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Design of Multi-sensor Cooperation Control System for Intelligent Tracking Car

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Abstract: Design of intelligent tracking car control system based on multi-sensors is introduced in this article. Based on XC866-4FR control core, we build up multi-sensor controlling cooperation system including track-sensor, speed sensor and degree sensor, and design the hardware theory of every unit. According the weighting coefficient of each sensor, we propose the cooperation strategy for multi-sensor, and Program the software. Finally, the system has been validated in actual match road environment with good testing effect. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Cooperation of multi-sensor, Tracking car, Control system, Intelligent Sensor, XC866-4FR.

1. Introduction

Smart car is a typical intelligent system, which is a kind of robot. The smart car mainly depends on tracking-sensor to detect the road and to design driving strategy and control methods. For example, when passing a curve with high speed, because of the low resolution of single sensor and insufficient information gathered, it is difficult to obtain, in the complex environment, vehicle real-time orientation or the path reorganization ahead , often leading to insufficient turning or deviation from the planned route and even overturn [1, 2].

With the development of intelligent sensor and multi-sensor data fusion technology, it is possible for intelligent car working in special condition to acquire accurate real-time position [3, 4]. In this paper, based on the analysis of intelligent car, we put forward a kind of design of fuzzy control system based on multi-sensor cooperation, introduce the control system including software design, the hardware and the control strategy, and validate control system by road test. Our research can serve as reference for intelligent tracking car with high-precision.

2. Basic Composition and Working Principle of the Control System for Intelligent Tracking Car

Road information collecting module is the input part of the system and it mainly use photoelectric sensors to collect information and translate into electrical signals, which the main controller can identify; Control module is the core part of the system, using 8-bit single chip as the processor, and its task is to regulate the input signal and the execute real-time control; Execute module contains rear wheel drive motor and the front wheel steering servo;

Feedback module's main function is to get real-time feedback of the left rear wheel speed and front wheel steering Angle based on photoelectric coding sensor; the system is charged by vehicle power supply system, voltage of driving motor and control module is 8 V and 5 V respectively. The control system for intelligent tracking car is shown in Fig. 1.

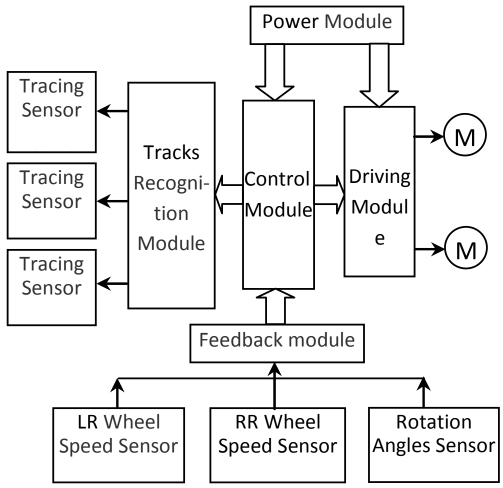

Fig. 1. Basic composition of the control system for intelligent tracking car.

The driving process of intelligent car is shown in Fig. 2. After the vehicle entering orbit, it can determine real-time position through trajectory tracking sensor. Two road wheel speed sensors can determine the speed and steering angle and feedback information to control module to generate vehicle driving route prediction and drive signal of the next moment by integrating the current vehicle position and speed information. Eventually we can achieve quick and accurate closed-loop control of driving motor.

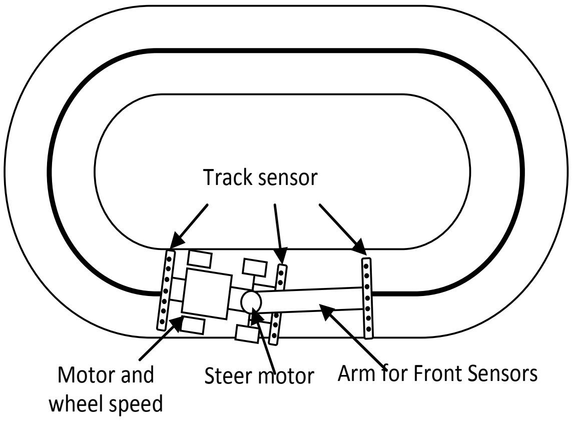

Fig. 2. The running diagram of smart car.

3. Hardware Design

3.1. Micro-control Chip

Fig. 3 shows the hardware structure of controller. The controller module contains auxiliary *XC866L-4FR*, peripheral module and interface modules. *XC866L-4FR* integrates on-chip oscillator and embedded voltage regulator, so it can be charged by 3.3 V or 5.0 V single power supply. In addition, an embedded Flash memory (*Flash*) device provides a lot of flexibility to develop and product. Flash group (*Flash Bank*) structural support online application programming (*IAP*), via an external host (such as *PC*).

XC866 also has the following superior features: it can generate *PWM* signals to control motor, has Capture (or compare) unit *(CCU6)*, can satisfy the requirements for motor and steering servo driver, and can be configured to capture mode to detect wheel speed signal [5].

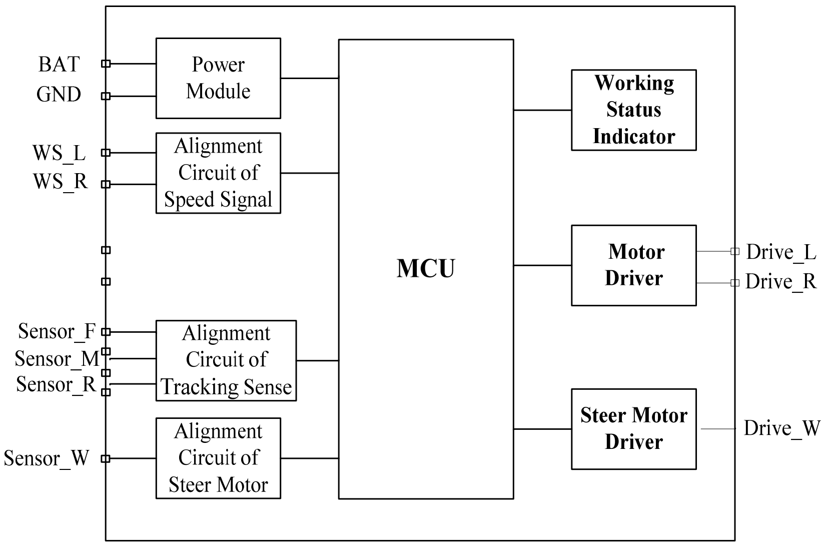

Fig. 3. Hardware components.

3.2. Motor Driving Circuit

Small DC motors with flexible control performance and good economic performance won the favor of many users. However, when the DC motor working, the electromagnetic interference cannot be ignored. Especially when the motor stop or start, pulse interference is serious. Sometimes it can burn chips or breakdown components and cause the failure of the whole system [6, 7] as shown in Fig. 4. In order to ensure the motor output enough torque, this design adopts 2 *BTM7700G* to implement the left and right rear wheel motor.

3.3. Feedback Module Circuit Design

Wheel speed signal of test prototype is sinusoidal alternating signal whose frequency and amplitude increases when car speed increase. It must be translated into the same frequency square wave signal. Wheel speed signal conditioning circuit is shown in Fig. 5. The circuit consists of four parts:
1) Limiting filtering processing circuit, composed of two zener diode 1N4728A (D2 and D3, D4 and D5) cathode tandem limiter diode circuits, is used to protect circuit when wheel speed feedback signal is too large;
2) Low-pass filter circuit, consisting of resistance *R9 (R21)* and capacitance *C17 (C19);* 3) Sine wave into square wave circuit, composed of first grade of integrated op-amp *LF353N*, can amplify 20 times the sine wave wheel speed signal; 4) Isolating circuit, as shown in Fig. 5, uses channel 1 and channel 2 of *TLP521-4* to achieve isolation two road wheel speed signal and uses channel 3 for the steering servo Angle signal isolation. Finally isolated signal output to the microprocessor *XC866*, respectively through resistance (*R4*, *R5*, *R6*) [8].

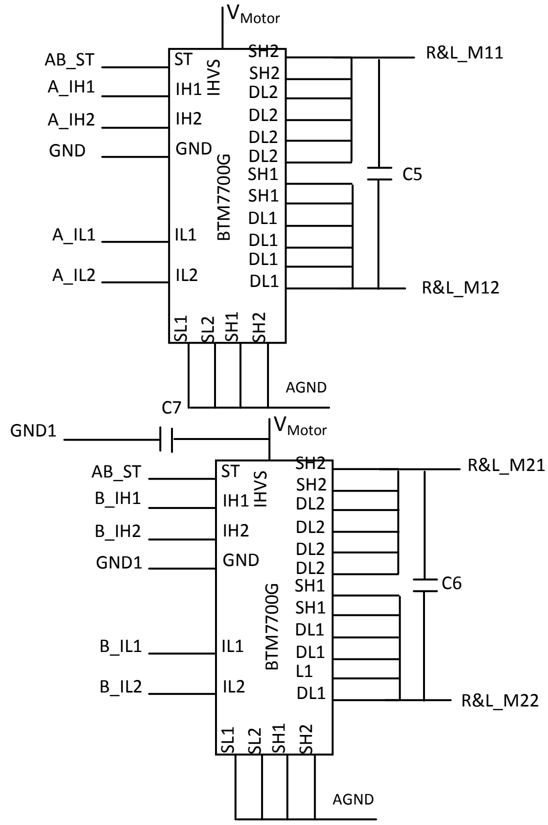

Fig. 4. Hardware of driving motor.

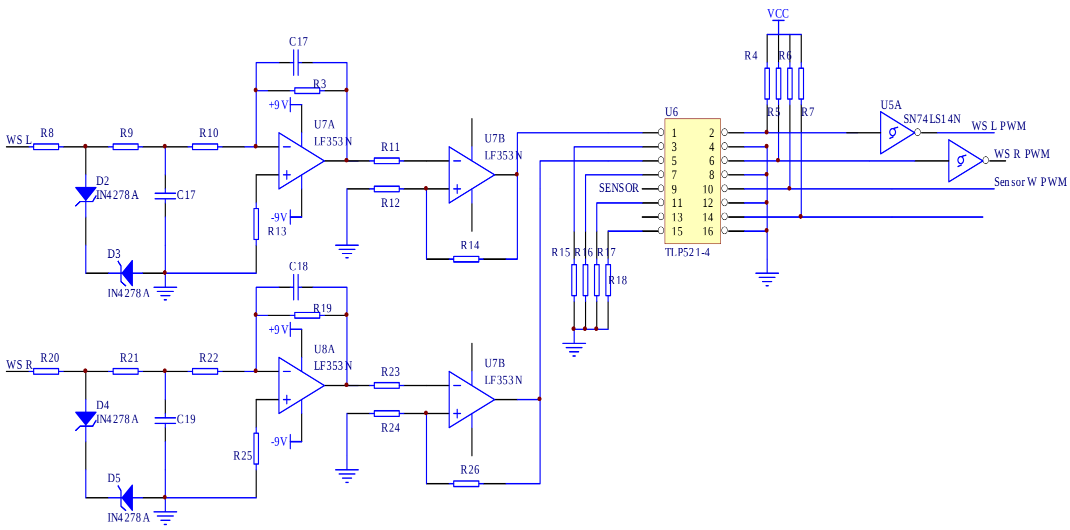

Fig. 5. Hardware of feedback module driving.

3.4. Power Module Design

The voltage of battery group is +9 V, so external voltage regulator is needed to provide +5 V and +3.3 V to motor driving board and XC866 chip. As shown in Fig. 6, 5v constant voltage generated by *1B1205SD* is processed by DC-CD ship (*REG1117-3.3*) before providing 3.3 V to tracking sensor.

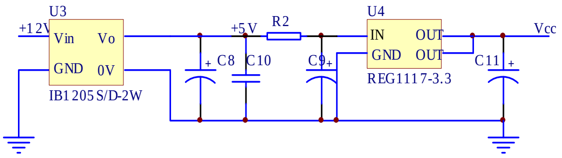

Fig. 6. Hardware of power module.

The rated current to drive motor is 0.5 A and the rated current of servo motor is 0.3 A. Those inductive loads can influence control signal a lot, therefore power module must consider those interference. This system adopts DC-DC ship to isolate power and motor, so disturbance can be avoided.

3.5. Road Information Collecting Module

Road information collecting system consists of 3 groups of infrared sensor. Each group has 7 sensor units. Every detection unit has tow value: 1 or 2. "1" represents this sensor detect black course line. "2" represents no black course line detected. As shown in Fig. 7, three 74ls224 chips are used to extend P2 port to enable each group of sensor to use P2 port to transport signal at different time. The time sharing multiplex function can be realized using P3 port to control *three 74L244* chips' *G1* and *G2* port.

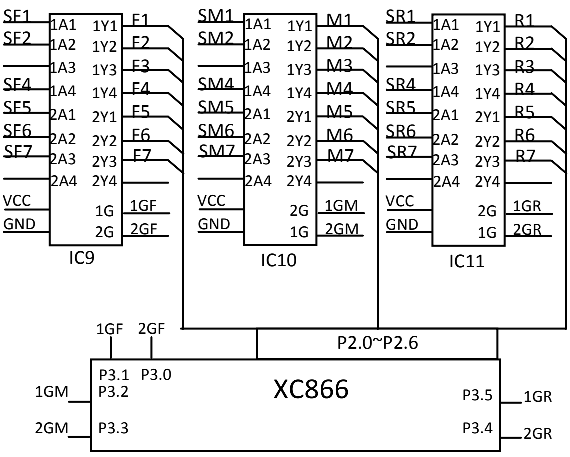

Fig. 7. Hardware of alignment module for tracking sense.

4. Software Design and Cooperation Strategy for Multi-sensor

As shown in Fig. 8, when smart car traveling on road, it can determine position and road condition according to three groups of sensor. Combining with speed and angle information, accurate control can be achieved [9, 10]. Definition of weight of different position is shown in Fig. 8. We define front, middle and rear tracking sensor as SF_x, SM_x, SR_x, as shown in Table 1.

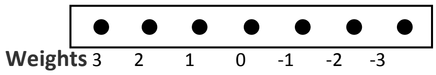

Fig. 8. Weights of tracking senses.

Table 1. Value of Tracking Senses.

No.	Value		No.	Value		No.	Value	
SF-3	0	1	SM-3	0	1	SR-3	0	1
SF-2	0	1	SM-2	0	1	SR-2	0	1
SF-1	0	1	SM-1	0	1	SR-1	0	1
SF0	0	1	SM0	0	1	SR-0	0	1
SF1	0	1	SM1	0	1	SR1	0	1
SF2	0	1	SM2	0	1	SR2	0	1
SF3	0	1	SM3	0	1	SR3	0	1

4.1. Methods of Detecting Car Position

Smart car position recognition relative to the lane line relies mainly on *SM* and *SR* feedbacking steering servo angle. Model of smart car is shown in Fig. 9. Point *A*, *B* and *C* indicate the front, middle and rear sensor group's position in the road, therefore the weight value *q* is between *-3* and *+3*. The method of recognizing position of car relative to lane line is: 1) Read sensor signals; 2) Judge position of sensor which detect the center line and giving values to *A*, *B* and *C*; 3) Calculate absolute value of "*B-C*"; 4) Compare *B*,*C* with *0*, and if *B* and *C* are all bigger than zero. It indicates that smart car is on the right side of road. If not, deviation is half of sum of *B* and *C*. Deviation is denoted by p; 5) Calculate deviating angle a of car and road according to equation *1*; 6) Calculate steering angle *b*; 7) Achieve control by *PID* method.

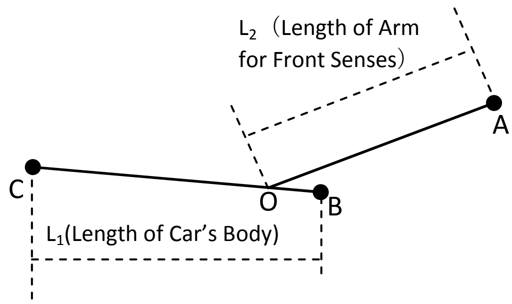

Fig. 9. Model for running status of the smart car.

$$a = \pm \frac{|q_B - q_C|}{L_1}, \tag{1}$$

$$b = a + \frac{p}{18}\pi, \tag{2}$$

4.2. Methods of Recognizing Road Condition

There are three main road conditions: straight, curve and changing road. By considering angel between *OA* and *OC*, deviating angle a and steer motor angle, we can determine current road condition. First we need to read sensor group, then repeat calculation process introduced in 3.1. According to equation *3*, we can get angle between *OA* and *OC*. Finally we can get radius of curvature of road.

$$\beta = \pi - \left(\frac{q_A - q_B}{L_2} + c\right), \tag{3}$$

In equation 3, *c* is the real-time angle of Steer motor.

$$r = \frac{L_2}{2\arcsin\beta}, \tag{4}$$

4.3. Software Design

The main program initializes hardware and checks whole control system. This system mainly achieve the following functions: 1) Initializing hardware; 2) Repeated checking three sensor groups; 3) Acquiring wheel speed sensor signals; 4) Determining current situation and achieving accurate control.

The flow chart is shown in Fig. 10. The system will initializing automatically after power is on, including configuration of MCU I/O port and working mode, initializing servo motor and correcting sensor initial value.

After initialization, the system waits for a signal. And when it detect valid go signal, system first read current track sensor, wheel speed sensor and steering angel sensor to determine current road condition.

Then, according to road condition, intelligent real-time controlling strategy is achieved.

4.4. Software Reliability Design

While increasing hardware reliability, the software reliability is also emphasized [11].

4.4.1. Noise Elimination Process

While accelerating and shaking, signal noise can be introduced. Therefore we need to eliminate that noise. In this article, we collect signal for many times and get average value of them without maximum and minimum values to ensure that we get accurate value.

4.4.2. Anti-interference of Software

4.4.2.1. Instruction Redundancy Design

When MCU take instruction, it first takes operation code, then takes the operands. When the PC (pointer) has errors, program deviate from normal orbit, called "fly"; The MCU tend to regard some operand as instruction code to execute, causing chaos program. When the program fly to a single-byte instruction, it can automatically go back to the right track, but when program fly to a double byte or three bytes instruction, it is possible to continue to go wrong. Therefore, we should use single-byte more when designing software instructions. And in the key part of program, we should insert some single-byte instructions or single-byte. This is the instruction redundancy.

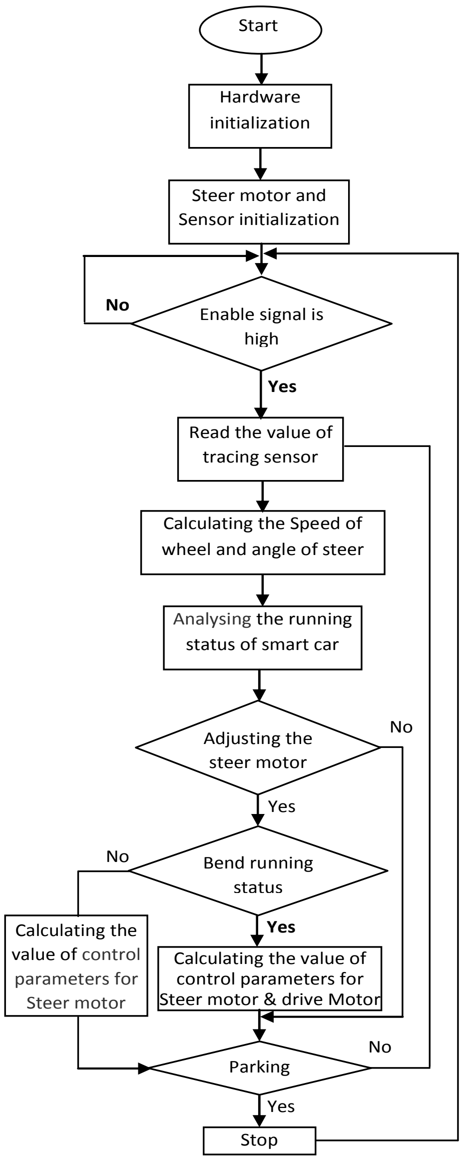

Fig. 10. Flow chart.

In this design, we insert more than two *NOP* instruction between double byte instructions and three bytes. So even if the program run fly , as a result of the existence of empty operation instruction *NOP*, also can avoid execution of following instruction. In addition, before some important the program, such as return, subroutine calls, jump, and hardware Settings reset instructions, we insert two *NOP* to ensure that these important instructions executed correctly. But when using the instruction redundancy, we also should notice that: 1) Too many redundant instructions will reduce the efficiency of the program; 2) Flying to external application area in running situation will not be able to guarantee into the right track.

4.4.2.2. Set up Software Trap

As mentioned above, when flying into the non-program area, redundant instruction technology is failed. For the situation, this paper adopts the method of setting software trap. Software trap design in this paper is two extra *NOP* plus a forced jump instruction, so that the trapped program will automatically be led to the error handling area.

4.4.2.3. Application of Watchdog Technology

When program run fly without touching the redundant instructions and software trap before forming an infinite loop, the above two methods of anti-interference is failed. so we use "watchdog" technology to deal with this situation.

The *MCU* come with *WDT* (watchdog timer). Considering the real-time demand of this system is not high, we set the watchdog refresh cycle maximum *159 ms*. In the cycle process of software, it needs periodic refreshes the WDT value.

5. Conclusion

Based on the analysis of the functional requirements and potential problems, from the perspective of multi-sensor cooperation, using the rich resources of *XC866L-4FR MCU* and high-speed processing power as the core of the control system, we design the smart car control system including design of trajectory sensor, wheel speed sensor and Angle sensor, control strategy, and the software reliability. By real vehicle test, the straight and cornering speed has improved significantly.

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