Intelligent trajectory tracking vehicle based on image sensors

Maoyue Li[1, a], Jiabin Sun[1,b], Lijun Song[1,c], Yue Chen[1,d] and Heng Sun[1,e]

[1]School of Mechanical and Power Engineering, Harbin University of Science and Technology, Harbin 150080, China

[a]lmynjfu@sina.com, [b]1043414046@qq.com, [c]1970300528@qq.com, [d]827394179@qq.com, [e]1205666300@qq.com

Keywords: Intelligent vehicle; camera; Bluetooth module; trajectory tracking

Abstract. In this paper, an intelligent trajectory tracking car is designed and an intelligent control system based on Freescale K60 is proposed. CMOS camera Ov7725 is used as the main sensor, and the Bluetooth module is used to implement the communication between the front car and the rear car in real time. The experimental front car is equipped with Bluetooth signal transmitter, which could send its steering and velocity information to the rear one, and then the rear car will use its own camera collecting midline location and distance information of the car in front through camera binaryzation and process received Bluetooth signal with corresponding reaction, so as to achieve the purpose of trajectory tracking.

Introduction

With the development of artificial intelligence and computer technology, it has already been applied to the control technology of automobile industry, and unmanned vehicle is one of the main goals of the next generation of automobile technology. In simple terms unmanned driving is to use camera, ultrasonic and other sensors to reflect road traffic information to the processor, the processor comprehensively processes these information and controls the vehicle movement. Intelligent tracking is a part of the unmanned driving contents. At present, most of the intelligent tracking only can implement the target tracking rather than the tracking of target movement trajectory. Trajectory tracking is more accurate than the target tracking.

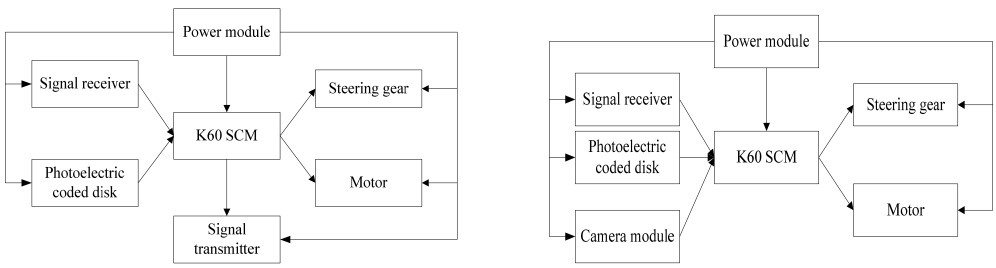
System structure of intelligent vehicle

There are two experimental vehicles, divided into the front and the rear one.

Hardware control system structure of front car

Fig. 1(a) is the front car hardware control system structure, in this system, this car is as tracked one, controlled randomly with controller by laboratory staff. The car consists of a K60 microcontroller, signal receiver, power module, steering gear and motor drive components (the parts of rear car is same as this).

Working principle: the remote control signal is received by the receiver to transfer to K60 Single Chip Microcomputer (SCM), the microcontroller transmits signal to the servo motor after the processing and analyzing, driving servo to make the rear reaction. At the same time, its own speed and steering signal through the signal transmitter is sent out. For the convenience of car identification in the camera, made a pure black shell for the front car, and draw the white mark.



(a) (b)

Fig. 1 Hardware control system structure of the front car and rear car

© 2016. The authors - Published by Atlantis Press

Hardware control system structure of the rear car

Fig. 1(b) is hardware control system structure of the rear car, as a tracking car, its purpose is to track the car before it, which is consisted of K60 core board, camera sensor, power module, photoelectric encoder, Bluetooth module, motor drive, steering gear and so on. Its work flow is through the Bluetooth module to receive the front car's speed and steering signal send by signal transmitter, and through the camera to collect the midline location information of tail of the front car to fine tune on the direction of the car.

(1) K60 core board

The CPU frequency is 100MHz, kernel for ARM CortexM4, has 32 DMA channels for data transmission with peripherals. It has the advantages of low cost, low power consumption, fast interrupt response, high processing efficiency, especially suitable for real-time control system. Intelligent vehicle control is high real-time, while image acquisition and processing require the controller has strong operation ability. In addition, K60 is rich in internal resources that be beneficial to smart car function expansion and system debugging, so choose K60 as a controller[1].

(2) Power module

The total power supply for intelligent vehicle system is from 7.2V nickel cadmium battery, but the smallest single-chip system, and some chips need 5V power supply, the servo motor operating voltage range from 4V to 6V, CMOS camera applies 5V power supply, drive circuit need 5V power supply, DC motor needs 7.2V battery powered directly.

(3) Photoelectric encoder

The photoelectric encoder is a rotary position sensor, which is widely used in the modern servo system to measure the angular displacement or angular velocity. Its rotating shaft is usually connected with the rotating shaft to be measured. The angular displacement of the measured shaft can be converted into a series of impulse.

The system uses the OMRON E6A2-CW3C encoder. This encoder is 200 line of the incremental encoder, each rotation to generate 200 pulses. Through detecting pulse in a certain number of time, the speed of the car can be calculated after conversion.

(4) Bluetooth module

HC-05 embedded Bluetooth serial communication module (referred to as module) has two working modes: command response mode and automatic connection mode, and it can be divided into three kinds of roles as Master, slave and loopback. The module in automatic connection mode will automatically transmit data according to pre-set; the module in command response mode can perform all of the following AT commands. The user can send a variety of AT commands to the module, set control parameters for the module or release control commands. By controlling the input level of external pins (PIO11) of the control module, the dynamic conversion of the working state of the module can be realized[2].

(5) Ov7725 camera

Ov7725 camera can quickly collect images and get hardware binaryzation. It uses RTL level circuit to collect images and data and carry on binary processing for images, in this way 8 data lines collect a byte signal each time during which each line represents each point of the image, 0 represents bright, 1 represents dark and a byte represents 8 pixels, rather than traditional products that each byte just represents gray level of a pixel. So the transmission capacity is reduced and the workload of main controller is released, thus drastically increasing the collecting speed. At the same time, due to reducing the amount of data, it also decreases the algorithm complexity of the controller and plays a certain role in promoting efficiency of the algorithm[3].

Target recognition

This system mainly researches on a single target recognition, namely recognizing and tracking specific objects under ideal undisturbed environment due to the external environment is relatively ideal. the front vehicle is specially processed by coating so that rear vehicle can recognize the former one more easily. Experimental vehicle uses camera binarization to implement the images binarization processing. So the color inside the reference threshold is regarded as 0 and the color outside the reference threshold is regarded as 1 as shown in as equation (1) and (2).

$$a_{i,j} = \begin{cases} 1, a < Threshold \\ 0, a > Threshold \end{cases} \tag{1}$$

Where $a_{i,j}$ represents the pixels color information in the i th row and j th column of the image data matrix, Threshold represents the image thresholds set.

$$D = \begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{pmatrix} \tag{2}$$

By processing each pixel in the image data matrix D, the image with a variety of color information is transformed into a binary image with only two kinds of color. When the software implements the binarization processing of image data, even if the resolution is below 80 * 60, MCU still needs to deal with 4 800 pixel points, which will occupy a vast resources and reduce the overall system's real-time performance for the micro controller with weaker operation ability. This problem is solved by choosing the camera YUV format among all the camera formats and collected images. Choosing camera YUV data format is more conducive to the binarization processing and digital camera Ov7725 supports the output of YUV format. The binarization processing can be implemented through using the Y data in which the real-time image recognition is also improved. And gray-level data is further processed, namely carrying out logical calculations like AND, OR, NOT or the binarization processing for some bits of the gray data, then the calculation results are inputted to I/O port of the microcontroller significantly shortening the software processing time[4].

Target tracking

(1) Mechanical part design

In the vehicle control scheme, the front wheel is used to steer while the rear wheel is used to drive. The tread in the experimental vehicle is 175mm and wheel base is 200mm. The physical photo of the experimental vehicle is shown as Fig. 2.

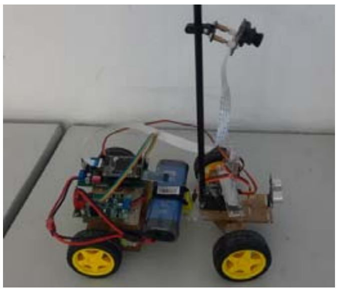


Fig. 2 Structure of behind vehicle

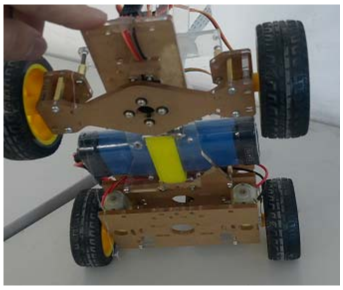


Fig. 3 Steering structure of experimental vehicle

(2) Choosing the way of steering

The experimental vehicle uses steering gear to carry on the implement of steering. The front wheel and its wheel shaft are mounted on the steering wheel. The steering angle of the steering gear is the angle between the axle and the vehicle midline. The steering gear installation is shown as Fig. 3.

Experimental preceding vehicle is equipped with Bluetooth signal transmitter and it can send the steering information and velocity information to the following vehicle using the Bluetooth functions. And the rear car will make corresponding reaction after analyzing the tail information of preceding vehicle captured by camera and Bluetooth signal received, so the goal of tracking trajectory can be achieved.

1) SCM's processing of the camera information received

The K60 SCM's treating process of the tail information of preceding vehicle captured by camera is shown as follow. Set the center point of each frame of image as the starting point (X_0, Y_0), target point as coordinates $(X\ ,Y\ )$, set the range of $(X_0 \pm \Delta X, Y_0 \pm \Delta Y)$ as a safe range. When the target is shown in this range, it is viewed that the vehicle runs properly and react nothing toward the information from the camera. When the target is located over the safe range, it is viewed that the target is lost and the vehicle will stop moving. When the target is located under the safe range, it is tacitly approved that these two vehicles are too close and the vehicle will stop moving. When it located in the left of safe range, it is believed that the rear car deviates from the route to the right and steering rudder should turn left. When it located in the right of the safe range, it is believed that the rear car deviates from the route to the left and steering rudder should turn right[5].

The tail information of preceding vehicle captured by camera is mainly used to control the accuracy of the travel route of the following vehicle having nothing to do with the speed of the vehicle. So the position that the target is located in the image captured by camera has no corresponding relationship with motor control.

2) SCM's processing of the Bluetooth information received

When the SCM only receives the speed signal from the Bluetooth, it controls the vehicle to run at the same speed. When the SCM only receives steering gear information of the front car, the rear vehicle reacts nothing. When the SCM only receives both the speed signal from the Bluetooth and steering gear information of the front vehicle, it will analyze the image information from the camera to determine the distance between the two vehicles, divide by the current speed, get the time t and then delay time t to execute the steering information received.

Table 1 Response of the steering gear and the signals received

Bluetooth signal	Speed signal	Rudder signal	Speed and rudder
Steering gear	No response	No response	Driven
Motor	Driven	No response	Driven

3) Integrated control of camera information and Bluetooth information

Table 2 Response of steering engine toward information of camera and Bluetooth

Image / signal	Target point in safe range	Above the safe range	Below the safe range	Left of safe range	Right of safe range
Speed signal	No response	No response	No response	Image processing	Image processing
Rudder signal	Bluetooth processing	No response	No response	No response	No response
Speed and rudder	Bluetooth processing	No response	No response	Bluetooth processing	Bluetooth processing

Table 3 Response of the motor toward information of the camera and Bluetooth

Image / signal	Target point in safe range	Above the safe range	Below the safe range	Left of safe range	Right of safe range
Speed signal	Bluetooth processing	No response	No response	Bluetooth processing	Bluetooth processing
Rudder signal	No response	No response	No response	No response	No response
Speed and rudder	Bluetooth processing	No response	No response	Bluetooth processing	Bluetooth processing

In accordance with the requirements of the system function, the main program consists of camera image acquisition, Bluetooth signal sending and receiving and reaction of steering gear and motor toward video signals and Bluetooth signal received. The detailed application process is shown in Fig. 4.

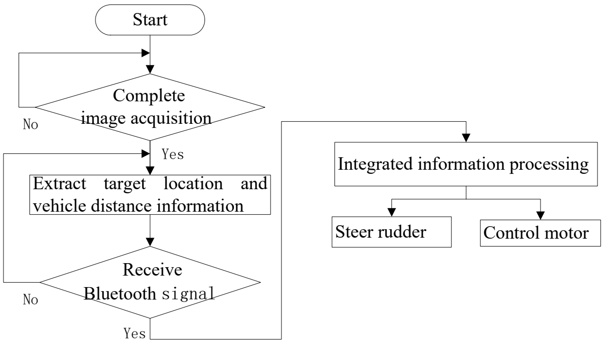


Fig. 4 Main program flow chart of rear vehicle

Conclusion

In this paper the trajectory tracking of intelligent vehicle system based on K60 is proposed. Using Bluetooth communication technology realizes the information transference from the front vehicle to the following one. the rear vehicle will achieve real-time tracking after comprehensively processing the tail information of preceding vehicle captured by Ov7725 camera sensor. The tracking methods mentioned in this paper emphasize on the tracking of the trajectory rather than the simple target tracking. This design can be used in large transport fleets, the team's guide car serves as preceding car and other cars act as the rear cars, so autopilot can be achieved in a certain extent.

Acknowledgement

In this paper, the research was sponsored by the College Students' Innovative Experiment Foundation of Harbin University of Science and Technology.

References

[1] Yu Shaodong, Huang Danping, Tian Jianping, Hu Yong. Design of intelligent vehicle control system based on K60 Kinetis [J]. Journal of Sichuan University of Science and Engineering (Natural Science Edition). 2014，27(5): 37-42.

[2] Yang Li, Kim Sui, Zhang Yan. Freescale cup smart car design and examples of tutorials [M]. Beijing: Electronic Industry Press, 2014.

[3] Wu Zhenhao, Zhang Ping, Zhang. Image acquisition and verification system based on OV7725 and serial port [J]. information technology.2015,10: 90-96.

[4] Liu Zuchen. Hardware binaryzation based on CMOS digital camera [J]. Electronic Science and technology.2014,27 (7):99-102.

[5] Gao Yunbo, Ji Cong, Han Peng Wu. Design of intelligent vehicle system based on camera recognition path [J]. Journal of Lanzhou University of Technology.2013,39 (6): 97-102.