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Smart transit car design based on STM32 and OPENMV

Chunkai Xu

Nanjing Tech University, Nanjing, China, 211800

202021139030@njtech.edu.cn

Abstract. Under the background of the times, Smart Operating Vehicle has wide application prospects. This paper designs a Smart Car based on STM32F103RCT6 MCU, which combines the functions of OPENMV digital recognition module and infrared route tracing, in order to realize the function of the car to reach the designated location and start its operation. The scheme in this paper breaks the limitation of conventional manual work and can replace manual work in extreme environments such as high temperature and small space, which fully reflects the era significance of smart hardware.

Keywords: STM32F103RCT6, OPENMV, smart car, automatic tracking.

1. Introduction

Under the background of industrial automation trend, intelligent and miniaturized product distribution and construction schemes have become an important part of industrial production. Its unique advantages lie in its flexibility and applicability. The smart car can operate in places that are difficult to reach and can expand and install different modules to meet different application scenarios. In addition, this car can also provide meal delivery solutions for residential buildings and hotels in the community, improve the last step of the meal from the delivery staff to customers, and greatly reduce the labor and time costs. This design scheme focuses on the analysis of the structure and software system of the car, and carries out experiments to improve it.

2. Conceptual design

2.1. Objective

Design and debug the smart car, accurately identify and reach the target location specified by the target number in the map as shown in Figure 1 and return, and leave an interrupt for other modules installed to send the return signal when they finish their work. The guide line is red solid line, with black line limit on both sides. The task flow is shown in Figure 2.

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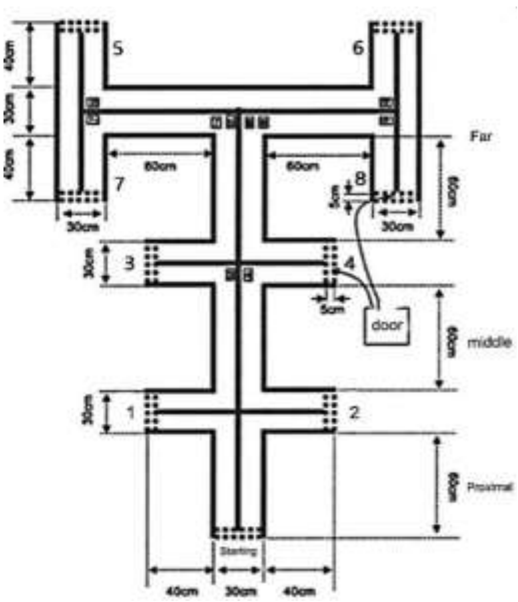

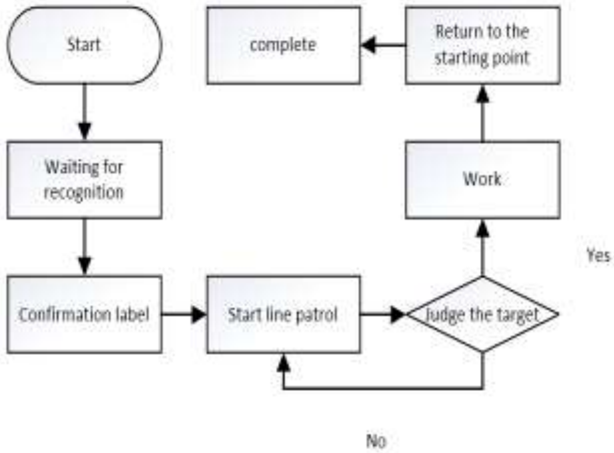

Figure 1. Map. **Figure 2.** Car operation process.

2.2. Car structure

The car frame structure design scheme adopts STM32F103RCT6 MCU, which has the following characteristics: M3 core, with the highest working frequency of 72 MHz, SRAM of 48 K bytes, board with DMA, ADC, timer, IIC, UART and other external devices, can realize multi-channel PWM output control motor [1], which is of great significance for the accurate and fast realization of the functions of the car. The car drive part uses L298N control chip and two stepper motors. The infrared tracking mode is selected for the tracking module, and the digital recognition module k210 chip communicates with the single-chip computer through I2C. The car structure is shown in Figure 3.

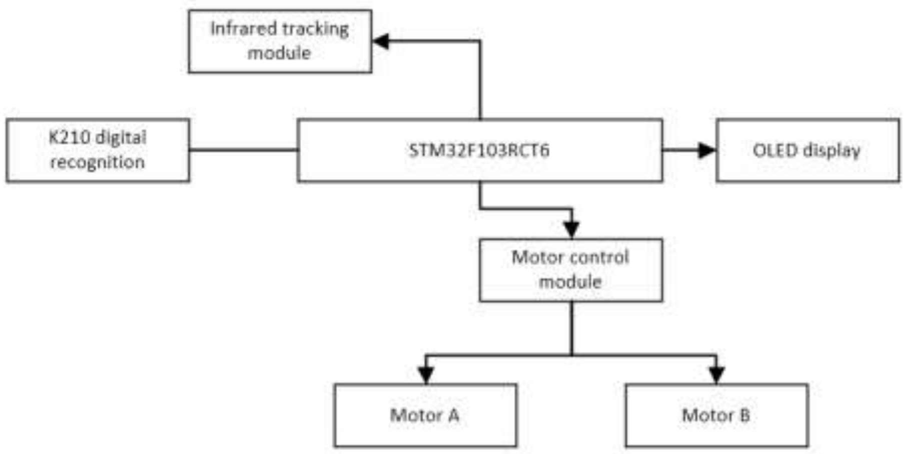

Figure 3. Car structure.

2.3. Scheme analysis

The biggest feature of this scheme is that the digital recognition module and the tracking module are independent of each other. Different from the scheme of combining digital identification and tracing function, the pressure of the single-chip microcomputer in this scheme to handle the instantaneous load is relatively low. Due to the size of the map, the camera sometimes cannot capture the route and target number at the same time, which makes it extremely difficult to debug the car in the later stage. In this scheme, the two modules are separated to solve this problem. In addition, the deficiency of this scheme lies in the need to design different power supply voltages and adopt different communication protocols.

3. Software system

3.1. Stepper motor

Two schemes are proposed when controlling the motor. Scheme One: Use the timer function to specify the working time of the stepping motor, and specify that the voltage concession stepping motor maintains a constant speed to reach the target position. Scheme Two: detect the number of wheel turns, introduce PID control algorithm to keep the speed stable, and modify the number of turns to make the car reach the specified point. PID control is controlled by comparing the error between the ideal result and the measured result through the proportion, integral and differential links. It is a quadratic linear controller, which is suitable for the modeling of unfamiliar controlled objects. Its essence is based on the input error; operate according to the functions of proportion, integral and differential, and use the results of operation to control the output [2]. In the actual test, due to the unstable voltage, uneven ground, electrical performance difference of the motor and other factors, there is a large deviation in the first scheme. In addition, the timing method in Scheme One brings challenges to the realization of infrared obstacle avoidance function. Once there is an obstacle on the target route, it will take extra time to bypass the obstacle, and finally the car will have finished the timing ahead of time before reaching the target. Therefore, the first scheme is abandoned, and the second scheme with more precise control and cooperation advantages with other modules is selected.

The PID control principle of scheme Two is as follows: the parameters Kp, KI, KD in the PID algorithm are set and initialized, and the pulse number in the unit sampling period is selected as the actual value. In this scheme, the unit period is set to 200ms. In addition, it is also necessary to set the parameter e (k) to calculate the target value minus the actual value, $\sum e(i)$ to calculate the accumulation of the error, e (k) - e (k-1) to calculate the error minus the last error, and then enter the formula (1) to calculate the control pulse value, and finally convert the PID calculation result into the frequency of the stepping motor based on the car wheel diameter. In this experiment, through a series of debugging, the parameters are set as follows: the expected speed is 1000rpm (104.7rad/s) ± 50rpm, Kp=10, KI=2.4, KD=0.0.

$$u(k) = K_p \cdot e(k) + K_I \cdot \sum e(i) + K_D \cdot [e(k) - e(k-1)] \quad (1)$$

It should be noted that in the design process, it is necessary to design the allowable error and limit the integration amplitude. In this design, the maximum deviation of output shaft per minute is allowed to be half a circle, and the corresponding weekly period is allowed to have an error of about 0.0105 radians. This design can avoid frequent adjustment of motor output speed and protect the motor to reduce heat. The integral is limited to -1000 to+1000 to prevent data overflow from causing the control chip to crash.

3.2. Infrared tracing

The road surface of the smart car is simulated as white, and the track is carried out according to the red line. According to the difference of the reflectivity of the red and white colors to the light, the infrared radiation is continuously transmitted to the ground through the infrared transmitter, and the light intensity received by the photosensitive receiver is used for tracking. When the receiving end receives a weak signal, it can be determined that it has hit the red line [3]. When the light is not received or the signal is very weak, the photosensitive triode is closed, making the detection circuit output a high-level signal. When the white area is detected, the photosensitive triode is turned on, the detection circuit outputs a low-level signal, and the single chip computer receives the continuous alternation of

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the two to control the rotation of the motor. In this algorithm, the PID algorithm introduced earlier is combined to control the motor. However, in the actual debugging process, due to the small difference between the red and white light reflectivity, the photosensitive triode is in the on-state for a long time, resulting in the tracking failure. Therefore, by setting the threshold value, the detection object is changed to a single white, and when the white is detected, the motor speed is controlled to achieve the tracking effect, but the effect is still poor after debugging. This is one of the shortcomings of this scheme. When facing the complex environment of multiple color detection, gray level sensor should be selected to complete the tracking. Figure 4 is the schematic diagram of the tracing module.

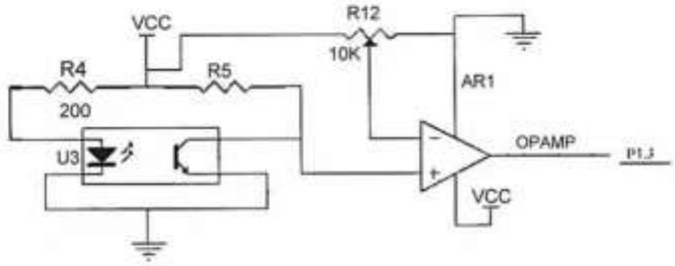

Figure 4. circuit for tracing module.

3.3. OpenMV digital recognition

This module is written in python language. First, perform hardware initialization settings. Because the label identified this time is black and white, OpenMV can be used for color recognition and image binarization to extract the target color in the image and output the average gray value in the image [4]. After consulting the hardware manual, we learned that the maximum support for QQVGA is available. At the same time, the observation window is set to meet the cutting requirements of the actual recognition image. The normalized cross-correlation matching (NCC) algorithm [5] is used for the matching of road signs in this scheme. This algorithm can calculate the similarity between the specified point in the actual image and the corresponding point in the model graph to determine whether the image matches. In practical applications, you need to set the bounding box tuples (x, y, w, h) that match the size of the image, where each value corresponds to the upper left x coordinate, y coordinate, box length and box width of the box selection position. In this scheme, the value is (55, 0, 50, 50). Call traversal function SEARCH_ EX keeps searching from the starting position until it finds the image corresponding to the template that is higher than the threshold. Finally, the matching value is returned to the master, who calls other processes. NCC algorithm formula is shown in formula (2).

$$NCC(x,y)=\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left\{\left[I(x+i,y+j)-\overline{I(x,y)}\right]\left[T(i,j)-\bar{T}\right]\right\}}{\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n}[I(x+i,y+j)]-\overline{I(x,y)}]^{2}}\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[T(i,j)-\bar{T}\right]^{2}}} \tag{2}$$

3.4. Master loop

In this scheme, it is necessary to program separately according to different conditions of reaching each position. After the initialization is completed, the car will enter the process of identifying the digital label. Once the label information is received, the car will follow the prepared route and arrive at the designated place. The car task process uses the if statement to judge the label nested switch case statement to segment the task. Take label 1 as an example. When the car recognizes label 1 in the if process, it starts to execute the switch statement and defines the expression count, whose initial value is 0. The car moves forward for 60cm, and then the count increases automatically. After break jumps out of case0, enter case1 to execute the left turn command, and then enter case2 to continue to move forward for 50 cm to reach the designated parking position. It is worth noting that when writing the task flow code with middle and remote labels, you can reuse the statements of case0, and then execute the corresponding branch statements according to the labels when reaching the corresponding

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intersection, so as to reduce the repetition of statements and the difficulty of compilation. The specific process is shown in Figure 5. Switch case statements can simplify the process. The switch case statement will generate a jump table to indicate the address of the actual case branch, while if... else needs to traverse the conditional branch until it hits the condition [6], and the switch case statement will not affect the operation of other codes, which will help improve the operation efficiency of the car.

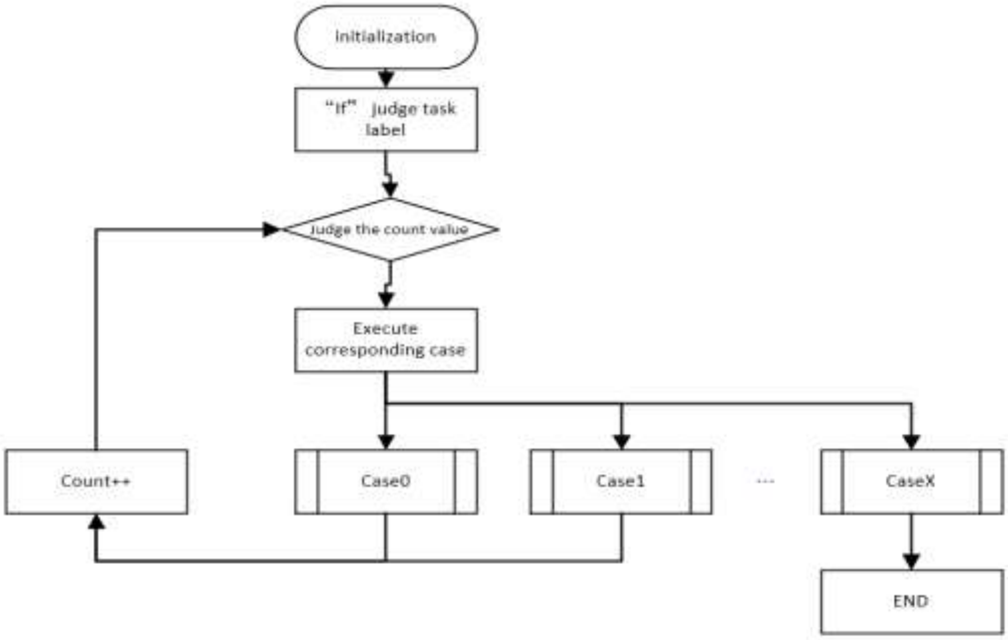

Figure 5. Process for master loop.

4. Experiment

4.1. Digital recognition test

Steps: Burn and write the digital recognition program separately, install the k210 camera module at about 25cm above the ground directly above the car and adjust the angle so that the ground at 25cm in front is at the center of the camera capture image [7], place the car at the initial position and start the power supply. Place the sign 25cm in front of the car, wait for the car to recognize and observe the results shown on the display screen. Repeat the test 10 times for each number. The results are shown in Table 1.

Table 1. Digital recognition test.

Label	Correct times
1	8
2	8
3	9
4	10
5	8
6	8
7	7
8	10

The correct recognition rate of the digital recognition module is about 85%. For some numbers with high similarity features, the correct recognition rate would be low.

4.2. Overall function test of car

Steps: Burn all procedures into the MCU, install all parts of the car in place, place the car in the initial position and start the power supply. Wait for the car identification mark according to the steps of testing the digital identification module, record the car driving route and track, and judge whether the car has completed the task well. The results are shown in Table 2.

Table 2. Overall function test of car.

Label	Arrive or not	Notes
1	Arrive	The car runs well
2	Arrive	The car runs well
3	Arrive	The car runs well
4	Arrive	The route deviated, but works well after resetting
5	Arrive	The car runs well
6	Arrive	The car runs well
7	Not arrive	Misidentification of label as 1
8	Arrive	The route deviated, but works well after resetting

From the table, it can be seen that the overall operation of the car is good.

5. Conclusion

The completion instruction of the car is mainly divided into two modules. First, the digital recognition module operates well in general, but its accuracy cannot meet higher requirements, which is far from enough for some complex environments. On the one hand, it is limited by the hardware itself, such as low camera resolution and low frame rate. On the other hand, the accuracy is not enough due to the fast search rate of the traversal coincidence function. Considering the requirements of this scheme on the recognition rate of the car, this assumption has little practical improvement. Another way to improve the accuracy is to perform secondary confirmation on the basis of searching the matching image through the coincidence function. That is, once the matching image is found, the block diagram position will be locked immediately, and the algorithm will be called to identify whether the image matches the result of the traversal matching image transfer. If it does not match, the traversal function will be restarted to search again. This assumption can improve the accuracy to a certain extent without spending too much time.

Second, motor driver introduces PID algorithm into the program for motor to help motor control more accurately, but there is still room for improvement in the infrared tracking module. The improved scheme is to use gray level sensor for tracking. The gray sensor only needs to consider the gray information of the road surface in the extraction process. This not only reduces the burden of controller processing, but also improves the efficiency of controller processing [8]. When facing the red, white and black road surface in this experimental plan, only the threshold of gray level needs to be set. At the same time, in this scheme, the data extracted by the infrared sensor only relies on the filter of the infrared module hardware to suppress noise [9], and there is no method to filter the signal value at the algorithm level, which further aggravates the instability of the infrared tracking.

The smart car has been applied in many aspects, which is closely related to its small size and excellent structural performance. The smart car designed in this scheme can be used in construction, delivery, navigation and many other aspects, which is conducive to improving the modernization level of industry and traditional service industry, and has certain reference value for the design of simple intelligent equipment.

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