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# Smart Cars Path Identification based on Optical Sensors

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**Abstract:** This paper describes the design of intelligent car control system hardware and software, the entire system is involved in car models mechanical structure adjustment, the sensor circuit design and signal processing, control algorithms and strategies to optimize other aspects. A 16-bit free scale microcontroller MC9SXS128 was selected as the controller; information of road condition and car speed collected by the integrated laser tubes could be obtained by the single chip. Digital PID and PWM control techniques are used to real-time control the servo steering and front wheel steering angle, so as to guarantee a fast and safe driving of smart car along the given path.

**Key words:** MC9S12XS128, Laser sensors, Intelligent Tracking PID speed control

## 1 MAIN IDEA OF INTELLIGENT VEHICLE DESIGN AND PRODUCTION

Intelligent vehicle is a wheeled mobile robot, a set of environment perception, decision-making planning, automatic driving and other functions in one of the integrated intelligent system. Intelligent vehicle use automatic control, pattern recognition, sensor technology, automotive electronics, electrical, computer, machinery and other disciplines of knowledge in a centralized manner. In this paper, the intelligent vehicle is a kind of automatic guided vehicle, which can travel along the track automatically in a given area. The trolley will move along the black guide lines on the white ground. Intelligent vehicle tracking system using the reflective laser tubes can identify the black line on the path, and to complete the tracing in the shortest possible time, then to adjust the speed and direction of the car. Intelligent vehicle based on photoelectric sensor is one of the most efficient types of intelligent vehicles, the sensor is the smart car's eyes and must be able to truly, quickly response to the track. Now the most popular track information acquisition sensor has the camera CCD, photoelectric sensor, electromagnetic sensor, optical fiber, light battery, etc. After the comparison test, the photoelectric sensor was chosen due to the simple detection method, anti-interference ability, and fast response speed. Photoelectric sensor is a kind of sensor that uses photoelectric element as detection element.

The model car uses laser as the road information sensor, hit a row of neat spot on the track with a laser in the steering system, using 12ms as a sample cycle, and control the actuator steering servo motor swing to make the center row of the sensor on the center spot of black guide line on the track, and always follow tightly with the black line. The fundamental requirements of the intelligent vehicle system is the accuracy of line detection, and higher requirements are "steady", "fast", "quasi", which requires rapidly adjust the angle and speed of the smart car.

## 2 REALIZATION OF TECHNICAL SCHEME

Intelligent vehicle control system is based on MCU, including steering servo motor and DC motor to provide power for the two actuators of the car while tracing sensor is mounted in the front of the car, and the speed sensor is installed on the driven gear, and power management module provides power for each part of the system.
Steering servo motor use the mechanical device to achieve the car's steering control, DC motor to provide power for the car, through the gear meshing directly to provide the driving force for the rear wheel. The overall structure of the intelligent vehicle control system is shown in Figure 1.

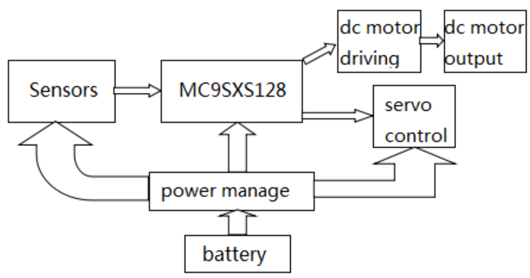


Fig. 1 overall structure of smart car control system

## 3 HARDWARE SYSTEM DESIGN

A smart car should be able to identify the route, automatically recognize the road on a specially designed runway, travel the entire process and not run out of the track. It requires smart car to run fast and steady, so the stability and rapidity of the control system are two important indexes of the control system design.

The smart car control system is divided into power module, sensor module, signal processing module, DC motor drive module, steering servo motor drive module and single chip microcomputer module. Each module has its own different design requirements:

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**(1) SCM module:**

SCM module plays a central position in the smart car control system, like the human brain. From the perspective of hardware design, firstly to ensure a stable power supply to the microcontroller, secondly to write the drive programs to other functional modules such as PWM channel, channel timer programming. Control algorithm design and the preparation of the control program are the most important parts of this module. Only a good combination of software and hardware, the system can be stable and running well.

The intelligent car system uses MC9S12XS128 as the main control chip, which has enhanced 16 bit CPU HCS12, the highest internal clock frequency is 40 MHz. The single-chip has rich on-chip resources: 8 KB RAM, 128 KB program flash memory, 2 KB data flash memory and 32K FLASH, which can meet the requirements of data processing of the system and the data storage of the liquid crystal display. Serial interface module: SCI, SPI, occupying less port, a16 channel 12 bit precision A/D converter can satisfy the system requirements of sampling signal modulation, pulse width modulation (PWM) can be set to 4 channel 8 bit or 2 channel 16 bit, the logical clock frequency is wide, and has a controller module, an enhanced capture timer. Free scale MCU programs can be written in C language, C language function can be called with the external function, so that the programming is more easily. A piece of free scale MC9S12XS128 single chip can complete the main function of the whole system, basically do not need to expand other devices, so the control system has small size and high reliability.

**(2) Tracking sensor module:**

Tracking sensor module in the smart car control system is like a person's eyes, how to design to make the car "look" more clearly and farther is the key to the design of the sensor module. The work of this module determines whether the system can quickly and stably work. In which the sensor and its signal processing part of anti interference design is particularly important.

Sensors detect the environmental information, and input the signals to the microcontroller. Then the microcontroller analysis the data and make a judgment next The sensor used in this paper is laser sensor. In order to get more prospective distance for the control system to save more time, the large forward-looking laser sensor is chosen in many photoelectric sensors, forward distance of laser sensor can reach ordinary photoelectric sensor several times or even ten times, fully meet the requirements. The principle of laser sensor is same as the common photoelectric sensor, but forward-looking capability of laser sensor is much greater than the ordinary one, the forward-looking distance can reach 40-50 cm, which is enough for the smart car. For the laser transmitting and receiving mode, use the basic mode as one transmission to one receive. When using the time division transmission, the multiple laser tubes are successively lit, and the road condition of the laser spot can be judged according to the time sequence. The operation sequence of the laser transmitting tube and the receiving tube is controlled by the analog switch of the single chip microcomputer.

By using the time sharing mode, only one laser tube is at work at a time, and the characteristic can avoid the mutual interference between the laser transmitting tube and the receiving tube.

**(3) Motor drive and power management module:**

DC motor drive module and steering servo motor drive module are the actuators of smart car control system, which is like the human limbs, the design of a good driver circuits are the key to this two modules. Power module in the smart car control system is like the human heart, supply power to the other modulesso as to ensure their normal work.

PWM is driven by a motor control method: by keeping the input signal frequency unchanged, then changing duty cycle of PWM to change the switch time of the bridge circuit, thereby changing the average voltage of the motor provided by the bridge circuit to change the motor speed.

The motor driver chip used in this paper has the function of internal protection, stable high power output BTS7960. The chip BTS7960 is a High Current PN Half Bridge NovalithIC 43 A chip, which is the highest over 43 A high current bridge chip. In the actual circuit design, 2 pieces of BTS7960 parallel method is adopted to form the motor drive circuit, which improves the current output power and the driving ability of the motor.

The design of power module mainly includes two parts: one part is to provide a stable DC voltage 5 V for MCU and motor drive, rotary encoder, laser sensor, and the voltage comparator element; the other part is to provide 6 V DC voltage for actuator; this design uses a low dropout voltage regulator chip LP38690 according to the principle diagram, it is a self-made voltage regulator module.

## 4 SOFTWARE DESIGN SCHEME

The control algorithm in this system includes two aspects: steering control and speed control, which together determine the stability and response speed of the smart car. The steering control determines whether the car travel along the black guide line stably, the response speed of steering engine is important to control precision, when the path parameters change greatly, it requires the steering gear to be turned in advance to prevent the car run out of the track due to slow response speed. Due to changes in the track curvature, it is required to adjust the speed of the car according to the road conditions to ensure that the car will not run out of the track. Speed control is focused on whether the speed of the control process is fast enough, so that the smart car can run at different speeds for different paths of curvature.

When start the car power, initialize all hardware, then timer interrupt, the laser tube scan and transmit, and the MCU receives and stores the sample signal. It will begin

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to process the sampling data after scanned 9 points, and calculate the relative position of the black guide line and body. According to the current position of the steering gear, MCU decides the rotation angle to ensure the car follow the black line. Single chip is based on the PWM value of up steering gear and the position of the point of light, when compared with the value of the previous time, the PWM value of the lower steering gear is obtained. According to the position of the steering angle and the light spot of the steering gear, the single chip microcomputer gets the desired value of the speed, then combined with the current speed value to control the motor, decide whether the motor speed is up or down, or to reverse the motor, reverse brake.

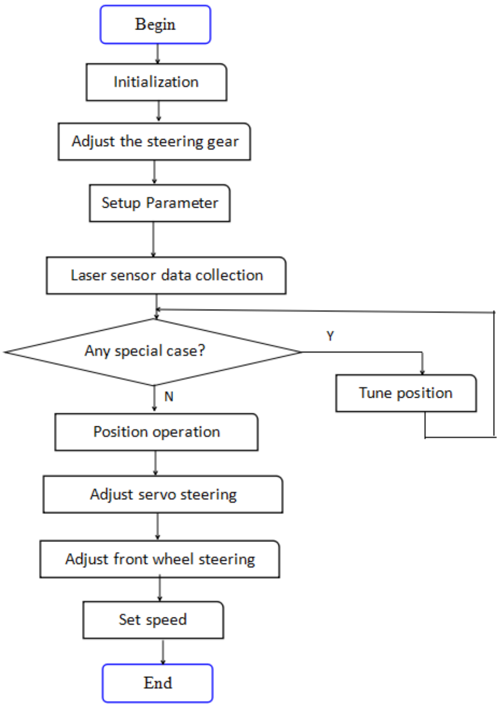


Fig. 2 flow chart of the main program

Because this design uses the pulse period method to detect the speed, so each time the speed detection is made in equal distance. The speed will be detected when the car travel a few meters. The speed can be detected in such a short distance that is also help to control the car speed. The speed of the car will change frequently in the process. The speed will quickly slow down when the car run into the curve, and speed up when on the straight road. In order to not to increase the power consumption of the motor by frequent acceleration and deceleration, this paper only uses the proportional algorithm. Select a relatively large scale coefficient, so that the steady error of the car speed is relatively small and the response speed is relatively fast. The speed control algorithm of the car is as follows:

$$es = V_{get} - V_{ref} \quad (1)$$

$$V_{out} = 10 - ks * e \quad (2)$$

Where is the error of speed; $V_{get}$ is the speed detected by the speed sensor; $V_{ref}$ is the set speed; $V_{out}$ is the output value of speed (which determines the speed and direction of rotation of the drive motor); $10$ is an initial value; is the Velocity ratio coefficient.

Because the motor drive circuit uses the H bridge driving circuit, the motor can freely rotate forward and backward. After testing, a relatively large proportional coefficient is elected, so that the car can achieve a very good deceleration when run into the curve, and can quickly accelerate to the maximum speed set point when run out of curve, thus quickly reach the maximum speed set point.

Speed can be quickly adjusted according to different curves. When the curvature radius of the curve is relatively large, the speed should not be too small, and vice versa.

Steering control algorithm: The car must be able to accurately follow the black line running in high speed, the steering system must have high response speed and low overshoot. Firstly, we consider to use of PID control algorithm in steering gear control, the algorithm has high response speed, low overshoot and steady-state error. But the integral part will reduce the response speed.

The control scheme has very high requirement for response speed, but lower requirement for the steady-state error, it is precisely to use its steady-state error to identify the radius of the curvature of the curve. Therefore, the PD control algorithm is selected. Its algorithm is as follows:

$$direct\_out = k * e_1 + kd * (e_1 - e_2) \quad (3)$$

Where $direct\_out$ the output of is steering; $k$ is the proportional coefficient; $kd$ is the differential coefficient; $e_1$ is the error of this time; $e_2$ is the error of last time.

## 5 DESIGN RESULT

According to the method mentioned above, the smart car has the following functions:
The car can detect the distance and angle offset between the black guide line and the car axis line by the laser sensor which is installed on the L type support of the steering engine in time division mode.

The speed of the vehicle is detected in real time by the rotary encoder which is installed in the rear of the vehicle between the gear wheel and the rear wheel; then steering and motor are controlled through the built-in MCU algorithm , so as to achieve the real-time control of vehicle speed, direction, thus to realize the intelligent tracking black line.


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The control error  is obtained by subtracting the set speed Vs from the real time speed V, then the error  is used as the input of the PID controller to get its output Vc, and Vc can be used as the control speed of this time to control the motor, that is to control the duty cycle of the PWM, and then control the input motor drive.
The battery power is uncertain because the power will change with time and intensity of use, so the duty cycle of the PWM is also uncertain, the speed will be controlled by constantly comparing the difference between the set value speed and the actual speed, then increase or decrease the output duty cycle ratio, the controlled speed Vc will change in a small range of the upper and lower distance of the set speed Vs. All of the above results are in line with the requirements of the plan, and at the same time, we also have many effective innovative points and design ideas:

High speed steering gear: For the rotation of the laser tube, it is hoped that the faster the better, this is the exactly reason to use a high-speed steering gear. When the high speed steering gear is not electrified, it is easy to turn it by hand. After testing, we found that high speed servo is nimble, but when the laser tube was placed in the center, the steering gear cannot be stabilized, it was shaking around the center, this will make the laser spot flutter affect the results of sampling on the track. In order to improve the stability, we also try a lot of models of high-speed steering gear, finally found that the use of metal teeth brushless motor speed servo will not have the problem and the speed is faster, and the control cycle is only 1.5ms.

Spot width: For the non swing plan, a large width of the spot is much better, because it is not easy to lose the line, but when using the swing plan, the large width is very dangerous. Since it has been using the laser sensor with great perspective and steering swing, so if you want the car to run fast, when the car run into the curve at a high speed, the steering gear must align to the spot center of the black line quickly, but if the spot width is too wide, before the spot center could be aligned, the spot on the outside of the curve could have been on the outside of the track.

Due to the complex and volatile track information, the car cannot be correctly judged, and will probably run out of the track. Narrowing and closing the width of the point of light will give full play to the advantages of swing steering gear.

After the actual test, the laser sensor smart car could steadily and rapidly run along the runway on the black line (The length of the track is 40m, with a straight road, 90 degree turn road, 180 degree turn road, S type continuous curve, cross bending, and the starting line signs). The fastest speed of smart car is up to 2.8m/s, in addition, when the sensor detects the starting line, the car would stop automatically.

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