

Fatigue Driving Detection Technology: An Overview

Yujie Huang, Fengrong Zhang, Yujing Huang, Zhengyang Zhu, Shicheng Xu,
Zhijun Kang, Jianxun Xue*

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

*Corresponding Author: xuejx@hyit.edu.cn

Abstract

In order to reduce the loss of life and property to the public caused by fatigue driving, the advantages and disadvantages of various fatigue detection methods are comprehensively analyzed based on the subjective evaluation method and objective measurement method of fatigue driving detection technology. At the same time, the future research trends based on detection standards and information fusion are proposed. This review can provide a reference for technicians who are committed to the research of fatigue driving detection.

Keywords

Fatigue Driving; Detection Technology; Machine Vision; Information Fusion.

1. Introduction

With the rapid development of China's economy, car ownership has increased year by year. The number of road traffic accidents is also increasing year by year, and most drivers have the experience of drowsing during driving. Unconscious falling asleep of drivers often leads to traffic accidents[1]. Therefore, the research on fatigue driving detection technology has important practical significance and has become a hot research topic at home and abroad.

2. Classification of Fatigue Driving Detection Technology

Since the state recognition of fatigue driving involves many disciplines such as medicine, psychology, optics, communication, computer and so on, scholars at home and abroad focus on the research of fatigue driving detection methods. At present, the industry generally believes that the identification of fatigue driving can be divided into two categories according to different research methods: subjective evaluation method and objective measurement method [2]. The subjective evaluation method is to analyze whether the driver is in a state of fatigue by answering some questions of the tester and the comprehensive performance of the driver with the participation of the driver. The objective measurement method is a method to collect relevant data during the driving process of drivers through external devices to evaluate their fatigue status. At present, it mainly includes: recognition methods based on physiological information, recognition methods based on manipulation behavior, recognition methods based on driving status, recognition methods based on machine vision, and methods based on multi-source information fusion[3].

3. Research Progress of Fatigue Driving Detection Technology

3.1. Subjective Evaluation Method

At the initial stage of fatigue driving research, due to the immature computer technology and electronic technology, the research on fatigue driving is mainly based on the driver's subjective

feelings or fatigue characteristics. The commonly used evaluation criteria are Karolinska Sleepiness Scale (KSS) and Stanford Sleepiness Scale (SSS)[4].

Although the subjective evaluation method is relatively simple to implement, due to individual differences, there is a certain degree of deviation in the subject's understanding of the problems in the table during the evaluation process, which leads to the subjectivity of the test results; At the same time, if the inquiry or evaluation occurs during driving, it will be invasive and interfere with the driver's normal driving. If it is carried out after the event, the timeliness is poor, it is difficult to reflect the real state of the driver at that time, and there are shortcomings such as the driver deliberately concealing the real feelings at that time after the event[5]. Therefore, at present, the subjective evaluation method is generally used as an auxiliary means of experimental research to prove the accuracy of other fatigue detection methods.

3.2. Objective Measurement Method

With the development of computer technology and electronic technology, various objective measurement methods based on physical sensors have developed rapidly. They have the advantages of high accuracy and are not affected by the driver's subjective consciousness, and have become the focus of research in the field of fatigue driving detection. At present, there are several detection methods that are widely used.

3.2.1. Identification Method based on Physiological Information

The fatigue driving detection technology based on physiological information recognition generally uses contact measurement to detect the driver's fatigue status by analyzing the physiological signals of the tester when driving. At present, the commonly used detection methods mainly include EEG, ECG, EMG, etc. Among them, EEG is considered as the "gold standard" for fatigue detection[6]. Jiao Yingying[7] found that α The phenomenon of wave attenuation and disappearance is more likely to be triggered in the event of long-term eye closure, indicating that the tester is more sleepy at this time, thus determining the EEG α The phenomenon of wave attenuation disappearance can be used as an indicator of the beginning of sleep for drivers. Zhang Xinran[8] found through the simulation driving test that if the driver is required to make a discriminant response when tired θ Power and α/θ The values of are quite different, so these two physiological indicators can be used as the criteria to judge whether the driver is tired, and further find out the relative θ Power reduction, and α/θ An increase in the value of indicates an increase in driver fatigue. Chai et al.[9] collected EEG data of 43 healthy drivers in fatigue state and awake state, extracted characteristic parameters using autoregressive model, and finally classified them using Bayesian neural network. The results show that the accuracy of this method is 88.2%.

The fatigue driving detection method based on physiological information recognition also includes ECG signal. Research has found that heart rate variability is closely related to the degree of fatigue, so many scholars have carried out research on it. Murugan et al.[10] extracted the features of ECG data, and used SVM, K-nearest neighbor and integrated classifiers for training. The results show that the accuracy of the system for cognitive inattention when drivers are tired is 96.6%, and the accuracy for drivers to fall asleep is 100%. In addition to EEG and ECG signals, surface electromyography (EMG) is also commonly used to monitor fatigue driving. Cheng Xuemin et al.[11] built a driving simulator based on grassland roads and analyzed the EMG data of the neck, shoulder and waist of drivers within 150 minutes. The results showed that the fatigue of the neck, shoulder and waist muscles gradually deepened with the increase of driving time, and the EMG signal curve of female drivers fluctuated more than that of male drivers. Wang et al.[12] further clarified that the driver's upper trapezius muscle of the sixth cervical vertebra is more prone to fatigue during driving through real driving tests, which can be used as the data acquisition location of electromyography (EMG) signals. They selected the approximate entropy of EEG and EMG as the independent variable,

and established a driver fatigue discrimination model based on the Mahalanobis distance theory. The accuracy of the model was verified to reach 90.92%.

It can be seen from the above that although the fatigue driving detection method based on physiological information is relatively accurate and reliable, it generally requires the driver to wear corresponding devices (electrodes, EEG caps, etc.) when collecting signals, which may interfere with the normal operation of the driver. Therefore, this method is not suitable for real vehicle mode at present, and is mostly used in driving simulation experiments.

3.2.2. Identification Method based on Manipulation Behavior

When the driver is tired, his control of the vehicle will also be abnormal. The recognition method based on manipulation behavior is to infer the fatigue state of the driver by analyzing the steering wheel angle, grip strength and pedal operation characteristics[13]. At present, the steering wheel angle and grip strength characteristics of drivers are considered to have a strong correlation with fatigue. Zhang Mingming et al.[14] proposed a method to predict driver fatigue by detecting the grip strength of the steering wheel. Firstly, the EEG signal and the driver's grip strength signal were collected, and the BP neural network method was used to establish the relationship between the fatigue characteristic parameters based on the grip strength signal and the fatigue degree value based on the EEG signal, and verify its accuracy. Li et al.[15] proposed to build a driver fatigue detection algorithm based on steering wheel angle by using recurrent neural network. By acquiring various potential characteristics of drivers when they are tired, they used information gain method to analyze the strong correlation between potential characteristics and fatigue level, so as to clarify the fatigue status of drivers.

Although the recognition method of fatigue driving based on manipulation behavior will not cause greater interference to the driver's normal driving, the driver's control of the vehicle, such as steering wheel grip, corner, etc., is often related to the driver's personal habits, operating skills, etc., so its accuracy and robustness still need to be improved.

3.2.3. Identification Method based on Running Status

The fatigue state of the driver can also be indirectly reflected by the driving state of the vehicle. The fatigue driving recognition method based on driving state is to infer the fatigue state of drivers by analyzing the driving speed, direction and whether the lane deviates. At present, this kind of research mainly focuses on lane departure detection. Gao Zhenhai et al.[16] proposed an unconscious lane departure recognition method that takes into account the characteristics of people, vehicles and roads. They divided the driver's unconscious lane departure behavior into fatigue deviation and subtask deviation. Then, based on the Gaussian mixture hidden Markov theory, they established fatigue deviation and subtask deviation unconscious state recognition models, and completed the offline test and online verification of the model. The offline test results show that the accuracy rate of fatigue deviation recognition is 94.21%.

The recognition method based on driving status is non-contact detection, which will not interfere with normal driving, but will be affected by the driver's driving habits, intentions, experience and other factors. The fatigue driving detection method based on lane departure requires a good road surface and clear signs, so the accuracy may be reduced at night or in rainy and snowy weather; At the same time, in order to obtain accurate vehicle driving status, in addition to upgrading the on-board sensors, it is often necessary to carry out special reconstruction on the road, so the cost is high.

3.2.4. Recognition Method based on Machine Vision

The recognition method based on machine vision refers to capturing the driver's head picture through a camera or other image sensors, and analyzing whether the driver is in a fatigue driving state by extracting the eye features, mouth features, and head features. Xu Lian et al. [17] proposed an eye state recognition network algorithm based on migration learning, which uses a multi task cascade convolutional neural network to detect the driver's face and eyes, and

then judges the driver's fatigue state according to PERCLOS criteria. The experimental results show that the method has high accuracy and strong robustness. Li et al.[18] designed a driver face detection system based on the improved YOLOv3 tiny convolution neural network, and separately used the eye feature vector and mouth feature vector as the evaluation parameters of the eye and mouth state, and then calculated the driver's eye closing time, blink frequency and yawning frequency. The accuracy of the algorithm is 95.1% through the simulation test on the bridge. Ling et al.[19] proposed a robust face landmark location model for eye location and state evaluation. The facial model was located with the eye position as the key point, then some facial landmarks around the eyes were extracted and the eye width height ratio was introduced to evaluate the eye state. Finally, the accuracy was about 97.7% on the BioID dataset. The recognition method based on machine vision, which infers the fatigue state of drivers by analyzing their facial expressions, has the advantages of real-time, non-invasive, convenient detection and low cost, so it has become one of the hot spots of current research. However, due to the driver's individual differences, lighting conditions and other factors in the driving process, the all-weather, highly robust algorithm still has technical bottlenecks.

3.2.5. Recognition based on Multi-source Information Fusion

Due to the differences of individual drivers, different drivers have different fatigue characteristics, and using only one kind of feature information for fatigue detection often has limitations. The method based on multi-source information fusion is to comprehensively analyze various fatigue characteristics of drivers, and then identify and warn the fatigue status of drivers. Compared with a single feature, its accuracy and stability are higher[20]. Ma Jialei et al.[21] proposed a driver state detection method based on facial multiple information. Taking facial multiple information as the analysis object, they used support vector machine algorithm to complete the recognition of driver's transient expression, and then used endpoint detection and feature matching methods to achieve driver fatigue state detection. Li et al.[22] proposed a new fatigue driving detection model based on multi feature fusion and semi supervised active learning. They fused the steering features of the vehicle and the facial features of the driver, and divided the fatigue state into nine levels. The test results show that the accuracy rate is 86.25%. Du Ying et al.[23] proposed a method based on multi feature fusion to detect fatigue. First, 68 facial feature points were marked with a cascaded residual regression tree, and then five fatigue characteristics, namely, eyelid opening and closing, blink frequency, mouth opening, yawning frequency, and head posture angle, were extracted to obtain seven feature parameters; Finally, the above features are fused by the support vector machine of Gaussian kernel function to establish the fatigue detection model. The test results show that the algorithm can meet the requirements of real-time detection and has high robustness. The method based on multi-source information fusion is to collect and extract multiple target features, which improves the disadvantage that single information is easily affected by individual differences of drivers and driving environment, and improves the accuracy of detection. However, how to design a reasonable fusion model is the key to improve the accuracy. If the model design is not reasonable, small data errors may lead to serious deviation of the prediction results from the normal value.

4. Conclusion

This paper summarizes the fatigue driving detection technology from two aspects: subjective evaluation method and objective measurement method. The research on fatigue driving detection technology is conducive to further improving road traffic safety, and has very important practical significance. At present, although domestic scholars have carried out corresponding research on fatigue driving, most of them are carried out on the simulation driving platform, which has greater limitations. It can be seen from the overview of fatigue

driving detection technology at home and abroad that the future research direction should be carried out from the following aspects:

Firstly, establish a unified and standardized fatigue driving detection standard. At the same time, based on the mechanism and essence of fatigue formation, constantly improve the classification of fatigue driving state, and establish a scientific and accurate fatigue state classification model.

Secondly, the experimental research of fatigue driving detection technology is gradually transformed from the simulation driving platform to the real road, and the accuracy and robustness of fatigue driving detection technology are verified on the actual road.

Thirdly, in order to further improve the accuracy and reliability of fatigue driving detection technology, the extraction and fusion of feature parameters related to fatigue driving should be constantly strengthened. Therefore, multi-source information fusion technology will gradually become a research hotspot.

Finally, the research on fatigue driving detection technology should not only be limited to the detection level, but also focus on early warning and control, so as to ensure the safety of road traffic more effectively.

Acknowledgments

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

References

- [1] Soares S, Ferreira S, Couto A. Driving simulator experiments to study drowsiness: A systematic review[J]. *Traffic injury prevention*, 2020(1): 29-37.
- [2] Zhang B. Research on the detection method of driver fatigue under complex working conditions based on machine vision[D] Beijing: Tsinghua University, 2015.
- [3] Du Y. Research on driver fatigue state classification method based on facial information[D] Harbin: Harbin Institute of Technology, 2012.
- [4] Lu B. Research on driving fatigue detection based on multiple physiological signal characteristics of human body[D] Jilin: Northeast Electric Power University, 2022.
- [5] Yang K. Research on fatigue mechanism and development law of railway train dispatcher[D] Chengdu: Southwest Jiaotong University, 2017.
- [6] Lal S K L, Craig A. A critical review of the psychophysiology of driver fatigue[J]. *Biological psychology*, 2001(3):173-194.
- [7] Jiao Y Y. Research on driver drowsiness detection based on EEG and EOG signals[D] Shanghai: Shanghai Jiaotong University, 2019.
- [8] Zhang X R. Research on driver's cognitive response characteristics and its impact mechanism on accident risk[D] Beijing: Beijing Jiaotong University, 2021.
- [9] Chai R, Naik G R, Nguyen T N, et al. Driver fatigue classification with independent component by entropy rate bound minimization analysis in an EEG-based system[J]. *IEEE journal of biomedical and health informatics*, 2016(3):715-724.
- [10] Murugan S, Selvaraj J, Sahayadhas A. Detection and analysis: driver state with electrocardiogram(ECG)[J]. *Physical and engineering sciences in medicine*, 2020(2):525-537.
- [11] Cheng X M. Rheological characteristics of driver muscle fatigue under monotonous environment of grassland highway[D] Hohhot: Inner Mongolia Agricultural University, 2021.
- [12] Wang L, Wang H, Liu J. Discrimination of Driver Fatigue Based on Distortion Energy Density Theory and Multiple Physiological Signals[J]. *IEEE Access*, 2021(9):151824-151833.

- [13] Zhang X B, Cheng B, Feng R J. Real time detection method of driver fatigue based on steering wheel operation[J] Journal of Tsinghua University, 2010 (7):1072-1076+1081.
- [14] Zhang M M. Research on fatigue driving detection based on steering wheel grip strength[D] Zhenjiang: Jiangsu University, 2016.
- [15] Li Z, Chen L, Nie L, et al. A novel learning model of driver fatigue features representation for steering wheel angle[J]. IEEE Transactions on Vehicular Technology, 2021(1):269-281.
- [16] Gao Z H, Le D D, Hu H Y, etc Identification method of driver's unconscious lane departure[J] Journal of Jilin University, 2017(3):709-716.
- [17] Xu L, Ren X H, Chen R X. Fatigue driving detection based on eye state recognition[J] Science, Technology and Engineering, 2020(20): 8292-8299.
- [18] Li K, Gong Y, Ren Z. A fatigue driving detection algorithm based on facial multi-feature fusion[J]. IEEE Access, 2020(8):101244-101259.
- [19] Ling Y, Luo R, Dong X, et al. Driver eye location and state estimation based on a robust model and data augmentation[J]. IEEE Access, 2021(9):67219-67231.
- [20] Shen Y Z, Hu L F, Feng J M. Multisource information fusion application to driving fatigue detection[J]. Computer Appl Softw, 2012(29):271-274.
- [21] Ma J L. Research on driver status detection based on facial multiple information[D]. Changchun: Jilin University, 2021.
- [22] Li X, Hong L, Wang J, et al. Fatigue driving detection model based on multi-feature fusion and semi-supervised active learning[J]. IET Intelligent Transport Systems, 2019(9):1401-1409.
- [23] Du Y. Research on fatigue driving detection technology based on multi feature fusion[D] Xi'an: University of Chinese Academy of Sciences (Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences), 2021.