ISSN: 2664-9640

F-type Smart Car Based on K60 MCU

Tala
Department of automation, North China Electric Power University, Baoding 071066, China
2819434551@qq.com

Abstract

Aiming at the problem of road recognition and control of the F-type smart car, an automatic tracking F-type smart car is designed based on the National College Students' Smart Car Competition. First, the hardware design needs to be completed.Then on this basis, the MT9V034 camera is used to collect and identify road information,obtaining the position information of the F-type smart car. Under the cascade control system, the system of car calculates the speed difference of the two wheels required for the steering of the F-type smart car according to the position deviation. Finally, after adding the speed difference value to the set speed, it is sent into the speed adjustment link to output a stable speed. Under the control of the cascade control system, the car can realize automatic tracking.

Keywords

K60, PID,circuit ,image processing.

1. Introduction

With the continuous development and progress of science and technology, the application of intelligent control is more and more extensive, and it penetrates into almost all fields. Relying on intelligent control, smart car technology has broad prospects and rapid development. At present, many well-known auto companies at home and abroad have developed experimental platforms for smart cars and commercialized vehicle assisted driving systems. Some studies believe that smart cars, as a brand-new car concept and car product, will become the mainstream product in car production and car market in the near future. Therefore, studying the design scheme of self-driving car will further promote the intelligence of modern cars.

The National College Student Smart Car Competition has been held for 16 sessions since 2006, and has been highly appraised by leaders at all levels and by teachers and students of various colleges and universities. The competition has cultivated a large number of reserve talents in the field of smart cars,which provided a stage for college students to fully demonstrate their imagination and creativity, and attracted more and more college students from different majors to participate. With the rapid development of automotive electronics as the background, the smart car competition is a scientific and creative competition covering multiple disciplines such as control, pattern recognition, sensing technology, electronics, electrical, computer, and machinery.

Next, F-type car model provided by the competition organizing committee will be used, and the NXP microcontroller-MK60 will be used as the core control unit to design the control scheme and system of the F-type smart car, including sensor signal acquisition and processing, control algorithm, motor drive, steering servo control, etc., and finally realize a set of intelligent car control hardware system that can identify the route autonomously and output the state of the car body in real time. The F-type smart car collects images in real time through the camera, and after processing them, it adjusts its own direction and speed in time to move along the set track. Moreover, in the case of unmanned intervention, autonomous adjustment and autonomous

ISSN: 2664-9640

judgment of track elements are completed according to the pre-established control strategy. The formulation of the motion strategy mainly relies on the four steps of collection, analysis, decision-making and execution of the road and driving information obtained by the sensor.

2. The overall framework of the F-type smart car

The F-type smart car uses a 32-bit microcontroller-MK60FX512VLQ15 from NXP as the core control unit for the overall control of the smart car system. The track information is collected by the digital camera and electromagnetic sensor module. The information is returned to the single-chip microcomputer after image processing, and then the corresponding control instructions are issued according to the pre-established control scheme. F car is composed of main circuit part, driving circuit part, motor and other external equipment. The overall frame of the F car is shown in Figure 1. Among them, the main circuit part is the core part of the entire smart car, which consists of MCU, voltage regulator module and optocoupler isolation. Other parts rely on the stable voltage provided by the main circuit board voltage regulator module to perform normal work, and exchange data with the MCU through the corresponding communication protocol. For example, the communication between the camera and the MCU uses the SPI protocol, and the communication between the gyroscope uses the I2C communication protocol. Therefore, only when the entire system of the F-type smart car is built, the F car can collect track information in time, making control decisions and adjusting its speed.This can ensure that it does not deviate from the race and moves forward according to the predetermined road.

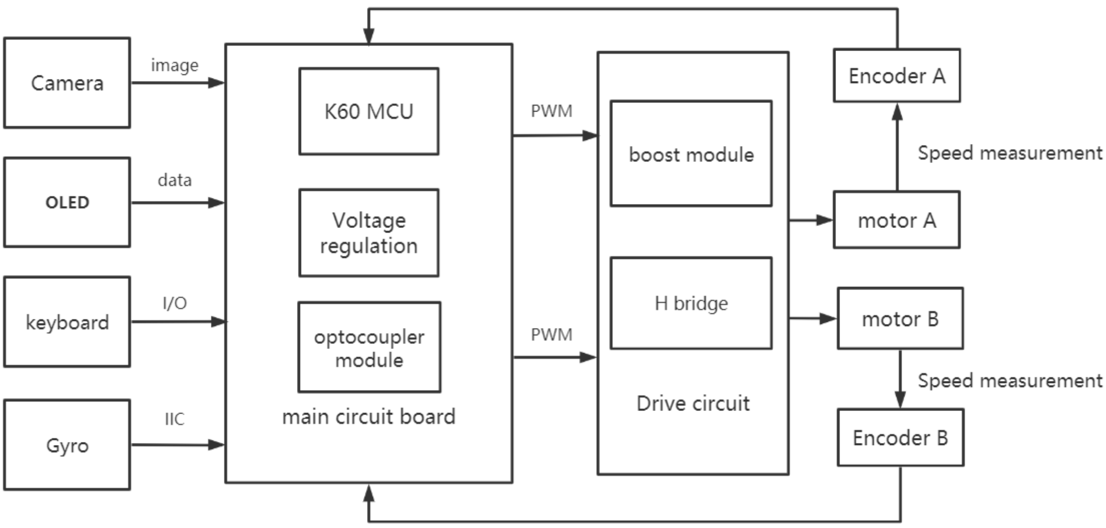

Fig. 1 The overall framework of the F-type smart car

3. Main circuit design of F-type smart car

The main circuit of F car uses K60 MCU as the core module of data processing and system control, and uses an AMS1117-5V voltage regulator module to provide stable working voltage. The voltage regulator module (as shown in Figure 2) uses 5 pieces of AMS1117-5V voltage regulator chip and 1 piece of AMS1117-3V voltage regulator chip to provide stable and reliable voltage to each module respectively. In addition, a 47uf tantalum capacitor is connected in front of each voltage regulator module, which can effectively remove the external interference current and avoid damage to other modules by the interference current.

ISSN: 2664-9640

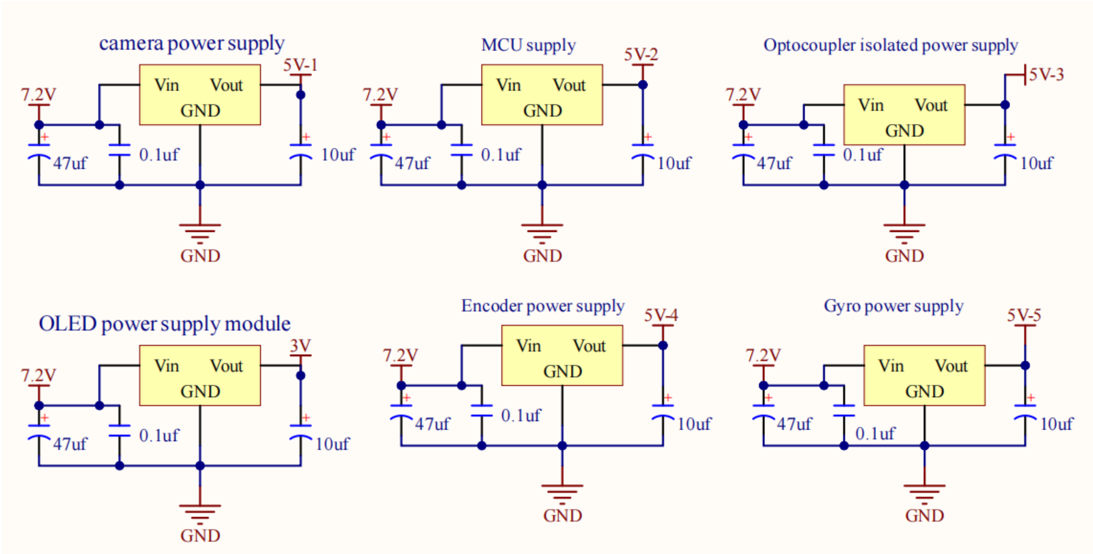

Fig. 2 Voltage regulator module

In order to prevent the large current generated by the motor rotation from pouring back into the minimum system and burning the minimum system, the HCPL0630 optocoupler isolation chip is added when the motor PWM signal is transmitted so that the signal can only be transmitted from the single-chip microcomputer to the motor driver board, thereby protecting the single-chip microcomputer. The protection optocoupler isolation circuit is shown in Figure 3:

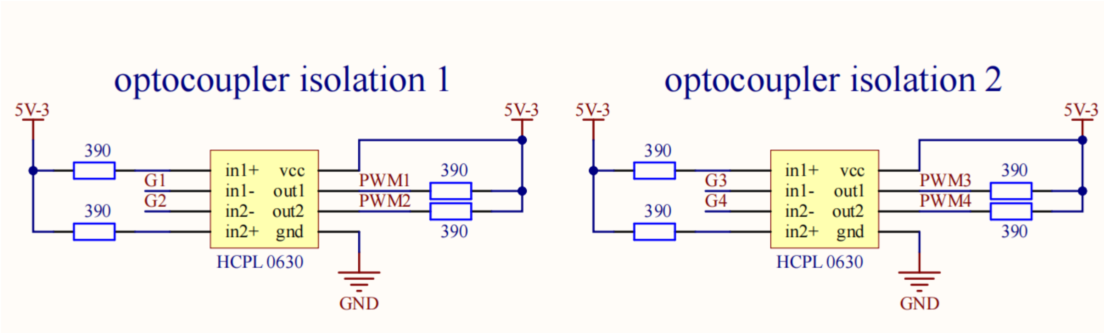

Fig. 3 Optocoupler isolation circuit

4. The drive circuit of the F-type smart car

The F-type smart car needs two motors as the power source, so two "H-bridge" are needed to control the forward and reverse directions of the motor and the speed of the motor. The stability of speed of the motor will directly affect the speed and stability of the entire vehicle. The motor speed can be controlled by the ratio of the ON and OFF times of the N-channel power MOSFET in the "H-bridge" in one cycle. Therefore, the HIP4082 chip can be used to control the on and off states of the N-channel power MOSFET in the "H bridge". When the MCU controls the MOSFET Q1 and MOSFET Q4 channels through the HIP4082 chip, the motor starts to rotate forward to drive the smart car forward. Conversely, when MOSFET Q2 and MOSFET Q3 are channeled, the motor starts to reverse and drive the smart car backwards. The other "H-bridge" works on the same principle.

The rated working current of the N-channel power MOSFET can easily reach more than 100 A, which greatly improves the working torque and speed of the motor. Among them, the H-bridge circuit needs a voltage of 12V. We select the MC34063A chip and other corresponding electronic components to form a boost circuit. The specific circuit is shown in Figure 4 .

ISSN: 2664-9640

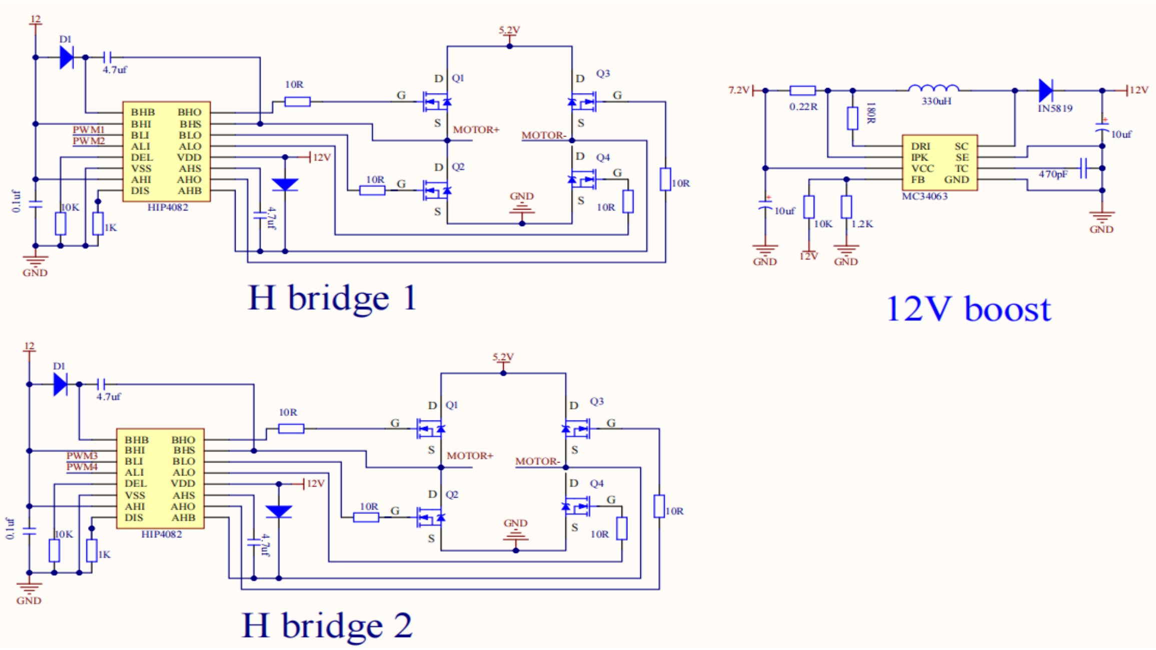

Fig. 4 The drive circuit

5. The sensor part of the F-type smart car

5.1. Camera

The F car adopts the MT9V034 camera developed by Zhufei Technology Co., Ltd. as the sensor for collecting images. This camera is designed based on the MT9V034 chip, which has superior performance and is most suitable for capturing images under high-speed motion. It has a frame rate of up to 498 fps and automatic exposure. These properties are sufficient to satisfy the image information required for F-car tracking.

5.2. Gyro

In order to ensure the attitude of the F car, the MPU6050 gyroscope is generally used as the measurement sensor for measuring the attitude of the smart car. The MPU6050 is the world's first integrated six-axis motion processing component, also known as a six-axis gyroscope. It can accurately measure the inclination angle and acceleration of the X, Y, and Z axes, and can be used for the control of the inclination angle of the smart car as well as the steering and speed control. MPU6050 adopts I2C communication protocol to transmit the collected data to K60 MCU. K60 MCU generally uses amplitude limiting filtering to digitally filter the data collected by the gyroscope to obtain more accurate data. The basic algorithm of limiting filtering is to subtract two adjacent sampling values, find the increment, and then compare it with the maximum difference △y allowed by the two samplings. If it is less than or equal to △y, take this time Sampling value; if it is greater than △y, the last sampling value is still taken as the current sampling value. The specific algorithm is as follows:

$|Y(k)-Y(k-1)|\leq\triangle y$, then $Y(k)=Y(k)$, take this sampling value;

$|Y(k)-Y(k-1)|>\triangle y$, then $Y(k)=Y(k-1)$, take the last sampling value.

6. Image processing technology

6.1. Using the Otsu to process grayscale images

In the national college student smart car competition, most groups use the MT9V034 camera as the image acquisition sensor. The images it collects are 160*120 grayscale images, which are easy to process and have mature algorithms. At present, the image processing in the smart car

ISSN: 2664-9640

competition is basically to binarize the grayscale image. Among them, the most commonly used binarization algorithm is the Otsu.

In computer vision and image processing, the Otsu's binarization is used to automatically binarize cluster-based images. In other words, it may degenerate a grayscale image into a binary image.The algorithm assumes that the image contains two types of pixels according to the bimodal histogram (foreground pixels and background pixels), so it calculates the best threshold that can separate the two types so that their intra-class variance is minimized. Since the squared distance between the two is constant , so that their inter-class variance is the largest. Therefore, the Otsu's binarization is roughly a discrete simulation of one-dimensional Fisher discriminant analysis.

The principle of Otsu's binarization algorithm is based on maximizing the between-class variance. The algorithm assumes that image pixels can be divided into background and target parts according to a threshold. Then, the optimal threshold is calculated to distinguish the two types of pixels, so that the two types of pixels have the maximum discrimination degree. Therefore, the core of the algorithm is to find the best threshold.

First, the algorithm counts the number of grayscale pixels in the image, and sets n_i as the number of pixels with grayscale i in the image,following is $\mathrm{n}_1,\mathrm{n}_{2,}\mathrm{n}_{3,}\ldots\mathrm{n}_{255}$.

Probability of grayscale i in the image: $\mathrm{P}_i = \dfrac{n_i}{n_1+n_2+n_3+\ldots+\mathrm{n}_{255}}, \sum_{i=0}^{255}\mathbf{P}_{\mathrm{i}} = \mathbf{1}$

Assuming that the threshold is T, the probability of pixels in the grayscale image being assigned to group A is $P_A(T)$, and the average grayscale of pixels assigned to A is $M_A(T)$. Similarly, the probability that pixels in the grayscale image are assigned to group B is $P_B(T)$, and the pixels assigned to the average gray level of the pixels of B is $M_B(T)$. The cumulative mean of gray level T is M, and M_G for the entire image. Therefore, the following relationship will be established.

$$M_A(T)*P_A(T)+M_B(T)*P_B(T)=M_G$$

$$P_A(T)+P_B(T)=1,\ P_A(T)=\sum_{i=0}^{T}P_{\mathrm{i}},\ P_B(T)=\sum_{i=T+1}^{255}P_{\mathrm{i}}$$

$$M=\sum_{i=0}^{T}iP_{\mathrm{i}},\ M_G=\sum_{i=0}^{255}P_{\mathrm{i}}$$

The variance can be expressed as: $\sigma^2 = \dfrac{(\mathrm{M}_G * P_A(T)-M)^2}{P_A(T)(1-P_A(T))}$

The best threshold can be obtained by bringing the above correlation formula into the formula for calculating the variance, and finding the threshold that makes the variance the maximum value. Using this optimal threshold, the pixels in the image can be divided into background pixels and target pixels, and then the black and white binarization of the image can be completed. The image before black and white binarization is shown in Figure 5, and the effect after processing by the Otsu is shown in Figure 6.

ISSN: 2664-9640

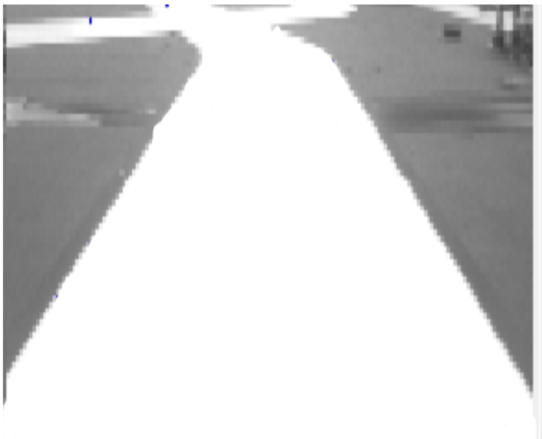

Fig. 5 The grayscale image

Fig. 6 The Binarize image

6.2. Finding road boundaries

If the smart car wants to run along the middle of the track during operation, it must scan two boundary lines, and then fit the center line according to the width of the two boundaries. Therefore, finding two boundaries is the first priority.

When finding the boundary line on the black and white binarized image, the first thing to do is to find the starting point of the boundary line. First, starting from the bottom row, scan the pixels of each column from left to right. If the situation as shown in Figure 7 is found in the scanning row, it means that the starting position of the left line is found. If the starting point is not found in this line, continue to search from the previous line until the starting point is found. The method for finding the starting point of the right line is similar, except that in the process of scanning a certain line, the situation shown in Figure 8 is its starting point. Finding the starting point can greatly simplify the complexity of subsequent image processing algorithms and improve the speed of single-chip image processing.

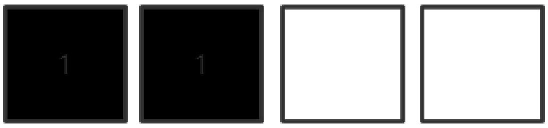

Fig. 7 The starting point of left side line

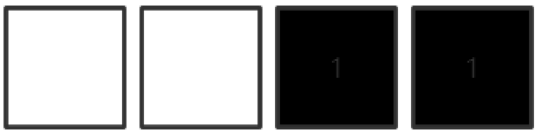

Fig.8 The starting point of the right side line

After finding the starting point, the image processing module use the Nine-square grid algorithm to calculate the left and right boundary lines. The principle of the nine-square grid algorithm is as follows: C in Figure 9 is the last right boundary line point, draw the nine-square grid with C as the center, and the next right line is generated by removing the eight points in the center from the nine-square grid. Class. That is, we scan the points 1->2->...->8 in Figure 9 in turn. Once it is found that one of the points is a black point, and at least one of the four points on the top, bottom, left, and right of the point is a white point, the point is determined. For the next right boundary point, and then repeat the process, until the eight points around a point do not meet the boundary line rules, the scan is terminated. The calculation method on the left is similar to the line on the right, except that the scan order is mirrored. The algorithm processing result is shown in Figure 10.

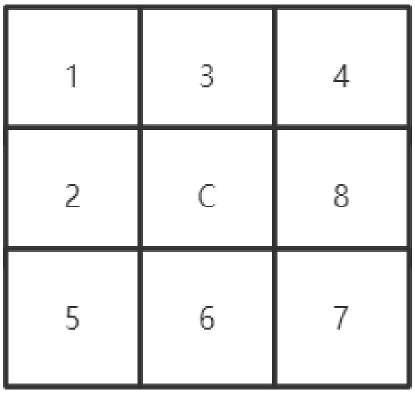

Fig. 9 Nine-square grid algorithm

Fig. 10 The boundary line

6.3. Fitting the center line

When fitting the center line, the image processing part find the width of the track dividing it by 2 and add it to the column number of the left line so that the center line can be obtained. The effect is shown in Figure 11 .

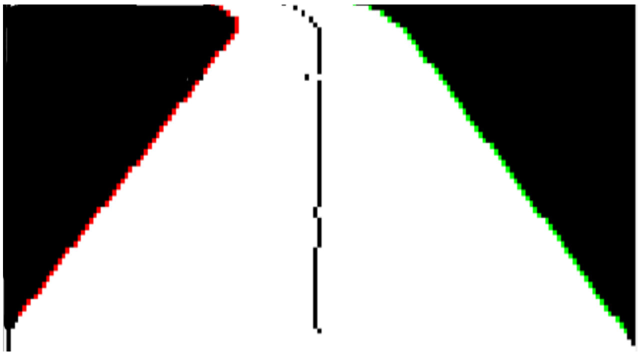

Fig. 11Centerline fitting

6.4. Handling of Crossroads

The method of judging can choose the strategy of continuous multiple lines that are almost all white. After recording the number of lines, use the least squares method to process the slope of the original edge and extend it. The specific processing results are shown in Figure 12.

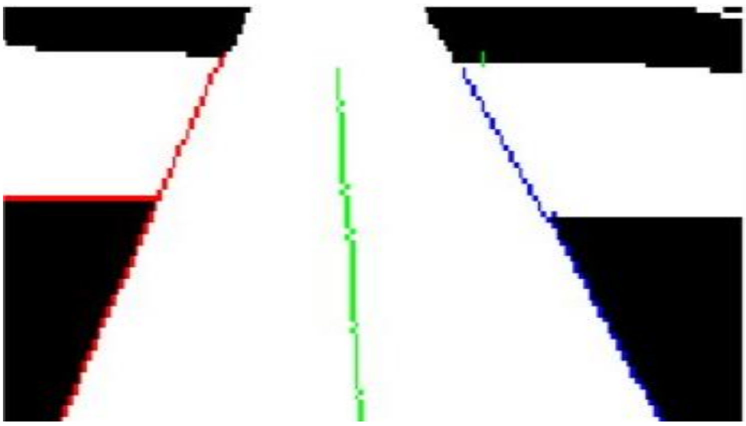

Fig. 12 The crossroads

7. Control System

Because the F-type smart car does not have a steering gear, the adjustment of its direction is to adjust the direction of the entire vehicle by considering the differential speed of the two wheels, which is the biggest difference from ordinary four-wheeled vehicles. And when we ignore the time when the single-chip microcomputer sends out the control command, there is a second-order integral relationship between the wheel speed difference of the F-type smart car and the position deviation of the car model. If the simple proportional control is used to control the differential speed, the system will easily oscillate. Therefore, a differential link is generally added to form a PD controller to control the differential speed. Because there are often many high-frequency interference components in the signal collected by the camera, and these interference signals are not easy to be filtered out. Therefore, a steering gyroscope is introduced on the car model to directly obtain the steering speed of the car model, which is introduced into the differential component to replace the differential of the detection signal.

The motor generally uses a PID to control its speed. When the actual speed of the two motors deviates from the set speed, the PID control stabilizes the motor speed at the set value by adjusting the PWM output. In most cases, incremental PID is generally used. Its formula is as follows:

$$\Delta \mathrm{u}[n]=K_p\{e[n]-e[n-1]\}+K_i e[n]+K_d\{e[n]-2e[n-1]+e[n-2]\}$$

Therefore, the control system of the F-type car is composed of a cascade control system. The direction adjustment link is connected with the speed adjustment link. The schematic block diagram of the entire vehicle is shown in Figure 13.

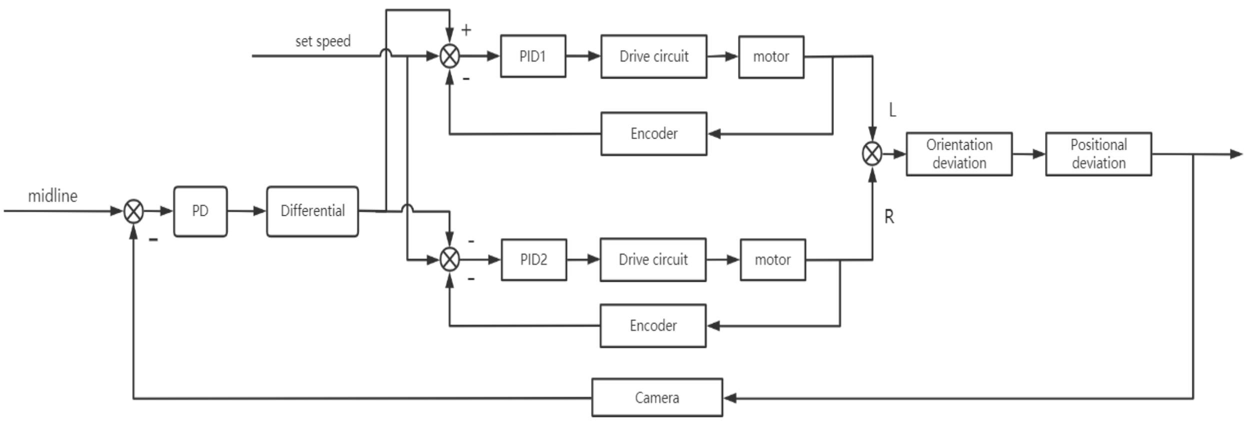

Fig. 13 The schematic block diagram

8. Conclusion

If the F-type smart car wants to achieve automatic tracking at a higher speed, the hardware and software must be perfectly matched. Hardware is the basis for the automatic tracking function of the entire smart car. The stability and reliability of each circuit module directly affect whether the entire system can work normally. Image processing is the premise of controlling the position and direction of the entire vehicle. The quality of the image processing algorithm directly affects the detection of vehicle direction, which in turn affects the control system. Therefore, many college students are currently devoted to the optimization and innovation of image processing algorithms. After the image processing results are sent to the controller, the F vehicle can make corresponding control decisions in different external environments to achieve automatic tracking.

ISSN: 2664-9640

References

[1] Fan Zhanyuan, Zhou Zhanpeng. Based on NXP smart car steering gear and PID control Research [J]. Information Recording Materials, 2019, 20(08) : 156-157.

[2] Zhu Longtao, Zhu Qingshan, Yang Yucan.Design and Production of Smart Car Machine Based on Enzipu[J].Electronic Test,.2020.13.009.

[3] Fan Hao , Xu Long , Lai Fuming , Cai Wenguang , Lu Mingze , Li Yuan . Attitude control system based on STM32 and MPU6050 [J]. Electronic Components and Information Technology, 2020, 4(02): 74-75+86.

[4] Xu Ting, Wang Kang, Tao Jiming. Design and implementation of trolley tracking based on NXP MK60DN512Z [J]. Automation Technology and Application, 2021, 40(4): 39-43+53.

[5] Xia Jie, Wei Shuwei. An intelligent automatic track car based on LPC54606 [J]. Electronic World, 2021(4): 120-122.

[6] Yuan Xin, Sui Long. Real-time processing method of binary image based on MCU system [J]. Doctoral Forum, 2009, 29.

[7] BU Wenbi,YOU Fucheng,LI Quan,WANG Huihua,DUAN Huaifeng.An Improved Image Segmentation Method Based on Otsu[J].Journal of Beijing Institute of Graphic Communication,2015,23(4),76-78.