The Design and Implementation of Automated Smart Car System Based on Camera

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Abstract:**In this paper, we have designed and implemented an automated smart car system based on camera. With the Freescale MC9S12XS128 microprocessor as its control centre, the system is consisted of both Software and Hardware. At first, the system extracts the horizontal signal and vertical signal from the camera video signal through the LM1881 external circuit, and then the MCU acquires the real time road images by capturing the horizontal and vertical interrupt signal. Combined with the continuity character of the road, the leading line position in the image can be extracted by edge detection algorithm, and then accomplish the steering and speed control of the smart car by PID algorithm. In addition, by adding the Beam Splitter at the input terminal of the camera, the system effectively lessens the impact from illumination to image formation. The system has also introduced speed measuring module to supply effective real time feedback for PID control algorithm. According to tests carried on specialized racing tracks, the system possesses great robustness and feasibility with great market prospect on a long view.**

Keywords: smart car, image acquisition（IMAQ）， PID control，pulse width modulation (PWM).

I. INTRODUCTION

With the proposition of the subjects of Internet of Things(IOT) as well as pilotless driving, a lot of countries began to pay attention to and do research in pilotless automobile. People believe that by accessing the Mobile Network, computer can acquire the real time road image and then choose the faster one, at last solve the current road congestion problem effectively. In the mean time, computers have strong anti-fatigue ability which could prevent traffic accident caused by anthropogenic factor like fatigue etc. For the sake of energy saving and environmental protection, Pilotless automobile generally adopts electric drive.

The main technologies of pilotless driving cover automatic navigation, automatic obstacle - avoidance, pilotless driving etc. Freescale National College Students smart car racing is taken as the research background of the smart car in this paper. By using electric model as the model car, the camera acquires the real time road information, and dominates the car on the specified road to achieve the exact trailing. According to the experiments, it has offered some solution tests for pilotless driving which possesses wide perspective and practicability.

II. SYSTEM PRINCIPLE AND ERROR ANALYSIS

A. Camera IMAQ

There are two types of cameras, one is digital camera, and the other is analog camera. Since the image continuity of the analog camera wouldn't be affected by resolution ratio and could be observed directly through video equipment, the smart car we designed in this paper would use CCD analog camera system as the input, and then by analyzing the road information from the acquired image we could control the speed and direction.

The output line of the CCD analog camera is merely video line. And the transmitted video signal contains not only image

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signal but also the horizontal synchronizing signal, horizontal blanking signal, vertical synchronizing signal, vertical blanking signal and broad pulse signal etc. For the system control-core is microprocessor, if we want to acquire the video signal, we must extract the horizontal signal and vertical signal, the specific circuit diagram is shown in following diagram 1, the CMPSYNC is horizontal synchronizing signal, and the V.SYNC is vertical synchronizing signal.

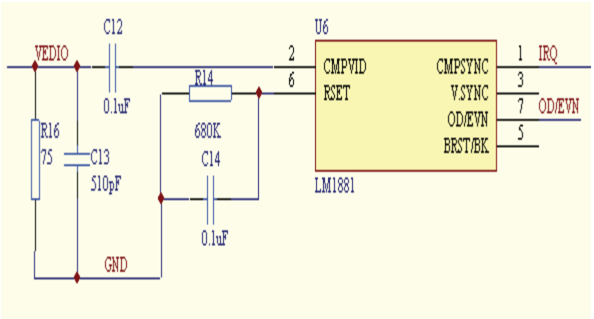

Figure. 1 circuit for separation of horizontal sync signal and vertical sync signal

As in Figure 2, through the horizontal and vertical synchronizing signal extracted from the LM1881 circuit, *a* is video signal, *b* is horizontal synchronizing signal and *c* is vertical synchronizing signal. They separately link to the microprocessor interrupt pin, when the vertical synchronizing signal comes, we will initiate a new frame of image acquirement, every time the horizontal synchronizing signal comes, and we would acquire the next row of continued image through AD. In particular, the video signal also contains the odd-even vertical signal, and every time the vertical synchronizing signal comes, it must at first jump over the blanking area.

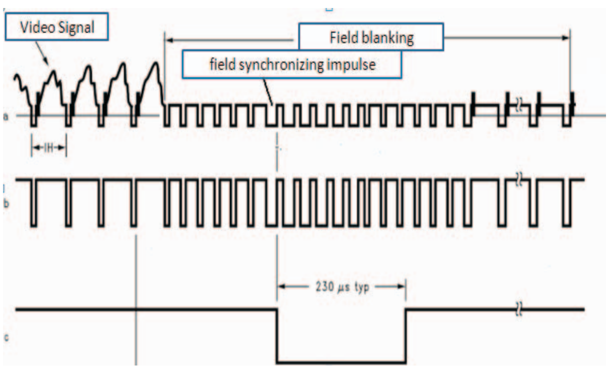

Figure. 2 Signal separation

B. Road recognition algorithm

After acquirement of the image, the most important thing is to extract the road information from the image. The smart car designed by this system is rely on the black leading line on the racing track, the car is driven fast on the racing track along the black leading line, as in Figure 3, the road recognition algorithm is mainly used to extract the leading line position in the image acquired by camera.

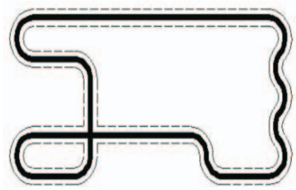

Figure. 3 racing track of Smart Car

From the above road features, we can find out in the middle of the road it is the black line, the road is generally white, by contrasting the grave value in the acquired image, we can find the position of the black line. The normal method is edge detection algorithm. Now we will use an ideal M rows and N lines road image $S_{ij},\ i = 1..M,\ j = 1..N$ to explain the edge detection algorithm and the mean gray value of every row is:

$$A_i = \sum_{j=1}^{N} S_{ij} \qquad (1)$$

In order to avoid pure black or pure white images in a row, we introduced the minimum value of white gray value W_{min}, the maximum value of black gray value B_{max}, then to revise the above A_i:

$$A_i = \begin{cases} W_{min} & A_i \geq W_{min} \\ B_{max} & A_i \leq B_{max} \\ A_i & \text{else} \end{cases} \qquad (2)$$

For S_{ij}, if $S_{ij} > A_i$, it is white, otherwise, it is black, then in every row, we can find out the two positions $Start_i$ and End_i, from left to right and right to left, the first points which suddenly changed from white to black, then the position L_i of the black line would be:

$$L_i = \begin{cases} \dfrac{Start_i + End_i}{2} & Start_i < End_i \\ L_{i-1} & \text{else} \end{cases} \qquad (3)$$

In reality, there are a lot of disturbance in the image, the blind side of the black line in the image would bring difficulties to the exact extraction of the black line position. However, there is always a tilt between the camera and the road, so the definition of the distant road is largely declined, the definition of the nearby road is relatively high. In the meantime, the leading line of the road is consecutive, so in the road recognition algorithm adopted in this system, we use the above method to deal with nearby situation, for the distant road, we will directly find out the black line position within the left and right area of the preceding row's black line position. If we lost the black line, we would directly use the preceding row's black line position as this row's.

C. PID control algorithm

PID (Proportional Integral Differential) mainly consists of P, I, D. By using combined Computational Methods of these three we can find out the required controlled quantity. On the basis of the features and requirements of the objects, we can also use only PI or PD to cope with different situations. PID has become the most popular basic controller for its variable operating methods and upgrading.

The position type PID equation of the continuous control system is as equation 4, e (t) is the offset between the model car and the racing track black line.

$$X(t)=K_p[e(t)+\frac{1}{T_i}\int_0^t e(t)dt+T_d\frac{de(t)}{dt}]+X_0 \qquad (4)$$

X_0 is a benchmark adjusting, when the previous adjust signal are all zero, X (t) is X_0.In this equation, there are proportional, integral and differential, and by using all these values we can fulfill adjusting and controlling under different conditions.

Taking account of the computing power of the microprocessor, in order to simplify the process of calculation, we will use Enclosing Rectangle to replace the numerical integration, first order backward difference method to replace differential, what said popular point is Accumulation and integral, and using differential calculus for the difference between the antecedent and the consequent, the sampling period is T, and this is called increase type of algorithm. And the above equation would be simplified into equation 5

$$X(t)=K_p[e(t)+\frac{T}{T_i}\sum_{j=0}^{j=k}e_j+\frac{T_d}{T}(e_k-e_{k-1})]+X_0 \qquad (5)$$

According to equation 5, $X_k - X_{k-1}$ is

$$\Delta X_k=X_k-X_{k-1}=K_p[e_k-e_{k-1}+\frac{T}{T_i}e_k+\frac{T_d}{T}(e_k-2e_{k-1}+e_{k-2})] \qquad (6)$$

Apparently, in this equation, the input variables are the offsets within 2 T of the current time. With respect to the original equation, it reduced large amount of the data storage, in the whole process, it only needs three data storage space to fulfill the calculating requirement with little computation workload. Meanwhile, the increment of the calculating results ΔXk is the increase or decrease on the basis of the last moment controlling export, the variation is relatively continuous and stable.

D. Pulse width modulation

The most important controlling elements in the actual driving of the smart car are electromechanical rotate speed and the steering engine direction, through nonlinear mapping, the calculation result of the PID could convert to rotate speed and directional control information. In this system, through PWM modulation technique, we could control the steering engine direction, as in the following Figure 4, when outputting different duty cycle pulse, steering engine would turn to different angle, and then complete relevant direction shifting.

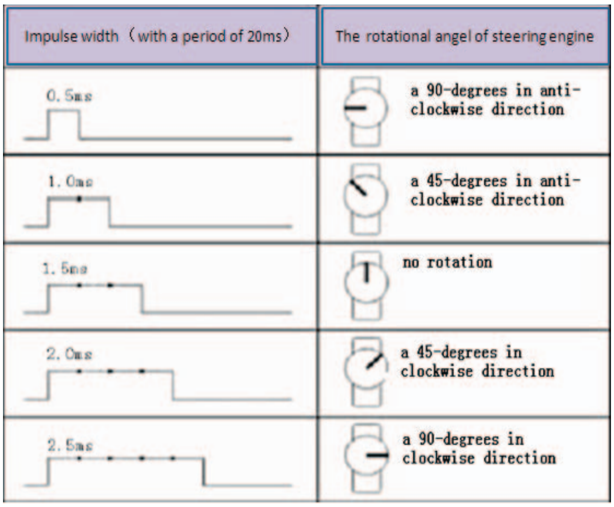

Figure 4 a demonstration of PWM

In the process of controlling rotate speed of the electric motor, the wider the pulse width, the quicker the rotate speed, the same principle as the steering engine control.

III. SYSTEM DESIGN AND REALIZATION

A. Overall framework design of the system

In terms of the outlook, we can find out that the smart car system designed in this paper, at first, after converted by external circuit the camera signal was inputted into the microprocessor, then, the microprocessor analyzed the video flowing into a series of road image frames, after that, we used the road recognition algorithm to acquire the road information, then used the PID algorithm to calculate the speed and steering parameters. Through the current amplification of the external currents we can control the electric motor and steering engine directly. On the other side, the testing device would feed back the real time actual car speed to PID; the framework design is as Figure 5.

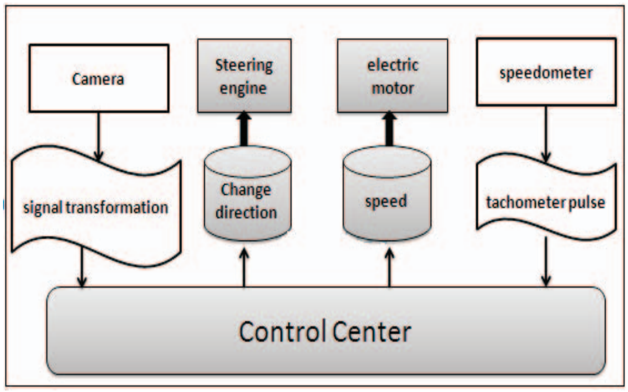

Figure 5 the input and output interface of the system

In reality, considering about the impact on camera from the sunlight, we added Splitter Plates on the top of the lens of the camera, it greatly reduced the impact on road image which brought about by reflection of light. During the design and practicing of the system, we pay more attention to the limits and gradation of the concrete software and hardware. Meanwhile, in order to debug and test, we introduced debugging module and auxiliary in-out module, which mainly used to set the parameter and feed back the real time result etc. As a whole, it could be abstracted to hardware, ports, algorithm, and system. Through the conceptualized design, it could not only reduce the error probability, but also good for the collaborative development of the system, the specific conceptualized design is as Figure 6.

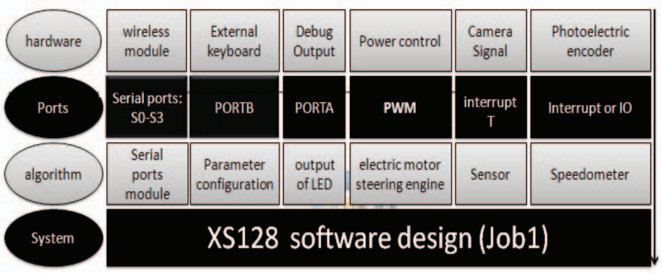

Figure. 4 hierarchical architecture of system

Moreover, the above framework is suitable for ordinary smart car system, which use photoelectric sensor to replace camera sensor, the design of the system still apply to. Besides, when the hardware function is weak, we can use software of the microprocessor to make up. As for the steering controlling, mechanical differential also plays an important role.

B. System implementation

From all the aspects, we can figure out that the software controlling system of the smart car plays an important role, especially for controlling of the speed and steering engine sheering off. Through the interrupt horizontal and vertical signal, the software system acquires the image, and then uses the road recognition algorithm to figure out the leading line position in the image. Through the PID algorithm, we can convert the information to speed and steering control information. In this system, control cycle of the PID algorithm is 10ms, while the overall design flow chart of the software is as Figure 7.

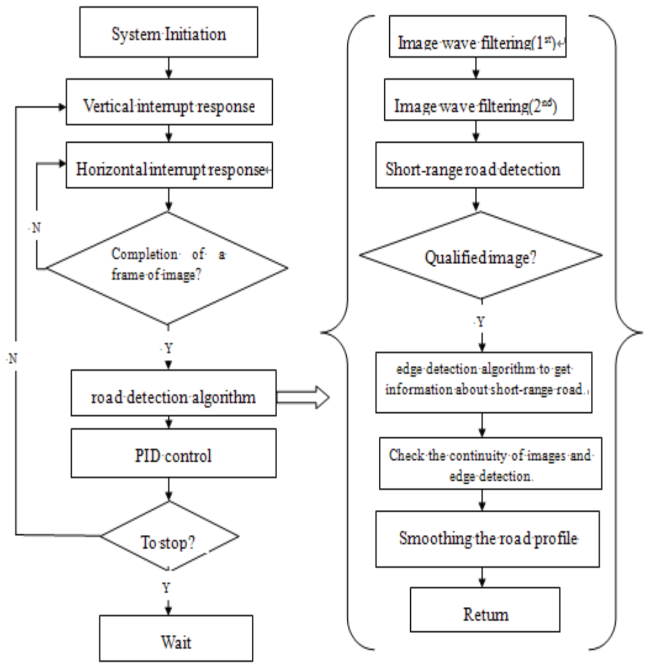

Figure 7 flow chart of software system

IV. RESULT ANALYSIS

Tests of the system should be carried out in the following hardware environment: Freescale MC9S12XS128 as its master chip, the microprocessor contains 16 M Crystal Oscillator, and through the phase locked loop circuit, by using frequency doubling method, it would be 64 M, This microprocessor could all together support 128 interrupts, in this system we totally used camera horizontal and vertical interrupt(PT0、PT1), velocity measurement interrupt(No.17), chronograph interrupt(No.16) etc. In addition, we used 7.2V rechargeable batteries as its power source, so there also exists Power Management Circuits, with 5V、7.2V、12V power source respectively supply power for microprocessor, electrical motor, camera etc.

Steering engine installation of the test system should adopt asymmetrical mode, for it's more convenient for controlling, for the sake of debugging, we put the ZigBee Wireless Module on the car, and the Experimental car after assembling is as Figure 8.

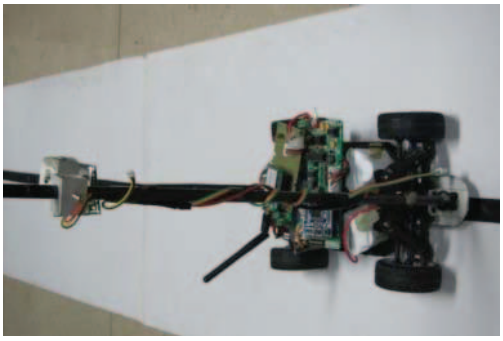

Figure 8 smart car

After Experiment measuring, on various types of roads (big S road, small S road, straightaway, rampway, crosswire and ringlets), the average speed could achieve 1.5m/s and maintains stable operation, the car comprehensively possesses great robustness and stability.

V. CONCLUSION

In this paper we designed a smart car system which could acquire real time road information through camera, and extract road position by road recognition algorithm, and then through PID to achieve speed and steering control. By introduced splitter on camera, we effectively avoided the impact from the reflect light on camera, meanwhile, the framework of the system would be easily expanded, and this is good for various types of sensors to work together, it also supplied certain experimental evidences and supports for pilotless driving and Intelligent obstacle avoidance. After actual testing, we found that this system possesses great robustness and has a bright research and development prospects.

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