Synchronous line-tracking robots based on STM32

ZHU Xiao-li(朱晓莉), LI Shi-guang(李世光), ZHANG Kai(张 锴),
CHEN Yue-yin(陈曰印), MENG Qiang-qiang(孟强强)

(*College of Information and Electrical Engineering, Shandong University of Science and Technology, Qingdao 266590, China*)

Abstract: A pair of synchronous line-tracking robots based on STM32 are designed. Each robot is actually a small intelligent car with seven reflective infrared photoelectric sensors ST188 installed in the front to track the line. Two rear wheels each driven by a moter are the driving wheels, while each moter is driven by an H-bridge circuit. The running direction is controlled by the turning of a servo fastened to the front wheel and the adjustment of speed difference between the rear wheels. Besides, the light-adaptive line-tracking can be performed. The speeds of the motors are controlled by adjusting pulse-width modulation (PWM) values and an angular displacement transducer is used to detect the relative position of the cars in real time. Thus, the speeds of the cars can be adjusted in time so that the synchronism of the cars can be achieved. Through experiments, the fast and accurate synchronous tracking can be well realized.

Key words: STM32; synchronous line-tracking robot; intelligent car; reflective infrared photoelectric sensor; angular displacement transducer

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A line-tracking robot is a relatively common event of intelligent car competition. Usually, it requires the robot to reach the finish line along the regulated path and the result of the competition is determined by the used time[1]. For attending the robot contest in the 12th college students science and technology culture art festival of Shandong province, a pair of synchronous line-tracking robots are designed.

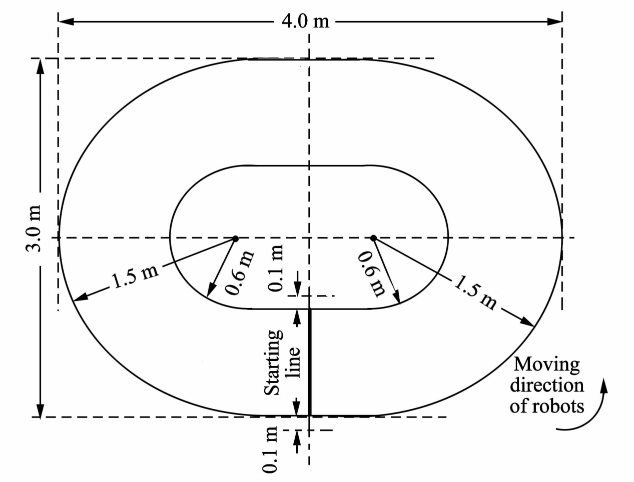

Fig. 1 Playing field and size

The rule of the competition is as follows: black skidproof adhesive tape is used to make up the path consisting of two parallel ellipses on a white foam board as shown in Fig. 1. Two robots carrying a synchronous rod start to move from the starting line and walk along the track, respectively. The contest will be end up with the second arriving at the starting line. Any part of the rod is not allowed to touch the ground during the race.

In this design, the rod and the small cars are fixed at both ends. The speeds of the rear-wheel motors are adjusted by changing pulse-width modulation (PWM) values in real time. Besides, the angular displacement transducer is used to detect the relative position of the cars so that their speeds can be adjusted promptly.

1 Overall structure and working principle of control system

Three-wheeled car body is adopted. Two driving wheels are installed on both sides in the rear. Only one driven wheel is in the front, lying in the mid-perpendicular of the two driving wheels. The advantage is that the touchdown of all the wheels can be guaranteed, so that none of the wheels hang in

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Corresponding author: ZHU Xiao-li (woshizhuxiaoli@163.com)

the air. Thus, the stable control can be realized[2].

The control system structure of synchronous robots is shown in Fig. 2. It is mainly composed of a master control module, a power module, a path detection module, a relative position detection module, a control module of the front-wheel servo and a driving module of the rear-wheel motors, etc.

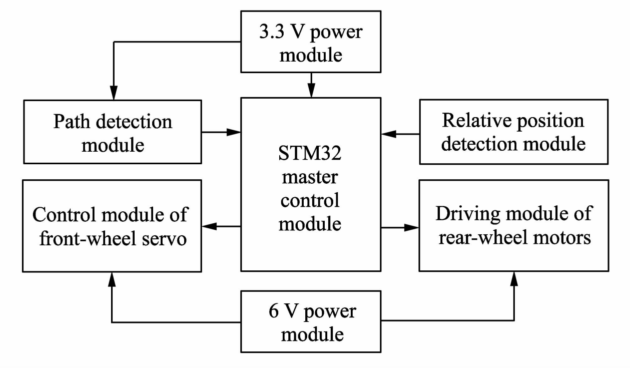

Fig. 2 System structure diagram

The working principle of the system is as follows: The route condition is firstly detected by the reflective infrared photoelectric in the front of the cars. The real-time leaning judgment of the cars is made after the analysis of the control part. Then, the angle of the servo motor is adjusted so that the cars can veer. In this way, the cars can run along the preset path accurately. At the same time, the speeds of the cars are controlled by the real-time adjustment of PWM values. Besides, the synchronous rod that the cars carry drives the angular displacement transducer to shift a corresponding angle. The speed of the inner car is then adjusted slightly after the data processing of the control part. Thus, the synchronous running of the two cars can be guaranteed.

2 Hardware design

2.1 Master control chip

Main control chip is the core of the whole design. It coordinates and controls all the work of the modules and plays a decisive role in the overall performance of the system. Given the requirements of low power consumption, high performance and low cost, and considering the stability of the system, the number of peripherals resources on chip and some other factors, the 32-bit microprocessor of STM32 series STM32F103ZE made by STMicroelectronics is adopted as the main control chip. The advanced Cortex-M3 ARM kernel is used inside every microprocessor of STM32 series. All devices offer an extensive range of I/Os, three 12-bit ADCs, four general-purpose 16-bit timers plus two PWM timers. With the operating voltage of 2.0 – 3.6 V, it has a series of power saving modes to ensure the low power consumption operation of the chip. Considering all the above, this chip can meet the demands of high performance and low power consumption well.

2.2 Path detection

Seven reflective infrared photoelectric sensor ST188 and 2 quad operational amplifiers LM224 are used to make up the path detection module. The detection circuit is shown in Fig. 3. Every sensor consists of an infrared light emitting diode and a receiving transistor. When infrared light is emitted to the playing field, white color absorbs few rays, and most rays are reflexed. The receiving transistor then switches into breakover when receives the reflexed infrared rays, and pin 7 of LM224 in Fig. 3 outputs high level. While black color absorbs many rays, only a few rays are reflexed and received by the receiving transistor. As a result, the receiving transistor doesn't get to breakover, and pin 7 of LM224 outputs low level.

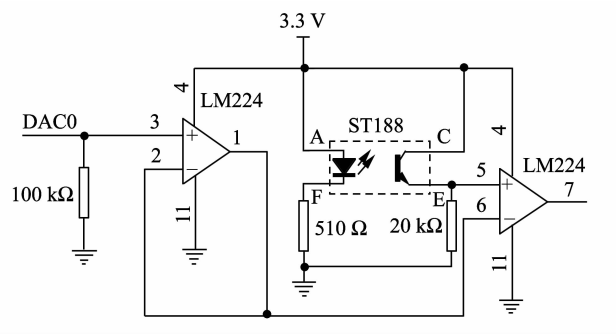

Fig. 3 Reflective infrared photoelectric sensors path detection circuit

As the difference in illumination intensity of the competition field, as well as that in fabrication process of the photoelectric sensors and some other factors, leakage current exists in receiving transistor. Thus, the accurate detection of the path is influenced. As a result, the operational amplifier LM224 is used to equip the system with self-learning function. In this way, the environmental lights interference to photoelectric sensor can be eliminated and the resisting disturbance capacity of the system can be enhanced. In Fig. 3, DAC0 is the given voltage comparison value which can be adjusted according to the site light condition. Thus, the light-adaptive line-tracking can be realized.

Radial reach-out distance refers to the radial distance that the photoelectric sensors reach out from the front of the car. Theoretically, the longer the reach-out distance is, the better the situation will be. This is because for the unknown track, the earlier the situation in front is known, the faster the adjustment can be made. In this way, the cars can run along the route with the best strategy[3]. Through experiments, when the radial reach-out distance is fixed to about 10 cm, the prompt and accurate turning can be ensured.

2.3 Relative position detection

Combined with the realtime control of the speeds of the cars in the program, angular displacement transducer is used to detect the relative position distance between the cars in real time to ensure the synchronism.

Angular displacement sensor converts the mechanical angular displacement of the measured parts to electricity parameter with internal potentiometer. Mechanical angular displacement makes mechanical structure inside the sensor to slide on the potentiometer. The corresponding electric signal is then output so that the angle can be measured[4].

One end of the synchronous rod is fastened to the shaft of the angular displacement sensor with a screw. The other end is fixed on the other robot car. The initial position of the angular displacement sensor should be regulated. As the cars running, the relative position distance between them is reflected through the angular displacement sensor shaft. The distance is then converted to digital quantity through ADC. Real-time deviation rectification according to the numerical value is then conducted with the program. Thus, the synchronous running of the cars can be further assured. Synchronization control flow chart is shown in Fig.4.

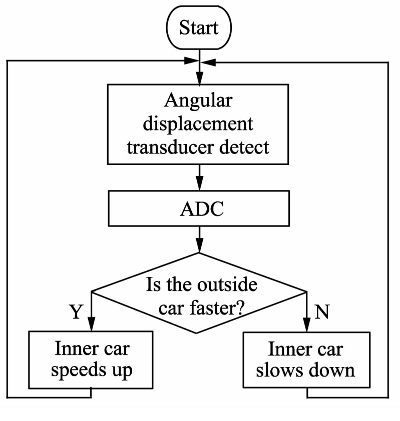

Fig.4 Synchronization control flow chart

2.4 Control of front-wheel servo

Servo motor is a kind of position servo driver. It is suitable for the control systems of which the angle changes continuously and needs to be held front-wheel servo. A servo is actually a position servo system composed of a tiller, a reduction gear group, a position feedback potentiometer, a DC motor and a control circuit. Through the internal position feedback, the output turning angle of the tiller can be proportional to the given control signal. Thus, when the load torque is smaller than the maximum output torque, the output turning angle will be proportional to the given pulse width[6].

The control signal of the servo motor is a pulse signal with a period of 20 ms. Its high level lasts for 0.5 − 2.5 ms, with the corresponding control angle of 0 − 180°, and the relationship between them is linear. The corresponding control relationship is shown in Table 1.

Table 1 Relationship between pulse high level durations and control angles

High level duration (ms)	0.5	1.0	1.5	2.0	2.5
Control angle (°)	0	45	90	135	180

Control circuit of the servo is shown in Fig.5.

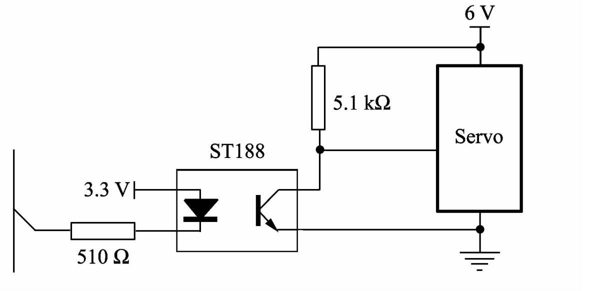

Fig.5 Servo motor control circuit

The veer of the cars are realized through the control of the front-wheels servo motor and the different speees adjustment to the rear wheels in the program.

2.5 Drivering of rear-wheels motors

Two H-bridge driving circuits are used in the drivering module of rear-wheel motors. An H-bridge structure, also named a whole bridge structure, has two half bridge drivers. It is composed of four metal oxide semiconductor field-effect transistors (MOSFETs)[7]. AO3400 and AO3401 MOSFETs are used in this design. As shown in Fig.6, when BG1 and BG2 switch into breakover, the current flows from the power supply VCC through BG1 to the motor, and then down to the ground though BG2 from left to right. Thus, the motor can be driven to run clockwise. Similarly, when BG1 and BG2 switch into breakover, the current flows through the motor from right to left. Thus, the motor can be driven to run anticlockwise.

The timers of STM32 can generate PWM waves generally used in motor control and power electronics field. The output voltage is controlled with PWM technology by changing the pulse width. And the change of output frequency can be achieved through changing the modulation cycle of the pulse. In this way, the needed wave, including the shape and amplitude, can be acquired equivalently[8]. TIM4 is used to produce PWM waves to regulate the speeds of the motors.

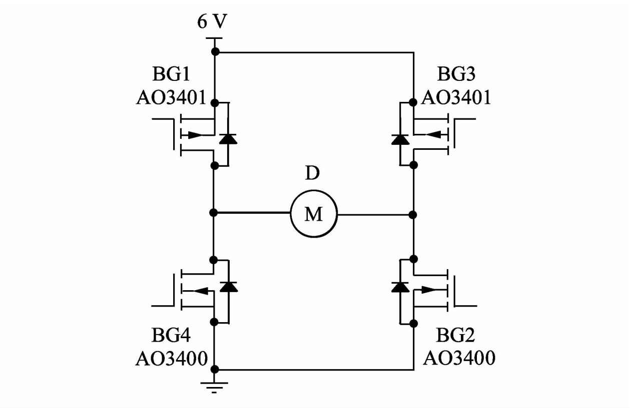

Fig. 6 H-bridge driving circuit diagram

2.6 Power supply

Two levels of power supply are adopted. One uses seven rechargeable batteries of 1.2 V and the voltage regulator AMS1117 adjustable voltage output version to get 6 V, which powers the motors (6 V, 646 r/m) and the servo (6 V, 0.09 s/60°). The other uses the AMS1117 3.3 V fixed voltage output version to get 3.3 V from 6 V, which powers the STM32 chip.

3 Software design

Based on the hardware circuit, the tested path information and running situation of the cars, it is available to realize the control of the servo and the motors with an information processing and control program. Thus, the cars can run along the track with high speed and good stability[9].

The software control program is mainly composed of ARM initialization, black and white calibration, track detection, steering control, speed control, synchronism control, finish line braking, etc. The control system software is realized in Keil μ Vision3 development environment programming with C language.

Among the above, the turning control flow is shown in Fig. 7. If the photoelectric sensor in the middle detects the black line, it shows that the car does not deviate from the track. The servo motor will not turn, and the car will run in the largest given speed. If the photoelectric sensors on the left (or right) side detect the black line, it shows that the car deviates right (or left) from the track. And the more left (or right) the sensors detect the black line, the more the car deviates right (or left) from the track. The servo motor is controlled to drive the car to turn left (or right). And the more the car deviates, the greater the deflection angle is given.

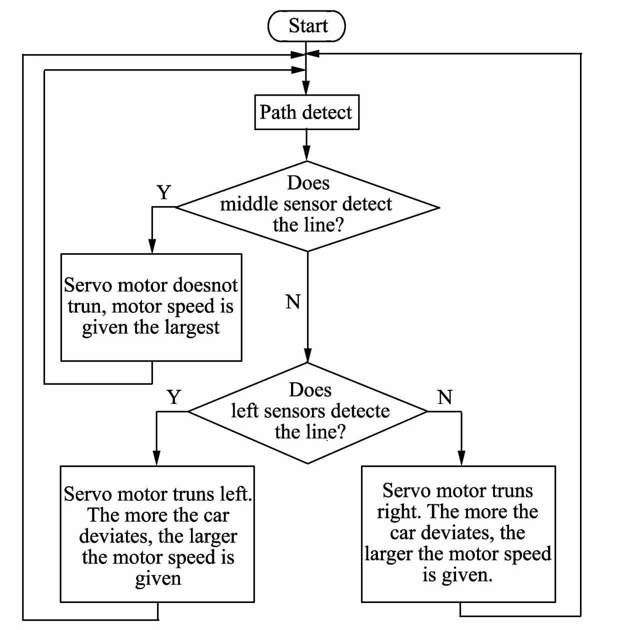

Fig. 7 Turning control flow chart

4 Robot cars and playing field display

This design has been made into material object and has actually been tested on the required playing field. The results show that this kind of synchronous line-tracking robots can track the line well.

The synchronism can be well realized and the synchronous rod will not drop. The speed is so fast that the cars can run around the field for a round within seven seconds and stop as they get to the starting line again. Cars and playing field is shown in Fig. 8.

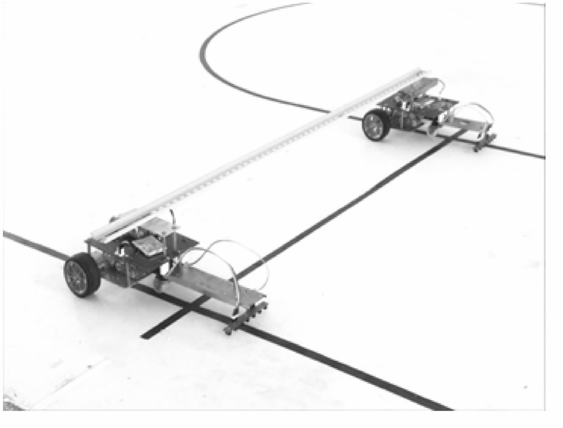

Fig. 8 Cars and playing field

5 Conclusion

For the robot contest, STM32F103 microprocessor of STM32 series is used to design a kind of synchronous line-tracking robots carrying a rod. Reflective infrared photoelectric sensor ST188 is used to track the line. Two H-bridge circuits are used to drive the motors. The direction of the cars is controlled by the turning of the servo motor and the speed adjustment of the rear wheels. The PWM technology and angular displacement transducer are used to guarantee the synchronicity of the two cars. Through experiments, the line-tracking robots can successfully run around the playing field for a circle with a rod in a short time. The robots can track the line well with a high response speed. They also have a certain ornamental value and practical application value.

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