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Design of Fire-extinguishing Car with Intelligent Tracking and Obstacle Avoidance

Hongze Zhang[1,2,*], Fuli Liu[2]

[1]Guangxi Key Laboratory of Machine Vision and Intelligent Control, Wuzhou University, Wuzhou, China
[2]School of Electronics and Information Engineering, Wuzhou University, Wuzhou, China
**Corresponding author*

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Abstract: With the rapid development of urbanization, the incidence of fire accidents has also soared, posing a significant threat to people's lives and property safety. In this context, the intelligent fire-extinguishing car was born. STC89C52 microcomputer unit (MCU) is the control core. The system circuit comprises the minimum system of MCU (including crystal oscillator circuit and reset circuit), sensor module, tracking module, infrared obstacle avoidance module, ultrasonic obstacle avoidance module, steering gear module, fire extinguishing fan module, and infrared remote-control module. The system has two control modes: manual and automatic. In manual mode, the car can be controlled by MP3 infrared remote control to move forward, backward, left, and right, and the steering gear can be rotated so that the car can go to the destination to carry out manual fire extinguishing. In the automatic mode, the car patrols along the set route and automatically avoids obstacles, detecting the temperature of the surrounding environment. When a fire occurs, the car's fire source detection module sends a signal to the MCU, and the MCU determines the flame position and drives the steering gear to rotate the corresponding angle so that the fan faces the fire source to extinguish the fire.

1. Introduction

Today, information technology and intelligence have penetrated people's daily lives. The research and development of smart cars have become the focus of public attention and people's unremitting pursuit of safe and convenient lives [1-5]. It is also an important standard of a country's intelligence level. With the continuous development of automobile intelligent technology, it is widely applied in people's production and lives [6-10], and their quality of life has been dramatically improved. Intelligent cars and related products have become an important driving force for the development of intelligent transportation systems (ITS) [11-15]. Combined with wireless communication technology, various sensing technologies such as infrared and ultrasonic waves are utilized to accurately track the location of the fire source and master the distribution of surrounding obstacles. Firefighters are helped to formulate the optimal action route to effectively avoid potential dangers and accurately track the trend of fire sources. Therefore, they can take appropriate measures to extinguish the flame to ensure the

safe and efficient completion of firefighting tasks. The dependence of the firefighting process on manpower is significantly reduced. Firefighting tasks under extreme conditions and dangerous environments with high temperatures, toxic gases, or extremely low visibility can be performed to reduce casualties effectively.

2. System working principle

The system circuit comprises an MCU minimum system (including a crystal oscillator circuit and reset circuit), a tracking circuit, a sensor circuit, a motor drive circuit, a fire extinguishing module circuit, and an infrared remote-control circuit. The tracking circuit uses two infrared sensors to detect and track the path. The sensors are installed on the left and right sides of the bottom of the car's front end. The sensor emits infrared light and receives the reflected light. When the car travels along the black or white trajectory, the infrared sensors capture the contrast difference between the trajectory and the surrounding ground, convert this into an electrical signal, and send the signal to the control unit. The control unit adjusts the car's driving direction according to the difference in the signal to ensure that the car always travels automatically along the correct trajectory. The flame detection module is arranged on the left, right, and front of the car to locate the fire source accurately. These modules work together to ensure that the location of the fire source can be accurately captured. The fire extinguishing module comprises a flame sensor and a DC fan. It is installed at the car's front end to facilitate fire-extinguishing tasks. The motor drive module includes two DC deceleration motors and a L298N motor drive chip. The system can adjust the speed of the car using PWM technology. The system is powered by the 5V DC module, which can provide stable and reliable power support for the MCU and the other modules. The infrared remote-control module can control the front, back, left, and right movement of the car and the rotation of the steering gear to ensure that the car can go to the destination to extinguish the fire.

STC89C52 MCU is based on MCS51 architecture, and it is the control core of the system. It has the advantages of excellent function, high operation efficiency, superior processing ability, and low power consumption. It is a powerful 8-bit microcomputer with a built-in efficient 8-bit central processing unit, 8-bit CPU, 256 bytes of memory, 8KB on-chip ROM, 32 I / O interface, three 16-bit timers/counters, five secondary interrupt structures, and full-duplex serial communication interface. It can provide a mighty processing power. It can download the program online through the ISP serial port, which is convenient for programming and debugging.

3. Hardware circuit design

3.1. MCU control module

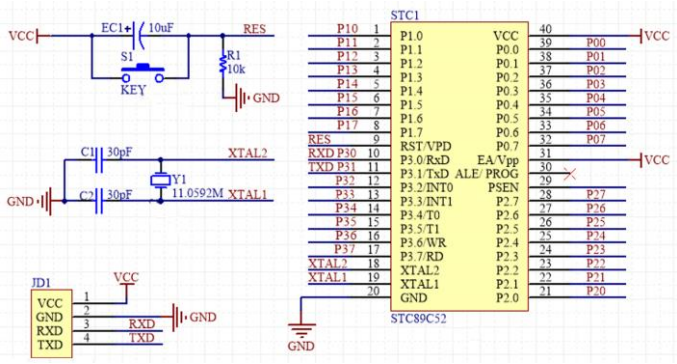


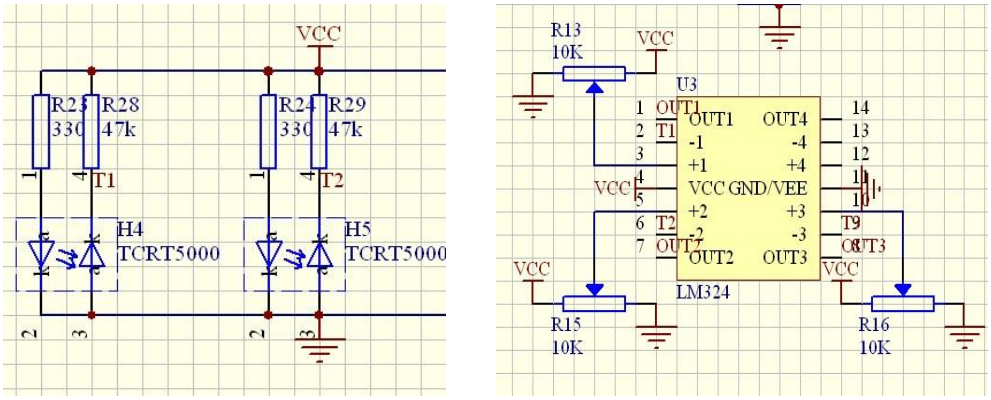
Figure 1: STC89C52 minimum system.

As shown in Figure 1, STC89C52 provides a variety of input and output interfaces, which can be connected to many external devices. The standard interface types include general input and output port (GPIO) and serial communication interface (UART).

3.2. Tracking module

Based on the principle of infrared light reflection, two infrared tracking sensor modules are equipped, usually including an infrared emitter and a receiver. These modules can recognize specific colors, predominantly black. When the infrared emitter's infrared rays irradiate the white surface, the reflected light will be captured by the receiver tube, and the infrared sensor module will output a low-level signal. The infrared light is absorbed when the infrared light irradiates the black surface. The reflected light captured by the receiver tube is reduced, and the infrared sensor module outputs a high-level signal.

As shown in Figure 2, when the black line is not detected, H4 emits light until the light of the white paper is absorbed to the end of H4 and reflected. The circuit will conduct when the H4 receiver detects the white paper, and the T1 potential becomes 0. When the black line is detected, H4 emits light until all the light of the black line is absorbed. The H4 receiver receives no signal and is not turned on (cut-off), so T1 = VCC.



(a) (b)

Figure 2: Infrared tracking circuit.

3.3. Flame detection module

As shown in Figure 3, the fire source detection circuit uses an infrared receiver to detect the fire source. When the fire source is monitored, the signal light is on. After comparison, the LM339 comparator outputs a high level, and the light-emitting diode is extinguished.

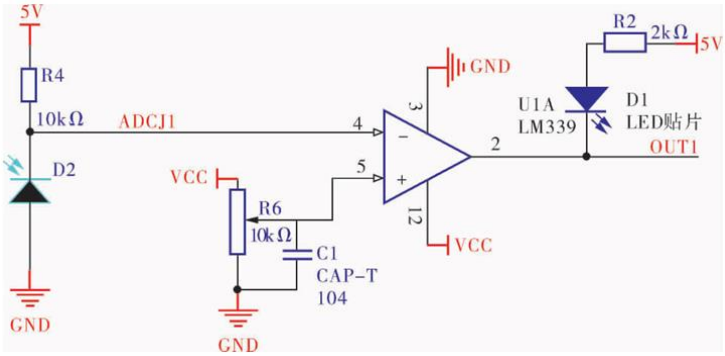


Figure 3: Fire source detection circuit.

3.4. Steering gear module

The SG90 steering gear control parameters are shown in Table 1.

Table 1: SG90 steering gear control parameters.

Angle (degree)	Pulse period (ms)	Pulse high-level time (ms)	Duty ratio (%)
0	20	0.5	2.50
45	20	1.0	5.00
90	20	1.5	7.50
135	20	2.0	10.00
180	20	2.5	12.50

3.5. Infrared obstacle avoidance

As shown in Figure 4, the infrared obstacle avoidance circuit comprises a V7 infrared emitting diode and a V4 receiving tube. The LM393 voltage comparator can conduct the obstacle avoidance according to the corresponding instructions. Each parallel circuit of the infrared obstacle avoidance module selects the corresponding color ring resistance to distribute the voltage to ensure the stability of the circuit. When the infrared light emitted by the V7 light-emitting diode hits an obstacle, it will be reflected, and the V4 infrared induction tube receives the infrared reflected light. If the infrared light intensity received by the V4 infrared sensor is high, it will output a high-level signal. LM393 monitors the signal from V4. If the output voltage (U2) of V4 is lower than the comparator's reference voltage (U3), the LM393 's output pin 1 will output a low-level signal and send the signal to the control system and the motor drive chip. The system processes the signal. It will trigger alarms and backward movements to avoid collisions between the car and the obstacles. The obstacles can be effectively detected in the range of 5 cm to 15 cm, and the car can be driven to perform obstacle avoidance actions.

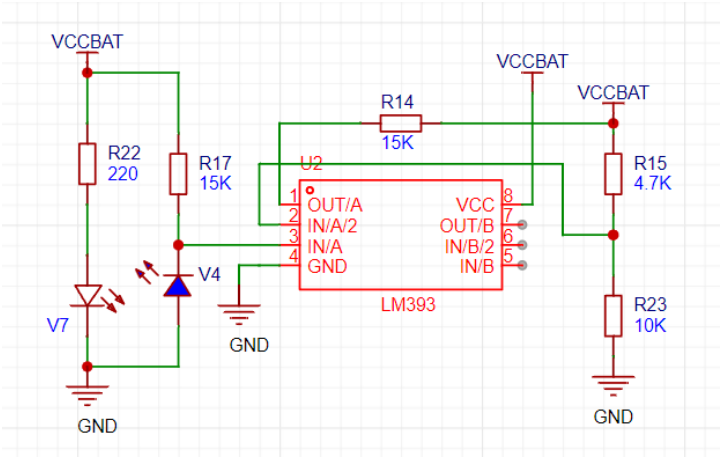


Figure 4: Infrared obstacle avoidance circuit.

3.6. Fire extinguishing module

As shown in Figure 5, the fire extinguishing module uses reliable 104 ceramic capacitors and right-angle USB seats as driving components. The USB interface ensures the stable operation of the fire extinguishing module. When the fire extinguishing module is connected to the P1.5 port of the MCU, it can work immediately, which ensures that the fire extinguishing module can respond quickly and

analyze the signal from the input device. If the input signal changes, such as voltage or current, the fire extinguishing module can accurately identify the changes and send them to the control system as new status information. When the voltage of the P1.5 port of the MCU reduces, it usually means that the power supply circuit fails. The USB port does not intervene and start the fan to prevent potential fire risks.

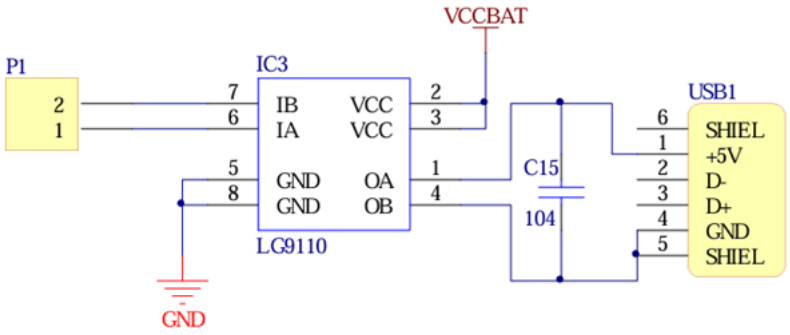


Figure 5: Fire extinguishing module circuit.

3.7. Motor driving module

As shown in Figure 6, L298N is a dual H-bridge DC motor driver. It can control the speed of two DC motors simultaneously. Its operating voltage range is 4.5V-36V, and it can provide a peak current output of up to 600mA. Its high current output capability makes it suitable for driving medium power loads.

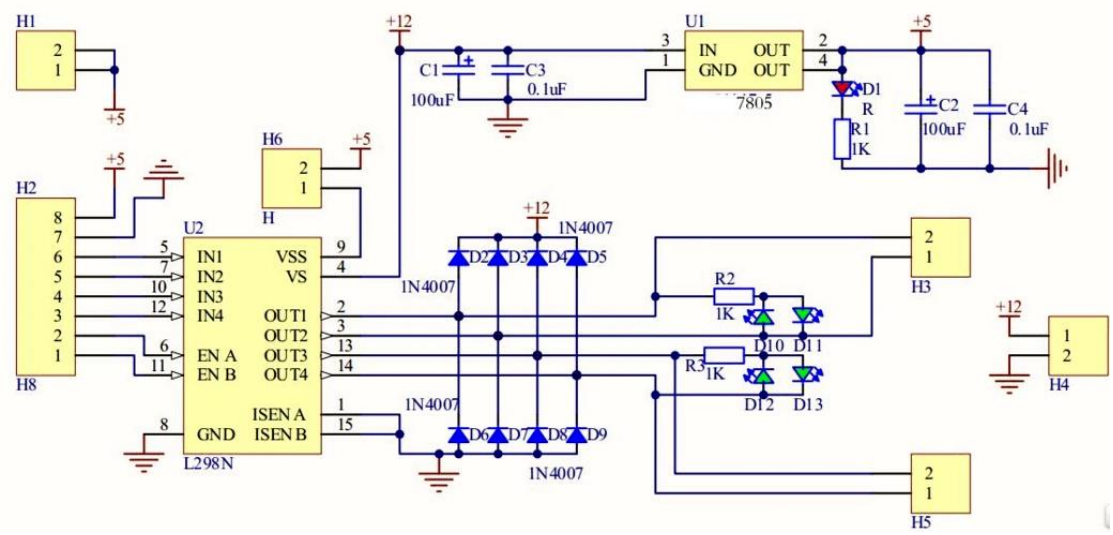


Figure 6: Motor driving module circuit.

4. Physical operation

In manual mode, the steering gear's initial angle is 0 degrees. As shown in Figure 7, the steering gear's rotation angle can be controlled with the MP3 infrared remote controller. When the buttons 3, 4, and 5 on the infrared remote controller are pressed, the digital tube displays 4, 5, and 6, indicating that the steering gear rotates to 180 degrees, 90 degrees, and 0 degrees.

(a) (b) (c)

Figure 7: Rotating angle of steering gear in manual mode.

As shown in Figure 8, when button 1 on the infrared remote controller is pressed, the digital tube displays the number 1, and the car switches from manual mode to automatic mode. As shown in Figure 9, when button 2 on the infrared remote controller is pressed, the digital tube displays the number 2, and the car enters the ultrasonic obstacle avoidance mode.

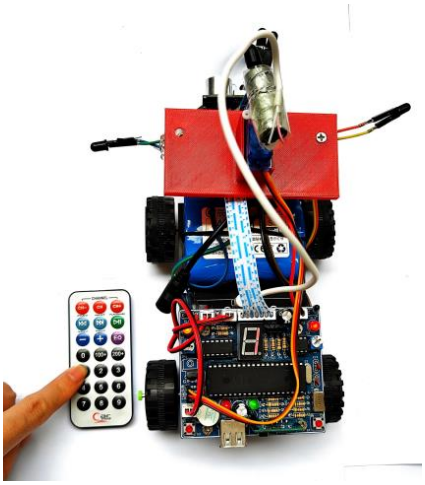


Figure 8: Automatic mode.

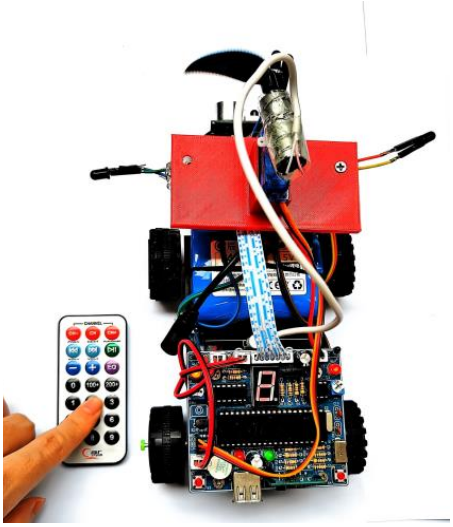


Figure 9: Ultrasonic obstacle avoidance mode.

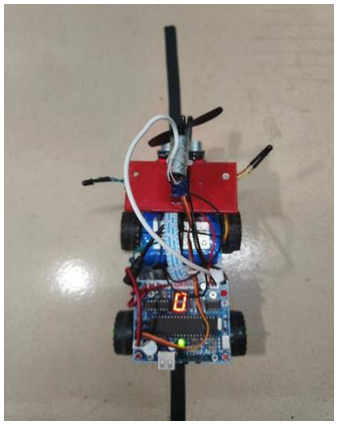


Figure 10: Infrared tracking.

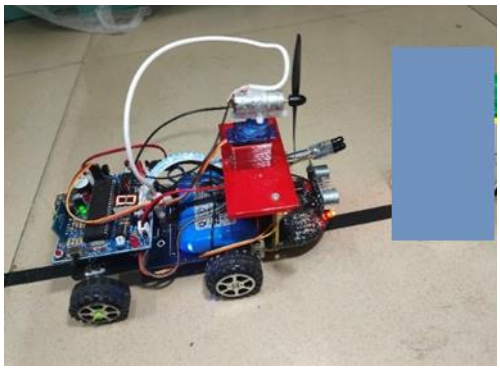
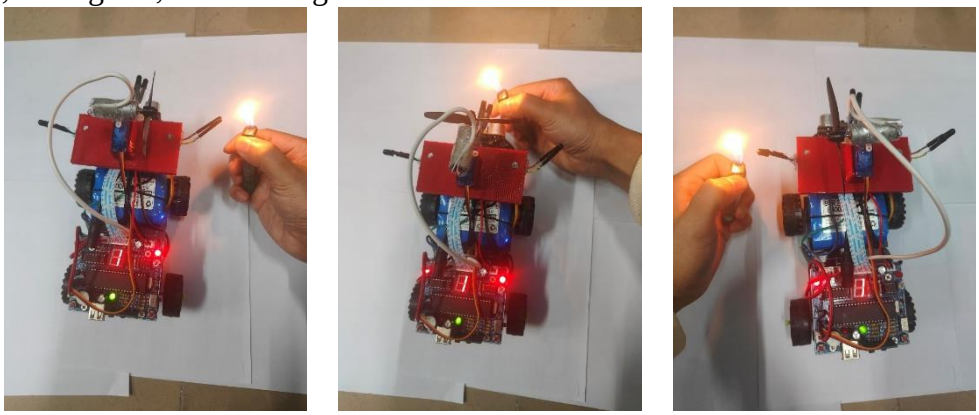


Figure 11: Avoiding obstacles automatically.

As shown in Figure 10, the car detects the black line with the infrared sensor and compares the

infrared light and the black line to realize the tracking function. When the black line is not recognized, the car will travel in a straight line. If the infrared sensor on the right or left side of the car detects the black line, the car will turn right or left. As shown in Figure 11, if the distance between the car and the obstacle is less than the safe distance, the system will control the car to stop moving, slow down, or change the driving direction to avoid collision.

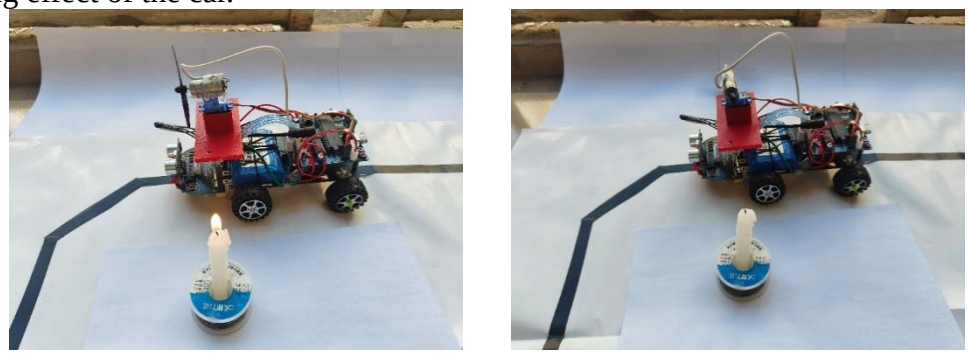
In automatic mode, the steering gear's initial angle is 90 degrees. As shown in Figure 12, when the flame sensors on the car's right, front, and left sides detect the fire source, the rudder rotates rapidly to 0 degrees, 90 degrees, and 180 degrees.



(a) (b) (c)

Figure 12: Flame detection.

Figure 13 (a) is the fire simulation scene, and Figure 13 (b) is the physical picture of the fire-extinguishing effect of the car.



(a) (b)

Figure 13: Fire extinguishing.

5. Conclusions

Taking STC89C52 as the control core, an intelligent car with tracing, infrared obstacle avoidance, flame detection, fire extinguishing, and ultrasonic obstacle avoidance is designed and manufactured. The car has manual and automatic modes. In manual mode, the infrared remote controller can control the car to move forward and backward and turn left and right. According to the user's intention, the car can go to the specified destination to extinguish the fire. In the automatic mode, the car patrols according to the set route. During the patrol process, the car can automatically avoid obstacles and detect the temperature of the surrounding environment. When a fire occurs, the fire source detection module of the car sends a signal to the MCU. The MCU determines the position of the flame and drives the steering gear to rotate at the corresponding angle so that the fan faces the fire source to extinguish the fire.

Acknowledgments

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