ISSN: 2688-8645

Design of a Vehicle Fatigue Driving Detection System Based on Multiple Signals

Yujie Huang, Fengrong Zhang, Shicheng Xu, Wei Wu, Min Gao*, Zhijun Kang and Hao Liu

Faculty of Applied Technology, Huaiyin Institute of Technology, Huaian 223001, China

*67514611@qq.com

Abstract

In recent years, traffic accidents have occurred frequently, and most of them are related to the level of fatigue of drivers. In order to avoid the dangers of fatigue driving, this article judges whether the driver is in a fatigued state by analyzing the changes in pressure, angle, and distance during driving, so as to remind the driver to reduce the probability of accidents. In terms of hardware, we use the AT89C51 microcontroller as the main control unit, and configure infrared sensors, ultrasonic sensors, angular velocity sensors, and pressure sensors to detect the physical state of the driver. In terms of software, we use C language to write code and optimize and compile it through Keil software. The system can display the detected data on the LCD display screen and send an alarm at the same time.

Keywords

Fatigued Driving; Intelligent Detection; Microcontroller; Sensors.

1. Introduction

Fatigue driving is considered an important risk factor for traffic accidents, leading to a significant number of casualties and property damage worldwide. With the continuous increase in the number of cars, the impact of fatigued driving on road traffic safety is becoming increasingly serious. Scientific research has confirmed that increasing the reaction time by more than 0.5 seconds before a traffic accident occurs can effectively prevent almost 60% of traffic accidents. Traffic accidents account for the greatest proportion of nonnatural deaths caused by motor vehicles [1]. Therefore, if we can use a real-time feedback method that can respond instantly to the driver's driving situation during the driving process, prompt the driver in a timely manner when they first experience fatigue, and warn them of distracted driving behaviors such as smoking, this can ensure that the driver is conscious, improve reaction speed, and avoid traffic accidents caused by fatigued driving. The development of an efficient, stable, and practical vehicle fatigue driving detection system from a technological perspective has profound scientific research value and practical significance for preventing traffic accidents and improving road safety levels. By tracking and analyzing the driver's fatigue status in real time, the detection system can issue warning signals in a timely manner, reminding them to take measures to alleviate fatigue, such as resting and taking a nap. Thus, through individual behavioral intervention, the adverse consequences caused by fatigued driving can be reduced. At the same time, this approach can help relevant government departments improve traffic management methods, intelligently optimize the travel environment, achieve the goal of reducing traffic accidents, reducing economic losses, and improving overall road use efficiency.

According to data released by the China Association of Automobile Manufacturers, it is expected that the total sales of automobiles will exceed 31 million units in 2024, a year-on-year increase of more than 3%. On January 11th, data released by the China Association of Automobile

ISSN: 2688-8645

Manufacturers (CAAM) showed that in 2023, China's automobile production and sales reached 30.161 million and 30.094 million, respectively, with year-on-year growth of 11.6% and 12%, respectively, both reaching historical highs. This is the first time in the history of Chinese automobile production and sales that it has exceeded the 30 million vehicle mark. According to WHO data [2], there are approximately 1.35 million deaths due to traffic accidents worldwide each year, resulting in approximately 158 deaths per hour and 35 million injuries and disabilities. Because China accounts for one-fifth of the world's population and ranks first in the world in terms of car ownership, China has a larger base of road traffic safety issues than other countries in the world. The casualties and property losses caused by traffic accidents are quite serious, and driving accidents caused by fatigued driving account for approximately 20% of traffic accidents in China every year. Among them, 40% of major traffic accidents are closely related to fatigued driving[3]. In recent years, with the increase in the number of national cars, frequent traffic accidents have caused considerable economic losses and casualties[4]. After active handling and rectification by the country, the situation has improved slightly, but due to the large population base in our country, the situation is still not optimistic. Fatigue driving is the main factor causing traffic accidents, accounting for approximately 20% of the total number of accidents. According to survey data from the NTSB and NHTSA in the United States, approximately 100000 accidents are caused by fatigued driving each year, resulting in approximately 70000 injuries[5]. Research has shown that if drivers are warned of fatigue one second before an accident occurs, 60% of fatigue-related traffic accidents can be prevented [6-8].

2. Current Research Status of Fatigued Driving Detection

The complex phenomenon of psychological and physiological abnormalities caused by excessive mental and physical exhaustion of drivers due to long-term driving is called fatigued driving. Objective fatigue detection methods can be divided into three categories: detection methods based on vehicle driving characteristics, detection methods based on driver physiological characteristics, and detection methods based on driver behavioral characteristics [9-11]. Generally, long-term driving can have negative effects on a driver's vision, attention, thinking, sensation, and other aspects, leading to abnormal adaptability and driving behavior. However, due to the gradual increase in fatigue, more serious phenomena, such as decreased judgment, inability to concentrate, drowsiness, delayed thinking, and limb fatigue, may occur. At this time, driving poses significant safety hazards and can easily lead to traffic accidents. According to investigations by relevant authorities, the proportion of road traffic accidents causing casualties due to fatigued driving in China has exceeded 76%. Due to the significant impact of fatigued driving on oneself and others, reliable measures must be taken to respond effectively to fatigued driving.

International research on fatigued driving detection technology originated in the 1980s and 1990s and gradually developed into a cutting-edge interdisciplinary field. Significant scientific research achievements have been made in countries and regions such as the United States and Europe. Researchers have also explored the key steps in computer vision-based fatigued driving detection methods, including calculating facial features [12], performing eye localization [13,14], calculating eye opening and closing, and calculating the blink frequency [15,16]. A complete research system has been established in areas such as physiological signal detection, behavioral feature analysis, and facial expression recognition. Although physiological signal detection methods are relatively accurate, their practicality and comfort still need to be improved due to the complexity and invasiveness of the acquisition process. Behavioral feature analysis and facial expression recognition methods are relatively simple and easy to implement and are gradually becoming mainstream methods. Since 2000, China has been paying attention to and researching fatigue driving detection issues in the development and improvement of intelligent transportation systems (ITS). Rich research results have been achieved in detection methods for physiological signals (such as EEG signals and heart rate variability), behavioral characteristics (such as wheel movement trajectory and manipulation characteristics), and facial expressions (such as eye closure and mouth opening). Through interdisciplinary, domestic and international cooperation, China is steadily catching up with the world's advanced level in this field.

To effectively control illegal behaviors caused by fatigued driving and reduce or even prevent accidents caused by fatigued driving, this paper studies fatigued driving characteristics based on the physiological characteristics of drivers (posture angle, body distance, and grip strength) and driving behavior characteristics and constructs a real-time fatigued driving detection system.

3. Design of the System

The vehicle fatigue driving detection system designed in this article uses an AT89C51 microcontroller as the controller, supplemented by a power module, pressure sensor module, display module, buzzer, etc., to form a complete system. The system uses an ultrasonic sensor module to detect distance, an angular velocity sensor module to detect numerical changes in angle, a pressure sensor module to detect steering wheel pressure values, and an LCD1602 display screen to display real-time changes in the current driver's distance, angle, and steering wheel pressure. The safe distance for the driver is 100 cm, and a change in angle exceeding 5° is within the normal range. A pressure greater than 50 indicates that the driver's hand is on the steering wheel. By pressing the button, the threshold for safe distance, angle change, and pressure can be changed. When the safe distance is less than 100 cm, the angle change is less than 5°, and the pressure is less than 50, which indicates that the current driver is in a fatigued driving state.

The functions of each module in the system are as follows:

Power module: This module provides power to the entire system and has overload protection as well as device activation and shutdown functions. Microcontroller module: This module is the central part of the entire control system and is mainly responsible for receiving and regulating sensor data and sending instructions. The sensor module collects distance, pressure, and angle information through sensors and transmits the collected information to the microcontroller for analysis through a serial port. A/D module: This module mainly performs analog-to-digital conversion, converting the analog signals detected by the sensor module into digital signals and facilitating data analysis and output. Display module: After the sensor module collects data, the data are transmitted to the display screen through a serial port for data display. Alarm module: When the system detects that the distance, pressure, and angle information values exceed the set values, the buzzer will sound an alarm to remind the driver that they are in a fatigued driving state. The hardware design diagram of the vehicle-mounted fatigue driving detection system is shown in Figure 1.

The power supply in Figure 1 provides power for the entire system. To ensure the stability of the power supply circuit, a power supply voltage stabilizing circuit is designed. The design of the MCU main control chip mainly includes hardware selection and its minimum system. The data acquisition module is responsible for collecting the required data in the fatigue driving detection system. The collected data are transmitted to the MCU main control chip through AD conversion. The display module can view real-time values of the driver's physical condition. The alarm module uses a buzzer for risk warning. When the collected data exceed the threshold, the buzzer sounds an alarm, indicating that the driver is in a fatigued driving state.

ISSN: 2688-8645

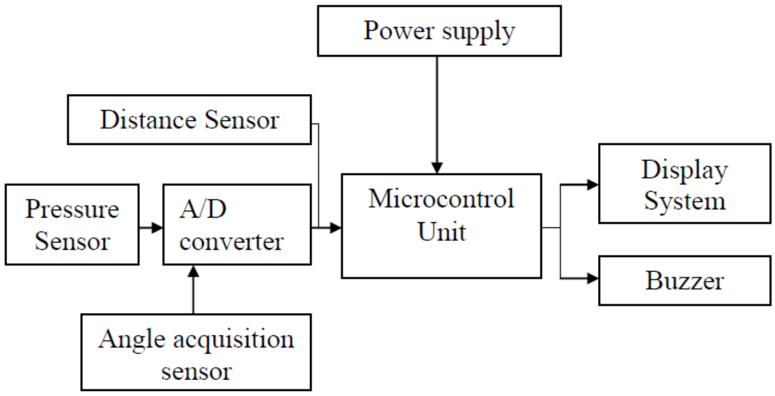

Figure 1. System Hardware Design Plan

In software design, the first step is to initialize the pins of the microcontroller. The data collected from pressure sensors, angle sensors, and distance sensors are uploaded to the MCU for analysis, and the values are displayed on the LCD screen. A value less than the set threshold indicates that the driver is not in a fatigued driving state. A value greater than the set threshold indicates that the driver is in a fatigued driving state, and the buzzer will sound an alarm. The main function of the system is shown in Figure 2.

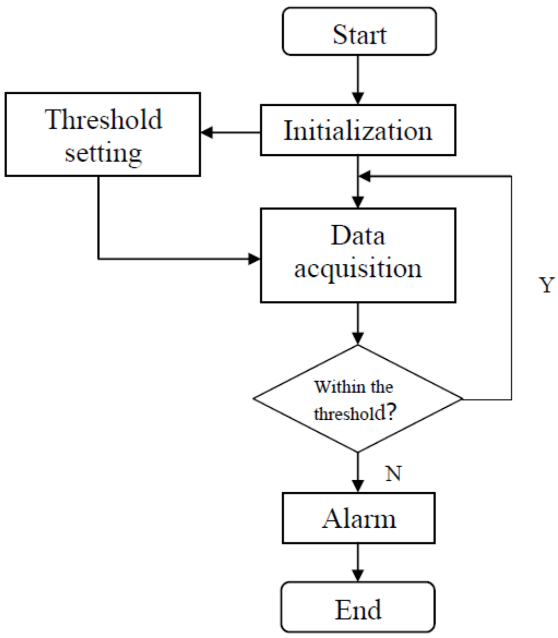

Figure 2. System Main Function Flowchart

The workflow of the pressure module subroutine is as follows: the pressure detection system collects data through the MPX4115 pressure sensor, and the AD conversion module converts the pressure value data collected by the pressure sensor. The converted signal is compared and judged with the preset threshold. If it is less than the threshold value, an alarm is triggered; if it is greater than the threshold, continue to check the pressure value. The workflow of the angle module subroutine is as follows: the angle detection system collects data through sensors, and the AD conversion module compares and evaluates the converted signal with a predetermined threshold. When it exceeds the threshold, the clock will start. The system selects the US-100 module as the core component of the ultrasonic ranging module. In the initialization state, when US-100 operates in the level trigger mode, the microcontroller only needs to send a positive pulse with a pulse width of at least 10 to US-100 to measure the trigger distance. After the US-100 instrument completes the measurement, it sends a high-level signal to the microcontroller, and the width of this high-level signal is the time it takes for the ultrasonic wave to propagate from the transmitting probe to the receiving probe. The width of the microcontroller only needs to be calculated to determine the propagation time of ultrasound in the air, and then, the distance between the target and the ultrasound probe needs to be calculated.

The system is simulated on proofs to verify its feasibility. After powering on, the parameter thresholds of the system are set, and the upper and lower thresholds of the angle, pressure, and distance are added or subtracted. The thresholds are displayed on LCD1602. Figure 3 shows the detection of the state within one minute. A pressure greater than 50 indicates that the hand is on the steering wheel. The lower limit of pressure is set to 50, the lower limit of distance is set to 100 cm, and the lower limit of angle is set to 5°.

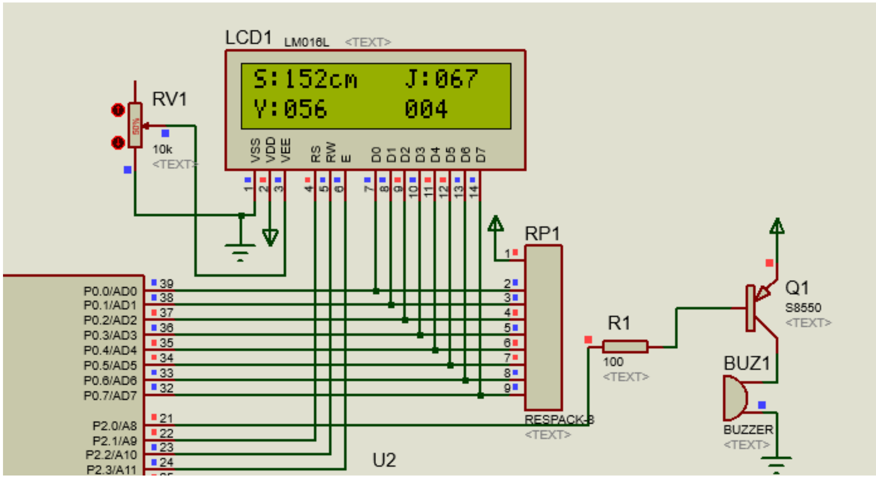

Figure 3. Interface for System Threshold Setting

At this point, the angle sensor, MPX4115 pressure sensor, and US-100 ultrasonic sensor begin to collect the driver's body information values, and the collected angle, pressure, and distance values are displayed on LCD1602. As shown in Figure 4, the distance collected at this time is 152 cm, the angle is 67°, and the pressure is 56. The detection results show that the driver is not in a fatigued driving state.

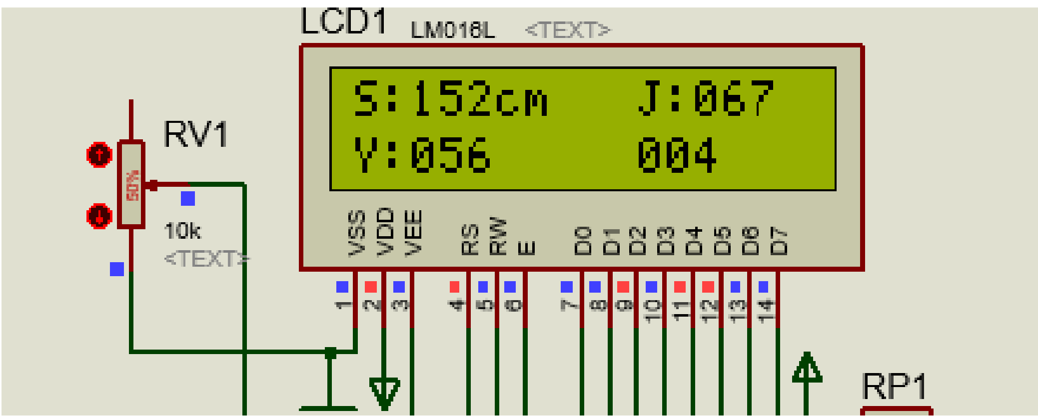

Figure 4. Schematic diagram of parameter acquisition

If the distance collected at this time is 90 cm and the distance is less than the minimum threshold, the buzzer will sound an alarm. As shown in Figure 5.

ISSN: 2688-8645

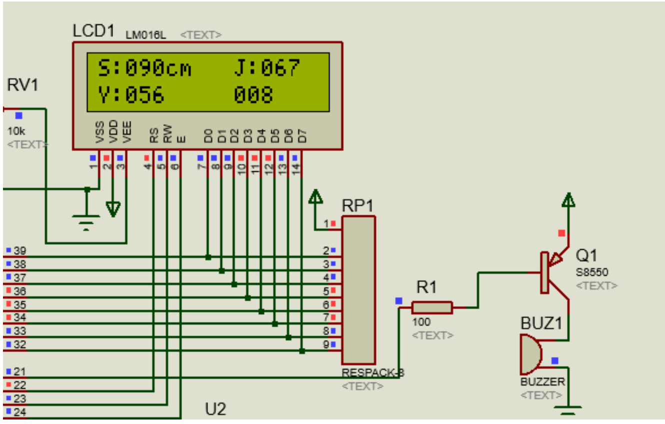

Figure 5. Simulation results when the distance is less than the lower threshold

If the angle collected at this time is 64° and the range of the change in the angle is less than the lower threshold of 5°, the buzzer will sound an alarm, as shown in Figure 6.

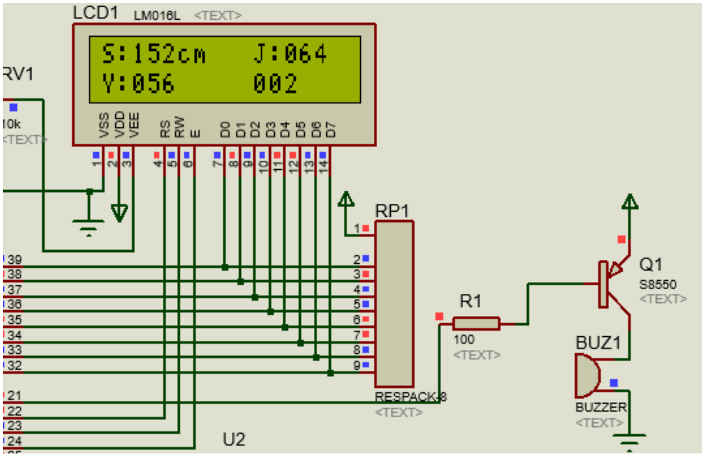

Figure 6. Simulation results when the range of the angle variation is less than the lower threshold

If the collected pressure is 46, then the pressure is less than the lower threshold of the pressure, and the buzzer will sound an alarm. As shown in Figure 7.

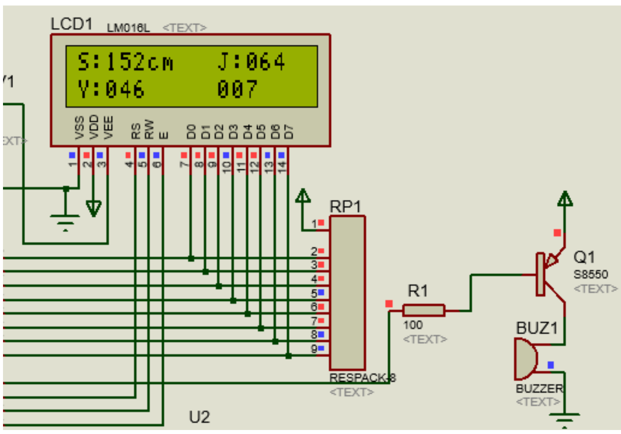

Figure 7. Simulation results when the pressure is less than the lower threshold

4. Conclusion

This article uses the AT89C51 microcontroller as the control core and constructs a hardware system with pressure sensors, ultrasonic sensors, angular velocity sensors, and other configurations outside the chip. C language is used to write code, and the Keil software environment is used to optimize and compile the code. The measured results can be transmitted to the microcontroller and determine whether the driver is in a state of fatigue driving.The LCD display screen was used to display the detection results and provide corresponding alarm prompts. This design is inexpensive and has significant practical value.

Acknowledgments

This study was supported by the Jiangsu provincial college student innovation and entrepreneurship training program (No. 202311049019Z).

References

[1] Wu Zhijun, Wang Wenchao, Yang Lulu, Design of a fatigue driving warning system for light vehicles based on microcontrollers[J]. China Science and Technology Information, 2023, (15): 115-120.

[2] Cai Suxian, Du Chaokan, Zhou Siyi et al., Fatigue Driving State Detection Based on Vehicle Running Data[J]. Journal of Transportation Systems Engineering and Information Technology, 2020, 20 (04): 77-82.

[3] Lin Mei, Xu Jiafu, Wang Yuchen et al., Research on the Mental State Monitoring System for Automobile Drivers Based on Artificial Intelligence[J]. Technology Innovation and Application, 2023, 13 (25): 27-32.

[4] Chen Zihao, Fan Jiale, Yan Ke et al., Design of driving safety assistance system based on STM32[J]. Modern Information Technology, 2022, 6 (21): 148-151+156.

[5] Zhang Qian, Yang Peizhao, Yan Cilei et al., Analysis of Human Factors in Road Traffic Accidents in China [J]. Practical Automotive Technology, 2016, (06): 7-8+27.

[6] Pei Yulong, Wang Wei, Causes and preventive measures of road traffic accidents [M]. Beijing: Science Press, 2004.

[7] Qiao Yantao, Zeng Kai, Xu Lina et al., A smartphone-based driver fatigue detection using fusion of multiple real-time facial features[C], 2016 13th IEEE Annual Consumer Communications & Networking Conference (CCNC), 2016.

[8] Zhang Wei, Zhang Weigong, Zhang Xiaorui et al., Research progress on fatigue driving detection methods[J]. Automotive Technology, 2009, 2:1-5, 17.

[9] Yang Haiyan, Jiang Xinhua, Nie Zuoxian, Overview of Driver Fatigue Driving Detection[J]. Computer Application Research[J], 2010, 27 (5): 1621-1624.

[10] Wang Lei, Wu Xiaojuan, Yu Mengsun et al., Research progress on detection methods for driving fatigue/drowsiness[J]. Journal of Biomedical Engineering, 2007, 24 (1): 245-248.

[11] Bo Chunjuan, Xu Guokai, Song Peng et al., A review of research on fatigue driving detection methods[J], Journal of Dalian University for Nationalities, 2013, 15 (3): 266-271.

[12] Lu Chunyu, Zhang Changshui, Wen Fang et al., Rapid facial detection method based on regional features[J], Journal of Tsinghua University: Natural Science Edition, 2001, 39 (l): 101-105.

[13] Song Zhumei, Wang Hailin, Liu Hanhui, Research on fatigue driving detection and recognition methods[J]. Journal of Shenzhen Institute of Information Technology, 2011, 9 (03): 38-42.

[14] Yu Xueyin, Cao Tuohuang, Chen Bensheng[J], Facial recognition and implementation based on feature faces, Hebei Industrial Technology, 2009 (5): 428-430.

[15] Zhang Aihua, Chen Yanfeng, EEG feature extraction and analysis under drowsy state based on energy and sample entropy[C]. 2012 5th International Conference on BioMedical Engineering and Informatics, 2012.

[16] U Trutschel, B Sirois, D Sommer et al., PERCLOS: An Alertness Measure of the Past[C], Driving Assessment Conference 6, 2011:172-179.