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Design of Automatic Serving Trolley based on RFID

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Abstract

This paper designs and implements an automatic food delivery trolley, which can not only improve the efficiency of food delivery and improve the quality of service in restaurants; today, as the novel coronavirus(COVID-19) continues to raging, it can also provide contactless food delivery.A physical model of the trolley has been built, which can automatically deliver the food to the designated location on the table according to the delivery table number pressed by the button, and when the return button is pressed, the trolley will automatically return to the zero point. The radio frequency identification module (RFID) is used to sense the IC card arranged in the restaurant to determine how the car should move. Double closed-loop PID algorithm is used to control the motor speed.The Ultrasonic ranging module is used to detect obstacles. In the system software, for different paths, two working modes of "original return" and "one-way forward" are designed.After testing, the trolley can operate in two working modes and achieve basic functions and can drive a load of at least 4kg which meet the needs of use.

Keywords

COVID-19; Serving trolley; STM32;RFID; Ultrasonic obstacle avoid; PID.

1. Introduction

1.1. Demand

According to the "China Catering Report 2020", the whole country's catering revenue was 4.7 trillion yuan in 2019, a year-on-year increase of 9.4%. This shows the huge consumption power in China's catering market, and China with an increasingly aging population is now facing a shortage of restaurant labor. In recent years, the food delivery robots on the market or the automatic trolley designed in this paper can effectively help restaurant waiters complete food delivery, alleviate the problem of insufficient waiters, improve waiters' work efficiency, and improve The level of service in the restaurant.

As the COVID-19 continues to raging today, the demand for contactless delivery is urgent. Many distribution robots play a role in the front line of the anti-epidemic: contactless drug distribution and contactless disinfection services in hospitals; in the crowded centralized isolation point "square cabin hospital", a large number of contactless distribution services are also required to reduce the risk of virus transmission. The replacement of robots can also relieve the fatigue of medical workers and the shortage of medical supplies such as protective clothing.

Figures 1 below shows a scenario where the delivery robot product "Happy Delivery"of the company "Pudu Technology" serves in "Jinyintan Hospital" during the outbreak of the novel crownvirus.

ISSN: 2688-9323

Figure 1. the robot serves in“Jinyintan Hospital”

1.2. The Serving Trolley

The function of the trolley is designed in the second chapter of the paper which introduces the design of the trolley using RDID for positioning, explaines the working process under the two paths for two working methods, Introduces the dual closed-loop PID algorithm for speed control of the trolley. The third chapter explains the circuit hardware design of the trolley. The fourth chapter explains the software design of the trolley. In the fifth chapter, the function test of the trolley model is carried out.

2. Design

2.1. Function Design

By Analyzing the structure and load of the trolley model, the model with a suitable size and a certain load capacity is designed and implemented, which meet the required functions.

At the beginning , the trolley is at the zero point. The chef prepares the dishes and places them in the delivery area. The waiter places the dishes in the trolley, then presses the corresponding button according to the table number.

The trolley completes five tasks in turn: (1)picking, (2)delivering, (3)recycling, (4)delivering and (5)zeroing[1].

During the entire operation of the trolley, when the ultrasonic sensor detects an obstacle within 50cm ahead, the motor stops and the buzzer works. It also has an alarm function to prevent others from picking up.

2.2. RFID Positioning

Taking into account the design difficulty of the trolley, the use environment and the operating cost, we can choose one of (1)widely used magnetic guidance, (2)optical guidance, and (3)direct coordinate as the guidance method of the trolley[2].

In complex environments such as restaurants, whether it is optical guidance or magnetic guidance, there are problems with black lines being contaminated or electromagnetic interference around the magnetic strip causing positioning failure. In this design, use RFID for positioning, and the placed IC card is the positioning point. RFID adopts a wireless card reading method. The reading distance is relatively short, but the anti-interference is relatively strong, and it is not affected by ground stains. The inductive IC card can be placed under the ground compartment and is not easily damaged.

2.3. Two Types of Working in Different Path

Two working methods are designed for the following two path schemes. Figure 2 below shows the first restaurant layout and path plan. This kind of path plan is suitable for restaurants with tables against the wall layout. In this path, the route of the trolley is not a closed curve. Since the trolley delivers the food to the innermost table, the front is blocked by the wall, so it can only return to the zero position by returning from the original road.

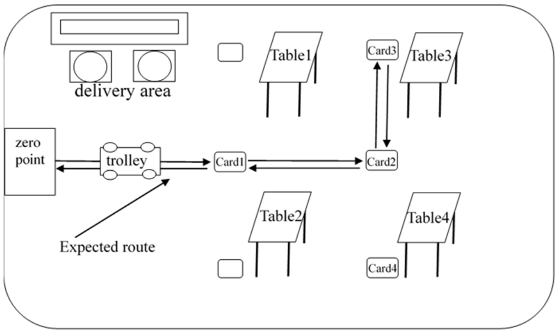


Figure 2. “original return”

Figure 3 below shows the second restaurant layout and path plan. This path is suitable for the restaurant tables to be concentrated in the center of the restaurant. Since the route of the trolley is a closed curve,one-way forward mode is designed. Returning to the zero position will be easier to achieve in the program, and multiple trolleys can be placed on the same route[4].

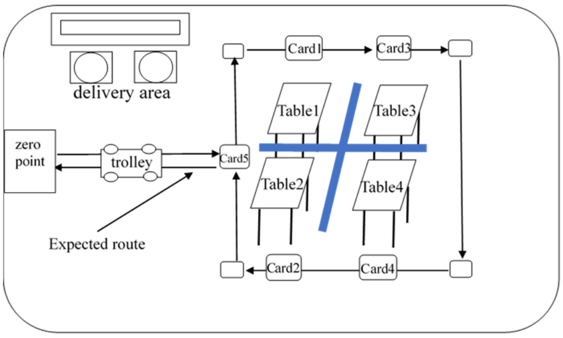


Figure 3. “one-way forward”

2.4. Motion Model of the Trolley

The chassis of the trolley is composed of two universal wheels and two driving wheels[2]. The motion state of the robot is shown in Figure 4.

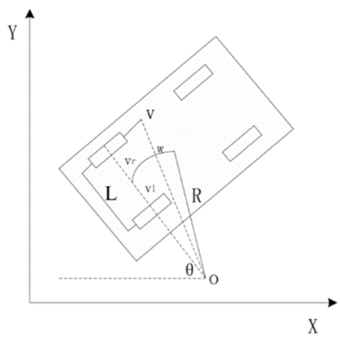


Figure 4. Kinematics model of the trolley

The linear velocity of the left wheel center relative to the ground is V_L, and the rotational angular velocity is ω_L; the linear velocity of the right wheel is V_R, and the rotational angular velocity is ω_R; V_C is the center of mass velocity of the trolley, and the distance between the two driving wheels is L, the driving wheel radius is r, the turning radius of the trolley around the

ISSN: 2688-9323

instant center O is R, and the angular velocity is ω. The linear speeds of the left and right driving wheels when the trolley is turning are:

$$\begin{cases} V_L = \omega(R - \frac{b}{2}) = \omega_L r \\ V_R = \omega(R + \frac{b}{2}) = \omega_R r \end{cases} \quad (1)$$

The linear velocity of the center of mass of the food delivery truck is:

$$V_C = \omega R = \frac{1}{2}(V_L + V_R) \quad (2)$$

Therefore, the rotational speeds of the left and right driving wheels of the trolley can be obtained as:

$$\begin{cases} \omega_L = \frac{V_C}{2}\left(\frac{2}{r} - \frac{b}{Rr}\right) \\ \omega_R = \frac{V_C}{2}\left(\frac{2}{r} + \frac{b}{Rr}\right) \end{cases} \quad (3)$$

2.5. Double Closed Loop PID Control

2.5.1. Positional PID

The ideal formula for the positional PID controller is as follows:

$$\mu(t) = K_P[e(t) + \frac{1}{T_1}\int_0^t e(t)dt + T_D\frac{de(t)}{dt}] \quad (4)$$

Where u(t) is the output of the controller ; e(t) is the controller input (deviation: e(t)=r(t)-c(t)) ; KP is the proportional amplification factor; TI is the integral time; TD is the derivative time.

Let u(k) be the output value of the controller at the kth sampling time, and the discrete PID calculation formula can be obtained:

$$\mu(k) = K_p e(k) + K_1 \sum_{j=0}^{k} e(j) + K_D[e(k) - e(k-1)] \quad (5)$$

Disadvantages: The output at the current sampling time is related to the past states, and integral saturation will occur; if the computer fails, a large change in u(k) will cause a large change in the position of the actuator.

2.5.2. Incremental PID

Incremental PID means that the output of the digital controller is only the increment Δu(k) of the control quantity. When the incremental algorithm is used, the control quantity Δu(k) output by the computer corresponds to the increment of the actuator position this time, rather than the actual position of the actuator. The accumulation function is implemented by programming using the formula u(k)=u(k-1)+Δu(k).The incremental PID control formula is as follows:

$$\Delta\mu(k) = \mu(k) - \mu(k\text{-}1) = K_p\Delta e(k) + K_1 e(k) + K_D[\Delta e(k) - \Delta e(k-1)] \quad (6)$$

Advantages:

(1) There is no need to add up in the formula;

(2) When the machine fails, the range of influence is small and will not seriously affect the production process;

ISSN: 2688-9323

(3) The impact is small during manual-automatic switching.

Based on the advantages of the incremental PID controller, the incremental PID controller is used to control the motor speed in this design.

2.5.3. Control Block Diagram

In order to make the trolley more sensitive, double closed-loop PID control is used to overcome the relatively slow response of single closed-loop PID control [5]. The following Figure 5 shows the PID control block diagram.

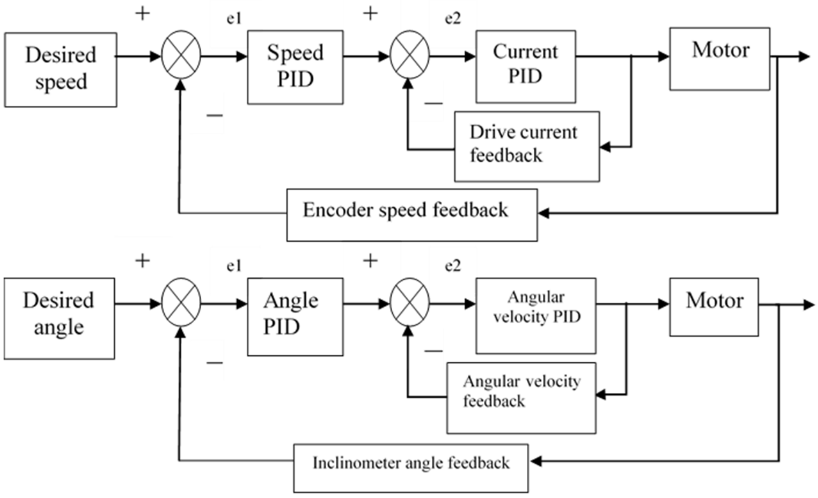


Figure 5. the PID control block diagram

3. System Hardware

Figure 6 below shows the system hardware block diagram. The modules of the trolley are independent buttons, common anode seven-segment digital tube, ultrasonic distance measuring module, active buzzer, L298N motor drive module, DC deceleration encoding motor, RFID module, power module, and the MCU.

The RFID module needs to communicate with the MCU in SPI, so the STM32F103C8T6 is used as the main controller of the trolley.

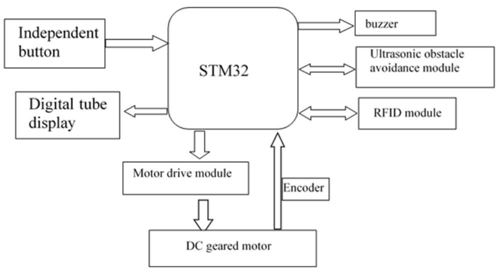


Figure 6. system hardware block diagram

3.1. Drive Module

In the drive of the trolley, the use of DC geared motors is suitable for the application scenarios .The designed trolley needs a certain load capacity, so the high-power, large-torque DC deceleration encoder motor 25GA-370 as shown in Figure 7 is selected. The power supply voltage is 12V, the rated speed is 46RPM, and the rated torque is 2.4kg·cm.

Figure 7. 25GA-370 DC geared motor

The motor drive module uses L298N as the main drive chip, as shown in Figure 8 for the definition of its pins. This module is composed of two H-bridge drivers, which can control two motors. By configuring the high and low levels of the logic input terminal, the motor can be controlled to rotate forward, reverse or stop. The speed of the motor can be controlled by inputting the PWM wave to the enable terminal.

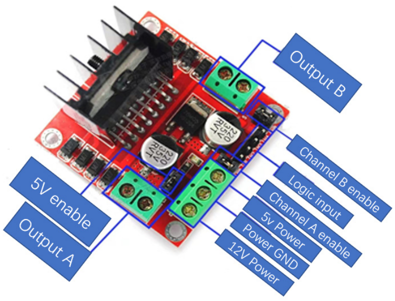


Figure 8. L298N Motor Drive Module

3.2. Ultrasonic Ranging Module

As shown in Figure 9 below, the HY-SRF05 ultrasonic sensor module has a ranging range from 2cm to 450cm, and the ranging accuracy can reach as high as 3mm, which meets the performance requirements of 50cm for obstacle avoidance of the trolley.

Figure 9. HY-SRF05 ultrasonic sensor module

Principle: The MCU gives a pulse of more than 10us to the module, and then the module sends out ultrasonic waves. When the module detects the echo, it outputs a pulse echo signal to the MCU. The high-level duration of the signal is proportional to the distance measured by the ultrasonic wave. The MCU obtains the measured distance through the following formula:

$$S = \frac{T \cdot V_S}{2} \tag{7}$$

Where S is the distance to the obstacle ahead, V_S is the speed of sound in the environment at this moment, and T is the duration of the high level of the echo signal.

ISSN: 2688-9323

3.3. RFID Module

The core of the RFID module is MFRC522 which is a highly integrated contactless (13.56MHz) card reader chip. The following Figure 10 shows the card reader module and a S50 contactless IC card. The card reader module of the trolley uses SPI to communicate with STM32.

Figure 10. RFID module and IC card

4. System Software Design

4.1. "Original Return" Working Mode

The system software part is completed in MDK development environment keil5.

The following Figure 11 shows the main program flow chart of "original return". The main function first executes a series of initialization functions, which configure the I/O pins and microcontroller resources used by each module. Then the program executes the key scan program. Then the program turns on the RFID module, and then the program executes subroutines such as obstacle avoidance and card reading.

In this working mode, the direction of turn of the trolley must be judged according to the card number each time a card is detected. In addition, it is necessary to write the corresponding program for the original path return, its logic is similar to the main program

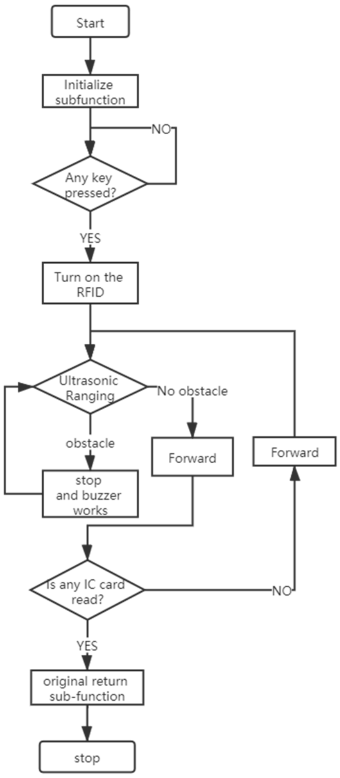


Figure 11. the main program flow chart of "original return"

ISSN: 2688-9323

4.2. "One-Way Forward" Working Mode

Different from the original way return work mode, the one-way forward work mode does not need to write the original way return sub-function. In addition, the order of the trolley is determined each time a card is detected, such as the first card which only needs to turn left, the card at the table only needs to park or go straight[3], while the card at the corner only needs to turn right. The same program as the original way mode is the ultrasonic ranging subroutine and RFID subroutine shown in section 4.3 below.

Figure 12 shows the main program flow chart of the one-way forward mode.

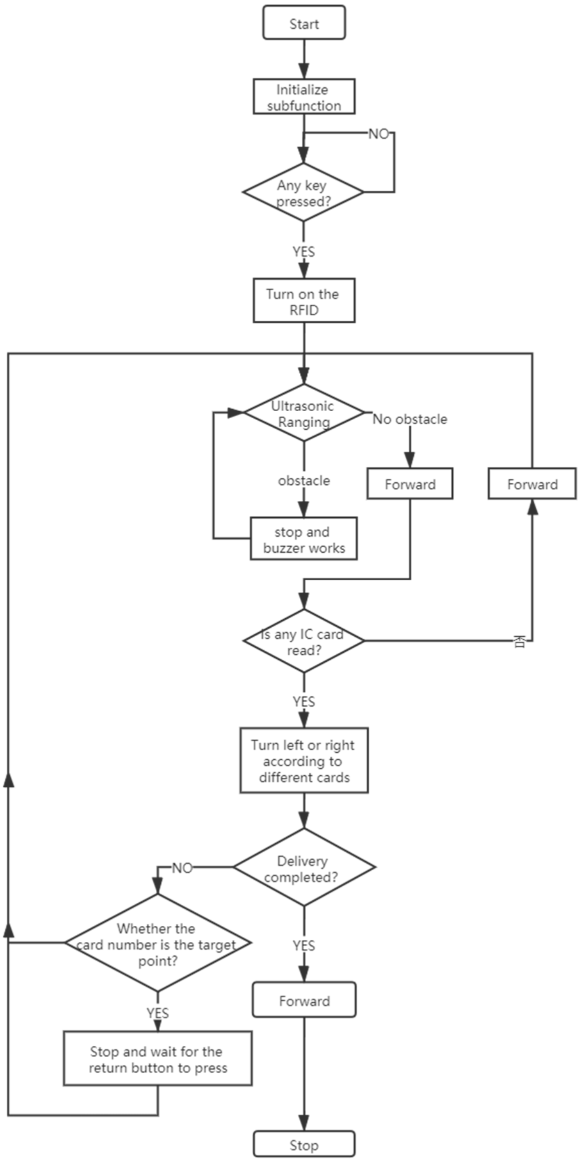


Figure 12. Main program of "one-way forward"

4.3. Subroutine

Judge the distance of the obstacle according to the distance value, and implement obstacle avoidance (stop, buzzer alarm) when there is an obstacle at 50cm in the software. The main program is designed to prevent the obstacle avoidance "jitter" function, that is, the obstacle avoidance is not performed for the obstacle quickly moving in front of the trolley. When the distance of the detected obstacle is less than 50cm, the first delay is 0.2s, and then the judgment is made again, if the distance measurement value is still less than 50cm at this time, then it is determined that there is an obstacle ahead and the obstacle avoidance is executed. The following Figure 13 shows the flow chart of the ultrasonic ranging sub-function.

ISSN: 2688-9323

The RFID module has been turned on in the main program, and then execute the card search function, use the RC522 and the card communication function, send data to the card, receive data, anti-collision function, read the card serial number, and assign the card serial number to "Card_ID", Finally return to the main program.

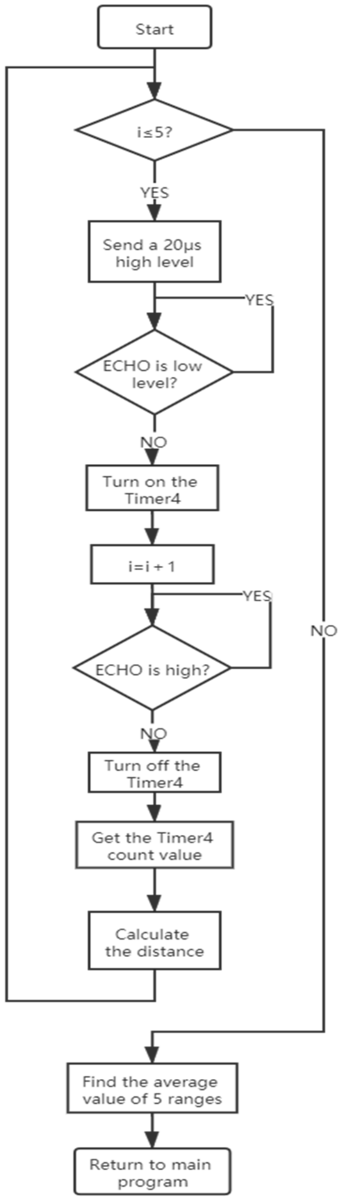


Figure 13. Flow chart of the ultrasonic distance measurement

4.4. PID Control

The following Figure 14 shows the PID control flow chart. When the trolley's current travel direction angle is consistent with the set direction angle, the direction angle PID control is not performed, and if the speed is also consistent, the speed PID control adjustment is not performed either. Otherwise, first control the direction angle of travel within the allowable error, and then control the speed, so as to ensure that the trolley travels in the set direction, and then on this basis , the trolley is then made to travel at a fixed speed.

ISSN: 2688-9323

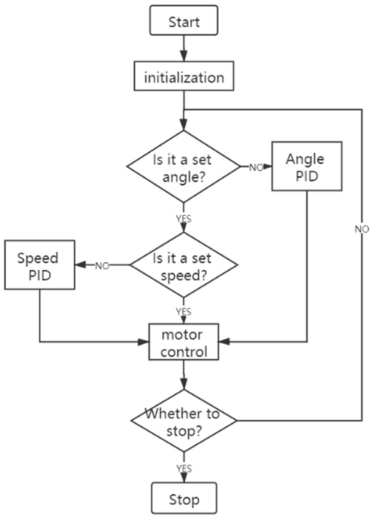


Figure 14. Flow chart of PID program

5. System Function Test

5.1. Ultrasonic Module Test

The obstacle avoidance function of the trolley is realized through ultrasonic ranging. The following Figure 15 shows the installation position of the ultrasonic module,it is installed in the front of the trolley. Obstacles are set about 10cm in front of the meal delivery car. Use the serial port debugging assistant to display the results, which are displayed starting from the third line shown in Figure. 16. According to the test, the trolley can stopped when there are obstacles within 50cm in front of it.

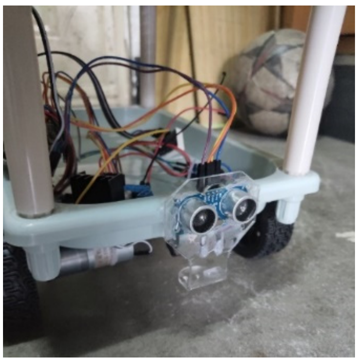


Figure 15. Installation position

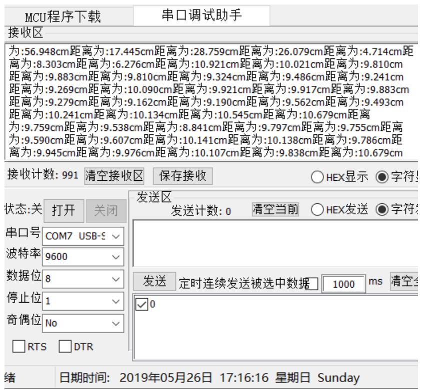


Figure 16. Ranging value

5.2. RFID Module Test

The following Figures 17 and 18 show the RFID read the number of the IC card and displayed in the serial port assistant. After testing, the reading distance of this module is about 4cm, which is relatively short. In order to prevent the card number from being unable to be recognized due to the long reading distance, the RFID module should be installed on the chassis of the trolley close to the ground, as shown in Figure 19 It is the installation position of the RFID module on the trolley.

ISSN: 2688-9323

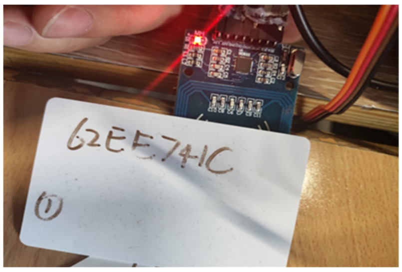


Figure 17. Read card

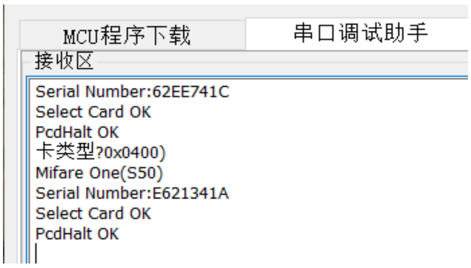


Figure 18. Display card numbers

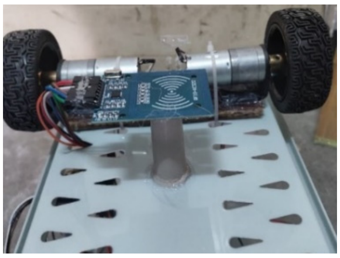
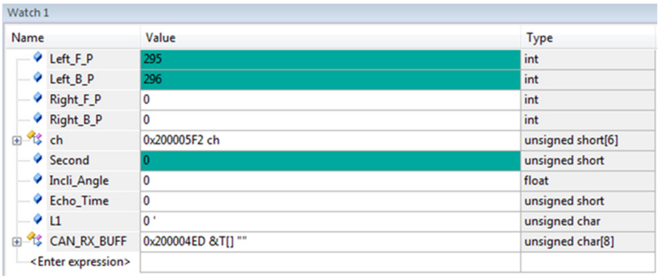


Figure 19. Installation position of RFID

5.3. PID Control Test

The control cycle in this design is 20ms, and the motor speed is controlled by the PWM wave. In the test, the speed of the two wheels is set to 300r/20ms. In order to obtain the PID response time, the time variable “Second” is set, which will increase by 1 every second. From the Figure 20 below, when “Second” has not reached 1s, the speed is close to 300r/20ms, which shows that the short PID response time in this design has achieved the expected effect.



Watch 1

Name	Value	Type
Left_F_P	295	int
Left_B_P	296	int
Right_F_P	0	int
Right_B_P	0	int
ch	0x200005F2 ch	unsigned short[6]
Second	0	unsigned short
Incli_Angle	0	float
Echo_Time	0	unsigned short
L1	0 '	unsigned char
CAN_RX_BUFF	0x200004ED &T[] ""	unsigned char[8]
<Enter expression>		

Figure 20. PID response time

5.4. Overall Operation

The following Figure 21 shows the installed trolley and loaded. Water bottles filled with water are used to simulate the load. The total water bottles is 3.6kg, and the trolley has a weight of about 1kg, totaling about 4.6kg. After testing, the trolley can drive the load and run successfully. After several speed measurements, the speed of the trolley is about 0.2m/s.

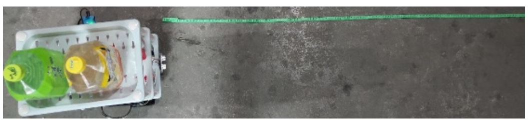


Figure 21. Overall test of the trolley

6. Summary and Outlook

6.1. Summary

(1) Setting obstacle avoidance "anti-shake" in the main program of ultrasonic obstacle avoidance can prevent the meal delivery car from shaking when encountering obstacles.

ISSN: 2688-9323

(2) The two designed operating modes conform to the layout of the restaurant. In the tests of both modes, the food delivery truck can run to all designated locations and return.

(3) RFID is designed to read the IC card number to judge the position.

(4) PID parameter setting is reasonable and the response time is short.

(5) The trolley model can run with a load of at least 4kg.

6.2. Outlook

(1) In the simulated operation of this trolley, the number of tables is relatively small. The program can be upgraded in the future to add additional tables as needed.

(2) In the future, if the positioning mode of the trolley is upgraded, the laser radar[6] and RFID can be used to locate the trolley. and the path planning algorithm can be added to make the trolley realize the minimum path.

(3) The RFID card reader module can be specifically designed to make the card reading distance farther.

References

[1] Yehuan Su, Jun Ren. Intelligent food delivery robot design *[J]. Technology Innovation and Application, 2018, (7):32-34.

[2] Chen kai. Design and Realization of Intelligent service Robot Control System [D]. Hangzhou Dianzi University,2017. p. 10-12,p. 16.

[3] HUA Yong-zhu;QIN Hui-bin. Design of Feeding Robot System Based on Fuzzy PID Algorithm [J]. Measurement & Control Technology, 2018, (3):51-54.

[4] Zhen xinjuan. Research on Path Planning and Collaborative Formation of Multi_robot [D] Wuhan University of Technology,2014.p. 4.

[5] Jen, FH; Mai, BT. Building an Autonomous Line Tracing Car with PID Algorithm. Proceedings of the 10th World Congress on Intelligent Control and Automation (WCICA). Beijing, CHINA, JUL 06-08, 2012, p. 4478-4483.

[6] Liu Bo. Design and Implementation of a Prototype of Indoor and Outdoor Routing Inspection Mobile Robot Based on Laser Lidar [D]. Southwest Jiaotong University,2015,p. 53.