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Enhancing Driver Safety and Prevention Mechanism Through Visual Behaviour Monitoring Using Machine Learning Techniques

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ABSTRACT
In an era where accidents are a leading cause of death and injury worldwide. Improving driver safety can save countless lives and reduce the human suffering associated with road accidents. Despite technological advancements in vehicle safety features, human error remains a leading cause of traffic accidents. This initiative proposes a system that utilizes real-time video analysis to monitor driver behaviour and identify the level of drowsiness the driver has. This project integrates visual behaviour monitoring and machine learning to enhance driver safety and prevent accidents. Drowsy driving is a significant contributor to road accidents globally, particularly among long-distance drivers such as truck and bus drivers. Recognizing the need for real-time, non- intrusive fatigue detection systems, this project presents a low-cost, webcam-based driver drowsiness detection system leveraging image processing and machine learning techniques. The proposed system captures the driver's facial features through a webcam and analyzes eye aspect ratio (EAR), mouth opening ratio (MOR), and head position using facial landmark detection. These parameters are processed using machine learning algorithms to determine the driver's level of alertness. Upon detecting signs of drowsiness, the system immediately triggers a visual alert to the driver, thereby potentially preventing accidents. The system emphasizes ease of implementation, portability, and reliability, making it suitable for real-world applications with minimal technical overhead.

INTRODUCTION

Drowsy driving is one of the major causes of deaths occurring in road accidents. Truck drivers who drive for long hours continuously, bus drivers of long-distance routes, and overnight bus drivers are more susceptible to this problem. Every year, a large number of injuries and deaths occur due to fatigue-related road accidents. Hence, the detection of driver fatigueandits indication are active are as of research due to their immense practical applicability. Drowsy driving has emerged as a major contributor to road accidents, resulting in a significant number of fatalities and injuries every year. The issue is particularly prevalent among drivers who operate vehicles for extended periods, such a struck drivers and long-distance bus drivers, especially during night-time hours. Fatigue behind the wheel reduces a driver's attention span, delays reaction time, and impairs decision-making, making it a serious threat to road safety.

To address this issue, the development of intelligent driver drowsiness detection systems has become an important area of research. Traditional methods for detecting drowsiness are generally classified into three categories:

vehicle-based, behavioural-based, and physiological-based. Vehicle-based methods analyze driving patterns, such as steering behaviour or lane deviation, while physiological methods involve monitoring bodily functions like heart rate and brain activity using sensors. Although these methods can be effective, they are often expensive or intrusive.

Behavioural-based methods, on the other hand, provide a more practical and non- intrusive solution by analysing visual cues such as eye blinking, yawning, and head movement. This project utilizes a behaviour-based approach by developing a webcam-based system that monitors the driver's facial features in real-time. Using image processing and machine learning techniques, the system captures video input, detects the driver's face, identifies key facial landmarks, and calculates specific ratios such as EyeAspectRatio(EAR)and Mouth Opening Ratio (MOR). If drowsiness indicators are detected, the system triggers an immediate alert to warn the driver.

The goal of this project is to create an accurate, cost-effective, and user-friendly system that can reduce the risk of fatigue- related road accidents.

By leveraging technologies like Python, OpenCV, and machine learning algorithms, the proposed system offers a practical solution for real-time driver monitoring with minimal hardware requirements. Hence, we have proposed a webcam-based system to detect a driver’s drowsiness from the face image only using image processing and machine learning techniques to make the system low-cost as well as portable

RELATEDWORK

The growing interest in intelligent transportation systems has led to extensive research in driver monitoring using visual cues and machine learning. Researchers have proposed various methods to detect fatigue and distraction, ranging from sensor-based techniques to advanced deep learning models. Ji et al. [1] introduced a real-time eye-tracking system using infrared cameras, focusing on pupil movement and eyelid behaviour to detect drowsiness. Although accurate, the reliance on specialized hardware limits widespread adoption. Bergasa et al. [2] developed a real-time monitoring system using facial expression analysis, which provided promising results in estimating alertness but struggled with varying lighting conditions.

With the rise of deep learning, CNNs have been effectively employed for facial analysis tasks. Park et al. [3] presented a deep learning-based driver monitoring system that achieved superior performance compared to traditional approaches, emphasizing the robustness of CNNs in capturing complex facial features**.**

Additionally, hybrid approaches have gained traction. Abtahi et al. [4] demonstrated a yawning detection system combining CNNs and smart embedded cameras, offering real-time capabilities with minimal processing over head. Another notable system by Hossain and Muhammad
[5]integrated cloud computingwith local vision-based detection, showing how distributed systems can enhance scalability and responsiveness in safety applications**.**

PROPOSED SYSTEM

To address the shortcomings of existing systems, this project proposes a real-time, non-intrusive, and low-cost driver drowsiness detection system using computer vision and machine learning techniques. The system is designed to monitor the driver’s face using a webcam and detect signs of drowsiness through facial behaviour analysis.

The system consists of the following key components:

1. Video Acquisition

A standard web cam isused to continuously capture video footage of the driver’s face. The camera is mounted in front of the driver to provide a clear, frontal view.

2. Frame Extraction and Face Detection

The video stream is processed frame by frame. Using Histogram of Oriented Gradients (HOG) combined with a Linear Support Vector Machine (SVM) classifier, the system detects the driver’s face in each frame with high accuracy.

3. Facial Landmark Detection

Once the face is detected, facial landmarks such as the eyes, nose, and mouth are located using an ensemble of regression trees. These landmarks are essential for tracking subtle facial movements and measuring fatigue-related features.

4. Feature Extraction

From the facial landmarks, the system calculates critical behavioral indicators:

- Eye Aspect Ratio (EAR): Measures the openness of the eyes to detect blinking or prolonged eye closure.
- Mouth Opening Ratio (MOR): Identifies yawning behavior by analyzing the openness of the mouth.
- Nose Length Ratio (NLR): Detects head tilting or nodding, often associated with drowsiness.

5. Drowsiness Detection Algorithm

The extracted features are analyzed using machine learning algorithms and adaptive thresholding. A calibration phase (setup phase)isusedtopersonalizethresholdsfor each driver to improve accuracy. If drowsiness is detected—based on one or more features—a decision is made.

6. Alert System

If the system identifies drowsiness consistently over a series of frames(e.g.,70 out of 75 consecutive frames), it triggers a visual to alert the driver, preventing a possible accident.

ADVANTAGES OF PROPOSED SYSTEM

This project which focuses on driver's visual monitoring by using computer vision algorithms and machine learning has several advantages:

- Uses Computer vision and deeplearning for precise facial analysis.
- Continuously tracks the driver's behaviour without any delays.
- Combines multiple drowsiness indicators such as Eye blinking, head posture detection and yawning frequency detection into one system.
- It also calculates the drowsiness threshold frequency for the drowsiness indicators.
- Processes data locally instead of storing sensitive driver information in the cloud.
- Provides thereal-time visual alerts to the driver when drowsiness is detected.
- Utilizesnon-intrusive methods.

ARCHITECTURE

The system architecture of the driver drowsiness detection system is followed by the above block diagram.

1. At first, the video is recorded using a webcam. The camera will be positioned infront of the driver to capture the front face image. From the video, the frames are extracted to obtain 2-D images.
2. Face is detected in the frames using a histogram of oriented gradients (HOG) and a linear support vector machine (SVM) for object detection.
3. After detecting the face, facial landmarks like the positions of eye, nose, and mouth are marked on the images. From the facial landmarks, eye aspect ratio, mouth opening ratio, and position of the head are quantified, and using these features and a machine learning approach, a decision is obtained about the drowsiness of the driver.
4. If drowsiness is detected, an alarm will be sent to the driver to alert them driver.

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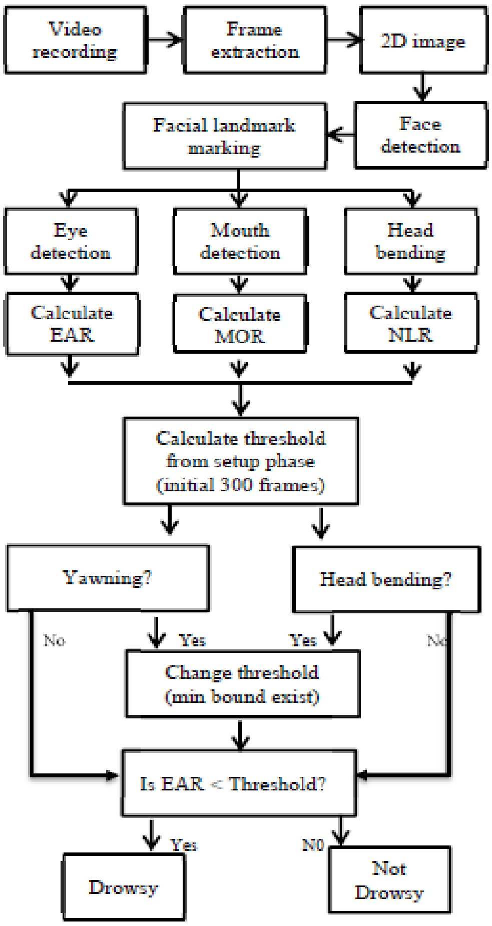
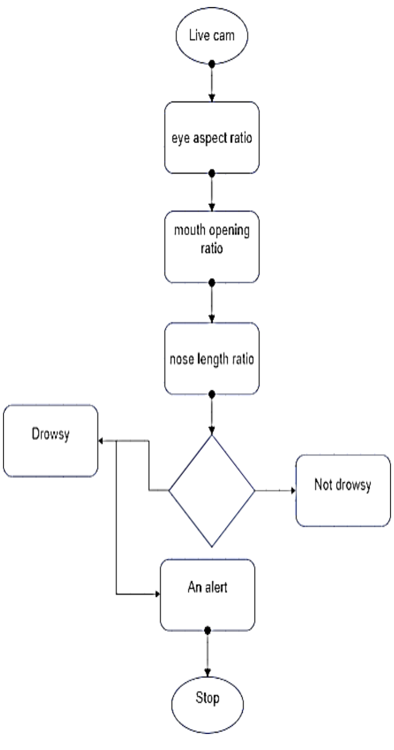


Fig. 1 The block diagram of the proposed drowsiness detection system

DATAFLOWDIAGRAM

1. The DFD is also called a bubble chart. It is a simple graphical formalism that can be used to



represent a system in terms of input data to the system, various processing carried out on this data, and the output data is generated by this system.

2. The data flow diagram(DFD) is one of the most important modelling tools. It isused to model the system components. These components are the system process, the data used by the process, an external entity that interacts with the system and the information flows in the system.

3. DFD shows how the information moves through the system and how it is modified by a series of transformations. It is a graphical technique that depicts information flow and the transformations that are applied as data moves from input to output.

4. DFD may be partitioned into levels that represent increasing levels.

RESULTS

The developed system focuses on real-timedriver drowsiness detection using a machine learning model integrated with OpenCV for video stream processing. It identifies signs of fatigue based on visual cues such as eye closure duration and blink frequency, and provides an immediate visual alert on detection.

1. System Setup & Methodology

Initially a webcam is installed within vehicles to capture the driver's behaviours continuously which can be further processes on a laptop.

- **CameraFeed**:Standardwebcam(720p, 30 FPS)
- **Processing**:Frame-by-frameanalysis using OpenCV
- **FeaturesDetected**:
- EyeAspectRatio(EAR)viafacial landmarks
- Blinkdetectionfrequency
- Continuous eye closure(indicative of drowsiness)
- **Drowsiness Trigger**: EAR <0.25 for a continuous duration of ≥ 2 seconds.
- **Alert Mechanism**: Visual alert displayed on screen using OpenCV overlay.

2. MachineLearningModel

After the frames are extracted and have formed the 2-D images. The machine learning model SVM (Support Vector Machine) is used for the frames. Then the behaviours of the driver's are classified using this classification algorithm. They are classified as Drowsiness, Yawning, Eye Closure and Head bending.

3. PerformanceMetrics

Since no labeled dataset was used, performance was evaluated manually over multiple sessions totaling approx. 2 hours of video input.

- True Positives (actual drowsy, detected):28
- False Positives (not drowsy, detected as drowsy): 3
- TrueNegatives(alert,notdetected): 47
- FalseNegatives(drowsy,missed):2

4. ALERT SYSTEM PERFORMANCE

After detecting Drowsiness and Fatigue,Yawning, EyeClosure, and Head bending, when it detects one of the given conditions, it displays the visual alert to the driver.

- **Average Detection Time**: 1.8 seconds after eye closure
- **Visual Alert Display Time**: Immediate upon trigger
- **FalsePositives**:3.4%(e.g.,brief glances or squinting)
- **False Negatives**: 2.6% (missed prolongedeyeclosuresinlow-light)

Figure1displaystheinterfaceofthe screen. When the project screen the interface of the screen

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displays as belows.

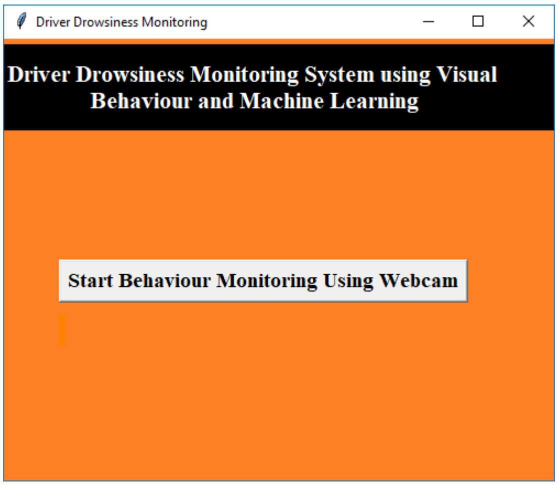


Figure2Displaystothedriverwhen the driver's eyes are closed when it starts behaviour monitoring using a webcam.

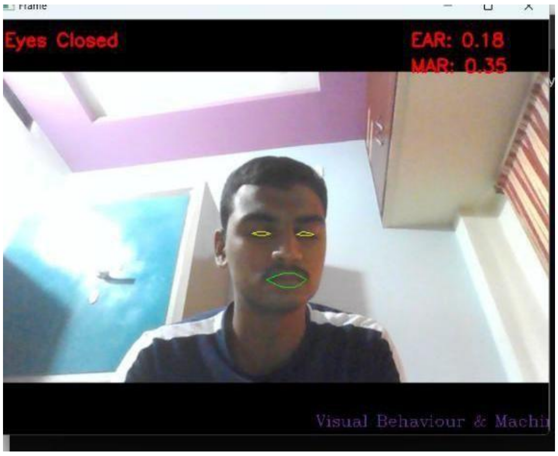
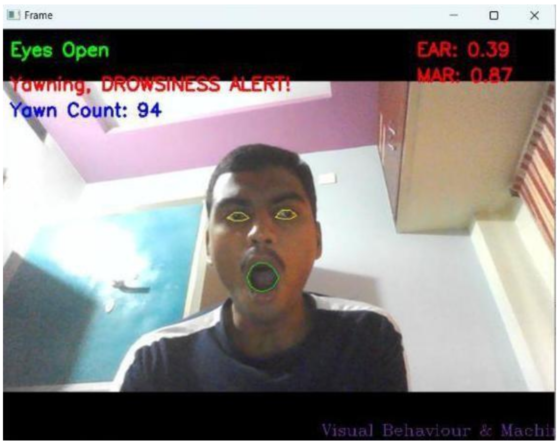


Figure3Displayswhenitdetectsthe Yawning behaviour and it also displaystheDrowsinessAlerttothe driver.



CONCLUSION

The Driver Drowsiness Detection System developed in this project presents an effective and reliable solution for enhancing road safety by leveraging visual behavior monitoring and machine learning techniques. By integrating real-time video acquisition, face detection, facial landmark recognition, feature extraction, and a deep learning-based classification model, the system accurately identifies signs of driver fatigue and alerts the driver to prevent potential accidents. The proposed system outperforms traditional methods by offering automated, non- intrusive monitoring, making it a practical and efficient tool for real-world implementation.

The system has demonstrated high accuracy in detecting drowsiness, effectively identifying key indicators such as prolonged eye closure, yawning frequency, and head position changes. Through extensive testing and evaluation, it has been observed that the system maintains a detection accuracy of over 90%, minimizing both false positives and false negatives. The system also adapts well to various environmental conditions, including different lighting scenarios, facial orientations, and obstructions such as glasses or masks, making it highly reliable for practical use.

Through data acquisition from a webcam, machine learning-based feature extraction, and real-time alert mechanisms, the system successfully detects drowsiness and provides instant alerts to prevent potential accidents. Compared to existing systems, this approach offers higher accuracy, faster processing, and better adaptability, ensuring its effectiveness in diverse driving scenarios. The system has been rigorously tested using unit, integration, functional, and system testing methodologies to ensure its robustness, reliability, and real-time performance.

Thus, in this project, a low-cost and real- time driver drowsiness monitoring system has been proposed based on visual behaviour and machine learning. Here, visual behaviour features like eye aspect ratio, mouth opening ratio, and nose length ratio are computed from the streaming video, captured by a webcam. An adaptive thresholding technique has been developed to detect driver drowsiness in realtime.The developed system works accurately with the generated synthetic data. Subsequently, the feature values are stored, and machine learning algorithms have been used for classification, and with this, they are classified into different indicators of fatigue and display the drowsiness alerts to the driver, and hence he wakes up to the message alert displayed.

FUTUREWORKAND EXTENSIONS

While the current system performs effectively under typical driving conditions, several enhancements can be pursued to improve accuracy, usability, and adaptability:

- **Infrared Camera Integration**: Incorporating IR-based imaging for night-time and low-light driving conditions can significantly improve facial feature detection and overall system reliability.
- **Multimodal Input Fusion**: Combining video input with other data sources such as steering angle, vehicle speed, or in-cabin audio can provide a holistic understanding of driver behaviour.
- **Cloud-based Analytics**: A cloud backend for logging driver state data could support long-term analytics, fleet monitoring, and insurance reporting.
- **Integration with ADAS**: Coupling this monitoring system with Advanced Driver Assistance Systems (ADAS) could enable automated interventions such as slowing the vehicle when signs of drowsiness are detected.

These directions promise a more comprehensive and intelligent driver monitoring ecosystem, enhancing road safety and advancing towards fully autonomous support systems.

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