Driver Drowsiness Detection and Alert System Using Machine Learning and Computer Vision

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Abstract- Driver drowsiness is a critical factor contributing to a significant number of road accidents globally, posing serious threats to public safety. Early detection of driver fatigue is essential to prevent such incidents and enhance transportation safety systems. Conventional methods, including physiological signal monitoring and manual observation, are often intrusive, costly, and lack real-time efficiency. In this paper, a real-time driver drowsiness detection and alert system based on Machine Learning and Computer Vision is proposed. The system utilizes visual features extracted from live video streams to monitor driver behavior. Key indicators such as eye closure, blink rate, yawning frequency, and head movement are analyzed using facial landmark detection techniques and metrics like Eye Aspect Ratio (EAR). A threshold-based decision mechanism is employed to identify drowsiness conditions accurately. Artificial Intelligence and Machine Learning technologies are transforming the transportation industry by enabling intelligent monitoring and automated safety systems. Driver monitoring systems are becoming increasingly important because they help reduce accidents caused by human fatigue and distraction. Real-time Computer Vision techniques allow systems to analyze facial expressions, eye movements, blinking behavior, and head posture continuously. Upon detection of fatigue, the system generates immediate alerts through audio signals to warn the driver, thereby reducing the risk of accidents. The proposed approach is non-intrusive, cost-effective, and capable of real-time performance, making it suitable for integration into modern vehicles and advanced driver assistance systems. Experimental analysis demonstrates that the system achieves high accuracy and reliability under varying conditions. The results indicate that the proposed model can serve as an effective solution for enhancing driver safety and supporting intelligent transportation systems. Unlike traditional sensor-based systems, the proposed approach is non-intrusive, affordable, and suitable for real-world implementation. The research demonstrates how intelligent transportation systems can improve road safety and reduce accidents caused by fatigue.

Keywords: Driver Drowsiness Detection, Computer Vision, Machine Learning, Deep Learning, Convolutional Neural Network (CNN), Eye Aspect Ratio (EAR), Facial Landmark Detection, Real-Time Monitoring, Intelligent Transportation Systems, Driver Safety, Advanced Driver Assistance Systems (ADAS).

I. INTRODUCTION

Driver drowsiness has emerged as a significant concern in modern transportation systems due to its direct impact on road safety and accident rates. According to global road safety reports, fatigue-related accidents account for a considerable percentage of total road incidents, often resulting in severe injuries and fatalities. Drowsiness impairs a driver's cognitive abilities, reduces reaction time, and affects decision-making, thereby increasing the likelihood of collisions.

With the rapid growth in the number of vehicles and long-distance travel, especially in commercial transportation, the need for intelligent monitoring systems has become essential. Traditional approaches to detecting driver fatigue rely on self-reporting, manual observation, or physiological sensors such as Electroencephalography (EEG) and heart rate monitors. While these methods can provide accurate results, they are often intrusive, expensive, and impractical for real-time deployment in everyday driving conditions.

Recent advancements in Machine Learning and Computer Vision have opened new possibilities for non-intrusive and automated driver monitoring systems. These technologies enable real-time analysis of visual data captured through cameras to detect behavioral patterns associated with drowsiness. Techniques such as facial landmark detection, eye tracking, and deep learning-based image analysis allow systems to identify signs like prolonged eye closure, frequent blinking, yawning, and head nodding.

The integration of such intelligent systems into vehicles can significantly enhance road safety by providing early warnings to drivers. In this context, this paper focuses on designing a driver drowsiness detection and alert system that leverages computer vision and machine learning techniques to monitor driver behavior continuously and generate timely alerts.

Future developments in this field may include IoT integration, cloud-based monitoring systems, infrared cameras for low-light environments, and advanced predictive models capable of identifying fatigue before visible symptoms appear. Continuous research and development will further improve the efficiency, reliability, and scalability of driver drowsiness detection system.

II. BACKGROUND OF THE STUDY

Road accidents caused by driver fatigue are a major global issue. Long driving hours, lack of sleep, and monotonous driving conditions often lead to drowsiness, reducing the driver's reaction time and awareness. Traditional monitoring systems rely on driver self-awareness or external observation, which are not reliable. With the rapid growth of computer vision technologies, automated detection of driver fatigue has become feasible using cameras and AI models.

Road safety has become a global priority due to the increasing number of traffic accidents caused by human factors, particularly driver fatigue. Studies have shown that drowsiness contributes to a substantial portion of accidents, especially during long-distance driving, nighttime travel, and monotonous road conditions such as highways. Unlike other risk factors, fatigue is difficult to detect externally, making it a hidden but dangerous threat.

Early research in drowsiness detection primarily focused on physiological signals such as brain activity (EEG), heart rate variability, and muscle movements. Although these methods provide high accuracy, they require specialized equipment and physical contact with the driver, making them inconvenient for practical use. As a result, researchers shifted toward behavioral-based approaches that analyze visual cues.

With the advancement of computer vision, camera-based systems have become a popular solution for monitoring driver behavior. These systems analyze facial features such as eye movement, blinking patterns, mouth opening (yawning), and head position to detect signs of fatigue. Techniques like Eye Aspect Ratio (EAR) and facial landmark detection have proven effective in identifying drowsiness in real time.

Furthermore, deep learning models such as Convolutional Neural Networks (CNNs) have significantly improved the accuracy of visual detection systems by automatically extracting relevant features from images. These models can operate under varying conditions and provide robust performance compared to traditional methods.

This study builds upon existing research to develop a non-intrusive, computer vision-based driver drowsiness detection system that provides real-time alerts and enhances overall driving safety.

III. PROBLEM STATEMENT

Driver drowsiness is a critical factor contributing to a large number of road accidents worldwide, particularly in long-distance and nighttime driving scenarios. Fatigue significantly impairs a driver's alertness, reaction time, and decision-making ability, making timely detection essential for preventing accidents. Despite the availability of various drowsiness detection techniques, existing systems face several limitations that hinder their effectiveness in real-world applications.

Traditional approaches based on physiological signals, such as Electroencephalography (EEG) and heart rate monitoring, provide accurate results but are

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intrusive, expensive, and inconvenient for continuous use in vehicles. On the other hand, behavioral and vision-based systems, although non-intrusive, often rely on limited indicators such as eye closure or blink rate, which may not be sufficient to accurately detect drowsiness under all conditions.

Moreover, many existing computer vision-based systems suffer from challenges such as poor performance in low-light environments, sensitivity to occlusions (e.g., glasses or face masks), and lack of robustness across different drivers and driving conditions. In addition, several models lack real-time processing capabilities and fail to integrate efficient alert mechanisms that can promptly warn drivers.

Another major limitation is the absence of a comprehensive system that combines multiple fatigue indicators such as eye closure, yawning, and head movement with real-time analysis and immediate alert generation. This lack of integration reduces the reliability and practical applicability of current solutions.

Therefore, there is a need to develop a robust, non-intrusive, and real-time driver drowsiness detection system using machine learning and computer vision techniques. Such a system should be capable of accurately analyzing multiple behavioral features, operating effectively under varying environmental conditions, and providing timely alerts to enhance driver safety and reduce fatigue-related accidents.

Despite advancements in drowsiness detection systems, existing solutions face several limitations:

- Most systems rely only on eye detection
- Poor performance in low-light conditions
- Lack of real-time alert mechanisms
- Limited accuracy in real-world environments
- No integration with alert and reporting systems

IV. MOTIVATION

Driver fatigue is a major cause of road accidents and poses a serious threat to public safety. Current methods for detecting drowsiness, such as physiological sensors or manual observation, are often intrusive, expensive, or impractical for real-time use. Vision-based systems exist, but many are limited to detecting only a single indicator, like eye closure, and may fail under low-light or varied driving conditions.

The motivation for this study is to develop a non-intrusive, real-time, and reliable system that can monitor multiple behavioral indicators such as eye closure, yawning, and head movement. By providing timely alerts to the driver, the system aims to reduce fatigue-related accidents, enhance road safety, and improve driver awareness. Integrating machine learning and computer vision allows for an intelligent, scalable, and cost-effective solution suitable for modern vehicles.

V. OBJECTIVES OF THE STUDY

The primary objective of this study is to design and develop an efficient and reliable driver drowsiness detection and alert system using Machine Learning and Computer Vision techniques. To achieve this, the study focuses on the following specific objectives:

- Objective 1: To analyze and evaluate existing driver drowsiness detection methods, including physiological, behavioral, and computer vision-based approaches.
- Objective 2: To identify key limitations and research gaps in current systems, such as lack of real-time performance, low accuracy under varying conditions, and limited feature integration.
- Objective 3: To develop a non-intrusive system that utilizes computer vision techniques to monitor driver behavior through facial features.
- Objective 4: To implement facial landmark detection methods for identifying critical indicators such as eye closure, blinking rate, yawning, and head movement.
- Objective 5: To design and apply algorithms such as Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) for accurate detection of drowsiness.
- Objective 6: To integrate an effective alert mechanism (audio/visual) that provides

immediate warning to the driver upon detecting fatigue.

VI. CONTRIBUTIONS OF THE PAPER

This paper presents several key contributions in the field of driver drowsiness detection using Machine Learning and Computer Vision techniques. The main contributions are summarized as follows:

Comprehensive Review of Existing Methods: The study provides a detailed analysis of existing driver drowsiness detection approaches, including physiological signal-based methods, machine learning models, and computer vision techniques, highlighting their strengths and limitations.

Identification of Research Gaps: The paper identifies critical challenges in current systems, such as lack of real-time performance, dependency on single fatigue indicators, poor robustness under varying environmental conditions, and limited integration of alert mechanisms.

Proposed Real-Time Detection Framework: A novel, non-intrusive system architecture is proposed that utilizes computer vision to monitor driver behavior through facial features captured via a camera.

Multi-Feature Drowsiness Detection Approach: Unlike traditional systems, the proposed model integrates multiple indicators of fatigue, including eye closure (EAR), yawning (MAR), blinking rate, and head movement, to improve detection accuracy and reliability.

Integration of Real-Time Alert Mechanism: The system incorporates an immediate alert system (audio/visual warning) that notifies the driver upon detection of drowsiness, thereby enabling timely intervention.

Performance Evaluation Using Standard Metrics: The proposed system is evaluated using performance metrics such as accuracy, precision, recall, and response time to ensure its effectiveness in real-world scenarios.

Scalable and Cost-Effective Design: The system is designed to be easily deployable in vehicles without the need for expensive hardware, making it suitable for large-scale adoption.

Contribution to Intelligent Transportation Systems: The research supports the development of smart vehicle technologies and Advanced Driver Assistance Systems (ADAS), contributing to improved road safety and reduced accident rates.

VII. ORGANIZATION OF THE PAPER

- Section 5 presents a comprehensive literature review of existing driver drowsiness detection techniques and identifies their limitations.
- Section 6 describes the proposed methodology, including system architecture, algorithms, and workflow for real-time detection.
- Section 7 discusses the expected results, performance metrics, and system advantages.
- Section 8 highlights potential applications and use cases of the system.
- Section 9 concludes the paper and suggests future work for improving driver safety using intelligent systems.

VIII. LITERATURE REVIEW

The literature review is conducted on various driver drowsiness detection systems, existing fatigue monitoring methods, and image processing techniques used for identifying driver fatigue in real time.

Christine Dewi et al. [1] proposed a method for automatically classifying blink types by calculating a new threshold value based on the Eye Aspect Ratio (EAR), known as Modified EAR. The study demonstrated that Modified EAR improves the accuracy of eye blink detection and provides better performance compared to conventional EAR methods. Their approach enhanced blink detection reliability under different facial conditions and reduced false detections.

Jinkwon Kim et al. [2] designed a driver monitoring system capable of detecting drowsiness, tiredness, and distraction by analyzing driving behavior and

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facial movements. Their video-based driver state monitoring system predicts the moment a driver may fall asleep. The model combines physiological signals and facial image analysis techniques such as eye blink detection and face direction estimation. The authors concluded that additional logic and optimization techniques are required to reduce false detection rates and improve detection accuracy.

Emma Perkins et al. [3] discussed several challenges faced by driver drowsiness detection systems, including noise, data loss, subject diversity, sensor contact loss, and varying lighting conditions. Their research highlighted how these challenges affect the performance and reliability of drowsiness detection models. The authors emphasized that although existing systems show promising results, further improvements are necessary before such systems can be effectively deployed in real-world driving environments.

Ajjen Joshi et al. [4] proposed a model that collects facial video data from overnight shift workers while driving back home. The collected data was categorized into four drowsiness levels: alert, slightly drowsy, moderately drowsy, and extremely drowsy. The researchers used Convolutional Neural Networks (CNNs) to analyze posture, facial expressions, and emotional indicators. Their model achieved a macro ROC-AUC score of 0.78 compared to 0.72 obtained by the baseline system, demonstrating improved drowsiness classification performance.

Arafat Islam et al. [5] developed an automatic driver monitoring system capable of detecting driver consciousness using two important parameters: eye closure duration and eye blink frequency per minute. Their system utilized facial landmark detection to monitor eye movements continuously. The eye closure duration and blinking rate were compared with predefined threshold values to identify fatigue conditions. Based on these parameters, the system generated different warning alerts to notify the driver.

Ali A. et al. [6] demonstrated that eye blink rate and visual comfort are significantly influenced by visual tasks such as reading from electronic devices. Their study analyzed how reading from digital screens affects eye blinking behavior compared to reading from paper. The research showed that prolonged use of electronic devices such as laptops and tablets increases blink rate and visual fatigue, which may contribute to driver drowsiness and reduced concentration levels.

Soukupová and Čech [7] introduced a real-time eye blink detection system using facial landmarks and Eye Aspect Ratio (EAR). Their method became one of the most widely used approaches for detecting eye closure in driver monitoring systems. The proposed algorithm provided high accuracy and real-time performance using simple mathematical calculations based on facial landmark points.

A. Thematic Classification

- Traditional Methods: Physiological sensors
- Machine Learning: SVM, Decision Trees
- Deep Learning: CNN, LSTM
- Computer Vision: Eye tracking, facial landmark detection

B. Comparative Analysis

	B	C	D	E	F
1	Authors	of Public	Title of the Paper	Journal / Conference Name	Publisher
2	Ayush Patil, Mubin Tamboli, Satyamsinha Patil, Pravin Game, Parth	2025	Accident Avoidance System using Drowsiness and Pothole	Presented at the 2025 Global Conference in Emerging Technology (GINOTECH), Pune,	IEEE
3	Chandramathi Murugadass, Mia Champion	2025	Driver Drowsiness Detection using Machine Learning and AWS IoT	Proceedings of the 4th International Conference on Automation,	IEEE
4	Akshayakumar N. G., Karpagam G. R., Avina C. O.	2025	Smart Vision: AI-Driven Driver Fatigue Monitoring	14th IEEE International Conference on Communication	IEEE
5	Dhivya P., Jaiganesh M., Kishore M., Kishore Kumar P., Srinivasan A.,	2025	Proactive Fatigue Detection for Improved Road Safety	Proceedings of the 6th International Conference on Inventive Research in	IEEE
6	Rawan Almousa, Raghad Alanezi, Majed Alzouri, Abdelmalek Zidouri	2025	Raspberry Pi-Based Driver Drowsiness Detection with	2025 29th International Conference Information	IEEE
7	A. Abirami, Yadam Karthik, Bhuvaneswari S., Saisuraj Shankar,	2024	An In-Depth Exploration of Advanced Driver Drowsiness	2nd International Conference on Computer, Communication and	IEEE
8	Nabil Bin Zamri, Fadhlan Hafizhelmi Bin Kamaru Zaman	2025	Driver Drowsiness Detection Using Multi-Frames Approach with	2025 IEEE 15th Symposium on Computer Applications &	IEEE
9	S. Sakthi Vinayagam, S. Sandhya, M. Nandakishor, V.	2025	Eyes on the Road: A Vision-Driven, Non-Intrusive Drowsiness	Proceedings of the 6th International Conference on Inventive Research in	IEEE
10	K. Anusha, B. Rikshith, M. Chandra Kanth, M. Maheshwar	2025	Real-Time Distracted Driver Detection and Monitoring using	Proceedings of the 8th International Conference on Trends in Electronics	IEEE

C. Traditional Approaches

Traditional approaches to driver drowsiness detection primarily rely on physiological measurements and basic image processing techniques. These methods were among the earliest attempts to identify fatigue but have several limitations in terms of practicality and scalability.

One of the most widely used traditional methods involves monitoring physiological signals such as Electroencephalography (EEG), Electrooculography (EOG), and heart rate variability. EEG measures brain activity and is considered highly accurate for detecting different stages of sleep and fatigue. Similarly, EOG tracks eye movements, while heart rate sensors monitor variations associated with drowsiness. Although these methods provide reliable results, they require specialized sensors to be attached to the driver's body, making them intrusive, uncomfortable, and unsuitable for real-time driving environments.

Another category of traditional approaches includes vehicle-based measures, such as monitoring steering patterns, lane deviation, and braking behavior. These methods assume that changes in driving performance indicate fatigue. However, such indicators may not always accurately reflect drowsiness, as they can also be influenced by road conditions, driver experience, or external factors.

Additionally, early systems used basic image processing techniques, including edge detection, color segmentation, and thresholding, to identify facial features like eyes and mouth. These methods were limited in their ability to handle variations in lighting, head pose, and facial expressions, resulting in low accuracy and poor reliability.

Overall, traditional approaches laid the foundation for drowsiness detection research but suffer from key drawbacks such as intrusiveness, high cost, lack of robustness, and limited real-time applicability. These limitations have driven the development of more advanced machine learning and computer vision-based methods.

D. Machine Learning Approaches

Machine learning approaches for driver drowsiness detection analyze extracted features from driver behavior to classify fatigue levels. Commonly used models include Support Vector Machines (SVM), Decision Trees, and Random Forests, which are trained on visual or physiological data such as eye closure duration, blinking rate, yawning frequency, and steering patterns.

However, machine learning approaches require manual feature extraction and preprocessing, which can be time-consuming and may limit adaptability to different drivers or driving conditions. Moreover, these models often struggle with real-time performance in dynamic environments, particularly under varying lighting, occlusions, or head movements. Despite these limitations, machine learning methods provide a foundation for more advanced deep learning and computer vision-based systems, which can automatically extract features and enable real-time, robust drowsiness detection.

E. Deep Learning Approaches

Deep learning improves accuracy:

- CNN for facial feature detection
- LSTM for temporal behavior analysis
- Real-time video processing

Critical Analysis:

- High accuracy but computationally intensive
- Poor performance in night conditions
- Limited real-world deployment

IX. RESEARCH GAP

Despite significant advancements in driver drowsiness detection using traditional methods, machine learning, deep learning, and IoT-based systems, several critical gaps remain that limit their effectiveness and real-world applicability.

One of the primary gaps identified is the lack of multi-feature integration. Many existing systems rely on a single indicator, such as eye closure or blink rate, to detect drowsiness. However, fatigue is a complex condition that manifests through multiple behavioral cues, including yawning, head movement, and facial expressions. The absence of a

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comprehensive approach reduces detection accuracy and reliability.

Another major limitation is the inadequate real-time performance of existing systems. While several models achieve high accuracy in controlled environments, they often fail to maintain consistent performance in real-world scenarios due to latency issues and computational constraints. This affects the system's ability to provide timely alerts, which is crucial for preventing accidents.

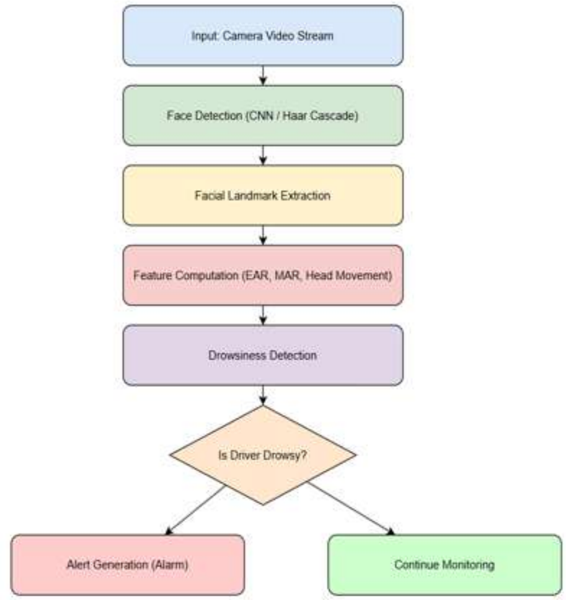
The sensitivity to environmental conditions is also a significant concern. Many computer vision-based systems struggle under varying lighting conditions, such as nighttime driving or glare, and are affected by occlusions like sunglasses or face masks. This reduces their robustness and limits their practical deployment.

Furthermore, there is a lack of scalability and generalization across different drivers and datasets. Most models are trained on limited or simulated datasets, leading to reduced performance when applied to diverse real-world populations with varying facial features and behaviors.

Another important gap is the limited integration of alert mechanisms. Although some systems can detect drowsiness, they do not effectively communicate warnings to the driver in real time. The absence of a reliable and immediate alert system reduces the practical usefulness of these solutions.

X. PROPOSED METHODOLOGY

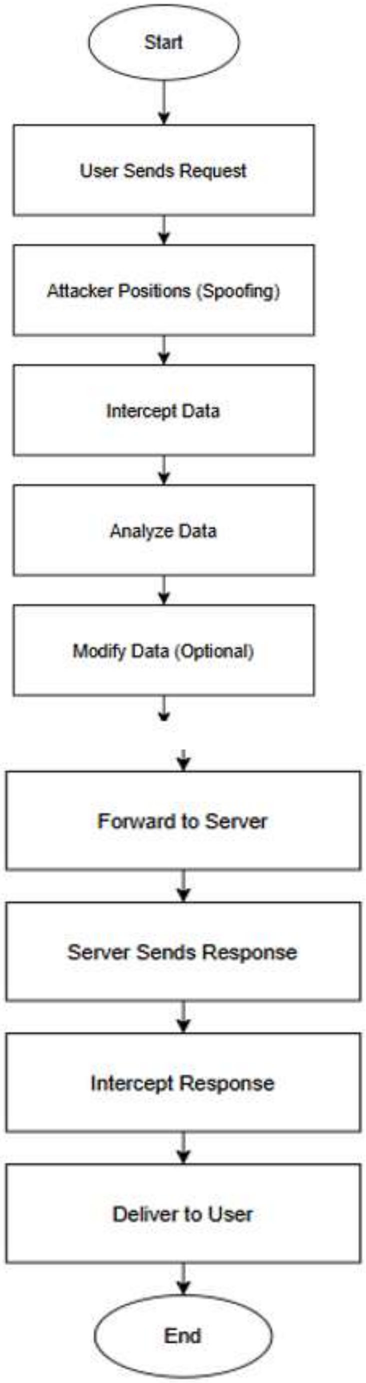
A. System Architecture



B. Working Process

The system operates in the following steps:

1. Video Capture: A camera continuously captures real-time video of the driver.
2. Face Detection: The system detects the driver's face using computer vision algorithms.
3. Facial Landmark Detection: Key facial points (eyes, mouth, nose) are extracted using landmark detection techniques.
4. Feature Extraction: Important features such as eye closure, blinking rate, yawning, and head movement are calculated.
5. Drowsiness Detection: The system analyzes these features using predefined thresholds or trained models to determine whether the driver is drowsy.
6. Alert Generation: If drowsiness is detected, an immediate alert (alarm sound or notification) is triggered to warn the driver.



C. Advantages of Proposed System

- Real-time detection: Detects driver drowsiness instantly without delay.
- Non-intrusive system: No need to wear sensors or devices; uses only a camera.
- High accuracy: Uses multiple features like eye, mouth, and head movement.
- Cost-effective: Requires only a basic camera and software.
- Easy to use: Simple setup and user-friendly.
- Immediate alert system: Gives quick warning (alarm/notification) to the driver.
- Improves road safety: Helps prevent accidents caused by drowsiness.
- Scalable system: Can be used in cars, trucks, and other vehicles.

XI. DATASET DESCRIPTION

The dataset used in this study consists of images and video samples of drivers under different conditions such as alert, drowsy, and fatigued states. It is used to train and test the drowsiness detection system.

A. Key Details of the Dataset

Type of Data: Image and video data of human faces.
Content:

- Open eyes and closed eyes
- Yawning and non-yawning faces
- Different head positions (tilt, nodding)

Annotations (Labels): Each image/frame is labeled as: Drowsy / Non-drowsy (Alert).
Variations Included:

- Different lighting conditions (day/night)
- Different facial expressions
- Multiple individuals (diverse dataset)
- With/without glasses

Dataset Usage: Training the model; Testing system accuracy; Real-time validation.

B. Purpose of Dataset

The dataset helps the system learn patterns of drowsiness such as eye closure, yawning, and head movement, enabling accurate detection in real-time scenarios.

XII. EXPECTED RESULTS AND DISCUSSION

A. Expected Results

- Accurately detect drowsiness using eye closure (EAR), yawning (MAR), and head movement

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- Provide real-time monitoring of the driver
- Generate instant alerts (alarm/notification) when drowsiness is detected
- Achieve high accuracy compared to single-feature systems
- Work under different lighting and environmental conditions

B. Discussion

The system combines multiple features such as eye blinking, yawning, and head movement, which improves detection accuracy compared to traditional methods.

- EAR (Eye Aspect Ratio): Helps detect eye closure effectively
- MAR (Mouth Aspect Ratio): Identifies yawning behavior
- Head movement: Detects nodding or fatigue posture

By analyzing these features together, the system reduces false detections and improves reliability.

The use of computer vision and machine learning allows the system to function without physical sensors, making it more practical and user-friendly.

However, performance may slightly vary due to:

- Poor lighting conditions
- Camera quality
- Face occlusion (e.g., mask, sunglasses)

XIII. APPLICATIONS AND USE CASES

Automobile Safety Systems: Used in cars to monitor drivers and prevent accidents caused by drowsiness.
Commercial Vehicles: Helps truck and bus drivers stay alert during long-distance travel.

Public Transportation: Improves safety in buses, taxis, and other transport services.

Fleet Management: Companies can monitor driver alertness in logistics and delivery vehicles.

Driver Assistance Systems (ADAS): Can be integrated with advanced driver assistance systems for better safety.

Night Driving Support: Useful for detecting fatigue during late-night or long-hour driving.

Smart Cars / Autonomous Vehicles: Acts as a safety backup in semi-autonomous driving systems.

Research and Development: Used in studies related to driver behavior and road safety.

XIV. CONCLUSION

This study presents a comprehensive analysis of driver drowsiness detection systems using machine learning and computer vision. Existing systems have limitations in accuracy, real-time processing, and scalability.

The proposed system introduces an integrated approach that detects drowsiness using facial features and provides real-time alerts. This enhances road safety, reduces accidents, and supports intelligent transportation systems.

Future work can focus on improving performance in low-light conditions and integrating with smart vehicle systems. The proposed driver drowsiness detection system provides an effective and reliable solution for improving road safety. By using computer vision and machine learning techniques, the system continuously monitors the driver's facial features such as eye closure, yawning, and head movement.

Unlike traditional methods, the system is non-intrusive, cost-effective, and capable of real-time detection, making it suitable for practical implementation in vehicles. The integration of multiple indicators like EAR, MAR, and head movement increases the overall accuracy and reduces false detections.

The system also ensures immediate alert generation, which helps in preventing accidents caused by driver fatigue. Although minor limitations such as lighting conditions may affect performance, the overall system proves to be efficient and scalable.

In conclusion, this work presents a smart and practical approach to enhance driver safety and reduce road accidents, making it highly valuable for modern transportation systems.

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