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Intelligent Car Following System Based on MSP432

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Abstract. This design is based on MSP432 single chip microcomputer as the core, combined with visual recognition technology, through the speed closed loop to control the intelligent car, and realize the dual car to follow and overtake on the predetermined track. In this design, MSP432P401Y is selected as the main control, and the identification information is sent to the master control through the serial port, so as to enter the corresponding road and prevent the car from deviating from the predetermined track; The leading car and the following car communicate with each other through Bluetooth module to achieve the goa of two vehicle collaborative transportation; Through the feedback information of the motor encoder, the speed closed-loop control system of the trolley is designed through the feedback information of the motor encoder to realize the precise control of the transportation distance. After detection, this design has the advantages of fast identification speed, high accuracy, stable transportation and high efficiency.

Keywords. PID speed closed loop, tracing, image recognition, wireless communication

1. Introduction

Smart cars have developed rapidly in today's society, from smart toys to other industries have substantial development results [1, 2]. This design takes the 2022 TI Cup College Students' Electronic Design Competition as the background, and designs a car following system, which is composed of a leading car and a following car. The car is required to have tracking function and adjustable speed, and can complete overtaking, following and other driving operations on the specified path; the car following system designed in this paper takes MSP432 as the control core, four-wheel model car as the mechanical platform, and realizes tracking, tracking and Bluetooth communication through sensors, serial port connection and motor control. The car is divided into two parts: hardware and software. The hardware part mainly includes main control, power module, drive module, tracking module and communication module. The software part realizes the function of the car through the program control single chip microcomputer. The research of intelligent car automatic identification route, obstacle and intelligent obstacle avoidance and Bluetooth remote control is based on the automatic guidance robot system, which is used to realize the automatic identification of the surrounding environment and make the corresponding control system response. It is an important part of the research field of

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intelligent car. The automatic following car system can reduce the probability of traffic jams in life, detect possible dangerous accidents, avoid traffic accidents, and make the car more intelligent and standardized.

2. Whole Project Design

The system is divided into 7 modules, including the main circuit module, the tracking module and the communication module. The overall design block diagram of the system is shown in Figure 1.

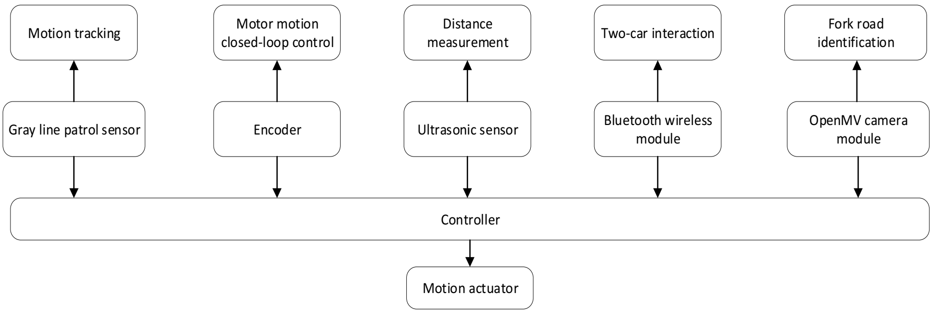

Figure 1. Overall system block diagram 1.

3. Hardware Design

3.1. Master Module

This design uses msp432 as the main controller. Msp432 series is a 32-bit low-power mixed signal processor with reduced instruction set, which is introduced to the market by Texas Instruments. It has the advantages of high operation speed, strong processing ability and ultra-low power consumption. At the same time, it is developed by using library function development, which has high readability and is easy to transplant.

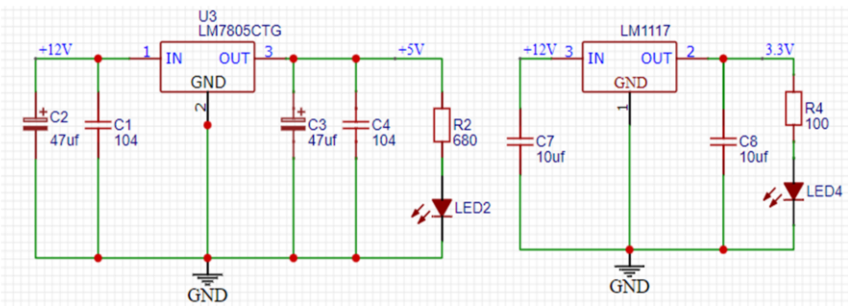

Figure 2. Power supply module schematic.

3.2. Power Module

This design uses 12V DC regulated power supply [3] for power supply, uses three wire voltage regulator LM7805 to output +5V DC voltage LM1117, supplemented by two filter capacitors and anti self excitation capacitor; Three terminal regulator LM1117 is used to output +3.3V DC voltage to provide current limitation and thermal protection. A tantalum capacitor of at least 10uF is required at the output to improve the transient response and stability; The DC output voltage with high accuracy and good stability is output. Figure 2 is the schematic diagram of power supply module.

3.3. Motor Driving Module

This design uses TB6612FNG [4] dual drive. Two motors AB can be driven at the same time, and PWMA/PWMB provides PWM pulse for the two motors; AIN1/AIN2, BIN1/BIN2 are used to control the positive and reverse rotation and stop of the motor. In the rated range, the chip has no heat and the efficiency of PWM control can reach 100kHz. Figure 3 is the schematic diagram of TB6612.

TB6612FNG is an H-bridge integrated circuit based on MOSFET, and its efficiency is higher than that of transistor H-bridge driver. Compared with the average drive current of 600mA per channel and the pulse peak current of 1.2A in L293D [5], its output load capacity is doubled. Compared to the L298N heat consumption and peripheral diode freewheeling circuit [6], it does not need to add a heat sink, peripheral circuit is simple, just external power filter capacitor can directly drive the motor, to reduce system size. For PWM signals, it supports frequencies up to 100kHz, which is also superior to the 5kHz and 40kHz of the above two chips.

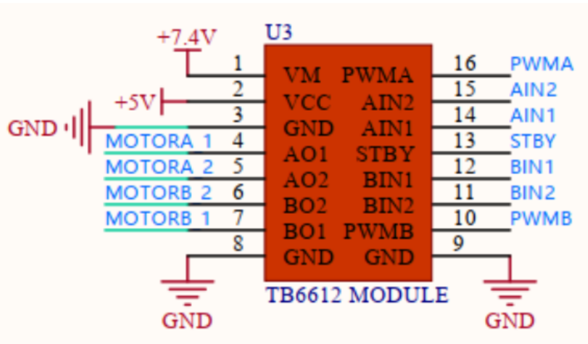

Figure 3. TB6612 schematic diagram.

3.4. Tracking Module

This design uses 5-channel gray line inspection sensor. The product has high sensitivity and strong anti-interference ability. The ordinary lamp has no effect on it. The receiving tube can compare the strength of different reflected light, as long as the light reflection intensity is different, the greater the difference, the better the resolution; Compared with ordinary infrared sensor, the anti-interference ability is much stronger. It is equipped with 5-channel LED signal indicator. When the gray value of the corresponding probe is higher, the output level changes from high to low, and the corresponding LED is on. At the same time, the sensitivity can be adjusted according to the actual track color. Thus, the position of the black line can be judged and the motion track of the car can be changed.

3.5. Ranging Module

This design uses HC-SR04 ultrasonic module, which is composed of 4 pins, and the power supply is +5V. The distance sensing function is completed through the input of echo signal and trig trigger control signal. Four functional pins are drawn out, as shown in Figure 4.

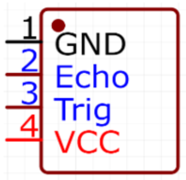

Figure 4. HC-SR04 pin.

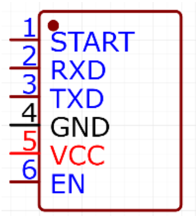

Figure 5. ZS040 pin.

3.6. Communication Module

In dual vehicle communication, there is no need to consider the problem of power consumption. In order to ensure the transmission rate and reduce the workload of networking, ZS040 Bluetooth module is used to realize the communication between the two workshops. The networking is simple, the volume is small, and the transceiver is sensitive. The transmission distance can reach 2-30m, and the transmission rate can reach 1Mbps. Six functional pins are introduced, as shown in Figure 5.

4. Software Design

4.1. Analysis of Communication Mode between Cars

Bluetooth technology is a wireless data transmission technology, which has great application requirements in short-range wireless data transmission. Bluetooth wireless communication can realize wireless communication between the serial ports of two single-chip microcomputers in the single-chip microcomputer application system. It can also realize wireless communication between mobile phones and single-chip microcomputers, and can realize two-way digital transmission, which provides a new method for wireless control and application of single-chip microcomputers.

After using the serial debugging assistant to debug the AT commands of the two Bluetooth wireless communication modules, the two microcontrollers can use the Bluetooth module to transmit data between the microcontrollers like serial communication. Through the Bluetooth wireless communication module, short-distance wireless data transmission between single-chip microcomputers and between single-chip microcomputers and peripherals can be realized, thus simplifying the wiring of the single-chip microcomputer control system and improving the diversity, convenience and intelligence of the single-chip microcomputer control mode [7].

4.2. Closed Loop Control Algorithm

The speed closed-loop control [8, 9] is to measure the speed information of the motor according to the number of pulses obtained per unit time, and compare it with the target value to obtain the control deviation, and then control the proportion, integral and differential of the deviation to make the deviation tend to zero. The incremental algorithm does not need to accumulate the integral term, and the control increment is only related to the recent errors. The calculation error has little effect on the control calculation. The positional algorithm to the recent deviation of the integral accumulation, prone to large cumulative error.

On the impact of system stability, incremental is better than the position, so this design uses incremental PID. The basic formula is as follows:

$$\Delta u_n = K_p(e_n - e_{n-1}) + K_i e_n + K_d(e_n - 2e_{n-1} + e_{n-2})$$

Among them, Δu_n is the nth output increment, e_n is the nth deviation, K_p, K_i, K_d The coefficients corresponding to proportion, integral and differential respectively.

Among them, the integral coefficient $K_i = K_p * T/T_i$, the differential coefficient $K_d = K_p * T_d/T$, T is known, representing the sampling period.

This design uses the following debugging steps:

(1) The proportion of gain P is determined. When determining the gain ratio P, the integral term of the PID needs to be removed, and the corresponding differential term is removed. In general, the T_i value needs to be determined as 0, and the Td value is determined as 0 to ensure that the proportional adjustment of the PID is not affected by other factors. At the same time, the maximum value allowed by the system needs to be determined, so that it is controlled at 60% -70%, promoting the proportional gain P, and starting from 0, gradually increasing until the system is observed to oscillate. Then, the proportional gain P is reduced until the system oscillation disappears, and the proportional gain P is recorded. If the proportional gain P of PID is set to 60%-70% in this study, the debugging of proportional gain P can be stopped when the relevant value is reached.

(2) Determination of the integral constant T_i. After completing the setting of the proportional gain P, it is necessary to set the initial value of a relatively large integral time constant T_i, and promote the reduction of the value, and gradually advance. When the oscillation occurs, the operation is stopped, and then the T_i value is gradually increased. After the system oscillation disappears, the operation is completed, and the corresponding T_i value is recorded as the main value of the PID integral time constant T_i. This study is set at 150%-180% to complete the debugging of the integral constant T_i.

(3) Confirmation of integral time constant Td. For the integral time constant T_d, it usually does not need to be set, mainly 0. If it needs to be set in special circumstances,

the determination method is the same as the above two methods, taking 30% of the non-oscillation.

When choosing the three links of PID, PI control and PD control are usually needed. As far as the speed control is concerned, it is required to meet the steady-state error-free situation. In order to meet the relevant conditions, it is necessary to apply the integral link and use PI control. In the process of direction control, it is usually not necessary to ensure that there is no steady-state error, so it is necessary to control PD, in which the main role of D is to eliminate the oscillation problem in P link.

PID control solves the most basic problem that automatic control theory needs to solve, that is, the accuracy, stability and real-time of the system. According to the situation of path identification, the corresponding control of the car is adopted to achieve the purpose of reasonable speed setting. According to the received speed value of the speed measurement module, the system adjusts it through PID algorithm, and then controls the speed change of DC motor, so as to control the acceleration, deceleration and steering of the car.

4.3. Automatic Tracking Algorithm

In this design, the gray sensor and OpenMV are used to track the common track [10-13], and the gray sensor is used to complete the inspection of the ordinary track, and the OpenMV is used to identify the fork in the road.

OpenMV [14] camera is an open source, compact, low power consumption, low cost and powerful machine vision module. OpenMV4 H7 PLUS takes STM32H743 processor as the core and integrates OV5640 photosensitive element. The camera itself has some image processing algorithms, which support RGB565 and grayscale and other image formats, which leads to UART, I2C, SPI, PWM, ADC, DAC and GPIO interfaces to facilitate the expansion of peripheral functions. The full-speed USB interface (12 Mbps) is used to connect to the integrated development environment OpenMV IDE on the computer to assist in programming, debugging, and firmware updates. Through the MicroPython language, machine vision applications can be easily completed. TF card slot supports high-capacity TF card with 100Mbps read and write speed, can be used to store programs and save photos. It is a feasible scheme for the car to use the visual module to identify the intersection.

For the gray sensor, when the left sensor detects the black line, it will control the car to move to the right. When the right sensor detects the black line, the same is true; For OpenMV, the acquired image should be preprocessed firstly. Noise may be generated in the process of image acquisition and transmission. Image binarization and filtering can reduce the interference to image processing. Then it analyzes the image. By judging the image characteristics of the intersection, it can identify the intersection. Then, OpenMV provides feedback information to msp432 to control the car to track independently. In order to find the track we want more quickly, we set the image size to QQVGA to reduce the image area to increase the speed.

4.4. Distance Control between Trolleys

The distance between cars is controlled by ultrasonic module and Bluetooth module. The ultrasonic module is placed in the slave car. The slave car detects the distance and transmits the data to the main vehicle, which is judged by the master car.

(1) Follow

The ultrasonic module of the slave car detects the distance in real time. When the distance exceeds the limited range, the data is sent to the master car. The master car calculates the speed of the slave car through the returned distance value and the speed of the two vehicles, and returns the speed to the slave car through Bluetooth, so as to achieve a certain follow-up distance without collision.

(2) Overtaking and anti overtaking

When the corresponding buttons of overtaking and anti overtaking are pressed, the slave car enters the inner circle at the intersection of the inner and outer circles, and the main vehicle enters the outer ring, and continuously communicates the speed of both sides to keep the speed of both sides equal. When the two vehicles drive out of the inner and outer circles, the distance remains the distance when entering the inner and outer circles. Reverse overtaking is the same, so as to achieve overtaking and reverse overtaking and keep the distance equal.

4.5. Program Design

In the system, the master car and the slave car need to cooperate with each other to form an automatic following car system. When the car is driving, the two cars need to communicate with each other. The master car receives the information of the sensor for processing and issues commands to control the slave car.

Bluetooth is configured as one master and one slave, which realizes data transmission and communication through the serial port. The slave car uses the serial port to interrupt, receive data and perform corresponding actions. The following is Figure. 6 main car program design flow chart and Figure. 7 from the car program design flow chart.

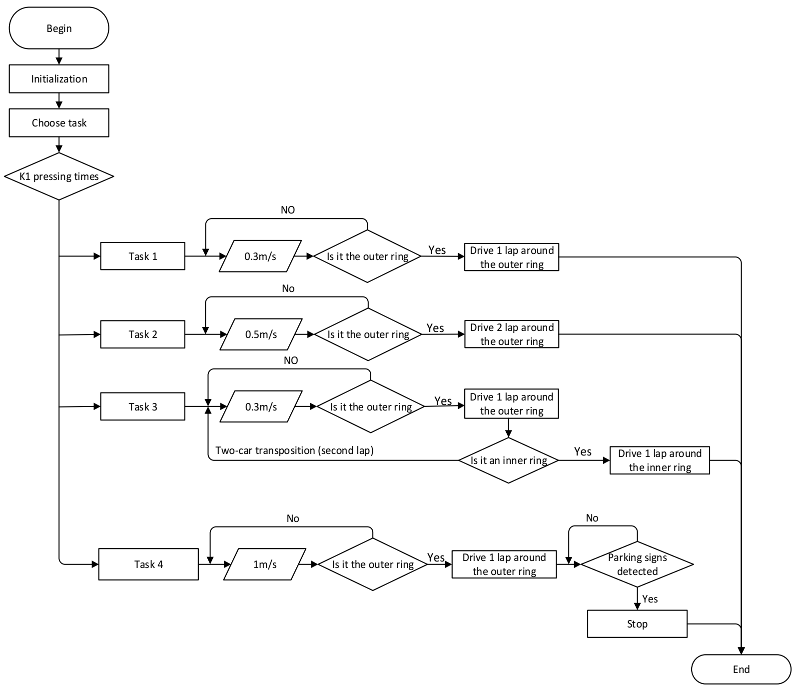

Figure 6. Main vehicle program design.

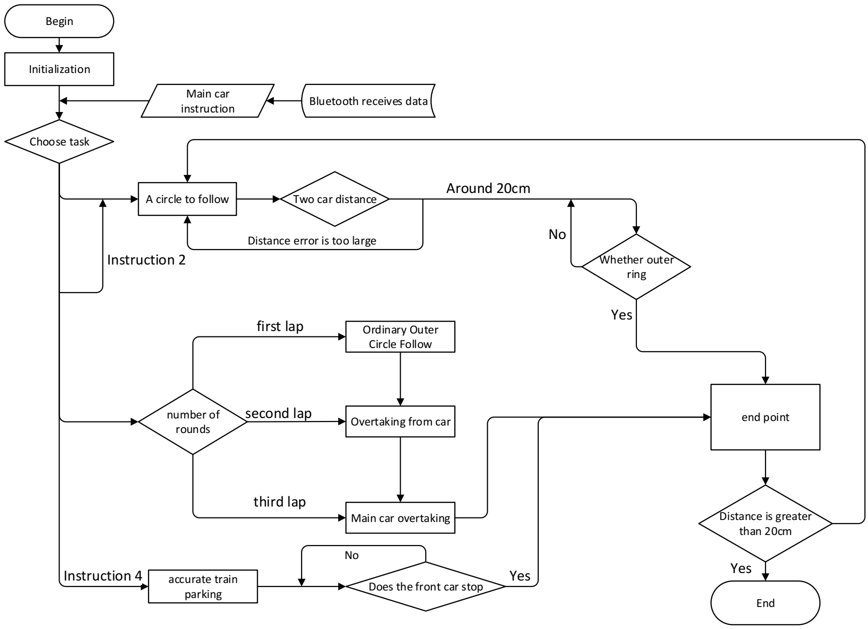

Figure 7. Flow chart of slave car program design.

5. Conclusion

This research topic is the intelligent car following system. Through the system design and detection of the car, the car passes the detected information to the single-chip microcomputer through the installed sensor, so as to realize the intelligent control. This design also realizes the following research results under the support of such technology: First, the car can accurately make judgments in different light environments to help the car run more smoothly and realize the tracking function; secondly, the car retains the expansion function and increases the Wi-Fi module, which makes the car more adaptable to the harsh environment. It can be used in various occasions and fully improves the adaptability of the car.

In the debugging process, this design first carries on the hardware debugging, with a multimeter to test whether the various components are welded well, and whether there is a short circuit or not. After ensuring that all the hardware modules can work normally, the sub-module writes the demo and then debugs the code. When all the modules can work separately, the software is debugged, and the expected effect is achieved. The results verify the effectiveness of the intelligent car control algorithm.

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