Real-Time Drowsiness Detection System

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ABSTRACT

Driver fatigue is a leading cause of road accidents worldwide. Long driving hours, sleep deprivation, night travel, and health conditions significantly reduce the alertness and reaction time of drivers. Traditional safety mechanisms in vehicles focus mainly on collision prevention rather than monitoring the physical condition of the driver. Therefore, this study presents a Real-Time Drowsiness Detection System that continuously monitors the facial features and eye movements of drivers using computer vision and machine learning techniques. The proposed system detects eye closure duration, blinking frequency, and facial fatigue indicators to determine a driver's alertness level. When drowsiness is detected, the system immediately generates an alert through an alarm or a vibration signal. The system is non-intrusive, cost-effective, and suitable for deployment in real-world settings. The main objective of this study was to develop an accurate, efficient, and real-time monitoring solution that enhances road safety and reduces accident risks.

Keywords: Drowsiness Detection, Driver Monitoring System, Computer Vision, Eye Blink Detection, Machine Learning, Real-Time Processing, EAR (Eye Aspect Ratio), Road Safety.

LITERATURE REVIEW

Over the past decade, researchers have explored multiple approaches for detecting driver fatigue. Early studies focused on physiological signal analysis, such as electroencephalogram (EEG), electrocardiogram (ECG), and heart rate monitoring. Although these methods provide high accuracy, they require wearable sensors, which can be uncomfortable for drivers and impractical for long-term use.

Later research shifted toward behavior-based detection techniques. These methods analyze visual indicators, such as eye closure, yawning frequency, head nodding, and facial expressions. Studies have demonstrated that eye closure duration is one of the most reliable indicators of drowsiness. The PERCLOS metric, which measures the percentage of eye closure over time, has become a widely accepted standard.

Recent advancements in deep learning have introduced Convolutional Neural Networks (CNNs) and facial landmark detection models for improved accuracy. Researchers have implemented algorithms capable of detecting subtle changes in facial features, even under varying lighting conditions. Some studies have integrated infrared cameras to enable nighttime detection. However, high computational requirements and hardware costs remain a challenge.

This literature review indicates that non-intrusive camera-based systems combined with lightweight machine learning algorithms provide an effective balance between accuracy and practicality. Therefore, this study focuses on real-time computer vision-based detection using facial landmark analysis and eye blink monitoring.

INTRODUCTION

Road accidents caused by drowsy driving are major public safety concerns. According to global safety reports, fatigue-related accidents account for a significant percentage of highway crashes, particularly during late-night and early morning hours. When a driver becomes drowsy, their reaction time slows down, decision-making ability weakens, and attention decreases.

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Modern vehicles are equipped with advanced safety technologies, such as collision detection and lane departure warning systems. However, these systems react only after unsafe driving behaviors occur. A proactive system

that monitors the driver's alertness can prevent dangerous situations from arising.

The primary aim of this study was to design and implement a Real-Time Drowsiness Detection System that operates continuously while the vehicle is in motion. The system uses a camera placed in front of the driver to capture the facial features. Using image processing and machine learning techniques, the system evaluates eye movements and blinking patterns. If prolonged eye closure or abnormal blinking is detected, an alert mechanism is activated.

This study emphasizes the affordability, real-time performance, and adaptability for practical deployment in vehicles.

Drowsiness Detection:

Drowsiness detection involves identifying signs of fatigue using measurable indicators. Human fatigue manifests as physical changes such as slow blinking, longer eye closure, yawning, drooping eyelids, and head tilting.

There are three major categories of drowsiness detection systems: physiological, vehicle, and behavioral. Physiological systems monitor brain waves and heart rates but require physical sensors attached to the driver. Vehicle-based systems monitor steering patterns and lane deviations but may fail to detect early fatigue. Behavior-based systems, particularly eye monitoring systems, offer a non-invasive and reliable solution.

In this study, behavioral indicators were prioritized because they provide real-time insights into the driver's condition without causing discomfort. Eye behavior, especially blink duration and eye closure percentage, is considered the most reliable parameter for detecting fatigue.

Existing System:

Existing systems fall into two main categories: intrusive and non-intrusive.

Intrusive systems rely on wearable devices, such as EEG headsets or smart bands, to measure physiological signals. Although these systems are accurate, they are uncomfortable and impractical for daily use.

Non-intrusive systems use cameras to analyze the facial expressions and eye movements of the user. Some commercial vehicles implement basic driver-monitoring systems; however, they often require high-end hardware and expensive processing units. Many existing models also struggle under low-light conditions or when drivers wear glasses.

Another limitation of existing systems is the delayed alert generation. Some models fail to differentiate between normal and fatigue-induced blinking, leading to false alarms.

Therefore, there is a need for a system that is accurate, cost-effective, robust under various lighting conditions, and capable of real-time detection without excessive computational requirements.

Proposed System Real-Time Drowsiness Detection:

The proposed system uses a camera-based monitoring approach integrated with a facial landmark detection algorithm. A webcam captured real-time video frames of the drivers. Each frame was processed to detect the face and identify key facial landmarks.

The system primarily focuses on eye region analysis. The Eye Aspect Ratio (EAR) was calculated using landmark coordinates. The EAR remains nearly constant when the eyes are open and decreases significantly when the eyes are closed. By continuously monitoring the EAR value across frames, the system determines whether the driver's eyes remain closed beyond a predefined threshold.

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If the eye closure duration exceeds a specific time interval, the system identifies it as drowsiness and triggers an alert. The proposed model is lightweight and optimized for real-time processing, making it suitable for deployment in embedded systems.

Real-Time Drowsiness Detection Algorithm:

The algorithm operates in sequential stages as follows: First, the camera captures live video frames. Next, a face detection model was used to identify the driver's face. Once the face is detected, facial landmarks are extracted to locate the eye region.

The Eye Aspect Ratio is computed using the vertical and horizontal distances between eye landmarks. The algorithm continuously monitored the EAR values across consecutive frames. If the EAR remained below a predefined threshold for a certain number of frames, the system classified the state as drowsy.

To reduce false detections, the system includes frame buffering and smoothing techniques. This ensured that temporary blinks were not misclassified as fatigue. The final stage involves activating an audible alert to warn drivers.

The algorithm was optimized to process frames at a high speed, ensuring minimal latency and real-time performance.

Eye Blinking Algorithm:

The eye-blinking algorithm is a core component of the proposed system. It calculates the blinking frequency and eye closure duration using facial landmark geometry.

When the eyes are open, the vertical distance between the eyelids is significant. When closed, this distance is drastically reduced. By measuring these distances and computing the Eye Aspect Ratio, the algorithm distinguishes between normal blinking and prolonged eye closure.

The algorithm maintains a counter for consecutive frames in which the EAR falls below the threshold. If the count exceeded a preset limit, the system confirmed drowsiness.

This method is computationally efficient and suitable for real-time applications. It does not require complex deep learning models, making it ideal for low-power devices.

METHODOLOGY

The methodology comprises data acquisition, preprocessing, feature extraction, threshold analysis, and alert generation.

Initially, real-time video data were captured using a camera. Preprocessing included grayscale conversion and noise reduction to improve the detection accuracy. Facial landmark detection was then applied to extract the eye coordinates.

Feature extraction involves calculating the Eye Aspect Ratio values. A threshold value was experimentally determined to differentiate between the open and closed eye states. Temporal analysis was applied to monitor the consecutive frames.

If the system detects prolonged eye closure, an alarm is triggered. This methodology ensures low computational overhead while maintaining high detection accuracy.

CONCLUSIONS

This study presents a Real-Time Drowsiness Detection System designed to enhance road safety by monitoring driver alertness. The system utilizes computer vision and eye-blink detection algorithms to detect fatigue in real time. Compared to intrusive physiological systems, the proposed approach is noninvasive and user-friendly.

The system demonstrated high efficiency, low latency, and cost-effectiveness. Future work may include the integration of yawning detection, head pose estimation, and deep learning models to improve robustness. The implementation of this system in real vehicles can significantly reduce fatigue-related accidents and improve transportation safety.

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