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Real-Time Standalone Driver Drowsiness Detection System Using Eye Aspect Ratio (EAR) and Edge Computing

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Abstract: Driver fatigue is a leading cause of road fatalities globally, particularly in India where long-haul driving and high speeds on expressways increase the risk of microsleeps. This paper proposes a real-time, non-intrusive Driver Drowsiness Detection System that utilizes the Eye Aspect Ratio (EAR) and computer vision to monitor driver alertness. Unlike traditional systems integrated into high-end vehicles, this solution is a cost-effective, standalone unit capable of functioning independently of a vehicle's Electronic Control Unit (ECU) or Electronic Control Module (ECM). The system employs an ESP-32 camera and Python-based libraries to trigger immediate multi-modal alerts—including audio, visual, and haptic feedback—to re-engage a drowsy driver.

Keywords: Driver Drowsiness Detection, Eye Aspect Ratio (EAR), ESP-32 CAM, MediaPipe, Real-time Monitoring, Computer Vision, Road Safety, Standalone ADAS

1. Introduction

In India, the lack of advanced safety features in many vehicles contributes to a high number of accident cases. Drowsiness leads to decreased attention, slower reaction times, and dangerous "microsleeps" lasting only a few seconds. Current automotive solutions from brands like Mahindra (e.g., XUV700) and luxury foreign manufacturers (e.g., Mercedes-Benz, Volvo) have begun addressing this through Integrated Driver Monitoring Systems (DMS). However, these are often expensive and limited to premium models. This research focuses on bringing this life-saving technology to all vehicles through a portable, standalone hardware setup.

2. Literature Review

Recent studies have categorized drowsiness detection into three types: vehicle-based (steering patterns), physiological (heart rate/EEG), and behavioral (facial features). While vehicle-based systems like Mahindra's "Attention Assist" are common, they are often prone to false alarms from poor road conditions. Physiological methods are highly accurate but intrusive. Computer vision-based systems using Eye Aspect Ratio (EAR) have emerged as the most reliable non-intrusive alternative. Recent advancements leverage MediaPipe for faster landmark detection on edge devices like the ESP-32.

3. Problem Formulation

The research aims to solve the following objectives:

- To develop a low-cost, standalone drowsiness detection system independent of vehicle hardware.
- To implement a real-time monitoring algorithm with high accuracy using the Eye Aspect Ratio.
- To minimize latency between drowsiness detection and alert triggering.
- To address the lack of affordable safety technology for commercial and legacy vehicle drivers in India.

4. Methodology and Dataset Description

4.1 System Architecture

The system follows a five-step real-time processing pipeline:

1. **Data Acquisition:** An ESP-32 CAM captures live video of the driver's face.
2. **Preprocessing:** Using MediaPipe and Open CV (CV2), the system detects the face and identifies facial landmarks.
3. **Feature Extraction:** Calculation of the EAR based on eye landmark indices**.**
4. **Drowsiness Detection Logic:** Threshold comparison (EAR < 0.22) for a set duration.
5. **Alert Mechanism:** Triggering of a buzzer and vibrating motor.

4.2 Dataset

The model was validated using the MRL Eye Dataset and real-time live-testing data captured in varying lighting conditions (Daylight, Evening, and Night with IR support).

5. Data Analysis

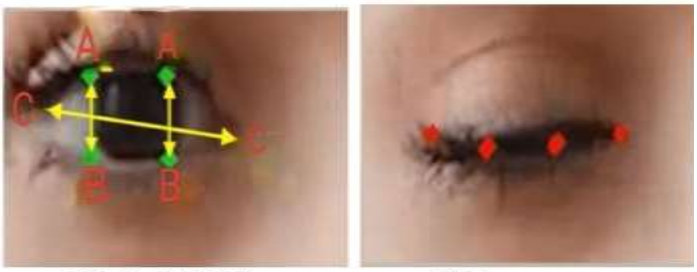
The Eye Aspect Ratio (EAR) is calculated as the ratio of distances between vertical and horizontal eye landmarks:

$$EAR = \frac{A + B}{2.0 \times C}$$

Where A and B are vertical distances and C is the horizontal distance.

Data points show that for an alert driver, EAR values fluctuate around

0.27. During a drowsiness event, the EAR drops to **0.22** or lower.



EAR= (A + B) / (2.0 * C) EAR=0

6. Model Development

The software is developed in Python 3.x using MediaPipe for lightweight landmark detection. The logic is implemented as a state machine that monitors the duration of eye closure to distinguish between natural blinks and drowsiness-induced closure.

7. Results and Discussions

Testing confirmed that the standalone nature of the ESP-32 setup successfully eliminated the need for a laptop or vehicle ECU connection. Unlike steering-based systems, this behavioral analysis remains accurate despite road conditions. The multi-modal alert (beep and vibration) proved highly effective in immediate driver re-engagement.

8. Conclusion and Future Work

The system provides a viable, low-cost safety solution for the Indian automotive market. Future work will focus on integrating **Alcohol Detection** and optimizing night-vision capabilities using dedicated IR LEDs.

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