Design of Intelligent Obstacle Avoidance Car Based on STM32

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Abstract. With the rapid development of science and technology and the continuous improvement of people's demand for automation and intelligent life, intelligent mobile robot technology has become a key field of scientific and technological research, development and application. In the development of intelligent mobile robot technology, intelligent car design has become a popular branch. This paper designs an intelligent obstacle avoidance car system based on STM32 microprocessor. This design uses 32-bit high frequency processor STM32F103C8T6 as the core processor of intelligent car system. It uses PWM to control the motor. The servo module, ultrasonic module, infrared tracking module and Bluetooth module are used to realize the following function, obstacle avoidance function, infrared tracking function and Bluetooth control function of intelligent obstacle avoidance vehicle. This design can be applied to the frontier design of intelligent field. It is hoped that it can provide useful reference and inspiration for researchers in related fields.

Keywords: STM32, Obstacle avoidance, Intelligent car

1 Introduction

With the rapid development of science and technology and the increasing demand for automation and intelligent life, intelligent mobile robot technology has become a hot field of research, development and application of science and technology. As an important branch in this field, intelligent obstacle avoidance car has a wide range of application prospects, such as intelligent furniture, warehousing logistics and so on [1]. Especially during the epidemic, intelligent obstacle avoidance robots are of great practical significance in reducing the burden of medical staff and the risk of doctor-patient contact, improving the safety of drug distribution and optimizing the utilization of medical resources. It has attracted the attention of scholars at home and abroad [2]. As an embedded microelectronic with excellent performance and low entry difficulty, the STM32 microelectronic plays a vital role in the design of an intelligent obstacle avoidance car.

This paper aims to discuss the design of an intelligent obstacle avoidance car based on STM32 single chip microcomputer, and will discuss the intelligent obstacle

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avoidance car in detail from hardware design, software programming, system simulation and other aspects. It is hoped that it can provide useful reference and enlightenment for other researchers in related fields.

2 Overall design scheme

The design of an intelligent obstacle avoidance car is mainly based on the STM32 single chip microcomputer. This design requires the car to realize four modes: infrared tracking mode, following mode, Bluetooth control mode and ultrasonic obstacle avoidance mode. From the perspective of modularity, it is divided into four modules, including:

1.STM32F103C8T6 MCU core module. It is mainly responsible for the data analysis and processing part, in order to achieve input and output, received signal control and processing; 2. Sensor module. It is mainly responsible for the collection and transmission of distance data to realize the automatic obstacle avoidance and infrared tracking function of the car； 3. The control module is mainly responsible for issuing control commands to realize the app control function; 4. Motor drive module. It is mainly responsible for the motor drive of the car to realize the motion control of the car. The overall design block diagram of the intelligent car is shown in figure 1.

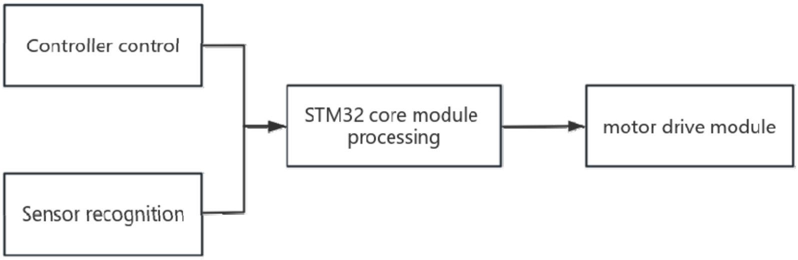

Fig. 1. Design flow chart (Photo/Picture credit: Original)

3 Hardware module Design

The hardware modules of the intelligent obstacle avoidance car mainly include: STM32F103C8T6 minimum system, ultrasonic module, infrared tracking module, motor drive module, ADC sampling module and so on.

3.1 STM32F103C8T6 minimum system

STM32 series is a 32-bit microelectronic developed by ST company based on ARM Cortex-M core. It is often used in embedded related fields, such as: intelligent cars, UAV and so on. STM32 has the advantages of powerful function, excellent performance, rich resources and low power consumption. It is a very classic embedded microelectronic.

This design uses the mainstream STM32 series STM32F103C8T6 chip. The STM32 representative product family is a 32-bit microelectronic based on ARM core. F represents that the product category is general type.103 means its product sub-series is enhanced. C stands for 48 pins. 8 represents a flash memory with a flash memory capacity of 64K bytes. This means its encapsulation is LQFP encapsulation. 6 represents the temperature range of industrial grade temperature range-40°C~85°C. The power supply range of STM32F103C8T6 chip is 2.0V~3.6V, and its standard power supply is 3.3V. The minimum system board of STM32F103C8T6 contains a buck module of 5V to 3.3V, so its normal maximum operating voltage can reach 5V [3].

3.2 Steering gear module

The steering gear is a kind of Angle drive. It is suitable for control systems where angles need to change continuously. It is mainly used in electronic creative practice, aerospace and other related fields. SG90 9g servo is used in this design.

The steering gear is controlled by PWM Angle. The Angle of the steering gear is adjusted by adjusting the duty cycle (pulse width) of PWM. The control of SG90 9g 180° servo generally requires a base pulse of about 20ms. The high and low levels of this pulse are generally 0.5ms-2.5ms in the range of Angle to control the pulse part [4]. Their correspondence is shown in Table 1.

Table 1. 180-degree steering gear corresponding control relationship

Input signal pulse width(ms)	0.5	1.0	1.5	2.0	2.5
Steering gear output shaft rotation (degree)	-90	-45	0	45	90

By controlling the deflection Angle of the SG90 9g 180° servo, the Angle position of the ultrasonic module is controlled. So that it can carry out ultrasonic ranging for the sector Angle in the direction of 180° to achieve automatic obstacle avoidance and other functions.

3.3 Ultrasonic wave module

Ultrasonic ranging module is a kind of ranging module. By sending and receiving ultrasonic waves, it uses the speed of sound propagation and the time difference between sending and receiving to calculate the distance to the obstacle in front of it.

This design uses the HC-SR04 ultrasonic ranging module. It uses IO triggered ranging. It gives a high-level signal of at least 10us. The module automatically emits eight square waves of 40kHZ and automatically detects whether there is a signal returning. If a signal returns, output a high level through IO and calculate the duration of the high level [5]. According to the formula:

$$\text{Test distance} = (\text{High level time} * \text{Sound speed} /2) \quad (1)$$

The speed of sound is 340m/s, and the distance of the obstacle in front is calculated with high accuracy (centimeter level accuracy).

3.4 Infrared tracking module

In this design, four tracking sensors TCRT5000 infrared reflection sensors are used to compose the infrared tracking module. It continuously emits infrared rays through infrared emission diodes. When the emitted infrared light is not reflected, or is reflected but weakly, the photosensitive triode is turned off. At this time, the output of the module is high, indicating that the diode has been in an extinguished state. When the detected object appears in the detection range, the infrared ray is reflected by the detected object, and the intensity is large, and the photosensitive triplet is saturated. At this point, the module output is low, indicating that the diode is lit. The TCRT5000 infrared reflection sensor working flow chart is shown in figure 2.

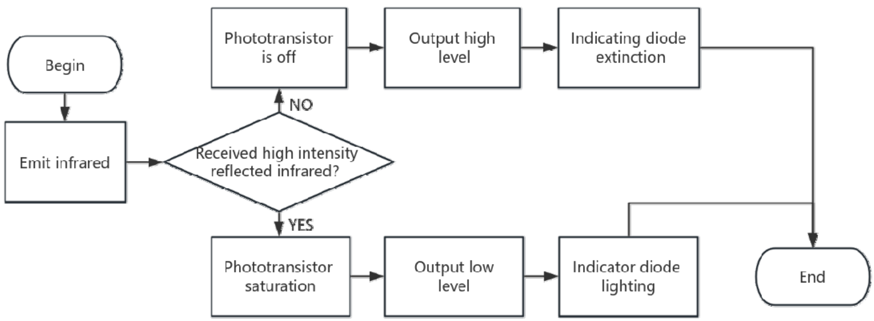

Fig. 2. TCRT5000 infrared reflection sensor working flow chart (Photo/Picture credit: Original)

3.5 Bluetooth module

Bluetooth module is a kind of PCBA board with integrated Bluetooth function. It is mainly used for short-range wireless communication. This design uses the HC-05 master-slave integrated Bluetooth serial port transmission module with chassis welding needle type. The use of the Bluetooth module makes the car have a Bluetooth control function. It makes switching between different modes of the car more convenient.

3.6 Motor drive module

This design uses the TB6612FNG motor drive module. As a new driver device, it is based on the design of the TB6612FNG driver IC. It uses a special logic control mode, only four pins to achieve dual motor control. At the same time, it can also independently control two DC motors in two directions. It has the advantages of high efficiency, small size, excellent performance, low energy consumption and high integration. Compared with the pure chip, two IO pins are reduced, which saves valuable IO resources for the controller.

Among them, IN1, IN2, PWM, STBY inputs; O1, O2 output; VM, VCC voltage level input. The input-output relationship is shown in Table 2.

Table 2. Input-output relationship [6]

Input				Output		
IN1	IN2	PWM	STBY	O1	O2	STATE
H	H	H/L	H	L	L	braking
H	L	H	H	H	L	corotation
H	L	L	H	L	L	braking
L	H	H	H	L	H	contrarotation
L	H	L	H	L	L	braking
L	L	H	H	OFF		halt
H/L	H/L	H/L	L	OFF		standby

3.7 ADC sampling module

ADC is an analog to digital converter. The ADC measurement and display module obtains the voltage through the micro-controller, and uses the ADC to sample and monitor the state of the lithium battery. The voltage of lithium battery is generally about 12V, and the maximum measured voltage of MCU ADC is 3.3V. The voltage of lithium battery can be measured by voltage division circuit. The schematic diagram of the ADC sampling part of this design is shown in figure 3.

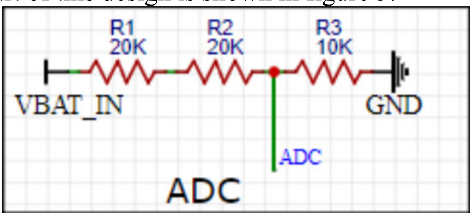

Fig. 3. Schematic of the sampling part of the ADC (Photo/Picture credit: Original)

It can be obtained from the series partial pressure formula:

$$U_{ADC} = \frac{R3}{R1+R2+R3} U_{BAT\_IN} \cdot \quad (2)$$

The maximum voltage of the lithium battery is 12V, so the ADC point voltage is 1/5 lithium battery voltage, which is 2.4V. So, the ADC point is secure.

4 System simulation design

The system simulation content of this design is mainly divided into three parts: development board design, module software design and main program design.

4.1 Development board design

The intelligent obstacle avoidance car uses a modular design. It mainly includes power input part, OLED display module, STM32F103C8T6 minimum system, infrared tracking module, ultrasonic module, Bluetooth communication module, motor drive module, servo module and so on. Figure 4 shows the design of the development board.

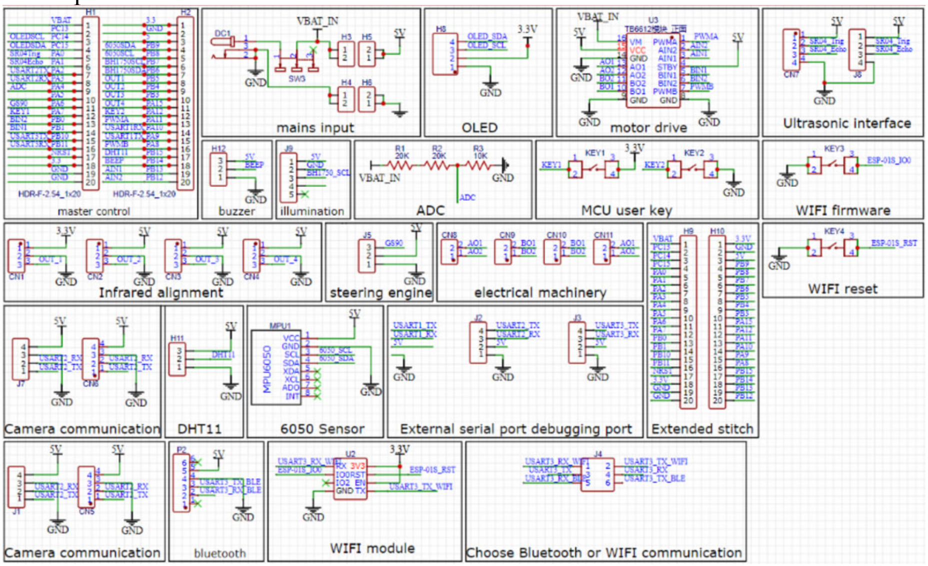

Fig. 4. Develop board design drawing (Photo/Picture credit: Original)

The placement and wiring of relevant modules after the EDA schematic diagram is converted to PCB diagram is shown in figure 5.

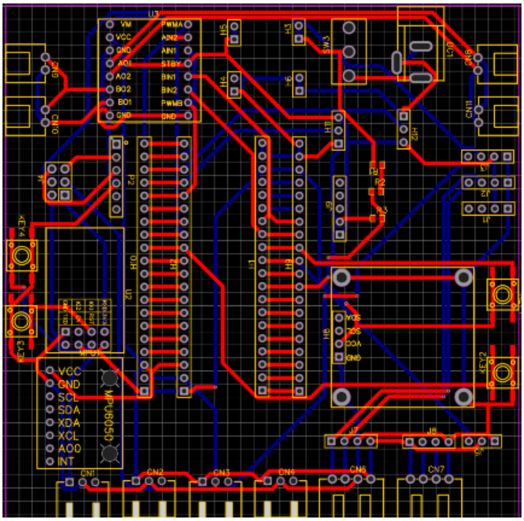

Fig. 5. PCB circuit layout (Photo/Picture credit: Original)

It is worth noting that, based on the size of the core board of the STM32F103C8T6 minimum system， the spacing between H1 and H2 should be 900.00mil. Otherwise, the core board of the STM32F103C8T6 minimum system will be difficult to place on the development board.

4.2 Module Software Design

Software design through software programming to achieve the control of the intelligent obstacle avoidance car. The main functions of the car include: infrared tracking, Bluetooth control, obstacle avoidance movement, following movement, etc. The software design mainly uses KeilµVision5 for STM32 micro-controller software development. According to the modular design idea, the software design of each main functional module is described as follows:

4.2.1 Motor control module

The motor control module drives the four DC motors of the smart car by using PWM. Let it be able to turn forward, backward, turn left, turn right, brake, standby simple commands. At the same time, the duration of each action can be changed to allow the car to achieve more complex actions [7]. Assuming that the motor on the left is AIN and the motor on the right is BIN, the basic logic of its different instructions is as follows:

1. Forward: the STBY pin of each motor gives a high level. Pin # 1 gives the high level, pin # 2 gives the low level, and the PWM pin gives the high level. Control four electric data are positive rotation, in order to achieve the purpose of forward.

2. Backward: the STBY pin of each motor gives a high level. Pin # 1 gives low level, pin # 2 gives high level, and PWM pin gives high level. Control the four motor data are reversed to achieve the purpose of backward.

3. Left turn: the STBY pin of each motor gives a high level. Pin 1 of the two motors ANI on the left gives the low level, pin 2 gives the high level, and pin PWM gives the high level. Pin # 1 of the two motors BNI on the right gives the high level, pin # 2 gives the low level, and pin # PWM gives the high level. Control the two motors on the left side to reverse and the two motors on the right side to turn forward to achieve the purpose of turning left.

4. Turn right: the STBY pin of each motor gives a high level. Pin 1 of the two motors ANI on the left gives the high level, pin 2 gives the low level, and pin PWM gives the high level. Pin 1 of the two motors BNI on the right gives the low level, pin 2 gives the high level, and pin PWM gives the high level. The left two motors are controlled to turn forward and the right two motors are reversed to achieve the purpose of turning right.

5. Brake: the STBY pin of each motor gives a high level. Pin # 1 to a higher level, pin # 2 to a higher level. Control four electric data to brake, in order to achieve the purpose of braking.

6. Standby: the STBY pin of each motor is low. Control four electric data are standby, in order to achieve the purpose of standby.

It is worth noting that this design uses a TB6612FNG motor drive module to control four DC motors. The current flow through the chip may be too large. So the driver chip of the DC motor is protected by using PWM to control the running speed of four DC motors [8].

4.2.2 Ultrasonic ranging follows the avoidance block

The obstacle avoidance function of the smart car is realized by ultrasonic ranging. Set the delay function (easy to observe the movement of the car) and the limited distance between the car and the obstacle. The ultrasonic ranging module emits a pulse of at least 10us (20us in this design). The timer is used to calculate the time from the beginning of the pulse emission to the end of the timing when the ultrasonic module receives the return pulse. Then calculate the distance according to the formula (1). If the calculated distance is less than the limited distance, the trolley stops. If the calculated distance is greater than the limit distance, the cart continues to move forward.

4.2.3 Steering gear module

This design uses a 180-degree SG90 9g servo to control the Angle position of the ultrasonic module. The use of servo is divided into two parts: the configuration of the timer and the control program of the servo. The specific situation is as follows:

1. Timer configuration: After defining the count and rotation Angle (range 1 to 5), set the mode for the 0.5ms timer. Write the interrupt function to zero out after the count reaches 40 (0.5ms for a minimum cell, 20ms for a period). Determine whether

the count value is less than the Angle. If so, give the PWM a high level, otherwise give the PWM a low level.

2. Control of servo: when the rotation Angle is set to 1, the servo is in the position of-90°. When the rotation Angle is set to 2, the servo is in the position of-45°. When the rotation Angle is 3, the servo is in the position of 0 (centered). When the rotation Angle is set to 4, the servo is in the position at 45°. When the rotation Angle is set to 5, the servo is in the position at 90°.

The Angle of servo rotation can be adjusted by controlling different duty cycles.

4.2.4 Ultrasonic obstacle avoidance module

Combining the steering gear module and ultrasonic ranging module, the ultrasonic obstacle avoidance module can be made. The logic of the ultrasonic obstacle avoidance module is: let the servo move forward and make the ultrasonic wave move forward. If there is no obstacle in front, continue to move forward, otherwise, make the servo deflect 30 degrees to the right, and judge whether there is an obstacle on the right. If not, turn right, otherwise, turn left 30 degrees after the steering gear is centered, and judge whether there is an obstacle on the left. If not, turn left; otherwise, turn back and then right [9].

4.2.5 Infrared tracking module

The car passed through four tracking sensors TCRT5000 infrared reflection sensors for data collection. The four tracking sensors are defined as D1, D2, D3, and D4 from right to left. There are four possibilities depending on the car:

1. The car passes the intersection: when the black line is detected in all four tracks (D1, D2, D3, D4 are all high levels), the car moves forward.

2. The car passes the S-shaped curve: when the black line is detected on the right side of the middle (D2 output is high level, D1, D3, D4 output is low level), the car is left, and the car moves to the right. After the car moves to the right, if no black line is detected in any of the four tracks (D1, D2, D3, D4 are all low levels), the car moves forward. When the black line is detected on the left of the center (D3 output is high level, D1, D2, D4 are low level), the car is right, and the car moves to the left. After the car moves to the left, if no black line is detected in any of the four tracks (D1, D2, D3, D4 are all low levels), the car moves forward. After the car moves, it continues to move forward after testing again, in order to prevent the car from swaying greatly from side to side and improve the stability of the car.

3. The car passes the right-angle curve: when the two sensors on the left detect the black line (D1 and D2 are low level, D3 and D4 are high level), the car continues to drive for 50ms. The test was carried out again, and no black lines were detected in all four tracks (D1, D2, D3 and D4 were all low level). The car stopped and kept for 50ms (to prevent damage to the motor) and turned left in place. When the two sensors on the right detect the black line (D1 and D2 are high level, D3 and D4 are low level), the car continues to drive for 50ms. The test was carried out again, and no black lines

were detected in all four tracks (D1, D2, D3 and D4 were all low level). The car stopped and kept for 50ms (to prevent damage to the motor) and turned right in place.

4. The car goes through an acute corner: When the leftmost sensor detects a black line (D1, D2, D3 are all low, D4 is high) or the leftmost and center-right sensors detect a black line (D1, D3 are all low, D2, D4 are high) or only the rightmost sensor does not detect a black line (D2, D3, D4 are all high, D1 is low), The car continues to drive for 100ms. The test was carried out again, and no black lines were detected in all four tracks (D1, D2, D3 and D4 were all low level). The car stopped and kept for 50ms (to prevent damage to the motor) and turned left in place. When the rightmost sensor detects a black line (D2, D3, D4 are all low, D1 is high) or the rightmost and center-left sensors detect a black line (D1, D3 are all high, D2, D4 are low) or only the leftmost sensor does not detect a black line (D1, D2, D3 are all high, D4 is low), The car continues to drive for 100ms. The test was carried out again, and no black lines were detected in all four tracks (D1, D2, D3 and D4 were all low level). The car stopped and kept for 50ms (to prevent damage to the motor) and turned right in place.

4.2.6 Bluetooth control module

The intelligent car is controlled by communication between the Bluetooth control module and the host computer. The Bluetooth control module is mainly divided into serial port configuration function, receiving function and interrupt function [10]. Its main contents are as follows:

1. Serial port configuration: The serial port configuration function contains 8-bit data, variable baud rate Settings. Setting the timer mode and its initial value. Disables the interrupt of the timer. The timer starts. Total interrupt setting. Open the serial port interrupt.

2. Receive function: When the received data is '2' , the car goes straight. When the received data is '4' , the car turns left forward. When the received data is '6' , the car turns right forward. When the received data is '8' , the car backs up. When the received data is '5' , the car stops. When the received data is '7' , the car turns left in place. When the received data is '9' , the car turns forward to the right.

3. Interrupt function: This interrupt function is the interrupt of the serial port function. First, let the car stop (to prevent the car from connecting to Bluetooth on the way to causing a collision). The received interrupt flag is then cleared (the last received signal is cleared). Then receive the upper computer data. Finally, the receiver function is executed.

4.2.7 OLED display module

The use of the OLED display module is displayed through I2C communication. This design uses software simulation to simulate I2C communication. It mainly includes pin configuration and initialization, basic timing of I2C configuration, OLED user call code, OLED font data and so on. First, we initialize the GPIO port and adjust the output frequency of the clock. Then the OLED module address is issued from the STM32 MCU. The slave determines whether the instruction has been received. After receiving the instruction, the write data instruction is sent. Verify that the write data instruction has been received. Finally, the host sends the stop command after the data is sent. One I2C communication is completed.

4.2.8 ADC measurement and display module

The ADC measurement display module, combined with the OLED display module through the ADC sampling, displays the voltage value of the lithium battery. The enabled ADC channel clock is first set. Then, the ADC divider factor 6 is set to enable the reset calibration. Wait for the reset calibration to end before starting the AD calibration. Wait for the calibration to end and finally calculate the ADC value. Convert to voltage value temp=adc* (3.3/4096), display voltage value.

4.3 Main program design

The main program design includes serial interrupt function, key processing function and main function:

1. After reading the received data, the serial interrupt function will set the corresponding flag bit according to the received data, and the flag bit will change.
2. The keypress handler consists of two parts: keypress 1 and keypress 2. When key 1 is pressed, the interrupt service function of key 1 will be entered to detect the mode. Then make it switch mode after each press. When button 2 is pressed, it returns mode to 0 (standby mode) [11].
3. The main function is the OLED display first. The display contents include the distance of ultrasonic ranging, the lithium battery voltage value of the ADC measured voltage, and the variable mode. Then the serial port output. Finally, keep judging the value of mode and enter the corresponding mode. When mode is equal to "1", a constant distance following will be performed. When mode is equal to "2", the remote-control car of Bluetooth will be executed. When mode is equal to "3", the ultrasonic obstacle avoidance mode will be entered. When mode is equal to "4", it will enter the infrared tracking mode.

The main program design flow chart of this design is shown in figure 6.

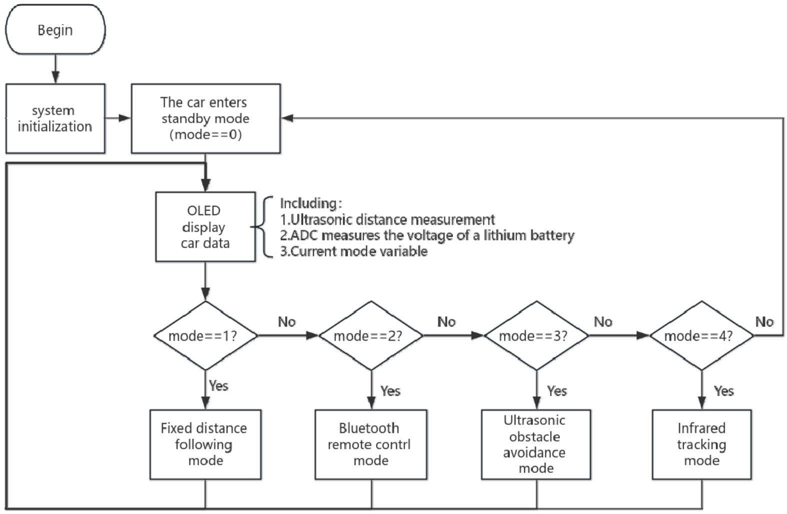

Fig .6 Main program design flow chart (Photo/Picture credit: Original)

5 Conclusion

The design of an intelligent obstacle avoidance car is based on the STNM32F103C8T6 microelectronic as the core. Infrared sensor to achieve infrared tracking function. The ultrasonic ranging module realizes the ranging and following function. The servo module and ultrasonic module cooperate to realize the ultrasonic obstacle avoidance function. Bluetooth module and PWM control motor drive to achieve Bluetooth control function.

In the process of designing the smart car, three parts of the test are included. The first is the first in the DRC testing section. DRC test was carried out on the development board through Jialichuang EDA, and the final DRC test results were 0 errors. The second part is the software running test. Through KeilµVision5 to build the environment of the intelligent car and write the program, it can finally successfully burn and control the car to carry out actions. Finally, the car runs functional tests. It can switch modes and use four modes through the app, and can display various parameters of the smart car. Finally, the design successfully completed the functional test of the smart car.

In the infrared tracking mode, the car passes through four infrared sensors, identifies the black and white line, and moves according to the predetermined route. In the following mode, the car passes through the ultrasonic module to identify the distance from the moving object in front and control the movement of the car. In the ultrasonic obstacle avoidance mode, the car detects whether there are obstacles in front and oblique front through the cooperation of the steering gear and the ultrasonic module, and controls the car to avoid obstacles. In the Bluetooth control mode, STM32F103C8T6 micro-controller and the host computer communicate through the

Bluetooth module to transmit control instructions. After receiving the control instructions, the micro-controller controls the motor drive, so as to realize the remote-control movement of the intelligent car and change the mode of the intelligent car.

There are still many shortcomings in the design of the intelligent car, such as the delay of Bluetooth control, the accuracy of ultrasonic ranging, and the body shaking problem of infrared tracking, which still needs to be improved constantly.

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