ECE445

Spring 2025

Senior Design Project Proposal

Driver Fatigue System

Group 76

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1. Introduction

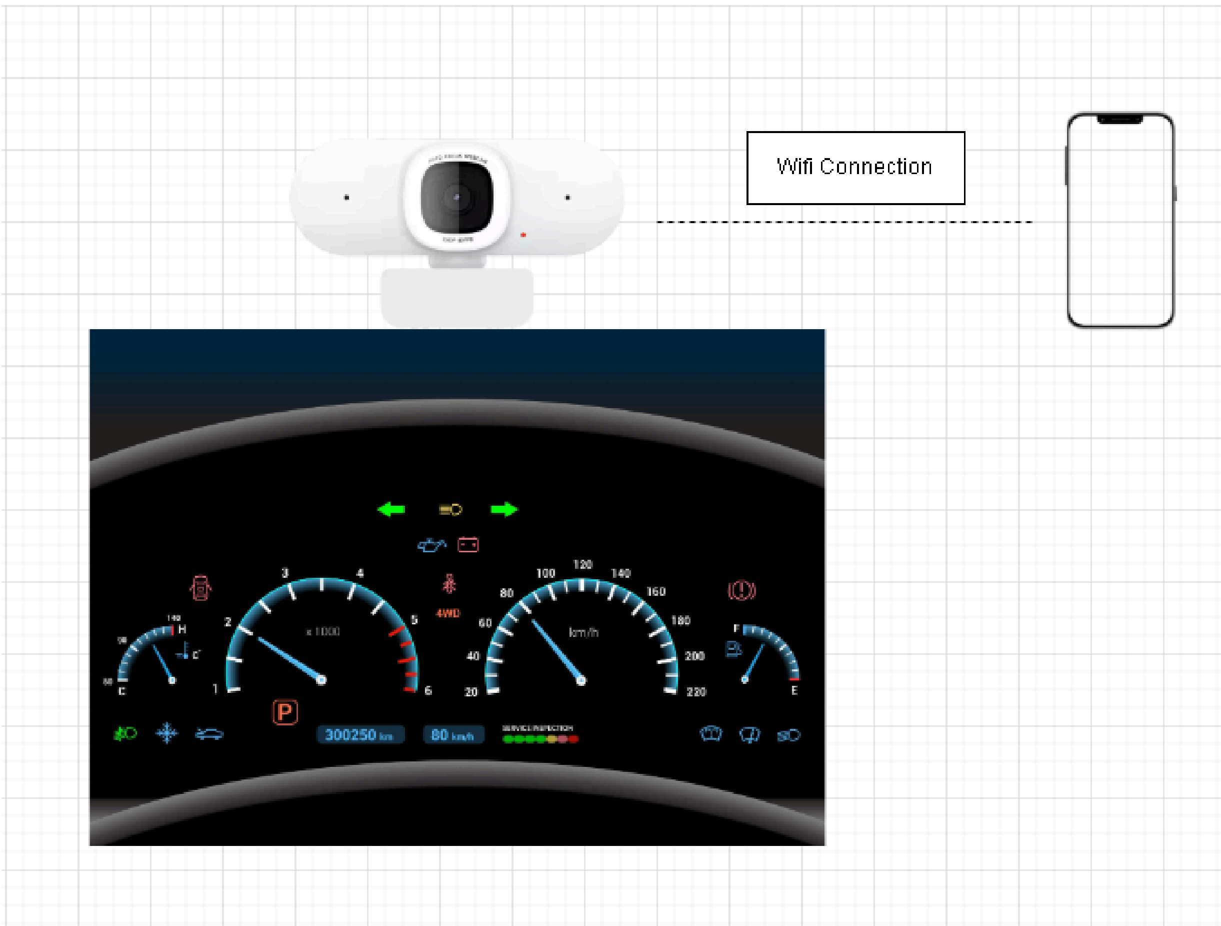
Problem:

When driving for prolonged amounts of time, some key body movements and facial changes can be made due to drowsiness. The drowsiness, if unmonitored, can pose dangerous conditions for other drivers and the drivers themselves. Intoxication while driving is also a rampant issue; there is no universal breathalyzer that prohibits driving based on BAC. I propose this device that uses facial recognition and eye-level detection sensors and cameras to detect symptoms of fatigue along the road while also prohibiting intoxicated drivers from proceeding to drive. This device can monitor head position, yawns, and register long blinks. It can also track the driving duration and eventually register all these symptoms if it detects fatigue. Once enough triggers are set, an app interface can assess your tiredness or driving incapability via Bluetooth transmission. It can suggest and locate the nearest rest stop or call emergency contacts (set by the user). When specific drowsiness scores are reached, the user's BAC and live drowsiness rating will be displayed with in-house buzzer systems.

Solution:

The system revolves around an algorithm that makes use of a variety of sensors and cameras. One is a breathalyzer that measures the blood alcohol concentration of the driver. Using the software, we monitor the live value and set triggers to call emergency contacts and monitor until a safe concentration for resumable driving. Drowsiness and tiredness can be detected in various ways ranging from yawn frequency, long blinks, and head tilts. They happen suddenly. Most traditional cars use your position in a lane to track tiredness. Tracking head movement and analyzing the face for more key indicators precisely provides more information that can be essential to identify when a driver needs to step away from the wheel and request a ride elsewhere. The PCB can be housed in a small, compact shape like a cube that sits over any dashboard with detachment features to trigger the BAC sensor correctly.

Visual Aid:



High-Level Requirements:

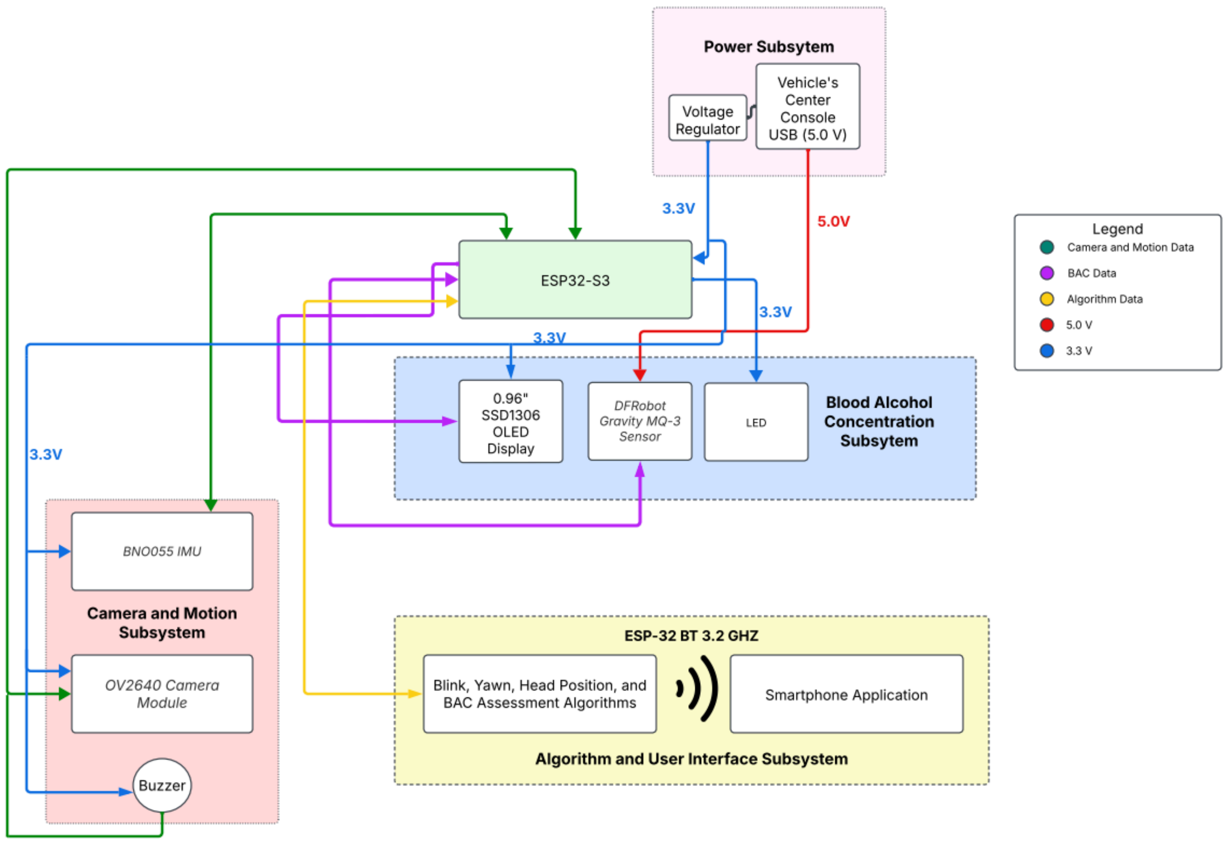
- Driver Inactivity Detection Accuracy: The system must detect eye closure and blink duration with at least 90% accuracy, using an EAR threshold of 0.2 for detecting closed eyes and registering blinks that last ≥500 ms as prolonged closures. The false positive rate for open eyes must remain below 5%.

- BAC Measurement Precision: The device must measure Blood Alcohol Concentration (BAC) with an accuracy of ±0.01% BAC, within a detection range of 0.00% - 0.20% BAC. The BAC sensor must update and log readings at least once per second.

- User Interface Accessibility: The system must provide a mobile/web-based interface that updates drowsiness and BAC data in real-time (latency ≤1 second), allows users to review at least the last 60 minutes of recorded driving data, and provides emergency alerts when thresholds are exceeded.

2. Design

Block Diagram:



Subsystem Overview:

Subsystem 1: Blood Alcohol Concentration System
Overview:
The functionality of this subsystem revolves around the MQ-3 breathalyzer sensor responsible for measuring the BAC of a potential driver. Accompanying the sensor is logistical device tools such as a display and LED. This module is connected to the ESP32 microcontroller and communicates directly with our designed algorithm for an automated emergency notification system if intoxication is detected. The BAC will also be locally displayed on the unit's OLED screen. A light will light blue when the device is ready to test an individual's BAC.

Requirements:

- The device must measure Blood Alcohol Concentration (BAC) with an accuracy of ±0.01% BAC, within a detection range of 0.00% - 0.20% BAC.

- The device must ensure the baud rate transmission is 9600 for the MQ-3's functionality.

- The LED accurately reflects the readiness and warm-up time of the MQ-3 to provide accurate measurements.

Subsystem 2: Power System
Overview:
Our primary power source for our power subsystem comes directly from a car's center console. Most cars have USB ports that provide 5V of power. Coupled with a voltage regulator to step down to 3.3V, we can power our ESP32 and sensor/camera modules. The MQ-3 is powered directly by the 5V source.

Requirements:

- Maintain overall voltage stability within a tolerance of 0.1V (+/-).

- Successful step-down conversion to 3.3V for smooth operation of the BNO055 IMU (Head position sensor), OV2640 Camera Module, SSD1306 OLED Display, and LED.

- Must provide consistent and stable 5V to operate the MQ-3's critical sensor.

Subsystem 3: Camera and Motion System
Overview:
This subsystem is the most critical component for sensing fatigue. Both sensors, BNO055 IMU for head movement and OV2640 Camera Module for eye blink and yawn detection are essential

inputs for our computer vision algorithm; both sensors are powered by a 3.3V power source and interact and transmit data directly to the ESP32. A buzzer is provided for temporary alertness in emergency-level drowsiness.

Requirements:

- Capable of capturing images with sufficient clarity for detecting blinks and yawns.
- The camera should interface with the ESP32 and quickly transmit image data to ensure real-time processing.
- The camera should support JPEG image compression for efficient data transfer.
- Minimum image resolution: 640x480 pixels.

Subsystem 4: Algorithm and User Interface Subsystem
Overview:
This subsystem will handle the processing of all sensor data, run the necessary algorithms to assess drowsiness levels based on eye blink frequency, head movements, and breathalyzer readings, and display the results on a web app accessible from a smartphone. It will communicate wirelessly with the ESP32 microcontroller via Bluetooth to receive real-time sensor data. The algorithm will analyze the data, calculate the drowsiness level, and send this information to the web app. Additional computation can include using a Raspberry Pi, which could be the backend server for further data analytics. The web app will provide a real-time drowsiness score to the user and display analytics.

Requirements:

- Using an efficient algorithm, the system must calculate a fair drowsiness score from real-time data (eye blinks, head movement, BAC levels), providing instant feedback on driver fatigue.
- The ESP32 should transmit drowsiness data wirelessly via Bluetooth with a minimum baud rate of 9600 bps.
- The web app should provide real-time feedback on the driver's drowsiness score, display analytics (e.g., blink frequency, head movement), and send alerts when fatigue levels are critical.
- The system must log drowsiness data for historical analysis and send push notifications or emergency contact alerts when the drowsiness score exceeds a defined threshold.

Tolerance Analysis:
One of this project's most critical and challenging components is the accurate detection of eye closure and blink duration using EAR. The system must reliably differentiate between normal blinking and drowsiness-induced prolonged eye closures while accounting for environmental factors such as low lighting, camera angle variations, and false detections. Reliable measurements are crucial as not to falsely alert drivers when driving on the road.
The Eye Aspect Ratio formula is given below:

$$EAR = \frac{\left(\left|P_2 - P_6\right| + \left|P_3 - P_5\right|\right)}{2\left|P_1 - P_4\right|}$$

P1-P6 are the eye landmarks detected by the OV2640 camera module

We can set the EAR threshold to:

Eyes open: 0.2-0.3
Eyes partially closed: 0.15-0.2
Eyes closed: < 0.15

However, these thresholds are not set in place and can be adjusted once the algorithm testing begins so that we can implement a more refined threshold.

We can also register blinks with these conditions:
EAR drops below 0.2 for three consecutive frames (assuming a 30 FPS camera feed).
If EAR remains below 0.2 for more than 20 frames, it is flagged as a sign of drowsiness
We can also implement a blink rate threshold with further analysis of traits of drowsiness (# blinks/min)

False Positive Rate Consideration
A key risk is misclassifying normal long blinks or head tilts as drowsiness. Therefore, we can introduce an adaptive threshold based on the driver's historical blink patterns, adjusting the EAR threshold dynamically.

3. Ethics and Safety

Our project's main ethical and safety concerns are privacy and data security.
The system collects sensitive biometric data, including facial recognition patterns, eye movement, and breathalyzer readings. According to the ACM Code of Ethics (Principle 1.6: Respect Privacy), developers must ensure that user data is stored securely and only accessed for its intended purpose. To mitigate potential privacy concerns:
Data will be processed locally on the ESP32-S3 or Raspberry Pi, avoiding unnecessary cloud storage. Encrypted communication protocols (e.g., HTTPS, TLS) will transmit data to the mobile application.

Another ethical concern highlighted by IEEE is Principle 2: Avoid Harm to Others, emphasizing that systems must be designed to avoid discrimination or bias based on race, gender, or disability. We will train our model on a diverse dataset to ensure fairness, including individuals of different ethnicities, backgrounds, and facial features. Not only that, but the EAR threshold will also be adjustable for individuals, allowing for an individualized experience.

Since our device also has a miniature built-in display, we have decided to keep it as minimal as possible to uphold safety guidelines and maintain a safe driving experience. Alerts, buzzer warnings, and the user interface must be designed to minimize distractions.
According to NHTSA guidelines, visual displays should be simple and non-intrusive.
Alerts should not require extended interaction from the driver while operating the vehicle.
The buzzer should produce audible but non-alarming signals to avoid panic responses.