A Safe Driving Monitoring System Based on Internet of Things Technology

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Abstract： The system adopts Raspberry Pi 4B, and the sensors include modules such as smoke sensor, heart rate sensor, GPS positioning sensor, etc. Raspberry pie, as the main control module of the system, has functions such as data collection, information output, and control. This system can be widely applied to different vehicle models, such as trucks, trucks, sedans, etc. After the system is started, each sensor detects environmental parameters and processes the data through data fusion algorithms. The processing results are sent to the main controller and Raspberry Dispatch Supervisor to process and judge the sensor parameters. If it is in a dangerous state, Raspberry Dispatch will alarm. In response to human fatigue, the system uses OpenCV for facial recognition and closed eye detection, uses cameras to obtain the required detection data, comprehensively analyzes the driver's eye movements, mouth shape, and head posture features, and makes fatigue judgments. The main advantage of this system is that it can achieve real-time monitoring and alarm of some potentially dangerous driving behaviors through machine intervention, nip traffic accidents in the bud as much as possible and ensure the safety of people and vehicles.

Keywords: Raspberry Pi, safe driving monitoring, OpenCV

1 Introduction

With the development of social productivity, social wealth is increasing rapidly, and the number of cars is also increasing. Cars are becoming a standard feature of every family, so road safety has become one of the social issues that people pay close attention to [1]. The main purpose of a safe driving monitoring system is to reduce the occurrence of safety accidents caused by human factors. To solve the problem of traffic accidents caused by driver fatigue or vehicle emergencies during driving, a safe driving monitoring system based on Raspberry Pi is proposed. The solution adopts steering wheel pressure monitoring, heart rate monitoring system, human driving state facial recognition system, intelligent voice assistant, alarm processing module and cloud platform, etc. When the system detects that the driver is fatigued, the system can issue an early warning signal, thereby minimizing the probability of safety accidents caused by fatigue driving or vehicle emergencies. The significance of an artificial intelligence system is to assist people in reducing the intervention of human factors in their daily production and life to the greatest possible. In addition, an artificial intelligence system does not need to rest and has no fatigue, so it can reduce the occurrence of accidents caused by long-term work.

2 Related technology research

2.1 OpenCV Face Recognition

The main algorithm learning method of OpenCV is to first take a photo of a person's face for learning, enter the database, collect data to create a training set, and the diversity of data ensures the accuracy of model training. In terms of driver behavior monitoring, the OpenCV open-source computer vision library is used. As a popular computer vision library, information is entered into the information database after collection and a serial number is entered when entering. One serial number represents face information, and each face information is 30 photos [2]. Figure 2.1 is a flowchart of the face recognition module.

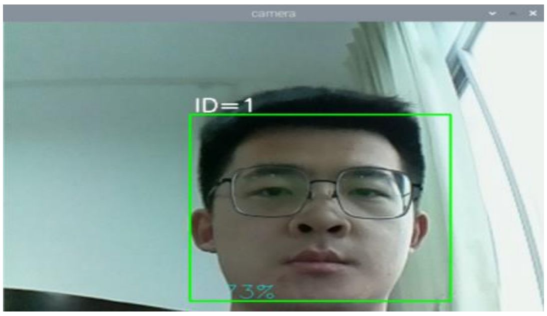

Figure 2.1 Face recognition module program flowchart

During the recognition process, OpenCV recognizes facial information through the camera, reads and writes video streams, loops out image frames, initializes the face detector HOG, creates facial landmark calibration based on the facial features of different people, introduces the face detection tools dlib.get_frontal_face_detector and dlib.shape_predictor in the database to build a face position detector, and obtains the 68-bit key point information of the face. Figure 2.2 shows the calibrated face key point information.

Figure 2.2 68-bit key point information of a face

After image acquisition, the acquired images are expanded frame by frame. After recognition and shooting, the photos are grayscale photos. Grayscale transformation is also called image point operation (only for a certain pixel point of the image). It is the simplest technology among all image processing technologies. The purpose is to eliminate the interference of some external factors. Then detector (gray, 0) is used to detect the position of the face, and predictor (gray, 0) is used to obtain the position information of the key points of the face, where gray is the representation method of the grayscale image. The acquired information will be processed into an array format.

2.2 Bad driving behavior recognition algorithm

For blinking while driving, OpenCV can also track the opening and closing of eyes through analysis and positioning. It can take photos of the driver through the camera and compare them with the database. If the eyes are closed, the buzzer will sound like an alarm.

After confirming that it is bad driving behavior, the corresponding behavior warning reminder will be started. When the system updates and obtains the driver's behavior again, if it is still not corrected, a serious warning will be issued, and the warning light will flash. The dlib face recognition feature point detection is grayed out by OpenCV, detecting the position of the human eye and judging whether the length/width is greater than the threshold [3]. Figure 2.3 is the flowchart of the eye closure detection module.

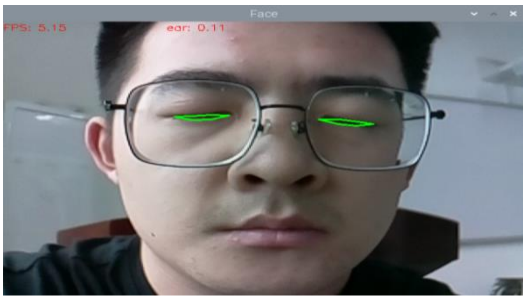

Figure 2.3 Block diagram of eye closure detection module

The EAR algorithm is an algorithm proposed in 2016 for detecting blinking frequency [4]. The algorithm aims to determine whether a person's eyes are open or closed by measuring the coordinates of the eyes in machine learning. Under normal circumstances, a person blinks 15 to 20 times in 1 minute. In the process of testing the opening and closing of the eyes, the length ratio of the left and right eyes is calculated respectively, and the average value is obtained. The final value is the EAR value.

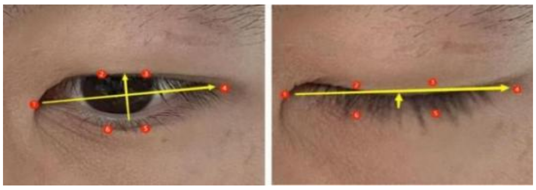

Figure 2.2 EAR algorithm diagram

The EAR calculation formula is as follows：

$$EAR = \frac{\| P_2 - P_6 \| + \| P_3 - P_5 \|}{2 \| P_1 - P_4 \|} \qquad (1)$$

The aspect ratio is used to measure whether the eyes blink; P1, P2, P3, P4, P5, and P6 are the key point coordinates of the human eye, and ||P2-P6|| represents the Euclidean distance between two key points. The same is true for the rest. Under normal circumstances, people close their eyes for a short period of time, but when they are tired, the opening and closing rate of their eyelids will be greatly reduced. Therefore, if the EAR set within a period fails to reach a certain value or the value is lower than the set threshold for a long time, it is judged as fatigue driving. The eye closing threshold set in this system is 0.21, that is, when the opening and closing degree of the human eye drops below 0.21, the system automatically alarms.

Similarly, after the driver enters the fatigue driving state, the behavioral characteristics shown are not only the degree of opening and closing of the eyes. This paper uses the key points of the mouth to calculate the length-width ratio MAR value of the mouth to determine whether the driver yawns or other behavioral characteristics that indicate the driver has entered a fatigue state

The MAR calculation formula is as follows:

$$\mathrm{MAR} = \frac{\| M_2 - M_6 \| + \| M_3 - M_5 \|}{2 \| M_1 - M_4 \|} \qquad (2)$$

Under normal circumstances, the mouth opening behavior occurs for a short time, and more time is spent in the mouth opening time. The mouth opening situation is judged based on the change in the MAR value. By recording the MAR value within the specified time, if it is less than the threshold value three times in a row, it is determined that the human body is in a fatigue driving state. In addition, since people may open their mouths in other situations while driving, multiple machine learning operations are required to distinguish different behaviors such as yawning, singing, and talking before this model is put into formal operation

.3 Design of driver fatigue monitoring system

3.1 System design architecture

The overall system is mainly composed of the following parts: sensors, Raspberry Pi mainboard, drive motors, camera cloud platform, etc. The system mainboard uses a development board based on Raspberry Pi, and the hardware part can be controlled and data collected through the regulation of Raspberry Pi; the software part is written in Python language, and each sensor is first independently run using targeted codes, and then the sub-functions of each sensor are called through the main function for linkage control.

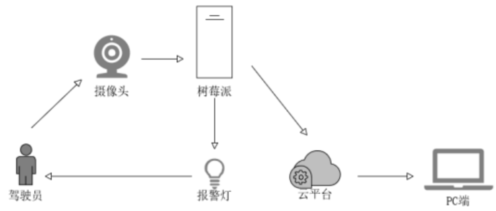

Figure 3.1 System architecture

The driver fatigue driving detection system mainly has two information collection modules for portrait collection: one is facing recognition technology, which uses the dib algorithm; the other is human eye closure degree monitoring, which uses EAR blink detection technology. The data collected from the sensor and the face information will be uploaded to the information terminal through the database.

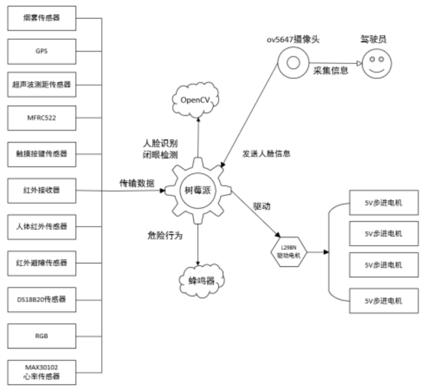

Figure 3.2 Relationship framework diagram of each sensor in the system

3.2 System hardware module design

3.2.1 Raspberry Pi

The fourth-generation product Raspberry Pi 4B, which was recently released, is used. The advantage of Raspberry Pi over STM is that STM uses MCU, while Raspberry Pi uses MPU. MPU is suitable for large programs that require complex calculations, which generally require external RAM and ROM, while MCU is suitable for small and medium-sized programs with relatively simple calculations, which are generally used for hardware management and control. Generally, external RAM and ROM are not required, and they are all integrated inside the chip. For this system, OpenCV and some sensor modules with complex functions are required. The performance of STM may not meet the design requirements, so Raspberry Pi is selected as the main control chip. On another level, Raspberry Pi has good expansion functions and can be well compatible with Camera V2 camera module. The OV5647 camera module is used in this system, and a 15-core cable is directly connected to the CSI interface dedicated to the Raspberry Pi 4B control system, which can effectively improve the system integration.

Raspberry Pi has stronger human-computer interaction capabilities than STM, and the most needed thing for the safe driving monitoring system based on the Internet of Things is human-computer interaction, so Raspberry Pi is better.

Figure 3.3 Raspberry Pi physical picture

3.2.2 OpenCV face acquisition module

The camera simulates the shooting of the driver's driving status and uploads it to the dataset library of the Raspberry Pi. The Raspberry Pi uses OpenCV to process the facial information by calling the facial information in the database. If it is determined to be the driver, it will run normally. If it is not, an alarm will be issued. During the operation of the vehicle, the person's eyes are closed continuously. If the characteristics that meet the judgment that the driver is fatigued driving occur during driving, an alarm will be issued. In addition, the camera module can simulate the driving recorder to realize single shooting, timed continuous shooting, video recording and other functions.

3.2.3 Driver module

This system uses L298N to drive four stepper motors. The two modules at both ends are responsible for controlling the rotation of the motors. The four pins are connected to the Raspberry Pi to transmit control signals, and the three interfaces on the front are responsible for powering the motors.

3.2.4 In-vehicle safety monitoring module

The in-vehicle safety monitoring module mainly uses smoke sensors, MAX30102, touch button sensors and intelligent temperature control systems. The main function of the smoke sensor module in this design is to monitor the indoor alcohol concentration, with the purpose of detecting whether the driver is drunk driving.

MAX30102 is an integrated pulse oximeter and heart rate monitor biosensor module. The purpose is to monitor the driver's sudden heart disease during driving, and an alarm will be issued if the heart rate is abnormal. This module uses a 1.8V power supply and an independent 5.0V power supply for the internal LED.

The touch button sensor module is used to monitor whether the driver's hands are off the steering wheel. It works based on TTP. Under normal circumstances, the module outputs "LOW" and maintains a low power state. This module is loaded on the steering wheel. If the driver's hands are off the steering wheel for a long time, the trigger condition is met, and an alarm is issued.

The intelligent temperature control system consists of the following functional modules: PS2 joystick, ds18b20 temperature sensor. The joystick is an input device consisting of a joystick that can rotate on a base and report its angle or direction to the device it controls.

The ds18b20 temperature sensor has the advantages of miniaturization, low power consumption, high performance, strong anti-interference ability, and easy matching with a microprocessor. It can directly convert temperature into digital signal processor processing.

3.2.5 External safety monitoring module

The external safety monitoring module uses detection sensors such as GPS positioning sensors, ultrasonic distance sensors, infrared obstacle avoidance sensors, and human infrared sensor.

The core of the ultrasonic distance sensor is two sensors, one of which is used as a transmitter to convert the electrical signal into a pulse signal with a frequency of 40kHz: the other is used as a receiver to monitor the transmitted pulse. In this system, three simulated distances are set: 0-5cm, 5-10cm, and 10cm away. In the first distance, the RGB light color is set to red; in the second distance, the RGB light is set to blue; in the third distance, the RGB light is set to green.

The infrared obstacle avoidance sensor is a module for identifying obstacles. It has a pair of transmitters and receivers. During operation, this sensor can automatically identify obstacles and achieve autonomous cruising.

The human infrared sensor is to monitor some pedestrians who may appear around the vehicle before the vehicle is started, and these people are in the driver's blind spot. Its basic principle is to detect infrared rays emitted by humans or animals and gather them on the infrared sensing source after being enhanced by a Fresnel filter and convert the sensed infrared signal into an electrical signal.

3.2.6 System monitoring module functions

(1) The smoke sensor can detect the gas in the car. If the driver drinks, an alarm will be sounded; if the carbon monoxide concentration in the car is too high, an alarm will be sounded.

(2) The GPS positioning system realizes real-time positioning and monitoring of the vehicle.

(3) The ultrasonic ranging sensor monitors the distance between the vehicle and the vehicle in front. If the distance reaches a dangerous distance, an alarm will be sounded.

(4) MFRC522 replaces the car key and performs human information recognition.

(5) The touch button sensor monitors whether the driver has his hands off the steering wheel for a long time. If so, an alarm will be sounded.

(6) The infrared receiving sensor receives the remote-control signal and controls the operation of the car.

(7) The human infrared sensor monitors whether there are pedestrians around the vehicle before starting.

(8) The infrared obstacle avoidance sensor simulates the automotive ultrasonic radar and plays a role in ranging and obstacle avoidance.

(9) The ds18b20 temperature sensor monitors the temperature in the car.

(10) The RGB light is the signal output display of other sensors.

(11) The MAX30102 heart rate sensor is mounted on the steering wheel to monitor the driver's heart rate status in real time.

4 System software module design

4.1 Schematic

When designing the overall circuit diagram, it is necessary to build the overall functional framework, including the overall architecture of the logic design system. The overall circuit diagram of the car's main control module is shown in Figure 4.1.

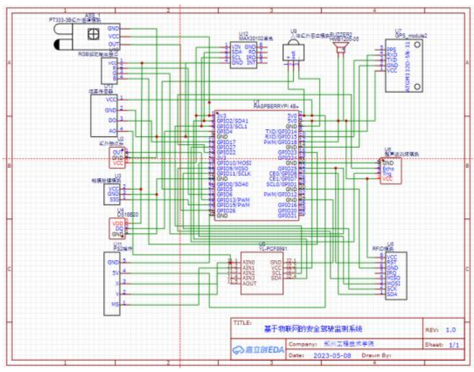

Figure 4.1 Overall circuit diagram of the car's main control module

4.2 System software subroutines

The car simulates the real driving environment. In the system, connecting the power supply means starting the car. The monitoring function modules in the real environment represented by each module are shown in Figure 4.2:

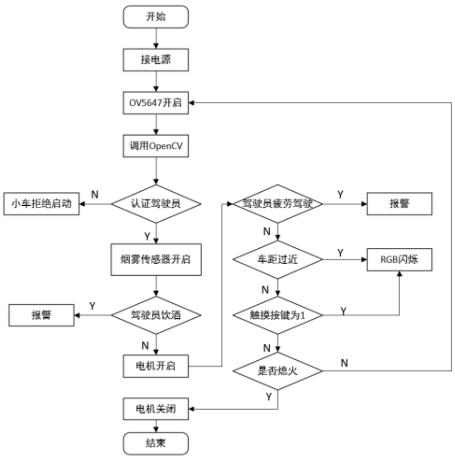

Figure 4.2 System subroutine overall flow chart

5 Experimental results and analysis

By testing each module, it is found that the system responds quickly, the overall operation is reliable, the expected design goals are achieved, and the design requirements are fully met. The test is successful. This experiment selects some sensors for data testing. The actual picture of the car is shown in Figure 5.1.

Figure 5.1 Actual picture of the car

5.1 Experimental procedures

The PC experimental environment of this experiment is based on the Win11 operating system, the Raspberry Pi is based on the Linux operating system, and the software environment is Python 3.8, dlib 19.24.0, OpenCV-python 4.7.0.68.

5.1.1 Experimental environment configuration

When configuring the Raspberry Pi, you need to pay attention to whether the Python version installed on the Raspberry Pi is consistent with the version number of OpenCV. If they are inconsistent, an error alarm will occur when calling the camera and the data packet related to cv2 cannot be found. In addition, when configuring the infrared remote control, you need to download the environment that enables the normal operation of the infrared remote control in advance, especially the installation of python-lirc requires the configuration of cython, gcc, liblircclient-dev, python{,3}-{dev, setuptools}. If cython cannot be installed, you can try cython3. When configuring the infrared button function, you need to pay special attention to the need to create a new lircrc file in the lirc package, and the built-in irexe.lircrc needs to be deleted.

In the latest Raspberry Pi 4B, the old version of the image is no longer available, and the latest is bulleye. Therefore, when setting the image, Alibaba Cloud cannot support the latest github download, so the domestic Tsinghua source is replaced, and when connecting to github, the IP address related to Raspberry Pi needs to be queried and entered into the source. When downloading the lirc library, the official guidance version is /liblirc0_0.10.1-5.2_armhf.deb ./liblircclient0_0.10.1-5.2_armhf.deb ./lirc_0.10.1-5.2_armhf.deb, but the latest version has been updated to 6.3. At the same time, it should be noted that the lirc downloaded in different python versions is also different, and it is necessary to check whether it is python3 or python2. Finally, the python-pylirc library needs to execute the pip3 command and enter the command pip3 list to check whether it has been entered into the library. Only when it is displayed, it can be called. In addition, it should be noted that in the main function, the library that needs to be imported is lirc instead of pylirc;

When configuring OpenCV, it is necessary to pay attention to whether the resolution size of the camera is appropriate. The video size in this system is as follows:

```
cap = cv2.VideoCapture(0)
cap.set(3, 640) # set video widht
cap.set(4, 480) # set video height
```

All OpenCV dependency packages and the main function must be placed in the same path, and the dependency packages must be clearly written in the code that calls OpenCV, so that the functions in haarcascades can be called. It is worth noting that the new version of OpenCV has a stronger dependence on Cmake. Therefore, if an error instruction related to Cmake cannot be found during the configuration process, it is necessary to check whether the version numbers of Cmake, OpenCV and python match.

(1) The permission change instruction for Raspberry Pi needs to run sudo chmod 777 ~/ in Terminal. This command means to open the file or folder permissions. In addition, it should be noted that the version of Raspberry Pi is constantly updated. It is not possible to download it normally using apt-get in the newer library. Therefore, a more powerful download tool aptitude is needed at this time, which can solve most download problems.

5.2 System Test

This experiment is divided into OpenCV face recognition module and sensor sensitivity test module. The OpenCV module collected a total of 5018 sets of data, which classified people by characteristics, such as whether they wear glasses; whether they are male; whether they have double eyelids; whether they have long hair; whether they have big eyes; skin color depth, etc.

For the fatigue driving detection module, the focus is on classifying the size of the eyes and whether they wear glasses. 508 sets of data were collected respectively, and the test participants were required to drive continuously for one hour in a real driving environment to determine their fatigue level. Figure 5.2 is the test program diagram of the OpenCV closed eyes detection module.

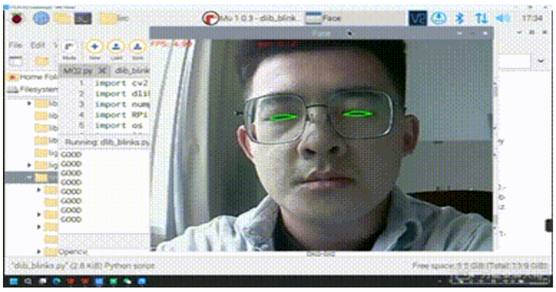

Figure 5.2 OpenCV closed eye detection module test program diagram

During the test, we first need to collect facial information. The camera takes 30 simulated driver's facial information and puts it into the dataset database. After each facial information entry, we need to train and learn the facial information. When the facial information is called, the system automatically extracts information from the database and automatically recognizes it.

The face recognition module displays the identity information and similarity percentage of the person, and the eye closure detection module displays the degree of eye opening and closing in the form of EAR values. During the test, the data displayed by OpenCV is extracted to obtain the EAR eye closure detection data as shown in Figure 5.3.

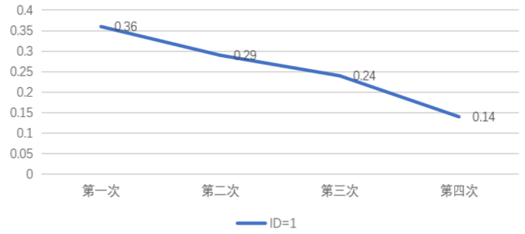

Figure 5.3 EAR closed eyes detection data

The test of the ultrasonic module selected five different distances. At different distances, the RGB light flashed different colors to give an alarm. During the test, three distances were selected, namely 0-5cm, 5-10cm, and 10cm away, to collect different signal feedback.

During the test, alcohol spray was used to simulate drunk driving. The experiment selected different concentrations of alcohol for data testing.

The monitoring of the heart rate sensor is to collect data by measuring the pulse data of the fingertips of the person. The experimental results are displayed in the form of a heart rate graph. The experimental data is shown in Figure 5.4.

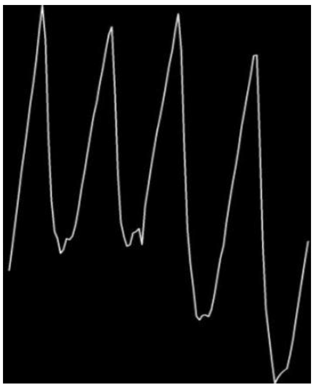

Figure 5.4 Heart rate data display

Use daily objects to simulate obstacles on the road. The infrared sensor test is carried out in a simulated scene in the laboratory, and real objects in daily life are selected for simulation.

To meet the needs of some drivers to warm up the car remotely, an intelligent temperature control system is added. Users can control the temperature threshold through the PS2 joystick. If it exceeds the upper limit, a red light will be displayed; if it is lower than the lower limit, a blue light will be displayed; and if it is within the threshold, a green light will be displayed.

The test of the GPS module is carried out by selecting different locations with an interval of more than 100m in an open outdoor scene. After obtaining the coordinates, enter the Baidu coordinate picking system to display the specific location of the coordinates on the map.

6 Conclusion

This design scheme has only been simulated and tested in the laboratory. At this stage, there has been a breakthrough in the assisted driving installed on the vehicle compared to ten years ago, but there is still a lot of technical research space in the interaction between people and vehicles. Today, when cars have entered thousands of households, the application of driving safety monitoring technology is urgent. The driving system installed on traditional cars can only help the driver to control the car and intervene in driving in emergency situations to reduce the incidence of accidents. However, the current driving environment and road conditions require a monitoring system that can remind the driver to return to normal driving status. Therefore, this article is based on the driver's daily driving behavior. Designed a safe driving monitoring system based on Raspberry Pi, combined with sensors and OpenCV to adjust the driver's status. Research is conducted on whether the hands are off the steering wheel for a long time, whether the seat belt is worn, whether smoking during driving, whether the eyes are closed for a long time, and whether the heart rate is too fast. The system is also humanized. Family members can also remotely monitor the driver's driving status and remind them through the terminal. This system not only improves the driving safety factor of drivers and passengers, but also standardizes the driver's driving behavior, reduces the workload of traffic police for daily monitoring, and reduces the incidence of road traffic accidents while ensuring normal driving.

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