Design of intelligent variable speed warehouse carrier system based on ARM SCM

Haojun Yang
School of Shandong University of Science and Technology, Tai an 271000, China
yanghaojun@sdust.edu.cn

Abstract. Aiming at the problem of motion instability caused by the climbing of intelligent vehicles in the process of warehouse transportation, a design of intelligent variable speed warehouse transport vehicle system was proposed. STM32F103C8T6 single-chip microcomputer is used as the core controller of the intelligent variable speed car. The hardware circuit of the system is composed of power module, servo motor module, ultrasonic sensor module, infrared sensor module, MPU6050 gyroscope, motor drive and other modules. At the same time, the software test of vehicle downhill intelligent transportation, tracking detection speed and differential steering conditions is completed. Finally, the performance of the car is verified, and the results show that the smart car has achieved high stability of avoidance tracking, speed and other key functions. It is a downhill process, which has a lot of practical value.

Keywords: single chip microcomputer; Smart car; MPU6050; Speed uphill; Obstacle avoidance tracking.

1. The introduction
With the rapid development of science and technology, automation technology and artificial intelligence technology have become an international key topic. Intelligent car is a research hotspot in the field of artificial intelligence, which can replace humans to complete much work, to meet the needs of all walks of life [1]. Intelligent car with advanced technology, powerful function, wide application and other advantages, in a variety of occasions have been very good application; But in the warehouse transportation, it is inevitable to encounter the problem of car climbing, so that the speed of the car is greatly reduced, reducing the work efficiency. This paper makes the following research on this problem [2].

The intelligent vehicle obstacle avoidance system proposed by Huang Yongtao uses the ultrasonic module to detect obstacles, which solves the problem of the car avoiding surrounding obstacles in the process of moving, but the tracking function is slightly lacking [3]. The automatic tracking obstacle avoidance light seeking system proposed by Shen Kouming uses the infrared module to detect the track route, which solves the problem of car route planning, but the structure is a little simple, and the obstacle avoidance function is not accurate enough[4]. The intelligent interactive balancing car designed by Huang Zhifang uses THE MPU6050 gyroscope to obtain the tilt Angle of the car, which solves the problem of slope measurement, but it is not suitable for practical applications[5]. The tracking and
climbing intelligent car designed by Li Yanlun realized the function of intelligent transportation, but the motor did not play to the maximum utilization in the process of moving [6].

In view of the above research basis, aiming at the problem of unstable climbing in the current storage and transportation, this paper designs an intelligent variable speed warehouse transport vehicle based on STM32 microcontroller control, which can not only run on the planned route in advance, but also realize the function of automatic obstacle avoidance. At the same time, it can effectively solve the load climbing problem of the intelligent vehicle in the face of uphill and downhill issues, enhance the adaptability of the car, improve the motor energy utilization rate and work efficiency of the vehicle.

2. Overall design of intelligent variable speed warehouse carrier system

The intelligent variable speed warehouse transport vehicle control system designed in this paper is based on STM32F103C8T6 single chip microcomputer as the main controller, the base is installed at the back of two small direct speed motor, used to drive the car driving or turning variable speed work. Intelligent variable speed vehicle in driving, need to move along the planned route, and the right to avoid surrounding obstacles. In order to achieve the tracking and obstacle avoidance function, infrared photoelectric sensor is used to achieve the tracking function. Using ultrasonic sensor to achieve the obstacle avoidance effect by ranging. Finally, the MPU6050 gyroscope is used to measure the tilt Angle between the car and the ground, and then the speed adjustment of the car is realized with software. Figure 1 is the overall design block diagram of the intelligent variable speed warehouse carrier system.

![Figure 1. Overall system design block diagram](image)

2.1. Control Module

The control module used in this paper uses the STM32F103C8T6 microcontroller as the core. It has extremely high performance, using cortexM3 kernel, with rich and reasonable peripherals, low power consumption and affordable advantages, using LPFP64 packaging form.
2.2. Infrared tracking module

In order to make the car accurately follow the black track line on the white ground, this paper adopts RPR220 reflective photoelectric sensor. By installing two infrared detection heads RPR220 on the left and right sides of the car, the tracking purpose is realized according to the different characteristics of infrared reflectance of different colors [2].

When the car is driving, when the infrared light meets the white plane, most of the white light will be reflected back. At this time, the photoelectric triode is on, and the comparator outputs the low level 0 to the SCM; When the black track is encountered, most of the black light is absorbed by the receiving tube. At this time, the transistor is in the cut-off state, and the comparator outputs low level 1 to the single chip microcomputer. After the microcontroller receives the information, it controls the motor to make the car carry out the corresponding action, so as to realize the automatic tracking function of the car.
2.3. Ultrasonic obstacle avoidance module

In order to make the car accurately avoid obstacles, the HC-04 ultrasonic sensor is widely used in robot obstacle avoidance, object ranging, liquid level detection and other fields. The measurement distance is accurate, the blind area is small, can achieve 2cm-450cm non-contact accurate ranging, the error range is within 2.5mm. In the car before and after the left and right directions are installed an ultrasonic module, ultrasonic ranging is pointing to a certain direction of transmitting ultrasonic, at the same time began to time, ultrasonic transmission in the air, on the way to encounter obstacles immediately back, ultrasonic receiver received reflected waves immediately stop timing. The propagation speed of sound wave in the air is 340m/s. According to the time t recorded by the timer, the distance X between the launching point and the obstacle can be calculated. Then, the distance obtained is:

\[ X = \frac{340 \text{m/s} \times t}{2} \]  

Figure 4. Physical drawing of ultrasonic module

2.4. Servo motor module

DS3119 steering gear is used in this paper to control the steering of the trolley. The steering gear integrates dc motor, motor controller and reducer, and is encapsulated in a servo unit in an easy to install housing. A motor system capable of relatively accurate rotation at a given Angle using a simple input signal [7].

When the obstacle avoidance tracking module needs to be adjusted, it sends a signal to the single chip microcomputer. After receiving the signal, the single chip microcomputer drives the servo motor to work. The servo motor receives the control pulse of the signal source through the control circuit and drives the motor to rotate.

Figure 5. Servo motor workflow

2.5. Slope survey Module

MPU6050 gyroscope module is used for design. The module is mainly communicated through IIC bus, its internal built-in 16bit A/D converter, can realize the Angle of high precision conversion to meet the needs of users; In addition, this module can be used in different working environments because it can quickly and accurately track the angular velocity and has a wide range of operating voltages [5]. The car obtains the current inclination Angle of the car through the module, analyzes it, and returns the data
to the single chip microcomputer, the single chip microcomputer sends pulses, so as to drive the motor for speed regulation.

2.6. Motor drive module

Motor drive module adopts L298N drive chip. L298N belongs to H-bridge integrated circuit, which can drive inductive load, such as high-power DC motor, stepper motor and other devices [8].

This design uses a L298N to drive two DC motors, and can realize the motor forward and reverse, to achieve this function only should change the input logic level.
2.7. Motor speed control module

Speed regulating motor is to use the method for changing the voltage of the motor to change the speed of the motor, in order to make the motor to achieve higher performance. The adjusting voltage is adjusted by software, and the CONTROL of DC motor is realized by controlling the PWM duty ratio, so as to realize the speed regulation of DC motor.

3. System software design

Only the hardware part of the intelligent variable speed warehouse transport vehicle can not work. It must cooperate with the software to realize the normal operation of the car. The program of this design adopts Keil 5 developed by Keil Software company, which contains a series of integrated tools such as STM32 compiler and linker.

3.1. Main program design

After the MCU is powered on, each module is first initialized. When the car is ready to drive, continuous cycle scan STM32F103C8T6 MICROcontroller I/O port received and collected each module signal. After the corresponding control processing, drive motor action to make the car complete the preset driving route. The main program flow chart of the system is shown in Figure 9.

![Main program flow chart](image)

**Figure 9.** Main program flow chart

3.2. Tracking subroutine design

The tracking subroutine consists of four infrared modules. When the four infrared detection heads all detect the black track, it means that the car runs in the normal route. When four infrared detection heads detect no black track, the car stops. When only one of the four infrared detection heads detects a black orbit, a turn is made. The infrared tracking flow chart is shown in Figure 10.
3.3. Obstacle avoidance program design
Obstacle avoidance procedure is the same as the judgment logic of tracking. When an object is detected by the infrared on one side, it is regarded as an obstacle, and the car will go in another direction, so as to avoid obstacles [9].

Table 1. Status analysis of obstacle avoidance module

| Distance          | Mode        |
|-------------------|-------------|
| x1 & x2 & x3 & x4 > 15cm | normal     |
| X1 < 15cm         | Right turn  |
| X2 < 15cm         | Straight ahead |
| X3 < 15cm         | Right turn  |
| X4 < 15cm         | Left turn   |

(x1: front-end ultrasonic module X2: back-end ultrasonic module X3: left ultrasonic module X4: right ultrasonic module). The obstacle avoidance procedure flow is shown in Figure 11.
3.4. Turn to subroutine design

The steering module in this paper uses 180° steering gear. A single-chip microcomputer generates a pulse width modulation signal to tell the steering gear rotation Angle. Pulse width is the coding information required by the steering gear controller. The control pulse period of the steering gear is 20ms, and the pulse width ranges from 0.5ms-2.5ms, corresponding to positions of -90 degrees to +90 degrees (for 180° steering gear). This is shown in the following table.

| Input signal pulse width (The cycle is 20ms) | Steering gear output shaft angle |
|---------------------------------------------|---------------------------------|
| 0.5ms                                       | -90°                            |
| 1ms                                         | -45°                            |
| 1.5ms                                       | 0°                              |
| 2ms                                         | 45°                             |
| 2.5ms                                       | 90°                             |
3.5. Variable speed subroutine design
The variable speed subroutine is designed by MPU6050 gyroscope module and DC motor. MPU6050 gyroscope is used to obtain the current tilting Angle of the car, which is analyzed and returned to the single chip microcomputer. The single chip microcomputer sends pulses and controls them by changing the duty cycle, thus changing the speed of the motor to achieve the function of speed regulation. The applied principle: \( P = \pi \times M \times n \) where: \( P \) is the motor power, \( M \) is the motor torque, \( n \) is the motor speed, \( \pi \) is about 3.14. Make the rated power unchanged, by changing the torque and motor speed to adjust the motor speed, to achieve the maximum use of car speed.

| Angle of inclination | Speed (r/min) | torque (N*m) |
|---------------------|--------------|--------------|
| 0°                  | 420±60       | 0.5          |
| 10°                 | 224±40       | 0.67         |
| 20°                 | 140±26       | 1.5          |
| 28°                 | 75±18        | 2.8          |
| 35°                 | 46±13        | 4.5          |

4. Experimental Results
The intelligent variable speed warehouse transport vehicle is divided into 7 modules: 1 is the ultrasonic module, which realizes the obstacle avoidance function of the intelligent vehicle; 2 for servo motor module, used for intelligent vehicle steering function; 3 for the single chip module, is the control core of the whole design; 4 is the power module, which supplies power to other modules. 5 for the slope module, used to measure the smart car inclination Angle; 6 are motor drive modules, used to provide kinetic energy to the intelligent car; Location 7 is the tracking module, which is used to detect the road information. FIG. 12 is the physical drawing of the trolley, and FIG. 13 is the structural drawing of the chassis of the trolley.

![Physical drawing of trolley](image1.png)

![Structural drawing of trolley lower plate](image2.png)

The hardware and software modules are combined together, and the accuracy rate reaches 89% in more than 100 debugging of intelligent variable speed warehouse transporter. And 6 kinds of slopes are extracted for illustration.
Table 4. Trolley operation data

| sequence number | Ideal time | Real-time | gradient | Is the expected speed achieved |
|-----------------|------------|-----------|----------|-------------------------------|
| 1               | 18s        | 18.2s     | 0°       | Yes                           |
| 2               | 20s        | 20.3s     | 10°      | Yes                           |
| 3               | 22s        | 21.8      | 15°      | Yes                           |
| 4               | 25s        | 24.7      | 20°      | Yes                           |
| 5               | 28s        | 28.1      | 25°      | Yes                           |
| 6               | 30s        | 30.5      | 30°      | Yes                           |

In the process of debugging, the least square formula is used to analyze the inclination and speed of the car, and the curve of inclination Angle and speed is obtained, as shown in Figure 14.

![Figure 14. The relation diagram of inclination angle and car speed](image)

Least square formula:

\[ y = k \times x + b \]  \hspace{1cm} (2)

(y: Average value of car speed at the same slope; intercept \( b = 0.3 \); Fit the slope of a line \( k = -0.005 \))

The results show that the functions of each module in hardware part can be used normally. When the software program is put into the microcontroller chip, the car can work normally. The idea of changing the speed of the car by measuring the slope change was proved. In the process of motor operation, the motor can play its maximum utilization rate.

5. Conclusion

The intelligent variable speed warehouse transport vehicle designed in this paper takes STM32F103C8T6 as the control core, based on the four-wheel model car, realizes the tracking, obstacle avoidance and variable speed functions through sensors, gyroscope and motor control. In this paper, from the design background, ideas, methods, hardware framework and software design to verify the intelligent variable speed warehouse transport vehicle, to achieve the expected design parameters. Slope change can be detected by MPU6050 gyroscope, which is more accurate, faster and convenient than the traditional method of detecting slope by ultrasonic sensor or infrared sensor [10]. Intelligent variable speed warehouse transport vehicle will be widely used in warehouse transportation, express sorting, unmanned inspection, automatic following and other fields in the future.

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