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The method of driver fatigue detection in intelligent driving

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Abstract. Fatigue driving is one of the main causes of traffic accidents, and currently available methods for detecting driver fatigue include sensor detection and intelligent driving assistance. The importance of driver fatigue detection lies in timely detection of the driver condition, which helps reduce fatigue driving accidents. The research on fatigue detection technology has also provided more sensors and data processing techniques for intelligent driving systems, promoting the improvement and optimization of intelligent driving systems. This article reviews the technologies available for fatigue detection, summarizes existing research on driver fatigue detection, analyzes various modal detection methods and the use of AI in fatigue monitoring, and proposes future research and development trends for fatigue detection systems. This paper discussed three parts of fatigue monitoring technology: sensor technology, data processing technology, and algorithm optimization, and analyzed their advantages, disadvantages, and future development trends. The conclusion is that fatigue monitoring technology should use the advantages of different sensors and combine them with intelligent driving. The accuracy of this technology still needs to be improved.

Keywords: Fatigue detection, intelligent driving, driver, monitoring.

1. Introduction

Fatigue driving is likely to lead to traffic accidents and its impact is serious. In order to effectively deal with traffic accidents, various methods for driver fatigue detection have been studied. These methods mainly include sensor detection and intelligent driving assistance. The importance of driver fatigue detection lies in its ability to monitor the physiological and behavioral status of drivers in real time, so as to detect and warn of potential fatigue driving risks in a timely manner. This not only helps reduce fatigue driving accidents but also improves the overall level of road traffic safety. At the same time, the research on fatigue detection technology also provides sensors and data processing technology for the development of intelligent driving systems, promoting the improvement and optimization of intelligent driving systems. Looking back at the application history of science and technology in fatigue detection, it can be seen that from the initial simple physiological parameter monitoring to the complex artificial intelligence algorithm analysis, fatigue detection technology has made significant progress. Existing research covers a variety of detection methods, including physiological parameters detection, behavioral characteristics detection, and detection according to vehicle driving data. These methods have their advantages and can comprehensively and accurately assess the fatigue state of drivers. With the assistance of artificial intelligence, fatigue detection systems can operate more intelligently and automatically. Through the application of algorithms, the system can automatically analyze the facial features of drivers and vehicle driving data, for real time assessment of driver fatigue level. This not only improves the accuracy and real-time performance of detection, but also reduces the burden of manual monitoring.

Looking ahead, the development of fatigue detection systems will become more diversified and intelligent.

2. Driver fatigue monitoring system

The following provides an overview of the means for driver fatigue detection, they are categorized into three types: physiological feature detection, vehicle behavior feature detection, and multimodal detection. The main purpose of this chapter is to summarize the techniques developed by other authors for fatigue monitoring and explore various methods that can be used for fatigue monitoring.

2.1. Physiological feature detection

2.1.1. The principle of ECG. The system of heart rate detection for driver fatigue is based on driver physiological characteristics to determine whether there is a risk of fatigued driving. It mainly relies on heart rate sensors to obtain real-time data. Wang et al extract HRV (Heart Rate Variability) features and use the LightGBM classifier to define driver fatigue levels, as shown in Figure 1 [1]. Butkeviciuts et al combine machine learning algorithms with the electrocardiogram (ECG) signals to extract features from fatigue detection signals [2]. Currently, the technology of using electrocardiogram to detect driver fatigue needs to serve as a warning of fatigue, but due to its direct contact with the driver, it may cause interference to the driving process or be easily affected by individual differences.

Figure 1. Step diagram for extracting HRV features and using LightGBM classifier to define driver fatigue level.

2.1.2. Characteristics of EEG. Generally, electroencephalography (EEG) can capture changes in the brain electrical activity of drivers during fatigue, such as an increase in slow waves and a decrease in fast waves, to determine the level of driver fatigue. The process of EEG signal analysis is the estimation of fractal dimensions by latent attractors based on the signal. Wang, F et al used EEG data set to establish a fatigue detection method according to brain functional networks, in which partial directed coherence (PDC) was applied to calculation such as the relevance among EEG channels, and SVMs(Support Vector Machine) were used as tools for fatigue detection [3].

2.1.3. sEMG methods. Wang, Z et al obtained surface Electromyography(sEMG) data from the driver's forearm and further processed the root mean square (RMS) value of the activation signal of the stainless-steel arm sensor after calculation [4]. With fatigue developed and deepened, the frequency of electromyography usually shows a decreasing trend, while the amplitude may increase. This change pattern is available for evaluate the driver fatigue level.

2.1.4. EOG methods. Electrooculogram (EOG) is a signal used to detect eye movements, especially blinking movements. It collects and processes eye electrical signals, identifies the frequency and action of blinking, and determines whether the driver blinks autonomously or consciously in order to detect driver fatigue. Némcova A. extracted key features to detect fatigue driving from EOG signals, including flicker, slow eye movement, amplitude, and periodicity [5].

2.1.5. Facial image. Facial image detection includes image acquisition, image preprocessing, and facial feature processing. Zhao, Z obtained the driver’s facial bounding contour and five selection points by a multi-task convolutional neural network (MTCNN). The next step is to classify the facial features, like eyes and mouth, by extracting regions of interest (ROI) through feature points and identifying the condition of eyes and mouth through Emotion semantics enhanced MCNN (EM-CNN). Finally, Zhao identified the driver's fatigue status by measuring the percentage of pupil upper eyelid closure and degree of opening [6]. Zhou, F used percentage of eyelid closure time as the basic fatigue indicator, and predicted a model that uses these key physiological features to predict fatigue [7]. Li, Z employed the RestNet10 SSD object detection algorithms used for facial image evaluation, enhanced face detection using Dlib tracking processing, and utilized algorithms to track faces for detecting fatigue driving [8].

2.2. Vehicle behavioral feature detection

By analyzing the driving behavior, like acceleration, braking, steering, and lane departure, to estimate whether the driver is fatigued. Fatigued drivers may exhibit unstable driving behavior or lane departure. Shiferaw BA generates a predictive model by recording lane departure and eye threefold in cases of sleep deprivation [9]. These data are mainly collected through onboard sensors, and the system can issue corresponding warnings based on the analysis results. The onboard system can also accumulate driving time. When the driver's continuous driving time exceeds a preset point, the system can issue a fatigue driving warning to remind the driver to rest in a timely manner. This method can effectively warn of fatigue caused by prolonged continuous driving.

2.3. Multi-mode solutions

The general system for detecting driver fatigue consists of multiple sensors that detect fatigue levels in a multimodal manner. For example, Liu, L et al introduced a rapid support vector machine (RSVM) algorithm, utilizing EEG and EOG, for the identification of fatigue-driven states [10]. Abbas, Q. et al employed a multi-sensor DFD (Driver Fatigue Detection) system to digitally record data via a heart rate monitoring system. This system extracts non-visual features physiological measurements of the driver and various vehicle parameters. Specifically, driver fatigue is predicted using parameters like accelerator pedal usage, wheel turning, and vehicle speed and utilizes EEG, ECG, EOG, and sEMG to calculate driver fatigue [11]. Hayley AC used a Driver Monitoring System (DMS) that combined biological behavior monitoring, especially eye indicators, and evaluated driving performance to identify conditions like fatigue and lack of Concentration [12].

In general, technologies for monitoring driver fatigue can be classified into the following categories.

2.4. Summary of fatigue detection methods

The techniques for detecting driver fatigue using different methods are summarized in Table 1.

Table 1. Different fatigue detection methods.

Physiological feature detection	Vehicle behavioral feature detection	Multi-mode
Heart rate	Acceleration	Fusion of multiple physiological signals
Brain electrical activity	Braking	Driver fatigue detection systems
Forearm data	Steering	Driver monitoring systems
Eye electrical signals	Lane departure	--
Facial Image	--	--

3. Limitations and future development

Fatigue monitoring technology can detect the driver fatigue state promptly and detect potential safety hazards in a timely manner. By integrating multiple technologies, personalized settings can be adjusted according to the driver's needs to improve monitoring effectiveness. Although fatigue monitoring technology has broad application prospects and important safety value, it still faces many limitations and challenges.

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Those challenges mainly lie in the technical elements of the monitoring system. Sensors are the fundamental core of intelligent driving detection technology, and the performance and accuracy directly affect the accuracy of detection results. At present, commonly used sensors for detecting physiological states include heart rate sensors, cameras, ultrasound sensors, etc. Although the method of using multiple sensors to detect driver fatigue is feasible, such sensors need to be contact with the driver directly, which may affect driver safety while driving. Moreover, many sensors still have certain limitations in practical applications, especially in terms of environmental factors such as weather and lighting conditions. Sensors used to detect vehicle behavior, such as image sensors, also have special requirements for weather and lighting. Although the performance of sensors is currently quite good, there is still a problem with how to apply sensors in driving fatigue monitoring.

Intelligent driving systems also require data processing techniques to extract useful information, and data collection is a fundamental task in fatigue monitoring. However, raw data often contains unfavorable factors such as noise and outliers. These factors directly affect the accuracy of monitoring results. Therefore, by using data processing techniques to process, extract features, and conduct in-depth analysis on raw data, the accurate fatigue detection can be ameliorated. Moreover, the system has efficient data technology that can make accurate judgments and decisions in a jiffy.

In addition, the algorithm is crucial for achieving high-precision detection in intelligent driving technology. Currently, deep learning and machine learning are extensively applied. However, optimizing the algorithm is a continuous process, requiring ongoing improvements in accuracy and real-time performance.

The implementation of fatigue monitoring technology is complex, involving the integration and application of multiple advanced technologies, and has a poor response to environmental interference, which affects monitoring results. At the same time, the high research and promotion costs, as well as privacy protection issues, also limit its widespread application. In addition, user experience and acceptance are also important issues that cannot be ignored. Many fatigue monitoring instruments can affect driver driving, and wearing devices may cause discomfort and accidents for drivers. Real-time monitoring of driver facial features and physiological signals may also raise concerns about privacy breaches.

This study reviews the research on multi-sensors in driver fatigue monitoring, which contains signals and data types. Future fatigue monitoring technology will pay more attention to the fusion of multimodal information, including facial features, physiological signals, and driving behavior, to improve monitoring effectiveness. Fatigue monitoring technology will be deeply integrated with intelligent driving systems to achieve more intelligent fatigue warning and intervention measures. By comprehensively utilizing the advantages of different sensors, the limitations of a single sensor can be made up for, achieving more comprehensive and accurate environmental awareness.

4. Conclusion

As a core technology in the field of intelligent driving, intelligent driving detection technology plays a crucial role in improving driving safety, reducing traffic accidents, and optimizing traffic flow. This technology integrates advanced sensors, computer vision, machine learning and other technological means to achieve real-time detection and perception of the surrounding environment of vehicles, providing key decision-making basis for intelligent driving systems. However, current technology still faces many challenges and limitations. On the one hand, the complex and ever-changing traffic environment and weather conditions have raised higher requirements for the accuracy and stability of intelligent driving detection technology. On the other hand, intelligent driving detection technology also faces challenges in processing massive amounts of data and achieving real-time response. How to improve data processing speed and reduce system latency while ensuring detection accuracy is an important direction for current technological development. With the continuous advancement and technological innovation, intelligent driving detection system is expected to develop towards a more intelligent and reliable direction. In the future, people can expect to see more accurate and efficient intelligent driving detection systems that can better cope with various complex environments and challenges, providing safer and more convenient services for people's lives. In future intelligent driving cars, detection systems can not only monitor road conditions and traffic signals in real time, but also predict the behavior trajectories of other vehicles and pedestrians, making decisions such as obstacle avoidance or deceleration in advance, further reducing the risk of traffic accidents.

In short, intelligent driving detection technology, as one of the core technologies in the field of intelligent driving, has broad development prospects and enormous application potential. By continuously optimizing and improving existing technologies, and actively exploring new technological directions and innovation points, it is expected to achieve a more intelligent, safe, and convenient intelligent driving system in the future.

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