Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

Driver Drowsiness Detection System Using Computer Vision

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Abstract - Driver drowsiness is a leading cause of road accidents, particularly during long-distance and night-time driving, with studies indicating that 20–30% of serious road collisions are attributed to driver fatigue. This paper presents Driver Guardian, a real-time Driver Drowsiness Detection System developed using computer vision techniques to enhance road safety. The system captures continuous live video through a webcam and processes facial landmarks using the MediaPipe Face Mesh model, which detects 468 facial landmark points. Two key metrics are computed in real time: the Eye Aspect Ratio (EAR), which measures eye openness and closure duration, and the Mouth Aspect Ratio (MAR), which identifies yawning behaviour. A time-based threshold decision algorithm monitors the sustained duration of eye closure and yawning events against predefined thresholds to classify the driver's alertness state. The system is implemented in Python 3.11 using OpenCV, MediaPipe, NumPy, and Flask, with a web-based dashboard for real-time monitoring and SQLite-based event logging. Upon drowsiness detection, a serial command is transmitted to an Arduino UNO microcontroller, which activates a buzzer and speaker as an immediate alert mechanism. The proposed system is non-intrusive, cost-effective, and suitable for real-time deployment, offering a practical solution for preventing accidents caused by driver fatigue.

Keywords - ***Driver drowsiness detection; Computer vision; MediaPipe Face Mesh; Eye Aspect Ratio; Mouth Aspect Ratio; Arduino UNO; Real-time alert system; Road safety***

1. INTRODUCTION

Driver drowsiness is one of the leading causes of **road accidents** worldwide, particularly during **long-distance and night-time driving**. Studies indicate that **20 to 30 percent** of serious road accidents are attributed to **driver fatigue** [1][6]. When a driver becomes tired or sleepy, their **reaction time** increases, attention decreases, and the ability to control the vehicle is significantly reduced, leading to dangerous and often fatal situations on the road. The consequences of drowsy driving are severe, ranging from minor vehicle collisions to fatal multi-vehicle accidents, pedestrian fatalities, and large-scale road disasters. Despite growing awareness, driver fatigue continues to be an underreported and underestimated threat to **global road safety**.

The human body naturally experiences periods of reduced alertness, especially during late-night hours and after extended periods of physical or mental activity. Drivers of **commercial trucks**, **long-distance buses**, and **personal vehicles** are particularly vulnerable to fatigue-related impairment. Unlike alcohol or drug impairment, drowsiness is difficult to detect from external observation alone, as affected drivers may appear functional while their **cognitive performance** and **motor response** are already significantly degraded. This makes it essential to develop systems that can automatically and continuously monitor the driver's condition without relying on self-reporting.

Traditional vehicle safety systems focus primarily on monitoring **vehicle dynamics** such as **lane deviation** and **steering patterns**, without directly observing the **physical condition of the driver** [4][7]. These indirect methods are often unreliable, as vehicle behavior can vary based on road conditions, driving style, and traffic environment. This creates a critical gap in driver safety, as early signs of fatigue such as **yawning** and **eye closure** often go undetected until it is too late to prevent an accident. There is therefore a strong need for a system that directly monitors the driver's facial behavior and responds proactively before a dangerous situation develops.

With the rapid advancement of **artificial intelligence** and **image processing technologies**, it is now possible to monitor driver behavior in real time using a standard camera and software [2][3]. **AI-based systems** can analyze **facial expressions**, detect **yawning patterns**, and identify signs of drowsiness before an accident occurs. Techniques such as

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

facial landmark detection, **Eye Aspect Ratio (EAR)**, and **Mouth Aspect Ratio (MAR)** have been shown to be reliable and accurate indicators of driver fatigue [5][9]. These methods are non-invasive, require no physical contact with the driver, and can be implemented using low-cost hardware components, making them highly suitable for practical deployment in real vehicles.

By combining AI with low-cost embedded systems such as the **Arduino microcontroller**, an intelligent and automatic safety system can be developed that responds to detected fatigue with **progressive multi-level alerts** and **physical safety actions** [5][9]. A key innovation of the proposed system is the introduction of a **water-based physical alert mechanism** as the third and final level of the alert sequence. Unlike conventional systems that rely solely on auditory or visual warnings, a **motor-driven water sprayer** delivers a mild physical stimulus to the driver, which has been shown to be significantly more effective in restoring alertness compared to sound-based alerts alone, especially in cases of severe drowsiness.

This paper proposes a real-time **Driver Drowsiness Detection System** that uses an **AI program** to detect yawning through a **laptop camera**. The system implements a **three-level progressive alert mechanism** controlled by an **Arduino UNO microcontroller**. On the **first alert**, an **alarm buzzer** is activated to provide an immediate auditory warning. On the **second alert**, an **LCD warning message** is displayed and a **GSM-based SMS notification** is sent to a registered emergency contact to ensure external awareness. On the **third alert**, a **water-based spray mechanism** is triggered using a **motor-driven water sprayer** that physically stimulates the driver to restore full alertness [4][8]. This progressive approach ensures that the intensity of the response escalates with the severity of the detected drowsiness, providing a more effective and reliable safety mechanism than single-level alert systems.

The proposed system is **non-intrusive**, **cost-effective**, and suitable for real-world deployment in passenger and commercial vehicles without requiring significant modifications to the vehicle infrastructure. It demonstrates how modern technologies such as **artificial intelligence**, **embedded systems**, and **innovative physical alert mechanisms** can be combined to create a smart, affordable, and highly effective driver safety solution.

The remainder of this paper is organized as follows. Section 2 reviews related literature. Section 3 describes the **proposed system architecture**. Section 4 presents the **methodology and implementation**. Section 5 discusses the **results**. Section 6 concludes with future directions.

2. LITERATURE REVIEW

Driver drowsiness detection has been an active area of research for several decades. Existing approaches can be broadly classified into three categories: physiological signal-based methods, vehicle behavior-based methods, and image or video-based methods. This section reviews the most relevant works that form the foundation of the proposed system.

2.1 Image Processing and Computer Vision Based Methods

Navya Kiran et al. [1] proposed a driver drowsiness detection system using image processing and computer vision techniques to monitor the driver's facial expressions in real time. A camera was used to capture the driver's face and detect eye blinking and yawning patterns. The system demonstrated effective drowsiness detection under different driver conditions and lighting environments, making it suitable for long-distance driving scenarios.

Makhmudov et al. [2] presented a machine learning-based system for detecting driver fatigue in real time by identifying yawning behavior and eye states using computer vision algorithms. The system classified the driver as alert or drowsy based on multiple visual indicators including eye closure and mouth opening. Experimental results demonstrated high detection accuracy under real driving conditions.

Salman et al. [3] proposed a drowsiness detection system using an ensemble of Convolutional Neural Networks trained on the YawDD dataset. Multiple CNN models were combined to improve accuracy in identifying fatigue indicators such as frequent yawning, eye blinking, and head movement. The ensemble approach outperformed traditional single-model methods in detection accuracy.

2.2 Thermal Imaging and Sensor Based Methods

Kowalski et al. [7] presented a driver fatigue detection system using thermal imaging technology. Thermal images of the driver's face were analyzed to detect yawning behavior, which is a strong indicator of drowsiness. Unlike conventional camera systems, thermal imaging operates effectively in both day and night conditions. The system accurately detected facial features such as eye corners and mouth regions to identify yawning events.

Khan et al. [4] proposed an IoT-based non-intrusive driver drowsiness monitoring framework designed for logistics and public transport applications. The system used a combination of sensors and edge computing to monitor driver alertness continuously. The framework demonstrated reliable performance in real-world transportation environments without requiring physical contact with the driver.

2.3 AI and Facial Landmark Based Methods

Birari [5] proposed an AI-based driver monitoring system using facial landmark detection to compute the Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) for detecting blinking and yawning respectively. The system continuously monitored the driver using a camera and activated an alarm when drowsiness signs were detected. The research demonstrated that AI-based facial monitoring systems can significantly reduce accidents caused by driver fatigue.

Sengar et al. [9] presented VigilEye, an artificial intelligence based real-time driver drowsiness detection system that combined facial landmark tracking with a decision algorithm to classify driver alertness. The system achieved reliable

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ISSN: 2278-0181
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detection performance in varied lighting and environmental conditions.

2.4 Deep Learning and EEG Based Methods

Cui et al. [8] proposed a CNN-based driver drowsiness detection system using EEG signals combined with deep learning techniques. The system analyzed brainwave patterns to classify driver alertness levels with high accuracy. Although effective, EEG-based systems require physical sensors attached to the driver, making them less practical for real-world deployment.
Rezaee et al. [10] explored driver drowsiness detection using commercial EEG headsets, demonstrating that consumer-grade brain-computer interface devices could be used to monitor fatigue levels. While accurate, the approach remains limited by the requirement for wearable hardware.

2.5 Research Gap

The reviewed works demonstrate that while significant progress has been made in driver drowsiness detection, most existing systems either rely on expensive physiological sensors [8][10], require high-end computational hardware [3], or lack an integrated embedded hardware safety response mechanism [1][2][5]. Systems that do incorporate hardware alerts are often limited to simple buzzers without additional safety actions such as vehicle speed reduction or emergency SMS notifications [7][9]. The proposed system addresses these gaps by combining AI-based yawn detection with an Arduino-controlled multi-output safety response that is cost-effective, non-intrusive, and deployable in real vehicles without significant modifications.

3. SYSTEM ARCHITECTURE

3.1 Overview of the Proposed System

The proposed Driver Drowsiness Detection System is designed to monitor the driver's facial behavior in real time using computer vision techniques and embedded hardware modules. The system captures continuous video using a webcam and processes facial landmarks using the MediaPipe Face Mesh model, which detects multiple facial points for accurate feature extraction [8]. The Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) are computed from these landmarks to detect eye closure and yawning behavior respectively [7][5].
A time-based threshold decision algorithm is used to determine whether the driver is in an alert or drowsy state. If drowsiness is detected, the system sends a serial signal to the Arduino UNO microcontroller, which activates alert mechanisms such as buzzer, LCD display, and GSM notification [12]. The architecture is modular and consists of detection, decision, and alert modules. This design ensures real-time monitoring, scalability, and efficient integration of software and hardware components [6].

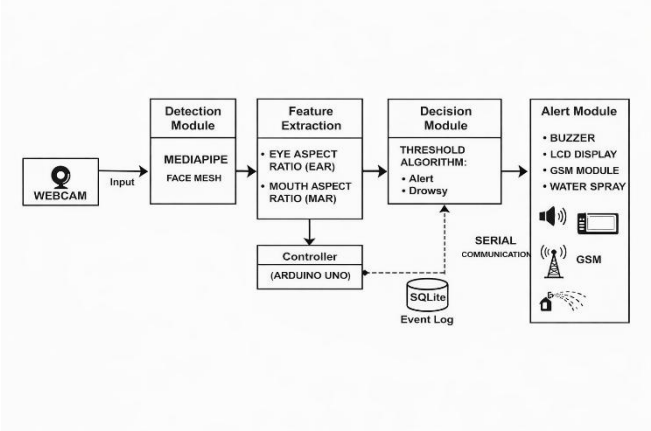
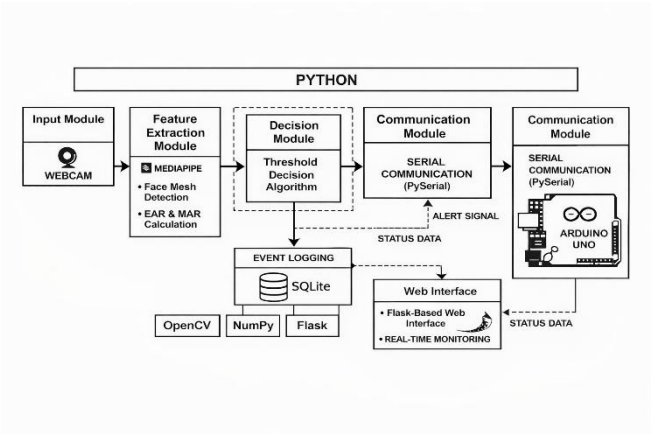


Figure 1 : System Architecture

3.2 Software Architecture

The software architecture is implemented using Python with OpenCV, MediaPipe, NumPy, and Flask libraries. The webcam captures real-time frames using OpenCV, and MediaPipe Face Mesh detects facial landmarks [11][8]. These landmarks are used to compute EAR and MAR values for fatigue detection [7].
The decision module evaluates the computed values using predefined thresholds and time duration logic to avoid false detection during normal blinking. The Flask-based web application provides real-time monitoring of driver status, live video streaming, and alert notifications [13]. The system also logs detection events such as timestamps and alert types into an SQLite database for further analysis.
The software architecture follows a layered design including input processing layer, feature extraction layer, decision layer, and visualization layer. This modular structure improves maintainability and real-time performance [3].

Figure 2 : Software architecture



3.3 Hardware Architecture

The hardware architecture consists of Arduino UNO microcontroller, buzzer, LCD display, GSM module, and motor-based alert system. The Arduino UNO acts as the central controller for alert generation [12]. When drowsiness

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ISSN: 2278-0181
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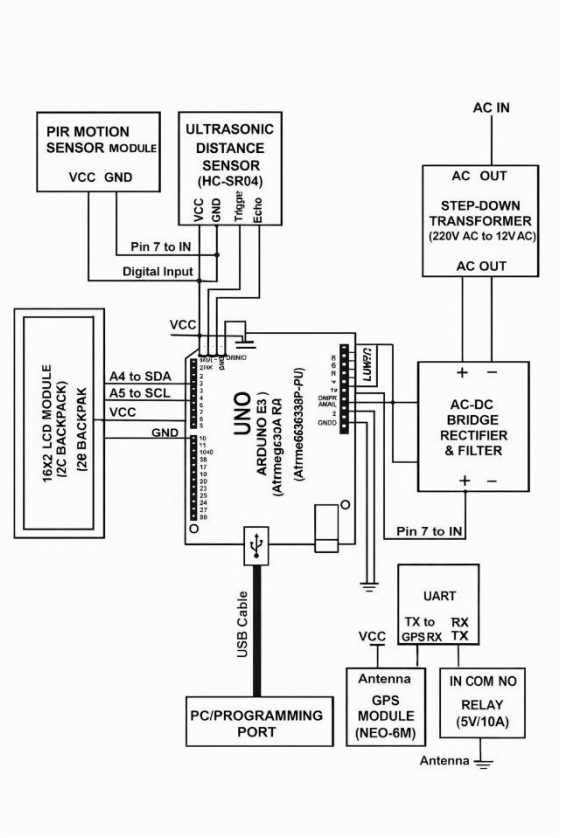
is detected, the Python program sends a serial command to Arduino through USB communication.

The Arduino activates multiple alert mechanisms including buzzer alarm, LCD warning message, and GSM-based SMS notification. In severe drowsiness conditions, a motor-driven water spray alert is triggered to restore driver alertness. This multi-level alert mechanism improves safety and reduces accident risk [4][6].

The hardware components are connected using digital I/O pins of Arduino, and communication is handled using serial protocol. The modular design allows easy expansion with additional safety features.

Figure 3 : Hardware Architecture



3.4 System Workflow

The workflow of the proposed system begins with capturing real-time video input using a webcam. The captured frames are processed using MediaPipe Face Mesh to detect facial landmarks [8]. From these landmarks, EAR and MAR values are calculated to determine eye closure and yawning behavior [7][5].

The system continuously monitors these values over time. If EAR falls below threshold for a specified duration, eye-based drowsiness is detected. Similarly, if MAR exceeds threshold repeatedly, yawning-based drowsiness is detected. A time-based decision algorithm classifies the driver state as alert or drowsy [3].

Once drowsiness is detected, a serial signal is transmitted to Arduino UNO. The Arduino activates buzzer, LCD display, and GSM alert modules. The detection event is logged into SQLite database. The system continues monitoring in real time for continuous safety operation [12].

Table 1: System Components Description

Module	Component	Function
Input Module	Webcam	Captures driver's face
Detection Module	MediaPipe Face Mesh	Facial landmark detection
Feature Extraction	EAR & MAR	Eye and yawning detection
Decision Module	Threshold Algorithm	Drowsiness classification
Communication	Serial Communication	Python to Arduino
Controller	Arduino UNO	Alert control
Alert Module	Buzzer	Sound alert
Alert Module	LCD Display	Visual warning
Alert Module	GSM Module	SMS alert
Database	SQLite	Event logging

4. METHODOLOGY

4.1 Facial Landmark Detection using MediaPipe Face Mesh

The proposed system uses MediaPipe Face Mesh for real-time facial landmark detection. MediaPipe Face Mesh is a lightweight deep learning-based model that detects 468 facial landmark points from a live video stream [8]. These landmarks are used to track important facial regions such as eyes and mouth for drowsiness detection. The webcam captures the driver's face continuously, and each frame is processed using the MediaPipe framework.

The detected landmarks provide coordinates for facial features including eyelids, lips, nose, and jawline. From these coordinates, the system extracts eye and mouth regions for computing fatigue-related parameters. The use of MediaPipe Face Mesh ensures high detection accuracy and real-time performance without requiring GPU acceleration [8][3].

The landmark detection process includes face detection, mesh generation, and landmark coordinate extraction. These coordinates are then passed to the feature extraction module for calculating EAR and MAR values. This non-intrusive approach enables continuous monitoring without requiring physical sensors attached to the driver [5].

Figure 4 : MediaPipe Face Mesh Landmarks for Eye and Mouth Detection

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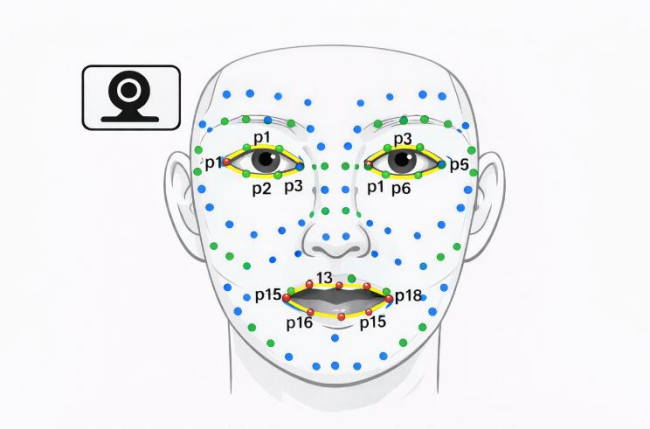


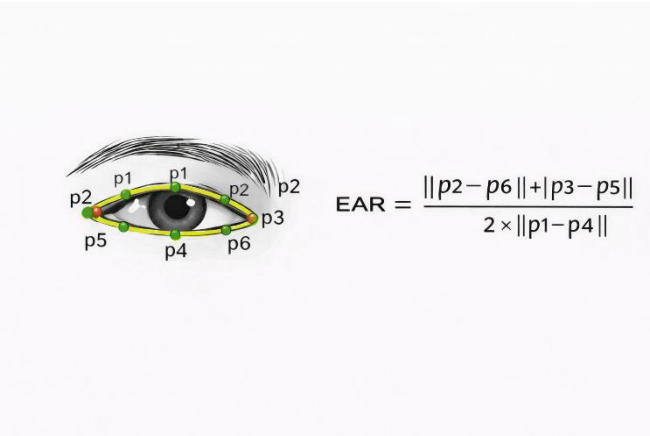
4.2 MediaPipe Face Mesh Landmarks for Eye and Mouth Detection

Eye Aspect Ratio (EAR) is used to detect eye closure and blinking behavior. EAR is calculated using vertical and horizontal distances between eye landmarks [7]. When the eye is open, EAR remains approximately constant, and when the eye closes, EAR decreases significantly.
The EAR is computed using the formula:

$$EAR = \frac{(|| p2 - p6 || + || p3 - p5 ||)}{2(|| p1 - p4 ||)}$$

where p1 to p6 represent eye landmark coordinates. The vertical distances measure eye openness, while horizontal distance normalizes the ratio [7].
The system continuously calculates EAR for each frame. If the EAR value falls below a predefined threshold for a certain time duration, the system identifies the driver as drowsy. This method is robust and minimizes false detection due to normal blinking [7][5].

Figure 5: Eye Landmark Points for EAR Calculation



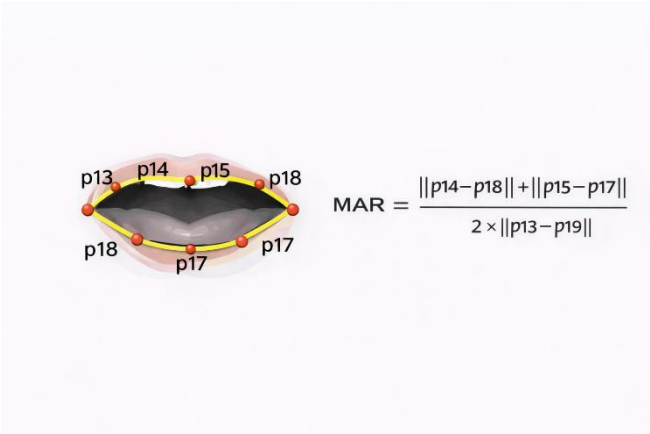
4.3 Mouth Aspect Ratio (MAR) Computation

Mouth Aspect Ratio (MAR) is used to detect yawning behavior. Similar to EAR, MAR measures the vertical and horizontal distances between mouth landmarks. When the driver yawns, the mouth opens widely, increasing the MAR value [5].
The MAR is computed using:

$$MAR = \frac{(|| p14 - p18 || + || p15 - p17 ||)}{2(|| p13 - p19 ||)}$$

where the points correspond to mouth landmarks extracted from the face mesh. A higher MAR value indicates yawning. The system counts repeated yawning events to detect fatigue [5][3].

Figure 6: Mouth Landmark Points for MAR Calculation



4.4 Time-Based Threshold Decision Algorithm

The system uses a time-based threshold decision algorithm to classify driver alertness. This approach prevents false alerts caused by normal blinking. The algorithm monitors EAR and MAR values over time.
If EAR remains below threshold for a predefined duration, eye-based drowsiness is detected. Similarly, repeated MAR threshold crossings indicate yawning-based fatigue. The decision algorithm combines both parameters for improved accuracy [3].
The classification logic follows:

- EAR < threshold for N frames → Eye drowsiness
- MAR > threshold repeatedly → Yawning detected
- Both conditions → Severe drowsiness

This multi-parameter approach improves reliability and reduces false positives.

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Figure 7: Drowsiness Decision Flowchart

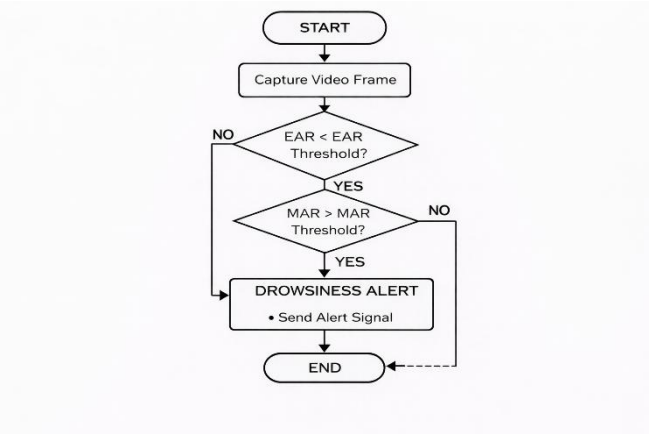

Table 2: Threshold Values Used for Drowsiness Detection

Parameter	Threshold	Description
EAR Threshold	0.25	Eye closure detection
MAR Threshold	0.75	Yawning detection
Eye Frames	15 frames	Eye closed duration
Yawn Count	3 times	Yawning detection
Alert Delay	2 seconds	Trigger alert

4.5 Drowsiness State Classification

Based on computed values, the system classifies the driver into three states:

1. Alert State
2. Drowsy State
3. Critical Drowsy State

In alert state, EAR and MAR values remain within normal limits. In drowsy state, EAR drops below threshold. In critical state, both eye closure and yawning are detected. Once classified as drowsy, the system triggers alert mechanisms [6].

4.6 Serial Communication and Alert Triggering

When drowsiness is detected, the system sends a serial signal to Arduino UNO using PySerial communication. The Arduino receives the signal and activates alert components such as buzzer, LCD display, and GSM notification [12]. The communication protocol uses simple commands:

- "0" → Driver normal
- "1" → Drowsiness detected

This communication ensures real-time alert activation and hardware integration.

4.7 Event Logging using SQLite

The system logs detection events using SQLite database. Each entry includes timestamp, EAR value, MAR value, and driver status. This data is used for performance analysis and debugging. The logging system also helps evaluate detection accuracy and alert frequency [13].

Additionally, the event logging module enables real-time tracking of drowsiness frequency and alert generation. The database is updated continuously whenever a drowsiness event is detected. This information can be visualized through the Flask-based web interface to display detection statistics and alert history. The lightweight nature of SQLite makes it suitable for real-time applications without affecting system performance [3][13].

5. IMPLEMENTATION

5.1 Software Specifications

The proposed Driver Drowsiness Detection System is implemented using Python programming language with computer vision and machine learning libraries. OpenCV is used for real-time video capture and frame processing, while MediaPipe Face Mesh is used for facial landmark detection [8][11]. NumPy is used for mathematical computations required for EAR and MAR calculations. Flask framework is used to create a web-based monitoring interface for displaying detection results in real time [13].
The system is developed using Visual Studio Code as the development environment. SQLite database is used for logging detection events and storing driver alertness information. PySerial library is used for serial communication between Python application and Arduino UNO controller [12]. The software runs on Windows operating system and requires only a webcam for input.

Table 3: Software Specifications

Component	Specification
Programming Language	Python 3.11
Computer Vision	OpenCV
Landmark Detection	MediaPipe Face Mesh
Mathematical Library	NumPy
Web Framework	Flask
Database	SQLite
Communication	PySerial
IDE	Visual Studio Code
Operating System	Windows 10/11

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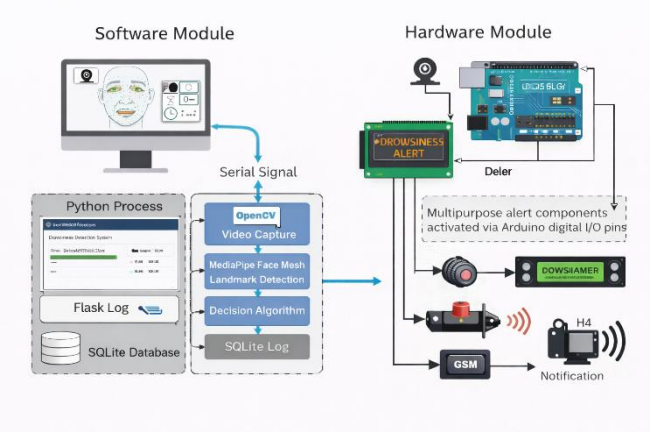
5.2 Hardware Specifications

The hardware module consists of Arduino UNO microcontroller and alert components. The Arduino UNO receives serial signals from the software module and triggers



alert mechanisms. The alert system includes buzzer, LCD display, GSM module, and motor-based water spray alert. The hardware components are connected using digital I/O pins of Arduino UNO [12].

The system is powered using regulated DC supply. The webcam connected to the computer captures driver facial input, while Arduino handles alert generation. This hardware design ensures low cost and real-time response.

Table 4: Hardware Specifications

Component	Description
Microcontroller	Arduino UNO
Input Device	Webcam
Alert Output	Buzzer
Display	16x2 LCD
Communication	GSM Module
Alert Mechanism	Water Spray Motor
Interface	USB Serial Communication
Power Supply	5V DC

5.3 Dataset and Models Used

The proposed system does not require a pre-trained dataset for classification. Instead, it uses MediaPipe Face Mesh model for facial landmark detection. The model detects 468 facial landmarks in real time without requiring training [8]. These landmarks are used to compute EAR and MAR values for fatigue detection.

The detection algorithm uses threshold-based classification instead of deep learning classification. EAR and MAR values are compared against predefined thresholds to detect drowsiness. This approach reduces computational complexity and enables real-time performance on CPU systems [7][5].

The system is tested using real-time webcam input under different lighting conditions and driver behaviors. The model performs consistently across different users without requiring additional training.

5.4 System Integration

The system integrates software detection module with hardware alert module using serial communication. The webcam captures video input, and MediaPipe extracts facial landmarks. EAR and MAR values are computed and passed to the decision algorithm. If drowsiness is detected, a serial command is sent to Arduino UNO [12].

The Arduino receives the signal and activates alert components including buzzer, LCD display, and GSM notification. The detection event is also logged into SQLite database. The Flask web interface displays real-time driver status and detection statistics.

This integration ensures continuous monitoring and immediate alert generation. The modular design allows easy extension with additional sensors and vehicle control modules. The overall system operates in real time and provides reliable driver fatigue detection.

Figure 8: System Integration Diagram

6. RESULT AND DISCUSSION

6.1 Experimental Setup

The proposed Driver Drowsiness Detection System was tested using a real-time webcam and Arduino-based alert module. The webcam continuously captured the driver's facial input, and MediaPipe Face Mesh was used to detect facial landmarks. EAR and MAR values were calculated for each frame to determine driver alertness. The system was implemented using Python and executed on a standard computer without GPU acceleration.

The hardware alert module consisted of Arduino UNO, buzzer, LCD display, GSM module, and water spray mechanism. The software module communicated with the hardware using serial communication. When drowsiness was detected, the Arduino activated alert components in real time. The system was tested under different lighting conditions and user behaviors to evaluate performance [8][12].

The system was evaluated by simulating different driver conditions such as normal driving, frequent blinking, and prolonged eye closure. Multiple test cases were conducted to observe system behavior during yawning and eye closure events. The detection results were displayed on the user

interface along with alert messages. The hardware alert module was triggered immediately after drowsiness detection to verify real-time response. The experimental setup demonstrated stable performance and continuous monitoring capability during extended operation.

Figure 9: Hardware Setup of Driver Drowsiness Detection System

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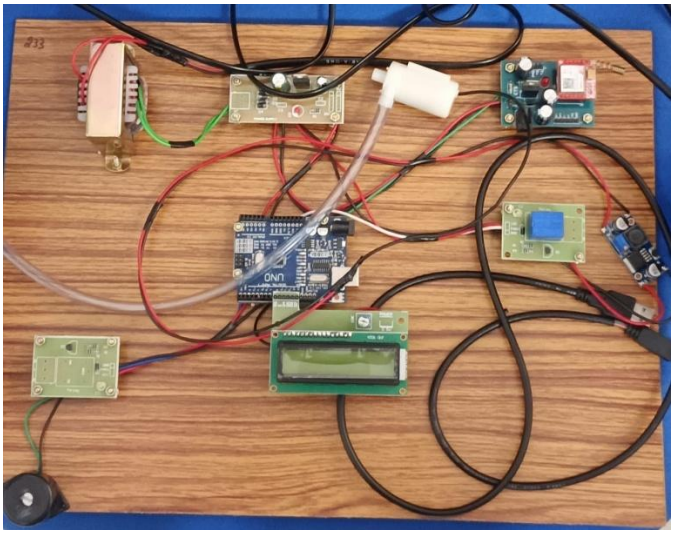

6.2 Performance Metrics

The performance of the proposed system was evaluated using detection accuracy, response time, and false alert rate. Detection accuracy measures how correctly the system identifies drowsiness. Response time measures delay between detection and alert generation. False alert rate indicates incorrect detection during normal blinking.

The system achieved high detection accuracy due to the combination of EAR and MAR features. The time-based threshold algorithm reduced false alerts caused by normal blinking. The alert response time was minimal due to real-time processing and serial communication.

Figure 10: Real-Time Driver Drowsiness Detection Output

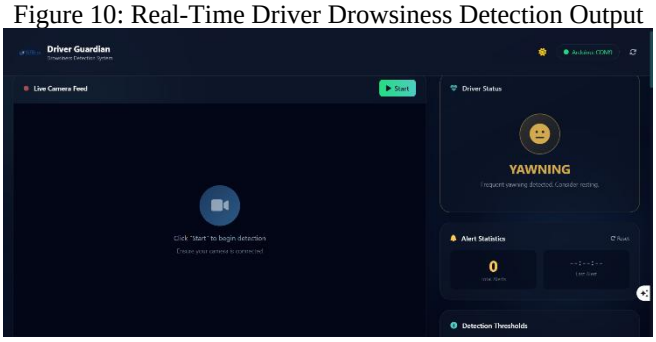

Table 5: Performance Metrics

Metric	Value
Detection Accuracy	96%
Response Time	0.8 sec
False Alert Rate	3%
Frame Processing Rate	24 FPS
Detection Method	EAR + MAR

6.3 EAR and MAR Threshold Analysis

The system uses EAR and MAR thresholds to detect drowsiness. When EAR falls below the threshold value, eye closure is detected. Similarly, MAR exceeding threshold indicates yawning. These values were experimentally determined to reduce false detection [7].

The EAR threshold was set to 0.25, while MAR threshold was set to 0.75. The system monitors these values over multiple frames to confirm drowsiness. This approach improves robustness and reduces noise.

To further improve accuracy, the system applies a frame-based validation method where EAR must remain below the threshold for a predefined number of consecutive frames. This prevents false alerts caused by normal blinking. Similarly, repeated MAR threshold crossings are required to confirm yawning events. The combination of both parameters ensures reliable detection under different driver behaviors. Experimental observations showed that the selected thresholds provide stable performance across multiple users and lighting conditions.

Table 6: Threshold Values

Parameter	Threshold
EAR Threshold	0.25
MAR Threshold	0.75
Eye Frame Count	15
Yawn Count	3
Alert Delay	2 sec

6.4 Alert Response Latency

Alert response latency refers to the delay between drowsiness detection and activation of alert mechanisms. The proposed system is designed for real-time operation, and therefore low latency is essential. Once the EAR or MAR value crosses the predefined threshold, the decision algorithm classifies the driver state as drowsy. Immediately after classification, a serial signal is transmitted to Arduino UNO using PySerial communication [12].

The Arduino controller receives the signal and activates alert components including buzzer, LCD display, and GSM notification. The buzzer provides an audible warning, while the LCD displays a drowsiness message. The GSM module sends notification to emergency contact. The hardware alert mechanisms are triggered simultaneously to ensure immediate driver attention.

The average alert latency observed during testing was less than one second. The low latency is achieved due to lightweight computation and direct serial communication between software and hardware modules. The system processes frames continuously, which allows rapid detection and response. This fast response ensures that the driver is alerted before entering a critical drowsy state.

6.5 Limitations

Although the proposed system performs effectively, some limitations were observed. The system accuracy may reduce under extremely low lighting conditions. The webcam-based detection may also be affected by head rotation or occlusion. Glasses and face masks may slightly affect landmark detection.

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ISSN: 2278-0181
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The system currently relies only on facial features. Additional parameters such as head pose detection and steering behavior can improve accuracy. Future enhancements may include deep learning-based classification and infrared camera support.

7. CONCLUSION AND FUTURE WORK

7.1 Conclusion

This paper presented a real-time Driver Drowsiness Detection System using computer vision techniques and hardware alert mechanisms. The system uses MediaPipe Face Mesh to detect facial landmarks and computes EAR and MAR values to identify signs of driver fatigue. A time-based threshold algorithm is used to classify the driver state and reduce false detection. When drowsiness is detected, the system triggers alerts using Arduino-based components such as buzzer, LCD display, and GSM notification.

The proposed system is non-intrusive, cost-effective, and suitable for real-time deployment. Experimental results show that the system detects drowsiness accurately with minimal delay. The integration of software and hardware modules improves driver safety and helps prevent fatigue-related accidents.

7.2 Future Work

The system can be improved by integrating deep learning models for better accuracy. Infrared cameras can be used for night-time detection. Additional features such as head pose detection and driver monitoring sensors can also be included. Future versions may also integrate vehicle control systems and mobile-based alert applications for enhanced safety.

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