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Design of Wheeled Robot Based on Visual Navigation

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ABSTRACT. *With the rapid development and innovation of science technology, the traffic intelligence level is improved day by day. In order to enable the wheeled robot to drive autonomously, STM32F103RCT6 MCU was selected as the controller of the path recognition wheeled robot, OV7670 digital CMOS image sensor was selected as the path information acquisition sensor, and SCA60C inclination sensor is selected as the road slope information acquisition sensor, A wheeled robot based on visual navigation was designed. In addition, in this paper, we compiled the control program of the wheeled robot for path recognition through Keil µVision5 IDE development software, and realized the automatic path recognition and autonomous operation of the robot with hardware circuit, and improved the mechanical structure and control algorithm of the robot in debugging. It was proved that the robot designed in this paper has the advantages of reasonable structure, CMOS image sensor foresight, and image binarization is stable with visual navigation algorithm, which has obvious advantages compared with traditional path recognition robot.*

KEYWORDS: *Visual navigation; Path recognition; CMOS*

1. Introduction

With the progress of science and technology, the intelligent transportation system is gradually improved, and people's requirements for intelligent transportation are getting higher and higher. Intelligent driving has changed the traditional way of driving vehicles. It applies advanced sensors and automatic control technology to moving vehicles, which can automatically complete driving operations. The control personnel only need to do upper-level purposeful operations, which can effectively protect human safety, and improve the efficiency of the transportation system, and improve the efficiency of industrial production, save labor costs, so it has wide application values in society. The research of wheeled robots for path recognition based on visual navigation will greatly strengthen our country's core advantages in the field of intelligent driving, and has great strategic significance for improving the technological innovation of intelligent electronics industry and automobile industry.

Route recognition navigation methods mainly include visual navigation, laser navigation, magnetic navigation, RFID positioning navigation, inertial navigation, and GPS navigation. Visual navigation is also called image recognition guidance. Its

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principle is: image vision sensor recognizes the path marking line, and judges the deviation of the robot's current position from the path marking line, and then controls the steering system and transmission system to keep the running deviation within the allowed range.

Currently, the related research and results may be too expensive to promote, or lack of stability and requires people to participate in control, and people expect better solutions. For this reason, this paper designs a wheeled robot for path recognition based on visual navigation, which applies visual navigation to path recognition, and cooperated with image analysis algorithms to make the robot run more stable, and used ordinary image sensors to reduce costs. The follow-up part of this article includes overall design, hardware circuit design, system debugging and conclusion.

2. Working principle

The robot obtains the main path image through the vision module--CMOS image sensor, and obtains the pitch angle change through the inclination sensor module, and provides these information to the controller STM32MCU for path recognition processing, and knows the current road information. After the controller analyzes the road information, the operating state of the robot is controlled by PID, and the motor drive circuit and the steering gear drive circuit are used to realize the speed control and the steering angle control through the PWM control method. The display module displays path information and robot running status, and the power module supplies power to the robot. The working principle of the wheeled robot for path recognition based on visual navigation is shown in Figure 1.

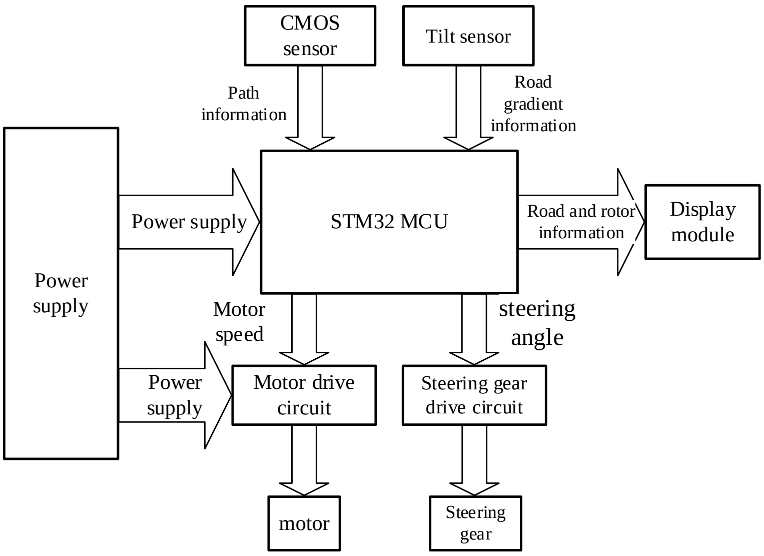

Figure 1 The working principle diagram

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As can be seen from the working principle diagram, there are two input signals that need to be detected and fed back to the MCU, including path image information and road gradient information. And the output signal of MCU is motor control signal, steering gear control signal, and display module control signal. The input signals of the motor drive circuit and the steering gear drive circuit are the PWM signal, and the output is the motor speed signal and the steering gear angle signal.

3. Hardware circuit design of wheeled robot

3.1 Hardware configuration

This robot mainly includes power module, STM32F103MCU controller, CMOS digital image sensor, tilt sensor, motor drive circuit, steering gear drive circuit, and OLED display module. The power module outputs multiple regulated power supplies to other modules, 12V to the motor drive circuit, 5V to the steering gear drive circuit, and 3.3V to the STM32F103MCU controller and CMOS digital image sensor. The CMOS digital image sensor sends the forward path information to the STM32F103MCU controller, and the controller processes the road information to determine the center line of the path and the position of the robot and its deviation angle. The inclination sensor module detects whether the robot is currently on a slope and makes appropriate acceleration and deceleration operations. The motor drive circuit outputs a large current of 30A to the motor, thereby providing huge kinetic energy for the robot. The steering angle value sent by the integrated controller of the steering gear drive circuit is sent to the steering gear, and the steering gear is stabilized and powered. The OLED display module displays real-time road images and robot running status, so that the robot can be debugged more intuitively.

3.2 Hardware Design

3.2.1 Power Supply

The voltage and current of all components in the hardware electronic system of the robot must meet the requirements. This design uses 3S2200mah lithium battery as power supply, which can provide the voltage of the motor drive circuit, and then use the XL4005 regulator chip to reduce the power supply voltage to 5V, which can provide the voltage required by the steering gear drive circuit, and then use the AMS1117-3.3 regulator chip to reduce the voltage to 3.3V, which can provide the voltage required by the STM32F103MCU and OV7670 digital image sensors. In order to reduce electromagnetic interference and improve the accuracy of the path information collected, dual 3.3V regulated power supplies are used to supply power to the STM32F103MCU and OV7670 digital image sensors. Finally, all the module circuits separately are grounded, which can improve the overall stability of the system and the anti-interference ability. After testing, the power module meets the

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design requirements. Figure 2 is the circuit schematic.

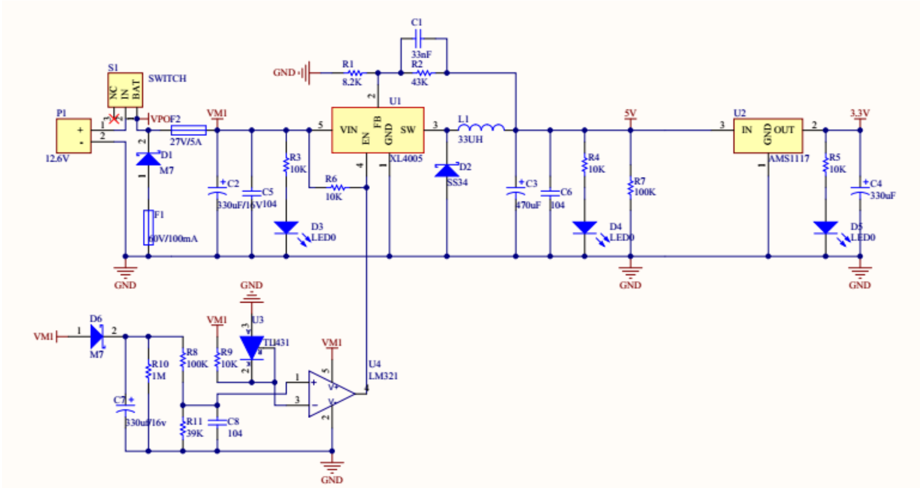

Figure 2 The circuit schematic of power supply

3.2.2 STM32F103MCU controller

In the robot hardware system, the main controllers we used are 51 single-chip microcomputer, Arduino single-chip microcomputer and STM32 single-chip microcomputer. Among them, 51 single-chip microcomputer has stable performance and low cost, but the information returned by the image sensor in this design is too much, and 51 single-chip microcomputer runs slowly, which cannot meet the design requirements. The Arduino MCU is an 8-bit processor like the 51 MCU, but its internal structure is different. It is developed based on the AVR MCU, which simplifies the development method. Although the Arduino single-chip microcomputer has richer interfaces than the 51 single-chip microcomputer, the operating speed is still slow, which cannot meet the design requirements. STM32 single-chip microcomputer runs much faster than 51 single-chip microcomputer and Arduino single-chip microcomputer, and after tested, it can meet the design requirements. STM32 single-chip microcomputer has many resources and strong functions, which can drive all the sensors in this design. Therefore, after comprehensively considered, we decided to use STM32 single-chip to complete this design, which improved the performance of the robot while taking into account the cost. This design uses the STM32F103RCT6 single-chip microcomputer, which uses Cortex-M3 as the core and has a maximum operating frequency of 72MHz. It has internal resources such as DMA, ADC, and timer. It has two debugging modes, SWD and JTAG, and it can output PWM waveforms through the timer. The schematic diagram of the STM32F103RCT6 microcontroller is shown in Figure 3.

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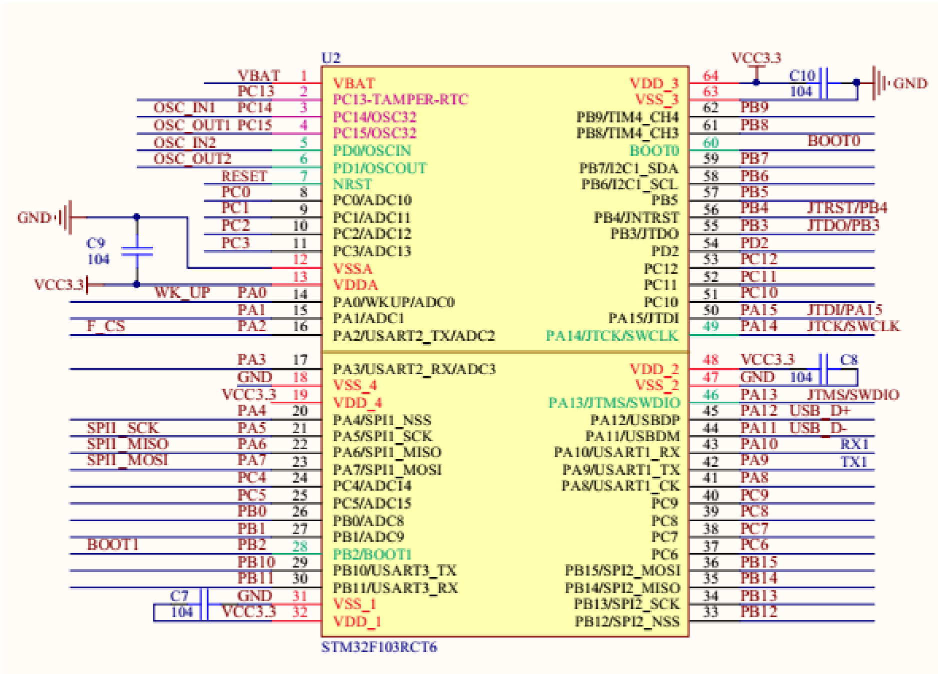

Figure 3 The schematic diagram of the STM32F103MCU

3.2.3 CMOS image sensor

The visual navigation module is equivalent to the eyes of the robot, so the visual navigation sensor is directly related to the final performance of the robot, so it is very important to determine the overall design. At present, the commonly sensors for robot vision navigation mainly include CCD image sensor and CMOS image sensor.in this design, we used CMOS image sensor.

The CMOS (Complementary Metal-Oxide-Semiconductor) digital image sensor is shown in Figure 4. The sensor has better predictive ability and longer look-ahead distance. The CMOS digital image sensor developed earlier and the technology is mature. Compared with the CCD image sensor, the power consumption is smaller and the cost is slightly lower. The CMOS digital image sensor collects more data information, and the entire image, which can be equipped with corresponding algorithms to make the robot run faster.

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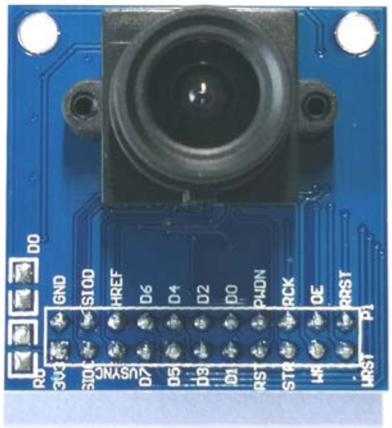

Figure 4 CMOS digital image sensor

3.2.4 Tilt sensor

This design uses the SCA60C tilt sensor to detect the road slope, as shown in Figure 5. The sensor works normally under 5V voltage. It has N1000060 tilt sensor probe and LM393 dual voltage comparator chip, which can output one voltage analog signal and two TTL level signals. The sensor can detect the tilt angle of a single-axis bidirectional range of 0-180°, and can adjust the inclination threshold value in two directions through two potentiometers, and can adjust accuracy of ±1°. When the tilt is lower than the threshold, the level interface outputs low level; when the tilt is higher than the threshold, the level interface outputs high level. After testing, the tilt sensor meets the design requirements.

Figure 5 Tilt sensor

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3.2.5 OLED display

OLED (Organic Light Emitting Diode), that is, polar light-emitting diode, has self-luminous characteristics and does not need a backlight source. The OLED display uses very thin organic coatings and glass substrates, which have the advantages of high contrast, fast response, and low power consumption. In this design we use a small OLED display of 0.96 inch and 128×64 resolution, as shown in Figure 6. The screen is small in size, high in contrast, does not require a backlight source, and performs well in various light environments. The display module adopts SPI communication mode, which can display path images and various parameters of the robot when it is running.

Figure 6 OLED display

3.2.6 The motor drive circuit

The motor drive circuit uses 74HC244 chip and AM2857 drive module to drive the motor, the drive module is AM2857 dual motor drive module. The module has two AM2857 driver chips on board, the maximum voltage is 24V, the maximum continuous output current of a single channel is 4.0A, and the peak current of a single channel is 6.5A. It can drive two high-power DC motors at the same time, and has functions such as motor speed protection and high temperature protection. The schematic diagram of the robot motor drive circuit is shown in Figure 7.

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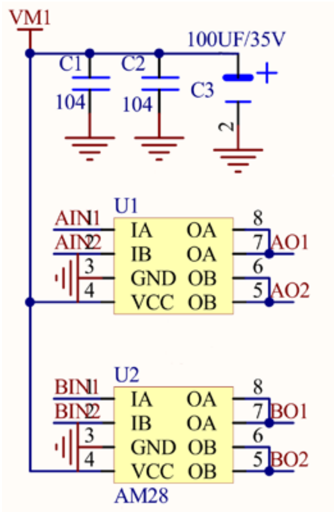

Figure 7 The schematic diagram of the robot motor drive circuit

3.2.7 Steering gear drive circuit

The steering gear of the robot response fast and it has high torque. It requires working voltage of 5V and requires a large driving current during operation. The power of steering gear is provided by an XL4005 voltage regulator chip, the voltage input range is 0.8~26V, the fixed voltage output is 5V, and the maximum current that can be maintained during long-term operation is 1A. The schematic diagram of the steering gear drive circuit is shown in Figure 8.

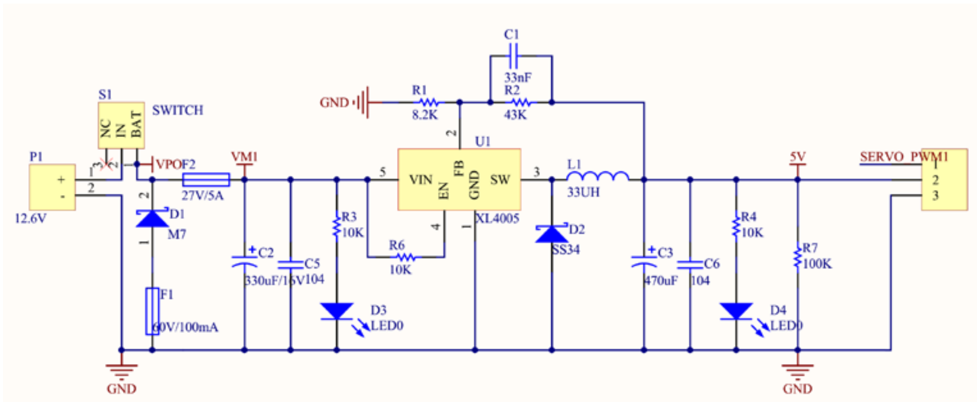

Figure 8 The schematic diagram of the steering gear drive circuit

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4. Development environment and debugging

4.1 Development environment

The design is based on Keil µVision5 IDE development environment, and use C language to design the control program of the path recognition wheeled robot.

4.2 Application of display module

Although we can monitor the CMOS image sensor in real time through the host computer during the debugging process, the road image information collected by the CMOS image sensor can be displayed on the host computer, this method is not convenient, and the cable connection cannot be used during the robot movement process. So if we want to observe the road image in the computer, we need to use wireless connection way, and transmit the road information to the host computer through devices such as WIFI module, Bluetooth module or 2.4G wireless module. In practice, it is found that the method mentioned above will take up memory, slow down the CPU processing speed, and affect the performance of the robot, and the it is not stable, and the upload speed is also very slow. Therefore, in order to solve these problems, we use an OLED display module to display the road image after the binarization process in real time, as shown in Figure 9. The problems were solved. And the display module can also display running information of the robot in real time, which made the debugging work more convenient.

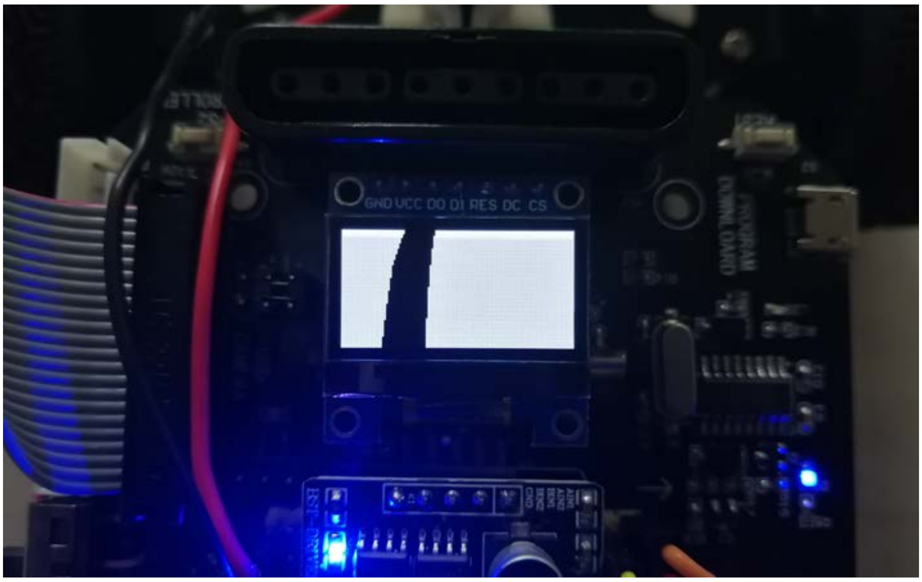

Figure 9 Road image information in OLED display

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5. Conclusion

The advantages of path recognition wheeled robots based on visual navigation are obvious, and with the development and progress of modern science and technology, this advantage is becoming more and more obvious, and the convenience of transportation of people and goods in production and life will be greatly improved. In this paper, the robot mechanism construction, the wiring of hardware modules and the development of software programs were completed, and the robot's fully autonomous running on the road was realized, so we completed the design purpose.

The robot in this design adopts the front steering gear and the rear dual motor drive, which can ensure the robot's motion performance; it adopts low-cost CMOS image sensor and high-performance STM32F103RCT6 MCU controller, combined with advanced image binarization and visual navigation algorithms, which Not only reduces the cost but also improves the stability of the robot operation.

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