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Driving innovation to create smarter, scalable solutions

Team Name : Virtus Synergia

Team Leader Name : SUJESH V

Problem Statement : AI-Enhanced Driver Wellness Monitoring

Brief about the Idea:

Our solution is a **privacy-first, multi-modal AI co-pilot** designed to enhance driver safety by continuously monitoring **fatigue, stress, and distraction** in real time.

The system fuses three complementary data streams:
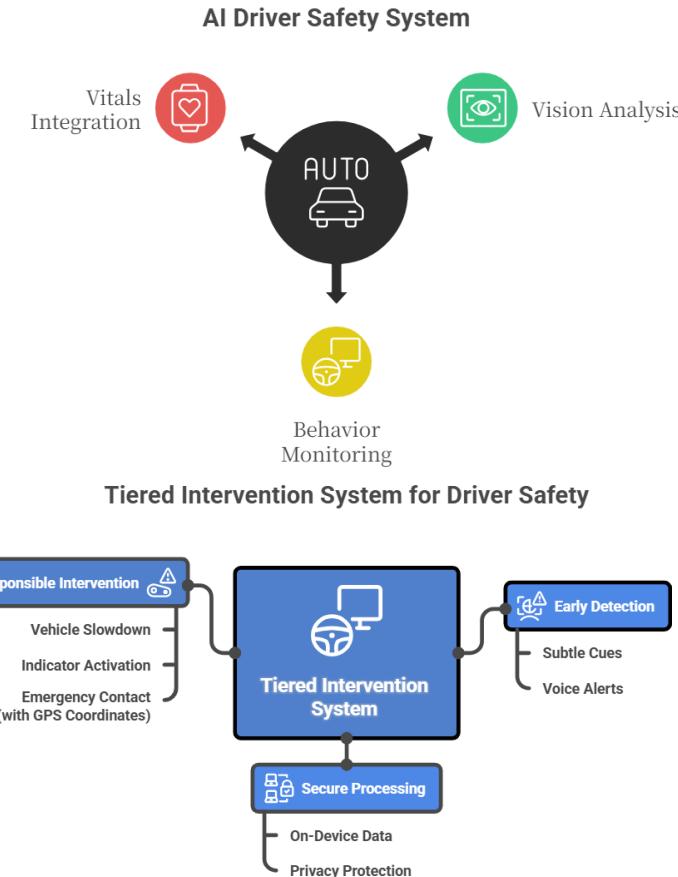
- **Vision (Camera):** Tracks facial landmarks such as **eye closure (PERCLOS)**, **gaze direction**, and **yawning** to detect drowsiness.
- **Behavior (Vehicle):** Monitors **steering wheel activity** (via potentiometer sensor) to identify erratic or inactive driving patterns.
- **Vitals (Wearable):** Integrates with a PC-based vitals simulator to test and validate the system's emergency logic against medical events, proving the multi-modal fusion works as designed.

All processing is done **locally on the edge device (Raspberry Pi 4)** — ensuring **privacy-first analysis** without cloud dependency.

When risk is detected, the **Tiered Intervention System** automatically activates:

- Subtle audio or visual cues to regain driver attention.
- Voice-based alerts prompting rest or focus.
- Intelligent assistance (e.g., **vehicle slowdown**, **indicator activation**, and **emergency contact notifications with GPS**).

This multi-modal, on-device approach ensures **early detection**, **secure processing**, and **responsible intervention**, significantly reducing fatigue-related road accidents.

AI Driver Safety System

Vitals Integration

Vision Analysis

AUTO

Behavior Monitoring

Tiered Intervention System for Driver Safety

Responsible Intervention

Vehicle Slowdown

Indicator Activation

Emergency Contact (with GPS Coordinates)

Tiered Intervention System

Early Detection

Subtle Cues

Voice Alerts

Secure Processing

On-Device Data

Privacy Protection

## Opportunity should be able to explain the following:
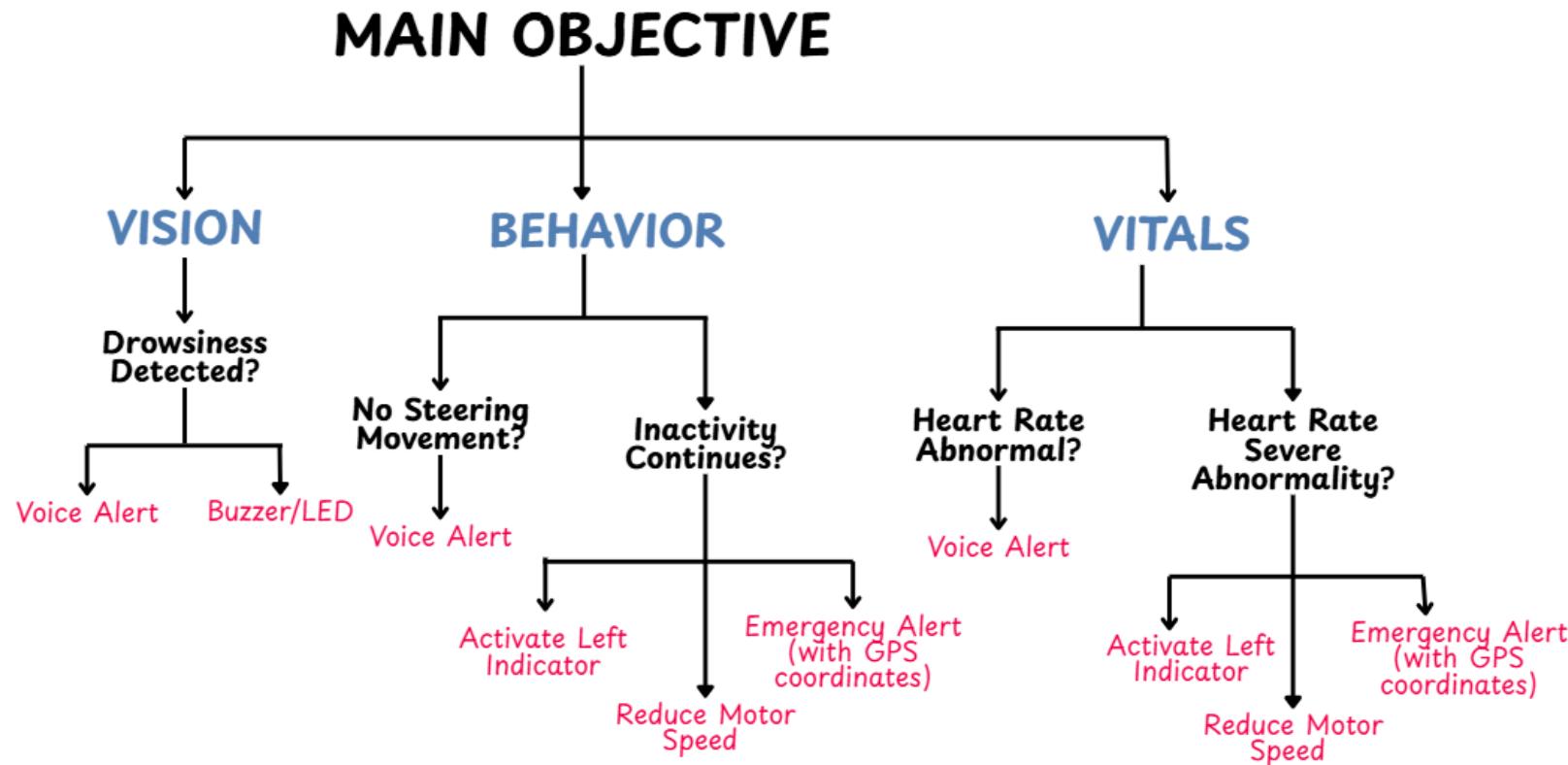
- **Privacy-first, multi-modal AI co-pilot** that fuses data from vision, steering behavior, and vitals to monitor driver wellness in real time.

- Detects **fatigue, distraction, and stress** early, enabling proactive accident prevention.

- Ensures **consistent performance** across all conditions — day, night, or when the driver's face is partially covered.

- Executes **on-device edge processing** on Raspberry Pi, guaranteeing **data privacy, low latency, and offline functionality.**

- Integrates **a tiered intervention system** with escalating responses — from subtle alerts to **automatic vehicle control and GPS-based emergency notifications.**

- Uses **lightweight AI models** (MediaPipe, TensorFlow Lite) optimized for low-power, embedded systems.

- Designed for **low-cost scalability**, making it feasible for **commercial fleets, personal vehicles, and public transport.**

- Provides a **holistic safety net** that combines intelligent detection, real-time decision-making, and human-centered intervention.

- Provides a **redundant**, **multi-modal safety net** by fusing diverse data streams. It triggers emergencies from behavioral (no steering) or physiological (vitals failure) anomalies—catching what vision-only systems miss.

List of features offered by the solution:

1. **Face Detection**: Detects and aligns faces using Medium pipe and OpenCV.

2. **Eye State / Blink Analysis:** Computes PERCLOS and uses a CNN to classify eye state.

3. **Gaze & Head Pose Estimation:** Tracks head orientation to detect prolonged downward gaze.

4. **Yawning Detection:** Uses a sequence-aware model to distinguish yawns from talking.

5. **Occupant Monitoring:** Detects phone use and hands-off-wheel behavior.

6. **Driving Anomaly Detection:** Monitors steering wheel data via steering column sensor (prototyped with 10k potentiometer) to detect erratic movements and lane weaving, acting as a non-visual confirmation of fatigue or stress.

7. **Tiered Intervention System:** Four-level alert system that escalates from subtle chimes to proactive voice guidance (e.g., "Please Take a break & Calm Down") using TTS and Maps APIs.

Driver Monitoring System Features

Intervention System · Face Detection · Anomaly Detection · Eye State Analysis · AUTO · Occupant Monitoring · Gaze Estimation · Yawning Detection
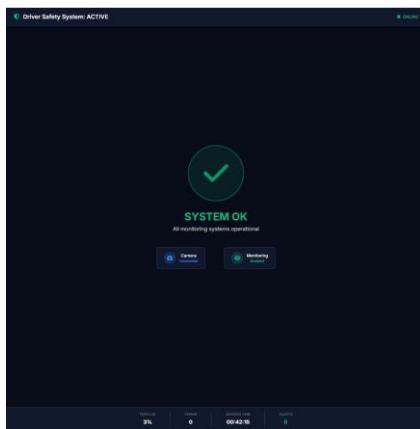
Process flow diagram or Use-case diagram:

MAIN OBJECTIVE

VISION
- Drowsiness Detected?
  - Voice Alert
  - Buzzer/LED

BEHAVIOR
- No Steering Movement?
  - Voice Alert
- Inactivity Continues?
  - Activate Left Indicator
  - Reduce Motor Speed
  - Emergency Alert (with GPS coordinates)

VITALS
- Heart Rate Abnormal?
  - Voice Alert
- Heart Rate Severe Abnormality?
  - Activate Left Indicator
  - Reduce Motor Speed
 - Emergency Alert (with GPS coordinates)

Wireframes/Mock diagrams of the proposed solution:
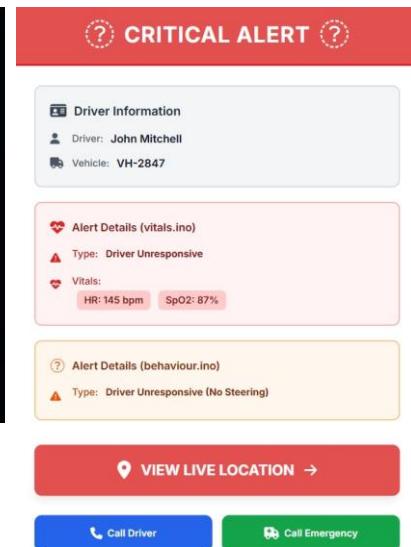
1. The Main Dashboard (Calm State)
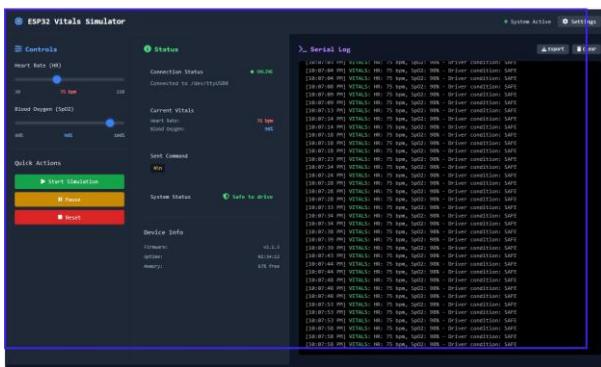
2. Fatigue Alert (Microsleep)

3. The Emergency Alert (Incoming)

**4. The Developer/Tester Control Panel**
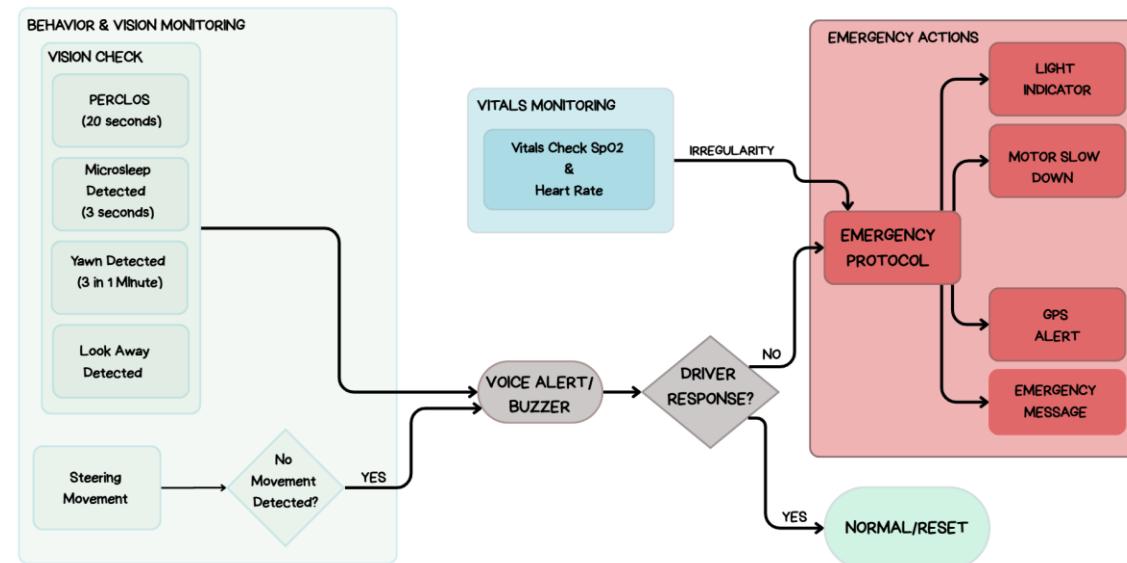
Architecture diagram of the proposed solution:

1. Data Collection: The system continuously collects parallel streams of data from the cabin camera, the vehicle's steering wheel, and a wearable (smartwatch).

2. Edge Compute Processing: All data is processed locally on the edge device. This includes video preprocessing, running AI perception models, and fusing all sensor data.

3. Decision Engine: The fusion engine weighs the inputs and makes a real-time decision on the driver's state (Alert, Drowsy, or Stressed).

4. Trigger Intervention: If a high-risk state is confirmed (e.g., high PERCLOS + steering anomaly), the system triggers the appropriate-level alert from the Tiered Intervention System.

BEHAVIOR & VISION MONITORING

VISION CHECK

- PERCLOS (20 seconds)
- Microsleep Detected (3 seconds)
- Yawn Detected (3 in 1 Minute)
- Look Away Detected

Steering Movement → No Movement Detected? → YES

VITALS MONITORING
Vitals Check SpO2 & Heart Rate → IRREGULARITY

VOICE ALERT/ BUZZER → DRIVER RESPONSE?

DRIVER RESPONSE? → NO → EMERGENCY PROTOCOL

DRIVER RESPONSE? → YES → NORMAL/RESET

EMERGENCY ACTIONS
- LIGHT INDICATOR
- MOTOR SLOW DOWN
- EMERGENCY PROTOCOL
- GPS ALERT
- EMERGENCY MESSAGE

Technologies to be used in the solution:

- **Hardware (Edge Compute):**
  - ➢ Raspberry Pi 4
  - ➢ Raspberry Pi Camera Module v2
  - ➢ 10k rotary potentiometer
  - ➢ DC Motor
  - ➢ Motor Driver Module
  - ➢ Neo-6M GPS Module
  - ➢ ESP32
  - ➢ Micro SD card
  - ➢ Buzzer
  - ➢ LED Indicator

- **Software & AI Models:**
  - ➢ Python
  - ➢ OpenCV
  - ➢ Mediapipe
  - ➢ Arduino IDE
  - ➢ Tkinter
  - ➢ Pyserial

- **APIs & Cloud Services:**
  - ➢ Twilio APIs
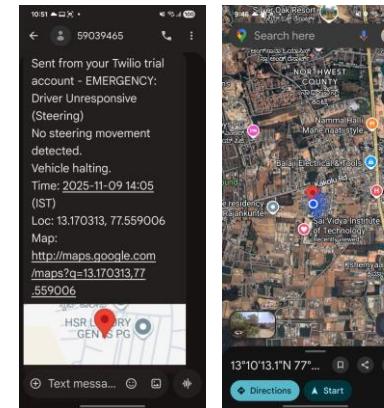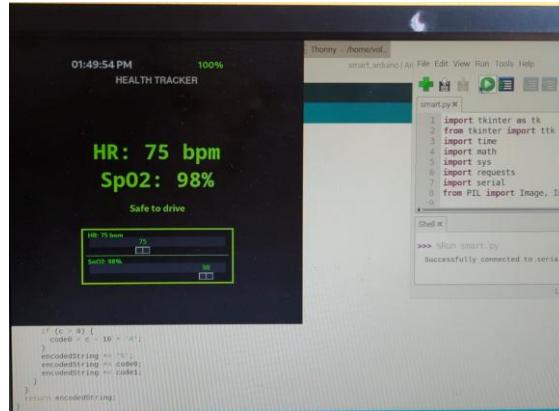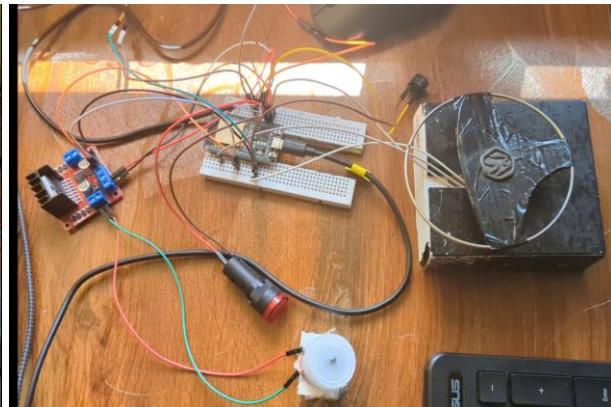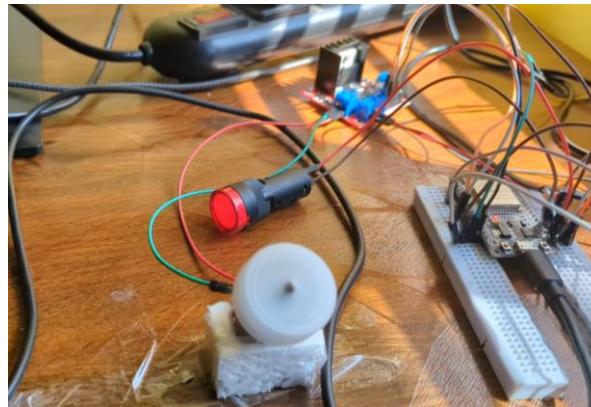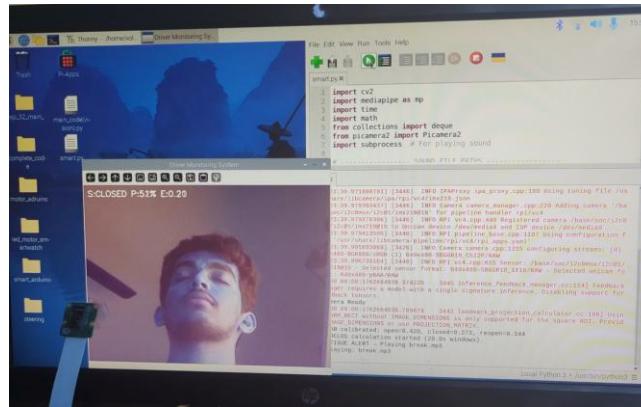
- **Development Tools:**
  - ➢ GitHub: For version control.

Mediapipe
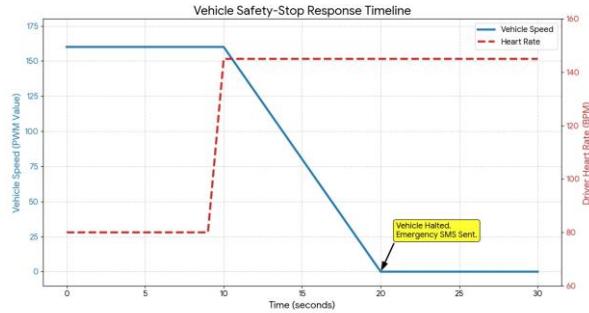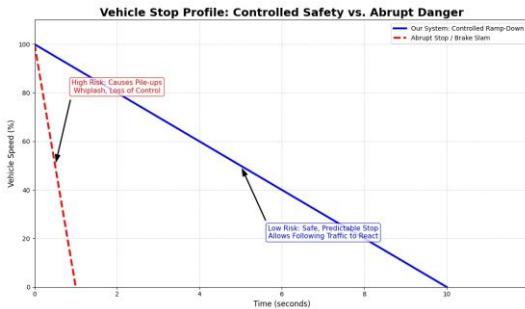
Estimated implementation cost :

Cost Component	Estimated Cost (INR)	Key Points
Hardware	₹8,000 – ₹10,000	▪ Covers essential hardware for development and testing. ▪ Includes a devices like a **Raspberry Pi** for edge computing, a quality camera etc.
Cloud Services & APIs	₹0 – ₹1,000	▪ This cost is allocated specifically for **Twilio API** usage (e.g., for sending SMS alerts). ▪ The budget suits Twilio's **pay-as-you-go model**, with free tiers covering initial testing.
Miscellaneous	₹0 – ₹2,000	▪ A small buffer for **unforeseen** expenses **or minor subscriptions**.
Total Estimated MVP Cost	**₹8,000 – ₹13,000**	▪ This represents a **realistic**, **lean budget** to get a functional and impressive prototype.
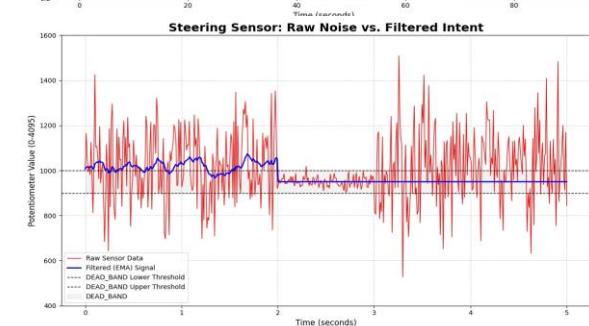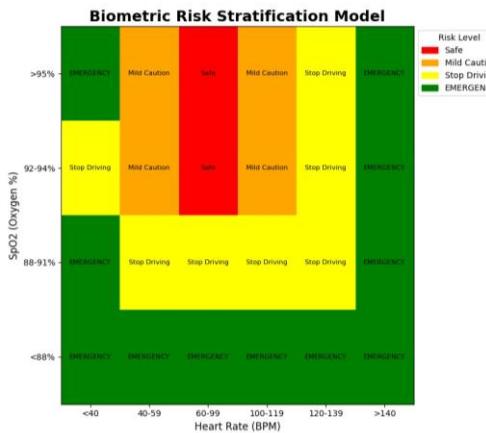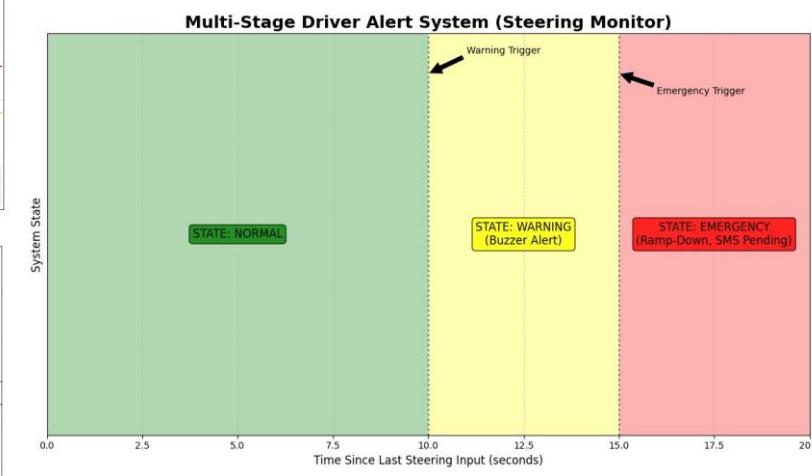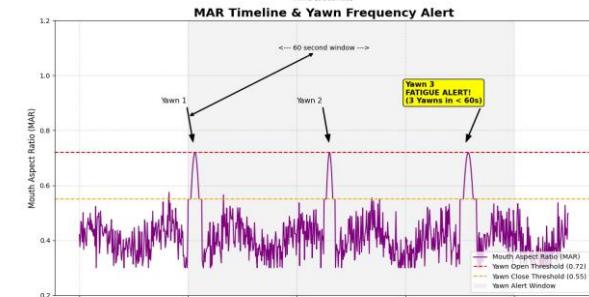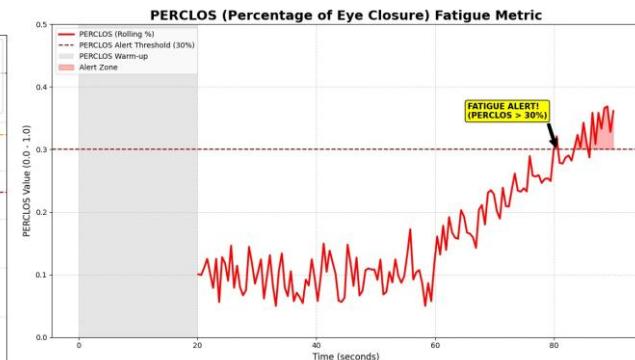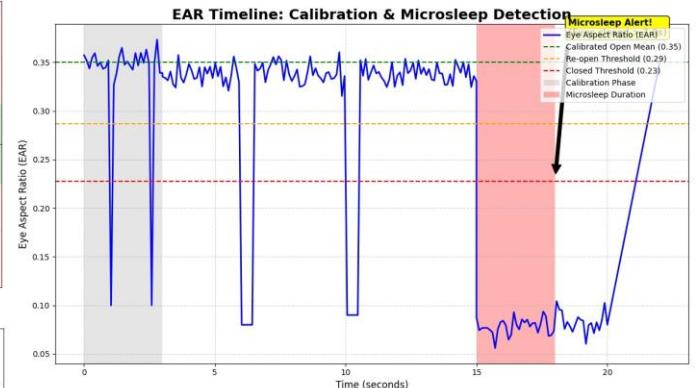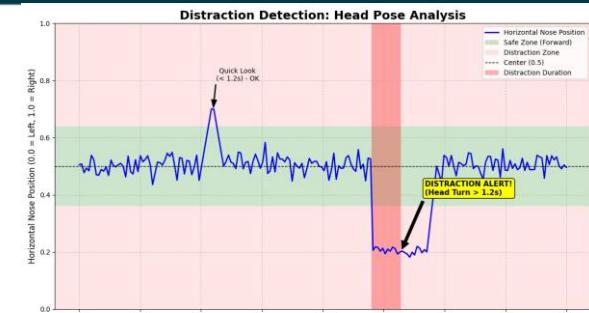
Snapshots of the Prototype:

Prototype Performance report/Benchmarking

Vehicle Stop Profile: Controlled Safety vs. Abrupt Danger

Vehicle Safety-Stop Response Timeline

Feature	Drowsiness detection in real-time via convolutional neural networks and transfer learning , Salem & Waleed, 2024	A systematic review on detection and prediction of driver drowsiness , Md. Ebrahim Shaik, 2023	Our proposed solution
Eye state detection (open/closed)	✓	✓	✓
Blink detection (PERCLOS/MAR)	✓	✓	✓
Yawn detection	✓	✓	✓
Head pose / gaze estimation	✓	✓	✓
Steering / vehicle data fusion	✗	✗	✓
Physiological signals (heart rate, SpO2)	Rare / ✗	✗	✓
Multi-class drowsiness states (beyond binary)	✓	✓	✓
Real-time on-device processing	Limited / Partial	Limited	✓
Tiered intervention alerts	✗	✗	✓
Privacy-focused on-device inference	Limited	Limited	✓
Alert escalation (audio, SMS)	Basic alerting	Basic alerting	✓
Landmark detection	✓	✓	✓

Future Development

Future Enhancements:

- **Direct Phone Integration:** Wireless connection enables **automatic emergency contact** with GPS location

- **Emergency Notifications:** Alerts sent to nearby **emergency services** and **designated contacts**

- **Production-Ready Sensor Fusion:** Combines **vision data with physiological signals**(heart rate variability, skin conductance) and behavior (Steering movement).

- **Advanced AI:** Machine learning models **for reducing false alarms and contextual awareness**

- **Connected Safety Ecosystem: Vehicle-to-Everything (V2X) communication** to warn nearby vehicles of driver state.

- **CAN Bus Integration:** Graduate from the potentiometer prototype to **direct CAN Bus integration** via the OBD-II port. This will allow us to read production-grade steering angle, vehicle speed, and ADAS status.

Benefits:

- Improved real-world robustness with **infrared cameras**

- **Personalized calibration** for driver variability

- Integration with **Advanced Driver Assistance Systems (ADAS)**

- Fleet management support with **data logging** and **analytics**

GitHub & Demo video URL:

Prototype Video URL:

https://vimeo.com/1135088291?share=copy&fl=sv&fe=ci

Idea Pitch URL:
https://github.com/Sjsh007/imobilothon5.0-virtus-synergie/blob/main/Prototype%20round%202/Idea%20Pitch.pdf

GitHub URL:
https://github.com/Sjsh007/imobilothon5.0-virtus-synergie

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