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Futurology on Driver Fatigue Processing Techniques

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Abstract

Objective: Driver fatigue is one of the most prevalent causes of road crashes. It affects physiological properties such as heart rate, breath rate, and EEG features, as well as other indicators like driver gestures and vehicle maneuvers. This paper aims to investigate various driver fatigue detection and processing techniques and provide future insights.

Method: This study conducted a comprehensive literature review to explore the current methods and suggest future directions for driver fatigue detection and processing.

Results: The results indicate that physiological properties have the strongest correlation with driver drowsiness, making them more precise than other methods. Additionally, machine learning-based methods demonstrated superiority over other techniques.

Conclusion: The findings suggest that future approaches should utilize fusion-based machine learning methods to report and analyze driver drowsiness. Data fusion can involve integrating physiological signals, driver behavior, and driver status. Combining various physiological properties such as EEG, heart rate, and breath rate can achieve the highest accuracy due to multiple validations. This fusion approach is expected to provide more reliable and precise detection and analysis of driver fatigue.

Keywords: Machine Learning, Road Crash, Drowsiness.

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Introduction

Every year, numerous people die in road accidents. In 2021, approximately 16,556 individuals lost their lives on Iranian roads. Two-thirds of these fatalities occurred on rural roads. Multiple factors contribute to traffic accidents, with human error being the leading cause. This has been the focus of recent research on driver behavior (Intini et al., 2024; Karimi, Aghabayk, & Moridpour, 2022; Kaur et al., 2023; Pan, Wang, & Szűcs, 2023). Driver fatigue and sleepiness are critical factors in the occurrence of accidents. Surveys indicate that road infrastructure (Liu & Wu, 2009), drug and alcohol use (Elvik, 2013; Horne, Reyner, & Barrett, 2003; NHTSA, 1998; Roehrs & Roth, 2001), and sleep disorders (Powell et al., 2007) contribute to driver fatigue Driver fatigue can be assessed through three general components: a) physiological properties such as EEG, heart rate, and breathing rate (Sriranga, Lu, & Birrell, 2023); b) vehicle maneuvers; and c) driver state. The collected data can be analyzed using various methods, including the analytical hierarchy process (AHP), machine learning (ML), the Viola-Jones algorithm, and the HOG-Gabor technique. This paper aims to propose future processing techniques for driver fatigue analysis. The research will address the visualization of potential methods and techniques for processing driver drowsiness, ensuring they are highly accurate and consistent with real-world scenarios.

Material and Properties

The main goal of future research is to identify, formulate, review, evaluate, and propose potential advancements in the field (Bell, 2003). This article aims to evaluate previous research both quantitatively and qualitatively. It also endeavors to advance research on techniques for processing driver fatigue. Initially, the study reviews the background of research on the factors contributing to driver fatigue and sleepiness. The objective is to identify the indicators of fatigue and sleepiness that devices and equipment should detect. Subsequently, various methods for extracting data related to fatigue and sleepiness are evaluated. The study also assesses different data processing methods, focusing on four specific techniques: the Analytical Hierarchy Process (AHP), machine learning, the Viola-Jones algorithm, and the HOG-Gabor algorithm. These methods are analyzed based on their frequency of usage over recent decades.

Results and Discussion

The review of previous research indicates that the assessment and processing of driver fatigue and sleepiness have been extensively discussed (Vanlaar et al., 2008). Recent studies have demonstrated that information on driver fatigue and sleepiness can be extracted with high accuracy using brain signal recording tools (Belcher et al., 2022; Chang et al., 2022; Gibbings et al., 2022; Zheng et al., 2022). Additionally, techniques have been developed to remove motion artifacts from EEG recordings (Qi et al., 2021). However, accessing physiological characteristics such as brain signals on a real scale may be challenging. In-car measurement of other physiological properties, such as heart rate and breathing rate, is more feasible (Sriranga, Lu, & Birrell, 2023). Furthermore, information such as car movement maneuvers (e.g., tracking road lanes, steering changes, lane crossings, and headway) and observable signs of driver drowsiness (e.g., eye-blinking duration, head dropping, yawning, and muscle relaxation) can be recorded by sensors and equipment installed in the car. A combination of these data points is likely to be more effective than any single measure. The article suggests that in the future, data fusion techniques will be beneficial for recording information on driver fatigue and sleepiness.

In terms of processing techniques, the study reviewed methods used for data processing from 2000 to 2025. As illustrated in Figure 1, the investigation revealed that machine learning, particularly deep learning, has been the most appropriate and frequently used method. This method is expected to remain relevant and useful in the future.

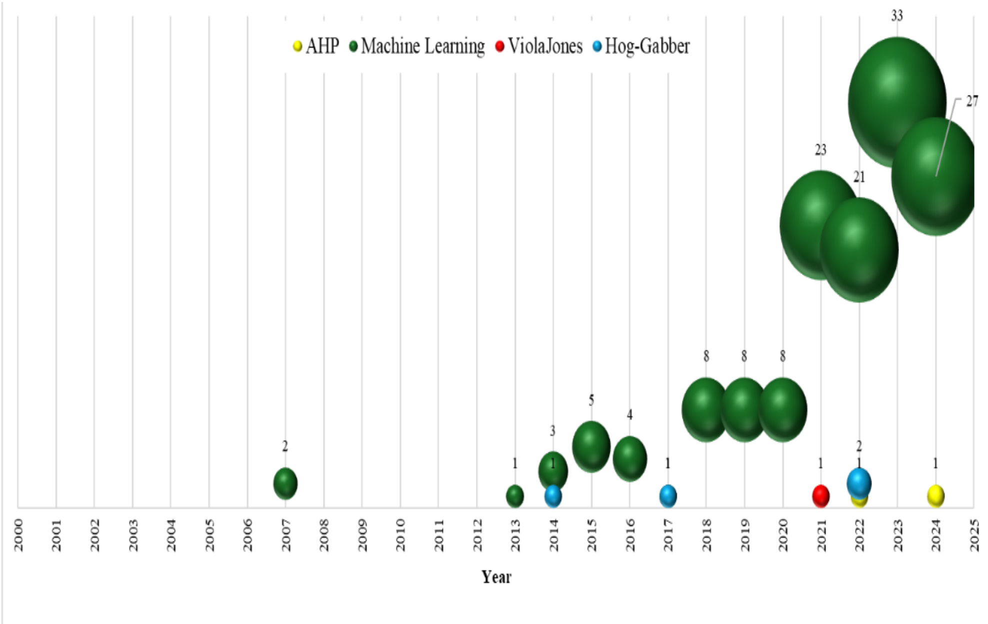

Fig. 1. Driver fatigue model processing techniques over time

To achieve proper accuracy in processing, it appears beneficial to combine various types of information using machine learning techniques. Consequently, future research will likely focus on two main areas: integrating information extracted from a single method and combining multiple methods. This dual approach is expected to yield more accurate results in the processing of driver fatigue compared to existing methodologies, making the findings more realistic and credible. Figure 2 illustrates this structure, presenting a schematic idea of the future direction in this field.

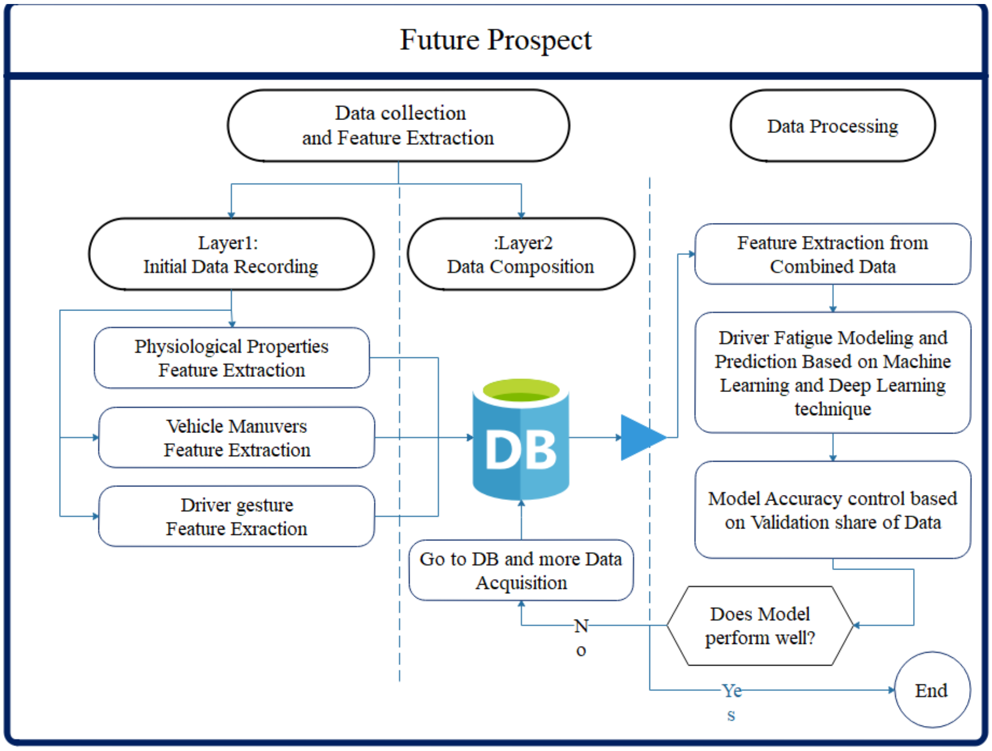

Fig. 2. The possible structure of processing and sleeping drivers in the future

Conclusion

This paper aims to study various methods for processing driver fatigue and propose future probable methods. It reviews previous research in this field and outlines the future direction of such studies. The investigations reveal that methods based on physiological characteristics are most compatible with assessing a driver's condition. Additionally, the analysis of trends in fatigue and sleepiness data processing shows that machine learning models, particularly deep learning, have been highly popular in recent research. Looking ahead, it appears that data integration can significantly enhance accuracy by combining information on physiological properties, vehicle maneuvers, and driver gestures during fatigue. This approach is expected to improve the validity of data processing. Furthermore, integrating various physiological signals, such as EEG features, heart rate, and breathing rate, can further refine model accuracy and data processing. Based on these insights, this research proposes a schematic view of future methods, emphasizing the potential benefits of combining diverse data sources and advanced machine learning techniques.

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