire, the fire scene image is collected for automatic flame recognition and positioning. Control commands are issued based on the recognition results, and automatic firefighting is achieved by adjusting the movement direction of the firefighting robot. It can effectively improve the shortcomings of fire robots in terms of intelligence and enhance their practicality [1].

2. The overall system architecture

This design mainly consists of two parts: a multi-sensor detection module and a machine vision detection module. The STC89C52 microcontroller is used as the minimum control system, and the multisensor detection module uses smoke sensors, temperature sensors, and infrared flame sensors to detect the concentration, temperature, and infrared light of smoke in the room in real time. If a flame is detected, the motor will be controlled to rotate to control the direction of the fire robot's movement. At positions close to the intended flame, the machine vision detection module will use a camera to collect flame data, 8

Using the YOLO algorithm on a Raspberry Pi card computer to achieve precise recognition of flames, further determining the direction of fire robot movement.

The overall design diagram of the system is shown in Figure 1.

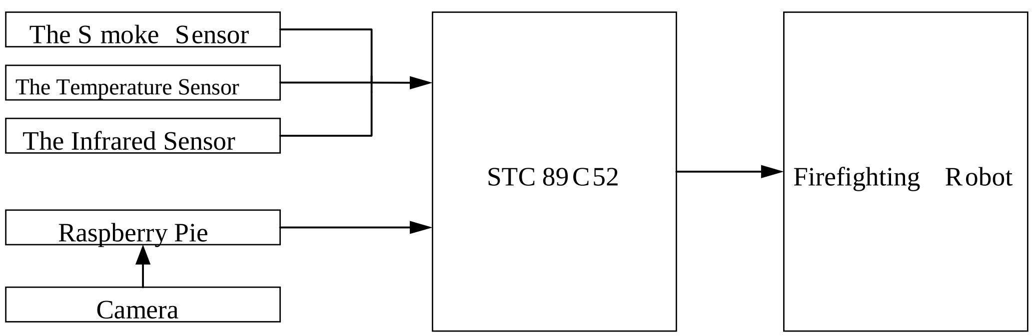

Figure 1: Neural network structure

3. System Hardware Design

3.1 Main control module

The minimum system circuit of the main control is shown in Figure 2.This system adopts STC system microcontroller, which has many advantages compared to other series microcontrollers. Generally, STC microcontrollers have more resources than other microcontrollers and have faster execution speed; The STC series microcontroller uses a serial port to burn and write the microcontroller, making downloading programs more convenient;

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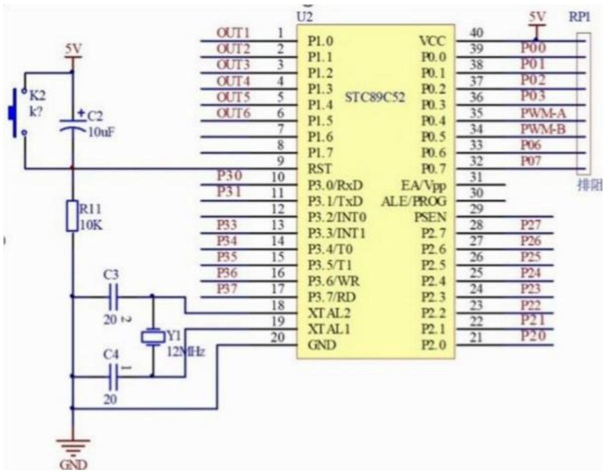

Figure 2: Single chip microcomputer schematic diagram

3.2 Design of multi-sensor detection module

3.2.1 Smoke sensor

The initial stage of flame combustion will release a large amount of smoke, so you can detect the smoke concentration in the surrounding environment through smoke sensors to identify the flame. The MQ-2 type smoke sensor was selected for this design, and the detection concentration was 300-10,000 ppm. The sensor is a combustible gas detector, which can realize the detection of smoke, hydrogen, liquefied gas, propane and other combustible gases. The MQ-2 smoke sensor can realize the conversion of the smoke concentration of non-electrical signal to the electrical signal. When the smoke concentration of the surrounding environment increases, the conductivity of the semiconductor material in the sensor will increase, the corresponding output resistance decreases and the output voltage will increase, so as

to realize the detection of the smoke concentration , as shown in Figure 3.

Figure 3: Physical picture of the smoke sensor

3.2.2 Temperature sensor

The flame produces huge heat when combustion, so the temperature sensor can be used to detect the change of the ambient temperature to realize the identification of the flame. This design uses a DS18B20 digital temperature sensor with the temperature measurement range of 55°C to + 125°C with an error of about 2°C. The sensor uses integrated chip and single bus technology, effectively reduce the interference of other factors, the measurement accuracy is high, to meet the requirements of temperature measurement. The module has three pins, namely power supply pin VCC, public ground terminal GND and digital signal input / output pin DQ pin, using DQ pin and MCU directly connected, the non-electrical signal temperature can be converted into digital signal and transmitted to the main control chip processing , as shown in Figure 4.

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Figure 4: Physical picture of the temperature sensor

3.2.3 Infrared flame sensor

Flame is composed of various combustion generation, intermediates, high temperature gas, hydrocarbon and inorganic matter as the main body of high temperature solid particles, the flame of thermal radiation including discrete spectrum of gas radiation and continuous spectrum of solid radiation, different combustion flame radiation intensity, wavelength distribution are different, but the radiation intensity is mainly in the near infrared wavelength domain and ultraviolet light domain, could be sensitive to the long wavelength radiation infrared detector to realize the identification of the flame. The infrared flame sensor used in this design can detect the wavelength range of 760nm~1100nm, and the detection Angle is about 60 degrees[2-3]. It is very sensitive to the flame spectrum and reaches the infrared light wavelength near 880 nm. The detection principle is that the far infrared flame probe transforms the strength change of the external infrared light into the change of the current, which reflects the change of the value ranging from 0 to 255 through the A / D converter. When the external infrared light is stronger, the value is smaller; when the infrared light is weaker, the greater the value is , as shown in Figure 5.

Figure 5: Physical picture of the infrared flame sensor

3.3 Flame recognition module

The flame recognition in this design mainly depends on machine vision. The camera is used to collect the room image, and the image information is transmitted to Raspberry Pi through the USB port. Raspberry PI analyzes and processes the image information through the corresponding algorithm, and finally realizes the flame recognition and feeds the results to the master microcontroller.

3.3.1 The camera collects the image information

The camera of the image acquisition module in this design is the S900 camera of Linbai Technology. The camera uses a CMOS 1 / 4 sensor, a 70-degree fisheye lens, an imaging range of 2cm to infinity, a default 640 * 480 resolution, and supports 320 * 240 resolution with a frame rate of 30 frames per second. The camera module also integrates automatic exposure, automatic gain, automatic white balance and gamma correction, so it has high image quality. In terms of communication, the camera uses the standard USB2.0 interface, and supports the UVC protocol of mainstream systems. UVC is

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USB Video Class, which is a protocol standard defined for USB video capture devices jointly launched by Microsoft and several other device manufacturers. It has become one of the USB org standards and is widely used in the message transmission of video devices based on USB interface. Two interfaces are provided in UVC protocol, namely, video control interface VC Interface and video streaming interface VS Interface. The former is usually used to control the behavior of UVC devices such as adjusting the image correction parameters and scaling the zoom, while the latter can correspond to a specific data format. This camera support has integrated UVC Drive system free drive use, that is, can be achieved plug and play, with great convenience, as shown in Figure 6.

Figure 6: Physical picture of camera

3.3.2 The Raspberry Pi reads the camera data

The image processing module of this design is the latest 4 generation B Raspberry Pi microcomputer. Raspberry pie is Raspberry Pi charitable foundation launched in 2012, a card computer its based on broadcom (Broadcom) company ARM processor, with SD or MicroSD card for memory hard disk, card motherboard integrated around multiple USB interface and ethernet interface, for the keyboard, mouse and network cable, at the same time it has video analog signal TV output interface and HDMI HD video output interface, the most wonderful is the above have the basic functions of the PC all integrated in a slightly larger than credit card motherboard. In addition, according to our needs for processing images, the operating system carried by Raspberry Pi has integrated UVC protocol, graphics library and other basic software, no need to install other basic software, and pre-installed Python environment, and supports the current popular open source computer vision library OpenCV1, providing a complete processing environment for image processing. The camera module is connected to it through the USB interface on the Raspberry Pi, and the currently collected camera image can be obtained by calling the Video Capture function in the Raspberry Pi , as shown in Figure 7.

Figure 7: Physical picture of the Raspberry Pi

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3.4 Motor drive module

Because the I / O output current of STC89C52 SU is small, it cannot drive the motor to rotate and realize the movement direction control of the firefighting robot, this design L298N chip is used as the core of the motor drive circuit to realize the controllable straight, left turn, right turn and head turn of the firefighting robot. L298N is a dual-road full-bridge motor drive chip mass-produced by STMicroelectronics (ST Semiconductor) Group. It has the characteristics of high working voltage, high output current, strong driving ability, low heat value, strong anti-interference ability and high reliability. The working voltage is up to 46V and the output current is up to 4A , as shown in Figure 8.

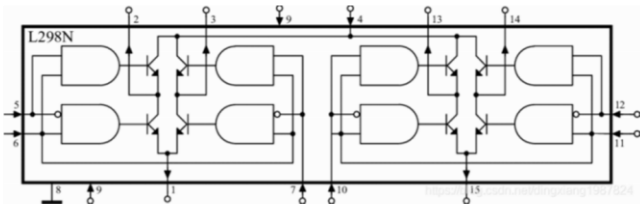

Figure 8: L298N driver circuit diagram

According to the circuit diagram, L298N adopts the dual H bridge circuit to control the direction of the DC motor by controlling the current flow direction on the H bridge. H bridge is a classic DC motor control circuit, which contains four switches, transistors (BJT or MOSFET), load and motor located in the center to form an H-shaped structure, which can change the direction of the current by activating two specific switches simultaneously, so as to realize the control of the rotation direction of the motor.

3.5 Avoidance module

The E18-D50NK infrared sensor is used to detect obstacles. E18-D50NK infrared sensor is a kind of infrared reflective proximity switch sensor, which has the advantages of small size, convenient application, low power consumption, stability and reliability. Its working principle is to use the light projector to emit infrared beam, if blocked by the object will be light radiated back, the light receiver will receive the reflected beam and make a judgment response. It can detect all the objects that can reflect the light, and the detection distance can be adjusted by the adjustable potentiometer, and the output signal is the digital quantity, which can be directly connected with the I / O port of the single-chip microcomputer. If the SU receives low level data, it means that an obstacle is detected, otherwise it is high level , as shown in Figure 9.

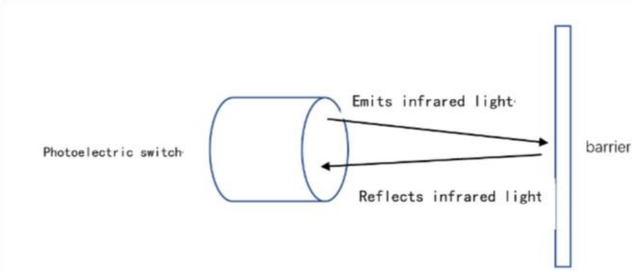

Figure 9: Schematic diagram of obstacle avoidance of infrared sensor

3.6 Display module

This design uses LCD1602 LCD screen to realize the real-time display of the working state for convenient debugging and control. LCD1602 The liquid crystal display is a widely used character type liquid crystal display module, it is composed of character type LCD display (LCD), control driver main

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circuit HD44780 and its extended driver circuit HD44100, as well as a small amount of resistance, capacitive components and structural parts assembled on the PCB board. It has the characteristics of clear display, rich display content, large display information and easy to use , as shown in Figure 10.
8

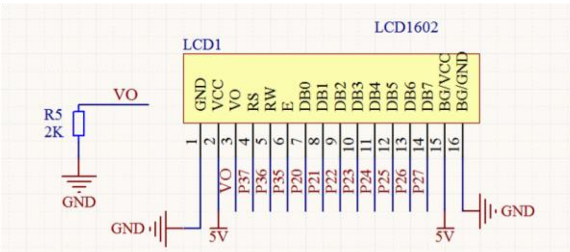

Figure 10: The Schematic diagram of LCD1602

4. System software design

4.1 Overall design

The work flow chart of the system is shown in Figure 11. This design uses Keil uVision5 as an integrated development environment to program and debug the functions of the flame automatic identification and tracking system. Program initialization fire robot will open cruise mode, when the sensor module detected the flame, according to the flame control fire robot moving direction, near the flame suspected point after the camera flame pictures, using raspberry pie YOLO algorithm based on the precise identification of the fire, and the control of fire control robot direction [4-6].

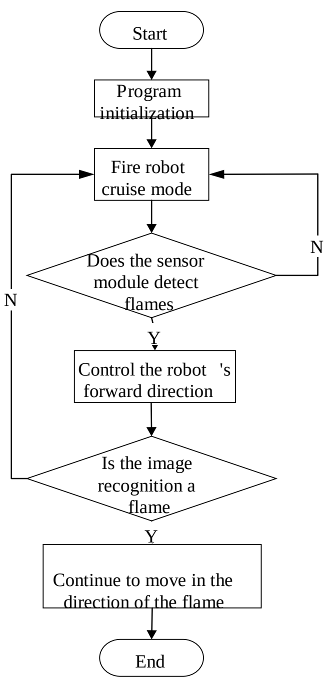

Figure 11: System work flow chart

4.2 Machine vision flame recognition algorithm

The system chose to recognize the flame. YOLO neural network was first proposed by R. Joseph et al. By taking the relationship between object classification and target recognition and positioning as regression problems and predicting the relationship between input and output variables, the model

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parameters learned from the given training data set can detect the unknown images. YOLO algorithm has the characteristics of open source structure, small model, good stability and fast detection speed, so it is widely used in target detection and image classification applications, as shown in Figure 12.

Figure 12: Flame recognition process

5. Conclusions

This paper designed and developed a convenient carrying on fire robot flame automatic identification tracking system, according to the fire smoke, temperature and infrared light changes, and collect fire image flame automatic identification and positioning, through the detection of multiple sensors and machine vision to identify the combination of two methods, improve the accuracy of the flame recognition. In the future, the automatic flame identification and tracking system can be continuously improved. For example, the flame image is used to identify the flame type, and different fire extinguishing media can be used for the flames induced by different materials, so as to further improve the efficiency of fire extinguishing.

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