**ABSTRACT**

This project introduces an AI-powered safety system for electric buses, utilizing Continuous Rapid Eye Motion Detection (CREM) technology to prevent accidents caused by driver drowsiness or incapacitation. The system leverages facial landmark detection algorithms developed in Python to monitor the driver’s eye movements in real time. When short-term eye closure is detected, an alert is issued to prompt the driver to remain attentive. If eye closure exceeds a critical threshold, the system interprets this as potential drowsiness or a health emergency, triggering autonomous vehicle control and activating emergency warning signals.

By combining real-time monitoring with automated responses, the system enhances road safety and reduces the risk of accidents in public transportation. It addresses a significant cause of road incidents—driver fatigue—through intelligent detection and intervention. This project demonstrates a practical and scalable solution for integrating AI in transportation safety systems, paving the way for wider adoption of such technologies in commercial and public vehicles.

Keyword: E-Bus, CREM Technology, Driver Drowsiness Detection, Autonomous Mode, Facial Landmark Detection, Fuzzy Logic, Vehicular Safety.

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**LIST OF ABBREVIATION**

**❖ AI** Artificial Intelligence

**❖ CREM** Continuous Rapid Eye Motion

**❖ E-Bus** Electric Bus

**❖ EAR** Eye Aspect Ratio

**❖ IDE** Integrated Development Environment

**❖ LCD** Liquid Crystal Display

**❖ DC** Direct Current

**❖ PWM** Pulse Width Modulation

**❖ I/O** Input/Output

**❖ ISP** In-System Programming

**❖ EEPROM** Electrically Erasable Programmable Read-Only Memory

**❖ SRAM** Static Random Access Memory

**❖ UART** Universal Asynchronous Receiver Transmitter

**❖ SPI** Serial Peripheral Interface

**❖ IIC** Inter Integrated Circuit

**❖ CNN** Convolutional Neural Network

**❖ EEG** Electroencephalogram

**❖ LSTM** Long Short-Term Memory

**❖ IOT** Internet of Things

**❖ POS** Point of Sale

**❖ USB** Universal Serial Bus

**❖ LED** Light Emitting Diode

**❖ CRT** Cathode Ray Tube

**❖ OLED** Organic Light Emitting Diode

**❖ ADC** Analog to Digital Converter

**❖ AVR** Absolute Value Rectifier

**❖ CISC** Complex Instructions Set Computers

**❖ GPU** Graphics Processing Unit

**❖ GSM** Global System for Mobile Communication

**❖ IMEI** International Mobile Equipment Identity

**❖ MIPS** Microprocessor without Interlocked Pipeline Stages

**❖ MSSC** Mobile Service Switching Centre

**❖ PDIP** Plastic Dual In-line Package

**❖ RISC** Reduced Instructions Set Computer

**CHAPTER 1**

**INTRODUCTION**

The rising number of road accidents caused by driver drowsiness is a growing concern, particularly in public transportation like electric buses (E-Buses). Drowsy driving impairs attention, reaction time, and decision-making, leading to accidents and fatalities. Traditional safety systems, often reliant on alerts or human intervention, are not always effective in preventing fatigue-related accidents.

This project introduces an innovative safety system for E-Buses that uses Continuous Rapid Eye Motion (CREM) technology to detect driver drowsiness. By integrating facial landmark detection and real-time data processing, the system continuously monitors the driver’s eye movements, focusing on eye closures that indicate fatigue.

The system follows a dual-response approach: brief eye closures trigger a buzzer alert, while prolonged closures initiate autonomous mode, activate emergency lights, and engage the braking system to bring the bus to a complete stop. This prevents the bus from moving while the driver is incapacitated, ensuring safety for passengers and other road users.

Built with a combination of Python software for eye tracking and an Arduino-based hardware module, the system incorporates fuzzy logic algorithms for efficient decision-making. The goal is to reduce drowsiness-related accidents and enhance safety in commercial vehicles, paving the way for broader adoption of such technologies in public transportation.

* 1. **Existing System:**

Existing vehicular safety systems largely emphasize passive features such as seat belts, airbags, and anti-lock braking systems, alongside some active technologies like lane departure warnings and basic drowsiness detection alerts. Drowsiness detection systems, in particular, aim to reduce accidents caused by driver fatigue. These systems commonly rely on simple sensors or camera-based technology to monitor driver behaviour, such as eye blink rates, head position, and vehicle steering patterns. When signs of drowsiness are detected, they typically issue visual or audible alerts urging the driver to take corrective actions like pulling over or resting.

* 1. **DRAWBACK OF EXISTING SYSTEM:**

Despite their usefulness, these systems have several critical limitations. Detection accuracy can be hindered by low lighting, individual driver traits, or environmental distractions, leading to false alarms or missed detections. Many systems use basic algorithms that cannot reliably distinguish between actual drowsiness and benign behaviours like eye rubbing. More importantly, current systems depend entirely on driver response, lacking escalation mechanisms if the driver is incapacitated. They also do not integrate with the vehicle's autonomous controls to initiate safety measures like slowing down or stopping. Furthermore, these systems lack communication with surrounding vehicles, failing to alert other road users to potential hazards caused by a drowsy or unresponsive driver.

**1.3 PROPOSED SYSTEM:**

The proposed system introduces an advanced safety mechanism for electric buses (E-Buses) using Continuous Rapid Eye Motion (CREM) technology, designed to overcome the limitations of existing drowsiness detection systems. It comprises two main modules: a software module and a hardware module. The software module, developed using Python and OpenCV, performs real-time facial landmark detection focused on the driver’s eyes. It classifies eye closures lasting less than three seconds as brief blinks and triggers a buzzer alert through the hardware module to regain the driver’s attention. However, if eye closure exceeds five seconds—indicating potential drowsiness or incapacitation—the system initiates a shift from manual to autonomous driving. Simultaneously, emergency lights are activated to warn nearby vehicles, ensuring road safety. The hardware module, featuring an Arduino microcontroller, LCD display, DC motor (to simulate bus motion), L298 motor driver, buzzer, and emergency lights, responds to commands via serial communication. It uses fuzzy logic to make context-sensitive decisions based on eye status data received from the software module. This integrated approach ensures not only real-time driver monitoring and alerting but also autonomous intervention and external communication, thereby providing a comprehensive solution to enhance both vehicle and road-user safety.

**1.3.1ADVANTAGE:**

* **Accurate Real-Time Monitoring**

Uses CREM technology with facial landmark detection to monitor eye movement precisely, reducing false positives and missed signs of drowsiness.

* **Multi-Level Response Mechanism**

Differentiates between minor and critical drowsiness, issuing alerts or activating autonomous driving mode based on eye closure duration.

* **Autonomous Safety Intervention**

Shifts control to autonomous mode and activates emergency lights if the driver is unresponsive, ensuring continued vehicle safety.

* **External Hazard Communication**

Notifies nearby vehicles of a drowsy or incapacitated driver using emergency signals, helping prevent potential accidents.

**1.3.2APPLICATION:**

* **Public Transportation (E-Buses)**

Enhances passenger safety by monitoring driver alertness in real time and taking autonomous control if the driver becomes drowsy or unresponsive.

* **Commercial and Long-Distance Freight Vehicles**

Reduces fatigue-related accidents in trucks and delivery vehicles, especially during long-haul operations.

* **Autonomous and Semi-Autonomous Vehicles**

Serves as a critical safety layer in vehicles with autonomous features, providing backup monitoring and control if the human driver is inattentive.

* **Emergency and Utility Vehicles**

Ensures alertness of drivers in ambulances, fire trucks, and other critical service vehicles where driver fatigue can delay urgent response times.

**CHAPTER 2**

**LITERATURE SURVEY**

**1. Real-Time Driver Drowsiness Detection Using Facial Landmarks and Convolutional Neural Networks**

**Author:** Zhang et al.  
**Journal:** IEEE Transactions on Intelligent Transportation Systems, 2022  
**Description:**  
This project focuses on detecting driver drowsiness in real-time using computer vision techniques. The authors developed a system that analyses facial landmarks to monitor eye and facial movements, feeding the data into a CNN model for classification.  
**Methodology Used:** Facial landmark detection and CNN-based classification.  
**Limitations:** Requires high-resolution cameras and consistent lighting for accurate results.  
**Findings:** Achieved 95% accuracy in real-time detection of drowsiness**.**

**2. Multi-Modal Driver State Monitoring Using Fusion of Physiological and Visual Features**

**Author:** Li et al.  
**Journal:** IEEE Access, 2023  
**Description:**  
This study integrates multiple sensing modalities, including EEG signals and facial feature tracking, to improve driver monitoring. The goal was to increase the system's robustness by combining physiological and visual cues.  
**Methodology Used:** Deep learning-based fusion of EEG and facial features.  
**Limitations:** Requires the driver to wear multiple sensors, which may cause discomfort.  
**Findings:** Multimodal integration improved detection accuracy by 7% compared to single-mode systems.

**3. Attention-Based LSTM Network for Driver Distraction Detection**

**Author:** Wang et al.  
**Journal:** IEEE Transactions on Vehicular Technology, 2022  
**Description:**  
The project aimed to detect driver distraction using sequential data and deep learning. An attention-based LSTM model was used to focus on the most relevant time-series features for accurate distraction classification.  
**Methodology Used:** Attention mechanism combined with LSTM networks for temporal feature extraction.  
**Limitations:** Performance affected under poor lighting or camera obstructions.  
**Findings:** Reached 93% accuracy in detecting multiple types of distractions.

**4. Robust Driver Fatigue Detection Using 3D Facial Landmarks and Gaze Estimation**

**Author:** Chen et al.  
**Journal:** IEEE Intelligent Transportation Systems Magazine, 2023  
**Description:**  
This system enhances fatigue detection by analyzing 3D facial landmarks and gaze direction using depth cameras. It addresses common issues with 2D systems, such as inaccuracies due to head movement or lighting.  
**Methodology Used:** 3D facial tracking and gaze estimation using specialized cameras.  
**Limitations:** Requires depth-sensing hardware, increasing implementation cost.  
**Findings:** Improved fatigue detection performance in varied head poses and lighting.

**5. Transfer Learning Approach for Cross-Vehicle Driver Monitoring Systems**

**Author:** Kim et al.  
**Journal:** IEEE Transactions on Intelligent Vehicles, 2024  
**Description:**  
This study explored how transfer learning can reduce the need to retrain models from scratch for different vehicle types. It aims to make driver monitoring systems more adaptable across vehicle fleets.  
**Methodology Used:** Transfer learning techniques to reuse models across vehicles.  
**Limitations:** Model performance still requires fine-tuning for each new environment.  
**Findings:** Significantly reduced the amount of new data required for deployment in different vehicles.

**6. Real-Time Driver Cognitive Load Estimation Using Multimodal Sensor Fusion**

**Author:** Singh et al.  
**Journal:** IEEE Sensors Journal, 2022  
**Description:**  
This project developed a cognitive load detection system using multiple data types, including physiological signals, facial expressions, and vehicle dynamics. The goal was to assess the mental state of the driver beyond just physical fatigue.  
**Methodology Used:** Fusion of sensor data using advanced fusion algorithms.  
**Limitations:** Complex sensor setup and potential privacy concerns due to sensitive data collection.  
**Findings:** Successfully estimated driver cognitive load in diverse driving conditions.

**7. Lightweight CNN Architecture for Edge-Based Driver Monitoring Systems**

**Author:** Patel et al.  
**Journal*:***IEEE Internet of Things Journal, 2023 **Description:**  
The research focused on building a lightweight CNN architecture optimized for deployment on edge devices within vehicles, enabling real-time processing without cloud dependency.  
**Methodology Used:** Optimized CNN for resource-constrained environments.  
**Limitations:** May have slightly reduced accuracy compared to larger, server-based models.  
**Findings:** Delivered reliable real-time monitoring on low-power edge devices.

**8. Federated Learning for Privacy-Preserving Driver Behaviour Analysis**

**Author:** Liu et al.  
**Journal:** IEEE Transactions on Intelligent Transportation Systems, 2024  
**Description:**  
This project explored federated learning to analyze driver behaviour across multiple vehicles while preserving privacy by avoiding the transfer of raw data. It supports collaborative learning without central data collection.  
**Methodology Used:** Federated learning for distributed model training.  
**Limitations:** Requires robust coordination and network infrastructure; potential communication delays.  
**Findings:** Enabled secure and privacy-respecting driver monitoring across multiple organizations or vehicle fleets.

**CHAPTER 3**

**PROJECT OVERVIEW**

**3.1 BLOCK DIAGRAM:**

The purpose of this project is to detect driver drowsiness in real time using eye movement analysis and respond through alerts and autonomous vehicle control. It aims to enhance safety in E-Buses by preventing accidents caused by fatigue or driver inattention. Figure.1 shows the Block Diagram of Drowsiness Detection and Safety Response System for E-Bus

Lcd Display

Battery

Camera

A2B Cable

Arduino Microcontroller

Buzer

Motor Driver

Dc Motor

System (Python)

Emergency Mode Light

**Figure.1 Block Diagram of Drowsiness Detection and Safety Response System for E-Bus**

**3.2 CIRCUIT DIAGRAM:**

The circuit diagram illustrates the hardware connections between the Arduino microcontroller, buzzer, LCD display, DC motor, motor driver, emergency light, and power supply. It supports the detection and response functionalities of the proposed system. Figure.2 Show the Circuit Diagram of the Drowsiness Detection and Safety Response System

**A diagram of a circuit board

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**Figure.2 Circuit Diagram of the Drowsiness Detection and Safety Response System**

**3.3 WORKING METHODOLOGY:**

The proposed system operates through the coordination of software and hardware modules to monitor the driver’s eye status in real time and respond appropriately based on the level of drowsiness detected. The working process is based on the duration of eye closure and system readiness. Below is a detailed explanation of the methodology:

1. **System Initialization (No Face Detected)**  
   At startup, the system remains in standby mode. The camera continuously scans for the presence of a face. No hardware action is taken until a driver's face is detected and properly positioned, ensuring the system only activates when monitoring can begin accurately.
2. **Driver Alert (Eyes Open)**  
   When the driver’s eyes are open and no signs of fatigue are detected, the software module continuously monitors facial landmarks. No hardware actions are required in this state. The system remains active in the background, ensuring readiness for any changes in the driver's condition.
3. **Short Eye Closure (Less than 3 Seconds)**  
   If the system detects that the driver’s eyes are closed for less than three seconds, it interprets this as a brief or non-critical blink. The software module sends an alert signal to the hardware module, which triggers the buzzer. This sound serves as a warning to keep the driver alert and attentive.
4. **Prolonged Eye Closure (More than 5 Seconds)**  
   If the driver's eyes remain closed for more than five seconds, the system identifies this as significant drowsiness or potential incapacitation. The software module sends a signal to the hardware module to switch from manual to autonomous driving mode. Simultaneously, emergency mode lights are activated to warn surrounding vehicles. This response ensures the vehicle can manage itself safely and alert nearby traffic, helping to prevent accidents.

This multi-tiered approach ensures that minor lapses are addressed immediately with alerts, while serious drowsiness triggers automated safety measures, enhancing both in-vehicle and road-wide safety. Figure.3 Show the Flow Diagram of the Drowsiness Detection and Safety Response System

**FLOW DIAGRAM:**

**A screenshot of a diagram

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**Figure.3 Flow Diagram of the Drowsiness Detection and Safety Response System**

**CHAPTER 4**

**HARDWARE IMPLEMENTATION**

**4.1 ARDUINO MICROCONTROLLER:**

The **Arduino Uno** is an open-source microcontroller board based on the **ATmega328P**. It is one of the most widely used boards in the Arduino family, designed for beginners and advanced users alike due to its simplicity, ease of programming, and extensive community support. Unlike general-purpose computers like the Raspberry Pi, the Arduino Uno is designed specifically for embedded control applications and is ideal for projects involving sensors, actuators, and automation.

The board includes digital and analog input/output (I/O) pins that can interface with various expansion boards (shields) and other circuits. It is often used in applications like robotics, automation systems, IoT devices, and sensor-based monitoring systems.

**Specifications:**

* **Microcontroller:** ATmega328P
* **Operating Voltage:** 5V
* **Input Voltage (recommended):** 7–12V
* **Input Voltage (limits):** 6–20V
* **Digital I/O Pins:** 14 (of which 6 provide PWM output)
* **Analog Input Pins:** 6
* **DC Current per I/O Pin:** 20 mA
* **Flash Memory:** 32 KB (ATmega328P) of which 0.5 KB used by bootloader
* **SRAM:** 2 KB
* **EEPROM:** 1 KB
* **Clock Speed:** 16 MHz
* **LED\_BUILTIN:** Pin 13
* **USB Connectivity:** Yes, via USB Type-B
* **Communication Interfaces:** UART, SPI, I2C
* **Dimensions:** 68.6 mm × 53.4 mm
* **Weight:** Approx. 25 g

**USB Interface:**

The Arduino Uno can be powered and programmed through the USB Type-B connector. This USB connection also enables serial communication with the host computer, making it easy to upload programs and receive data.

**Microcontroller (ATmega328P):**

The ATmega328P is an 8-bit AVR RISC-based microcontroller featuring 32 KB of ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, and three flexible Timer/Counters.

**GPIO and PWM:**

The Arduino Uno features 14 digital I/O pins and 6 analog inputs. Out of the digital pins, 6 can be used for PWM (Pulse Width Modulation) output, which is useful for controlling motors, LEDs, and other actuators.

**Analog Input and ADC:**

The board includes a 10-bit analog-to-digital converter (ADC) connected to 6 analog input pins. This allows it to read varying voltages from sensors and convert them into digital values for processing.

**Power Management:**

Arduino Uno can be powered via the USB connection or an external power supply. It automatically selects the most appropriate power source. The board features a voltage regulator that ensures stable 5V and 3.3V outputs for powering peripherals.

**Communication Protocols:**

The Uno supports multiple communication protocols:

* **UART (Serial)** – Communicates via digital pins 0 (RX) and 1 (TX) as well as over USB.
* **I2C (TWI)** – Uses pins A4 (SDA) and A5 (SCL).
* **SPI** – Uses pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK).

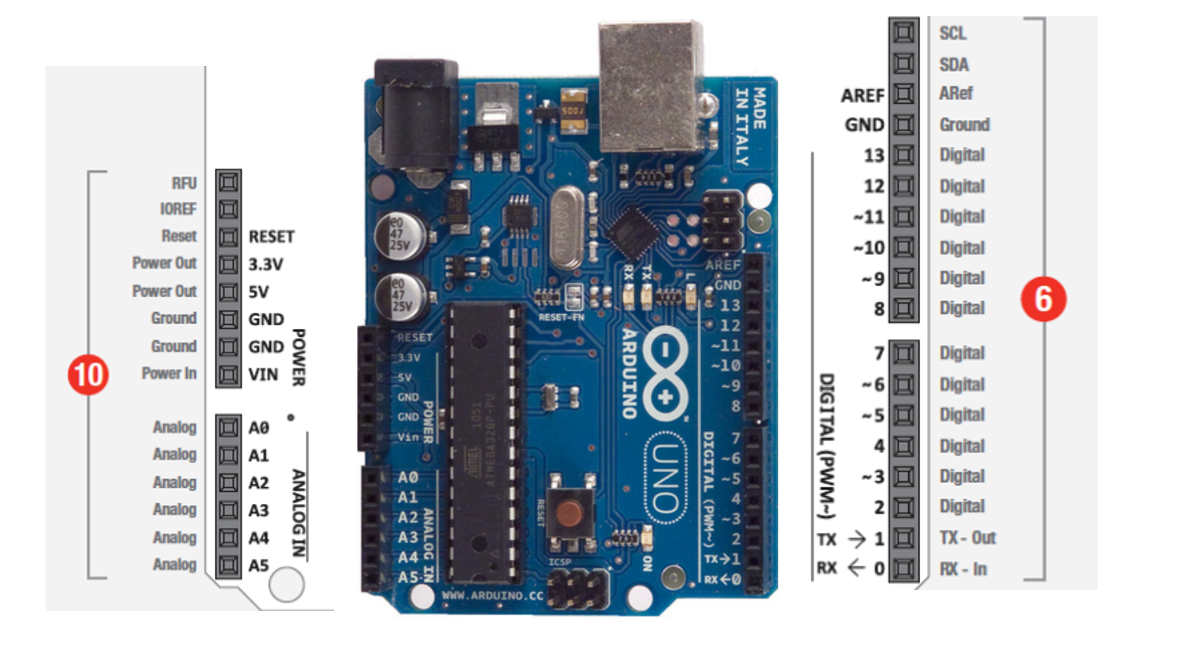
These protocols allow the Uno to interface with other microcontrollers, sensors, and modules.

**Programming:**

Arduino Uno is programmed using the **Arduino IDE** (Integrated Development Environment), which supports a simplified version of C/C++. Programs are uploaded to the board via a USB cable and stored in its flash memory.

**Bootloader:**

The board comes pre-loaded with a bootloader, allowing code to be uploaded without an external programmer. This simplifies the development process significantly. Figure.4 diagram show the Pin Diagram of Arduino Uno Microcontroller



**Figure.4 Pin Diagram of Arduino Uno Microcontroller**

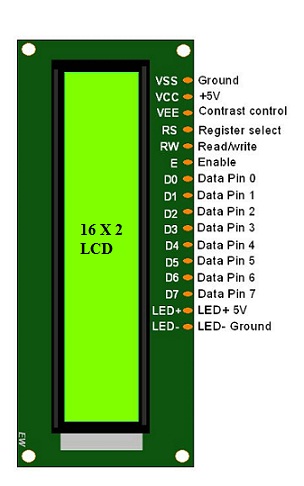
**4.2 LCD DISPLAY:**

LCD (Liquid Crystal Display) screen is an electronic display module and finds a wide range of applications. A 16x2 LCD display is a very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs.

The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in a 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. Click to learn more about the internal structure of an LCD. Figure.5 diagram show the Pin Diagram of LCD

**PIN DIAGRAM:**

****

**Figure.5 Pin Diagram of LCD**

**PIN DESCRIPTION:**

**Table 1 shows the pins description of LCD**

**A white sheet with black text

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LCDs are used in a wide range of applications, including LCD televisions, computer monitors, instrument panels, aircraft cockpit displays, and indoor and outdoor signage. Small LCD screens are common in portable consumer devices such as digital cameras, watches, calculators, and mobile telephones, including smart phones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks. LCD screens have replaced heavy, bulky cathode ray tube (CRT) displays in nearly all applications.

LCD screens are available in a wider range of screen sizes than CRT and plasma displays, with LCD screens available in sizes ranging from tiny digital watches to very large television receivers. LCDs are slowly being replaced by OLEDs, which can be easily made into different shapes, and have a lower response time, wider colour gamut, virtually infinite colour contrast and viewing angles, lower weight for a given display size and a slimmer profile (because OLEDs use a single glass or plastic panel whereas LCDs use two glass panels; the thickness of the panels increases with size but the increase is more noticeable on LCDs) and potentially lower power consumption (as the display is only "on" where needed and there is no backlight). OLEDs, however, are more expensive for a given display size due to the very expensive electroluminescent materials or phosphors that they use. Also due to the use of phosphors, OLEDs suffer from screen burn-in and there is currently no way to recycle OLED displays, whereas LCD panels can be recycled, although the technology required to recycle LCDs is not yet widespread. Attempts to increase the lifespan of LCDs are quantum dot displays, which offer similar performance to an OLED display, but the quantum dot sheet that gives these displays their characteristics cannot yet be recycled. Since LCD screens do not use phosphors, they rarely suffer image burn-in when a static image is displayed on a screen for a long time, e.g., the table frame for an airline flight schedule on an indoor sign. LCDs are, however, susceptible to image persistence.[3] The LCD screen is more energy-efficient and can be disposed of more safely than a CRT can. Its low electrical power consumption enables it to be used in battery powered electronic equipment more efficiently than a CRT can be. By 2008, annual sales of televisions with LCD screens exceeded sales of CRT units worldwide, and the CRT became obsolete for most purposes

**4.3 BUZZER ALERT SYSTEM:**

The **buzzer** used in this project is a compact electronic sound component capable of producing a continuous tone when powered. It is black in color, features a sealed structure, and comes with an internal drive circuit, making it suitable for integration in embedded electronic systems. Its sealed and washable design allows for durability and ease of manufacturing, especially during soldering processes like wave soldering.

The buzzer is typically used in various applications such as computer peripherals, communication devices, portable systems, automobile electronics, and POS terminals. In this project, it serves a critical function: providing audible alerts to the driver when drowsiness is detected, especially during short eye closures. This immediate feedback is crucial for drawing the driver's attention back to the road.

**Specifications**

* **Rated Voltage:** 6V DC
* **Operating Voltage Range:** 4V to 8V DC
* **Rated Current:** ≤30 mA
* **Sound Output (at 10cm):** ≥85 dB
* **Resonant Frequency:** 2300 ± 300 Hz
* **Tone Type:** Continuous
* **Operating Temperature:** -25°C to +80°C
* **Storage Temperature:** -30°C to +85°C
* **Weight:** 2g
* **Housing Material:** Noryl
* **Structure:** Sealed, wave solderable, and washable

This buzzer provides high sound output with low power consumption and is an essential part of the alert mechanism in the proposed drowsiness detection system. Figure.6 show the Buzzer for Alert System.

A close-up of a black device

AI-generated content may be incorrect.

**Figure.6 Buzzer for Alert System**

**4.4 DC MOTOR:**

A **DC motor** is an electromechanical device that converts direct current electrical energy into mechanical motion, typically rotational. It operates based on the interaction between magnetic fields generated by the motor’s internal components and the current supplied. In this project, the DC motor is used to simulate vehicle movement, representing how the bus would respond to driver drowsiness by shifting into autonomous mode.

The motor includes an internal mechanism such as a commutator and brushes that help reverse the current flow, allowing for continuous rotation. By adjusting the voltage supplied to the motor, its speed can be easily controlled, making it ideal for applications requiring variable speed and torque. DC motors are widely used in electronic projects, robotics, electric vehicles, and automation systems due to their simplicity and effective performance. Figure.7 diagram show the DC Motor Integration for E-Bus Motion Simulation

**Key Features:**

* Converts DC electrical power into mechanical power.
* Speed can be easily varied by changing input voltage.
* Capable of producing high torque, especially during startup.
* Commonly used in automation, robotics, and control systems.

**Specifications (Typical for Miniature DC Motors):**

* **Operating Voltage:** 6V–12V DC
* **Current Consumption:** 100mA–300mA (approx.)
* **Speed Range:** 1000–3000 RPM (depending on voltage)
* **Type:** Brushed DC Motor
* **Control:** ON/OFF or PWM (via microcontroller/motor driver)
* **Direction:** Reversible (by changing polarity)

A yellow electric motor with a white plastic cover

AI-generated content may be incorrect.

**Figure.7 DC Motor Integration for E-Bus Motion Simulation**

**Application in Project:**

In the proposed drowsiness detection system, the DC motor simulates the bus’s driving mechanism. When the driver is detected to be drowsy for more than 5 seconds, the software module instructs the hardware to switch from manual to autonomous mode. The motor’s behaviour changes accordingly, showcasing the vehicle's transition to self-driving control.

**4.5 L298 Motor Driver:**

The **L298 Motor Driver** is a high-voltage, high-current dual full-bridge driver designed to control inductive loads such as DC motors, stepper motors, solenoids, and relays. It accepts standard TTL logic levels, making it compatible with microcontrollers like Arduino and Raspberry Pi. The driver enables bidirectional control of two DC motors or one stepper motor, which makes it ideal for robotic and motor control applications.

The L298 includes two enable pins that allow for independent activation or deactivation of the motor channels, giving more control over the connected load. Its built-in protection features, such as over-temperature protection and Schottky diodes for back EMF suppression, ensure durability and reliability in demanding environments. The device also features a low-dropout 5V regulator and power indicator LEDs for user convenience. Figure.8 diagram show the L298 Motor Driver Configuration for DC Motor Control

**Key Features**

* Operating supply voltage up to **46V**
* Total DC current output up to **4A**
* **Low saturation voltage** for better efficiency
* Over-temperature protection for safe operation
* TTL compatible input signals with high noise immunity
* Integrated **5V regulator**
* Dual motor control capability
* Screw terminals for motor and power connections
* Onboard direction indicator LEDs

A red circuit board with black and green components

AI-generated content may be incorrect.

**Figure.8 L298 Motor Driver Configuration for DC Motor Control**

**Applications**

* Microcontroller-based vehicle control systems
* Robotic wheel drives
* Automation systems
* Line-following and obstacle-avoiding robots
* Any embedded application requiring precise DC motor control

**Role in Project**

In this project, the **L298 driver module** is used to control the **DC motor** that simulates the E-Bus’s motion. It acts as an interface between the low-power control signals from the Arduino and the higher power required by the motor. Based on the driver drowsiness detection status received from the software module, the motor driver controls the direction and power to the motor for appropriate response actions (e.g., shifting to autonomous mode or stopping).

**4.5 POWER SUPPLY UNIT:**

The Power Supply Unit (PSU) plays a critical role in ensuring all electronic components in the system receive stable and appropriate voltage levels for optimal operation. In this project, a dual-voltage configuration is used:

* **5V DC** is supplied to all low-power electronic components, including the Arduino microcontroller, LCD display, camera module, and sensors.
* **9V DC** is provided specifically for the DC motor via the L298 motor driver, ensuring sufficient torque and speed for simulating vehicle motion.

The 5V supply can be derived from a voltage regulator (such as a 7805) or directly from the Arduino’s onboard regulator when powered through USB or an external adapter. The 9V power source is typically a battery or external DC adapter connected through the motor driver, which isolates the high current motor load from sensitive control electronics.

This configuration ensures reliable performance, protects components from over-voltage, and separates power domains to prevent interference between control logic and mechanical actuation.

**CHAPTER 5**

**SOFTWARE IMPLEMENTATION**

**5.1 Python Programming Environment**

The core of the software module for the E-Bus safety enhancement system was developed using Python 3, a highly popular and powerful programming language well-suited for rapid development and real-time computer vision applications. Python was selected due to its simplicity, cross-platform compatibility, and rich ecosystem of open-source libraries that support image processing, machine learning, and hardware integration—all of which are critical components of this project.

The software was developed and tested using two primary integrated development environments (IDEs): Jupyter Notebook and Visual Studio Code (VS Code).

* Jupyter Notebook provided an interactive, cell-based interface ideal for testing algorithms in segments, visualizing real-time data plots, and debugging portions of the code with immediate output.
* VS Code, on the other hand, offered a more traditional development experience with robust plugin support, Git integration, and advanced debugging features, allowing for efficient development of the complete software pipeline.

The primary function of the software is to continuously analyze live video input from a connected webcam in order to monitor the driver’s eye movements and detect early signs of fatigue or inattention. This involves detecting facial landmarks, computing the Eye Aspect Ratio (EAR), interpreting blink frequency, and determining the duration of eye closures. These operations are performed in real-time to ensure immediate response to potential drowsiness symptoms.

To build this monitoring system, the Python software module integrates several essential libraries:

**1. OpenCV (Open Source Computer Vision Library)**

OpenCV is the cornerstone of image and video processing in the system. It is used for:

* Capturing live video feed from the webcam.
* Converting each frame to grayscale to reduce computational complexity.
* Drawing visual overlays (such as eye contours and status messages) on the video feed.
* Displaying the real-time processed frames to aid development and debugging.

**2. DLIB**

Dlib provides the pre-trained 68-point facial landmark detector, which is a crucial component of the system. It enables:

* Precise detection of facial features such as the eyes, nose, mouth, and jawline.
* Identification of the six specific points surrounding each eye used to calculate EAR.
* Robust performance under different lighting conditions, head orientations, and face shapes.

**3. IMUTILS**

This utility package simplifies various OpenCV functions by offering high-level wrappers for common image processing tasks. It is particularly useful for:

* Resizing video frames to standard dimensions for processing efficiency.
* Rotating or translating frames as needed.
* Managing frame orientation and cropping operations.

**4. PySerial**

PySerial is responsible for enabling real-time serial communication between the Python software and the Arduino hardware via a USB interface. It is used to:

* Send alert signals (such as “eyes closed” for more than 3 or 5 seconds) to the microcontroller.
* Trigger hardware responses like activating the buzzer or switching to autonomous mode.
* Ensure synchronized operation between the software and the embedded control system.

**5.2 Facial Landmark Detection and EAR Calculation**

The detection of the driver’s eye position and shape was performed using facial landmark detection techniques powered by Dlib. The 68-point facial landmark model provides coordinates for facial regions such as the eyes, nose, mouth, and jawline. For this project, only the eye landmarks were extracted to calculate the Eye Aspect Ratio (EAR).

The EAR is calculated based on the distances between specific vertical and horizontal points around the eye. When the eye is open, the vertical distance is relatively high; when it is closed, this distance shortens, reducing the EAR. The following steps were involved:

* Extract key eye landmarks from each frame.
* Apply the EAR formula to compute real-time values.
* Compare EAR against predefined thresholds to detect eye closure.

The EAR value is a reliable metric that remains stable when eyes are open and drops during blinks or drowsiness. This value forms the foundation for the alerting logic in the system.

**5.3 Eye State Monitoring Using CREM**

This project integrates a unique technique called **Continuous Rapid Eye Motion (CREM)** to monitor and assess the driver’s eye behaviour over time. Unlike traditional blink detection systems, CREM observes the duration of eye closure continuously to differentiate between normal blinks and potentially dangerous drowsiness.

The Python program processes the live video feed and keeps track of how long the eyes stay closed:

* If the eyes are closed for less than 3 seconds, the system considers it a blink or momentary distraction. It sends a warning signal ('1') to the Arduino to activate a buzzer.
* If the eyes remain closed for more than 5 seconds, the system interprets it as a sign of drowsiness or unconsciousness. It sends a critical signal ('2') to activate autonomous driving mode and emergency lighting.

This time-sensitive logic was implemented using Python's internal timers and conditional checks. The CREM methodology ensures that the system reacts appropriately based on the seriousness of the eye closure event.

**5.4 Serial Communication with Arduino**

To achieve real-time interaction between the vision-based software module and the physical hardware components, serial communication was established between the Python application and the Arduino Uno microcontroller. This communication forms the backbone of the system’s integrated response mechanism, enabling the software to transmit detection outcomes to the hardware for immediate action.

On the software side, the PySerial library was used to configure and manage the USB-based serial port. PySerial provides a high-level interface for opening, writing to, and reading from serial ports, making it ideal for communicating with embedded systems like Arduino. The serial port was initialized with standard parameters such as baud rate (typically 9600 bps), data bits, and timeout settings to ensure smooth and error-free transmission.

In the Python script, specific character codes are transmitted over the serial interface based on the state of the driver's eyes, which is evaluated using the Eye Aspect Ratio (EAR) and fuzzy logic logic modules. The most commonly used character codes are:

* '1' – Indicates that the driver's eyes have remained closed for a short but non-critical duration (typically between 2–3 seconds). This signal prompts the Arduino to activate a buzzer, providing an immediate audible warning to alert the driver and prevent further inattention.
* '2' – Signifies a critical event where the driver’s eyes are closed for more than five seconds, suggesting severe drowsiness or incapacitation. Upon receiving this command, the Arduino:
  + Switches to autonomous driving mode (simulated using a DC motor controlled by an L298 motor driver).
  + Activates emergency lights to alert nearby vehicles and pedestrians of a potential hazard.

On the Arduino side, the Serial class (part of the standard Arduino library) is used to read incoming bytes from the USB serial port. The Arduino code includes a Serial.available() check within the main loop to continuously monitor the communication buffer. Once data is detected, Serial.read() retrieves the character, and a conditional structure (e.g., if-else or switch-case) is used to execute the appropriate hardware response.

This setup ensures that the hardware operates in close synchronization with the real-time output from the Python detection algorithm. The system responds immediately to driver state changes, thereby enhancing both safety and system reliability.

Moreover, this serial interface is bidirectional by design, which means that future versions of the system can be expanded to include feedback signals from the Arduino to Python—for instance, sending sensor readings, status updates, or confirmation of action completion.

**5.5 Arduino IDE Programming**

The hardware control logic was developed using the Arduino Integrated Development Environment (IDE) v1. The program (Arduino sketch) was written in C/C++ and uploaded to the Arduino Uno via USB.

The sketch includes:

* Initialization of serial communication using Serial.begin(baudRate).
* Reading input commands using Serial.read().
* Controlling hardware components like buzzer, DC motor, and LEDs using digitalWrite().

Each command received from Python is processed in the loop() function, which continuously runs on the Arduino. For example:

* When '1' is received, the buzzer is activated for a short time.
* When '2' is received, the motor runs (simulating bus movement in autonomous mode) and emergency lights flash to signal the transition.

This embedded program enables the Arduino to serve as the action executor, completing the feedback loop of the intelligent monitoring system.

**CHAPTER 6**

**SYSTEM INTEGRATION AND RESPONSE LOGIC**

This section describes how the software and hardware modules of the driver monitoring system interact to provide timely safety responses based on driver eye state detection. It outlines the system’s dual-level alert mechanism—using buzzer alerts for short eye closures and autonomous driving mode activation for prolonged closures—along with the fuzzy logic that governs decision-making.

**6.1 SHORT EYE CLOSURE RESPONSE (BUZZER):**

In the proposed E-Bus safety system, one of the key functionalities is the detection of early signs of driver drowsiness through eye state analysis. When the system detects that the driver’s eyes remain closed for a short duration—specifically, less than three seconds—it is interpreted as a non-critical blink or a brief lapse in attention. This behavior is considered within the normal range of human eye activity and does not immediately signify a dangerous level of fatigue.

To achieve this, the software module continuously processes real-time video input using the Eye Aspect Ratio (EAR) algorithm, which quantitatively measures the openness of the eyes based on facial landmarks. The EAR value decreases significantly when the eyes close and returns to baseline upon reopening. By tracking the EAR in continuous frames, the system can precisely determine the duration and frequency of eye closures.

When the EAR falls below a predefined threshold and remains there for a short, yet measurable period, the software triggers a warning signal. This signal is transmitted via serial communication to the Arduino microcontroller, which acts as the central hub for managing hardware responses.

Upon receiving this signal, the hardware module activates an onboard buzzer to emit a sharp and immediate audible warning. The buzzer is strategically used as a first-level defense mechanism to prevent the onset of drowsiness. Its purpose is to alert the driver without causing panic or unnecessary distraction, ensuring that the driver quickly regains focus on the road.

This subtle yet effective alert helps reduce the risk of accidents resulting from momentary inattentiveness or early-stage fatigue. By intervening early in the drowsiness progression, the system enhances road safety without being overly intrusive. If the system continues to detect longer eye closures or abnormal blinking patterns, it escalates the response in accordance with its fuzzy logic-driven decision tree, potentially enabling autonomous safety features in severe cases.

**6.2 PROLONGED EYE CLOSURE RESPONSE (AUTONOMOUS MODE):**

When the driver’s eyes remain closed for a period exceeding a predefined critical threshold—specifically, more than five seconds—the system interprets this prolonged eye closure as a strong indicator of driver drowsiness or potential incapacitation. Unlike brief blinks or momentary lapses, extended closure suggests that the driver may no longer be in control of the vehicle, posing a serious safety risk.

The detection process is governed by the software module, which employs the Eye Aspect Ratio (EAR) algorithm in conjunction with Continuous Rapid Eye Motion (CREM) monitoring. As the EAR value remains consistently below the critical threshold across multiple frames, the system classifies the driver’s state as “very drowsy” based on fuzzy logic evaluation. This triggers a second-level response protocol that goes beyond simple alerting mechanisms.

Upon confirming the drowsiness condition, the software module sends a high-priority signal to the Arduino microcontroller, commanding it to execute a fail-safe response. The microcontroller then initiates a mode switch from manual to autonomous operation. While full vehicular autonomy is simulated in this prototype, the concept is demonstrated using a DC motor driven by an L298 motor driver module. This setup emulates the vehicle’s propulsion and control transition to an automated safety mode.

Simultaneously, the system activates a set of emergency indicator lights, signaling to nearby vehicles and pedestrians that the bus is in an emergency state. These visual alerts serve to enhance road awareness and reduce the chances of collision or misjudgment by surrounding traffic.

The autonomous intervention routine is designed to perform controlled deceleration or halting of the vehicle, thereby minimizing risks to the driver, passengers, and other road users. This integrated response underscores the project's emphasis on proactive safety and smart automation. By ensuring the vehicle transitions into a safe state without relying on human input, the system effectively addresses one of the most critical failure points in long-haul or fatigue-prone driving scenarios.

This layered, intelligent response framework not only strengthens the safety infrastructure of electric buses but also exemplifies how human monitoring, fuzzy logic, and hardware integration can work harmoniously to create real-time, life-saving interventions in modern transportation systems.

**6.3 FUZZY LOGIC IMPLEMENTATION**

To enhance decision-making precision in the driver monitoring system, fuzzy logic is integrated into the hardware control module. Unlike traditional binary or threshold-based systems that rely on rigid true/false decisions, fuzzy logic provides a flexible, human-like reasoning framework capable of interpreting degrees of uncertainty—such as partial eye closure or inconsistent blinking patterns—common in real-world driving conditions.

Fuzzy logic is particularly valuable in this application because drowsiness is not a binary state; instead, it progresses through varying stages, from mild fatigue to severe inattention. This system accounts for such variability by allowing gradual transitions between alertness levels, which in turn inform the hardware's behavior more intelligently and responsively.

**Input Parameters to the Fuzzy Logic Controller**

The fuzzy inference system receives crucial input variables derived from the software module and environmental sensors, such as:

* **Eye Aspect Ratio (EAR):** Continuously calculated by the computer vision module, this value serves as a quantitative indicator of eye openness. A lower EAR sustained over several frames suggests potential drowsiness.
* **Eye Closure Duration:** Tracks how long the eyes remain below a critical EAR threshold. Longer durations imply higher drowsiness risk.
* **Blink Frequency and Consistency:** Helps differentiate between natural blinks and fatigue-induced closure patterns.
* **Ambient Lighting Conditions (optional):** Adjusts sensitivity based on whether the system operates in low-light or bright environments to avoid misclassification due to shadow artifacts or glare.

**Fuzzification and Membership Functions**

Each input is mapped to a fuzzy membership function, converting crisp numerical values into linguistic variables such as:

* EAR: High, Medium, Low
* Closure Duration: Short, Moderate, Long
* Blink Frequency: Normal, Inconsistent, Sparse

These fuzzy sets are defined using triangular or trapezoidal membership functions to reflect the gradual change between states. This step allows the system to interpret continuous input data in a qualitative manner, mimicking how a human would assess drowsiness.

**Rule Base and Inference Mechanism**

The heart of the fuzzy system is a rule base, comprising IF-THEN rules that describe how input conditions relate to output actions. Example rules include:

* IF EAR is Low AND Closure Duration is Long THEN Driver State is Very Drowsy
* IF EAR is Medium AND Closure Duration is Short THEN Driver State is Attentive
* IF Driver State is Very Drowsy THEN Activate Autonomous Mode Immediately
* IF Driver State is Drowsy THEN Increase Buzzer Intensity

The inference engine evaluates these rules in parallel using techniques like the Mamdani method to derive fuzzy output values for each possible action.

**Defuzzification and Output Response**

The final fuzzy output is defuzzified—typically using the centroid method—to convert the fuzzy output set into a crisp numerical value. This value determines:

* The intensity or duration of the buzzer sound, if a warning is needed.
* The timing for initiating autonomous mode, if critical drowsiness is detected.
* Activation of emergency indicators, based on the severity of drowsiness.

These responses are then relayed to the Arduino microcontroller, which translates them into physical actions such as controlling the DC motor, activating the buzzer, or turning on LED indicators.

**Benefits of Fuzzy Logic Integration**

* **Dynamic Sensitivity:** Adjusts thresholds and responses based on real-time input conditions.
* **Reduced False Alarms:** Minimizes unnecessary interventions by differentiating between genuine fatigue and benign behaviors like extended blinking.
* **Human-Like Reasoning:** Better aligns with the subjective and gradual nature of fatigue.
* **Real-World Robustness:** Adapts more effectively to environmental changes such as lighting variations or camera angle shifts

**CHAPTER 7**

**RESULT**

The hardware implementation of the E-Bus Safety Enhancement System using Continuous Rapid Eye Motion (CREM) detection is demonstrated with the help of four figures as described below.

Figure.9 illustrates the complete hardware setup of the project, including the Arduino Uno microcontroller, LCD display, buzzer, DC motor, L298 motor driver, and emergency alert LEDs. This setup simulates real-time driver monitoring and vehicular control responses.

**A circuit board with wires and wires

AI-generated content may be incorrect.**

**Figure.9 Hardware implementation of the project**

Figure.10 shows the system in its initialized state. The camera is active, and the display outputs the welcome message "EYE MOTION" through the LCD, indicating that the driver monitoring system is now operational.

**A green electronic device with a yellow screen

AI-generated content may be incorrect.**

**Figure.10 The System In Its Initialized State**

Figure.11 displays the system in normal operation mode. When the driver is attentive and no drowsiness is detected, the LCD shows “RUN,” and all safety systems remain on standby. The DC motor simulates regular bus movement without interruption.

A green electronic device with a yellow screen

AI-generated content may be incorrect.

**Figure.11 The System In Normal Operation Mode**

Figure.12 demonstrates the detection of short eye closure (less than 3 seconds). Upon recognizing a non-critical blink, the system sends a signal to activate the buzzer via Arduino, prompting the driver to stay alert. The buzzer serves as an immediate alert mechanism.

**A person with dark hair and green eyes

AI-generated content may be incorrect.**

**Figure.12 The Detection Of Short Eye Closure (Less Than 3 Seconds)**

Figure.13 Show The System Sends A Signal To Activate The Buzzer And Emergency Alert LEDs Via Arduino

A green electronic device with wires and a red light

AI-generated content may be incorrect.

**Figure.13 Activate The Buzzer And Emergency Alert LEDs Via Arduino**

Figure.14 presents the response to prolonged eye closure (more than 5 seconds). The system identifies this condition as potential drowsiness or incapacitation. Consequently, it transitions to autonomous mode, simulates braking using the DC motor, and activates emergency lights to alert nearby vehicles. This response ensures enhanced safety for passengers and road users.

A person taking a selfie

AI-generated content may be incorrect.

**Figure.14 The Detection Of Prolonged Eye Closure (More Than 5 Seconds)**

Figure.15 Show the Alertdrowsy Message In LCD Display

A green electronic device with wires

AI-generated content may be incorrect.

**Figure.15 The Alertdrowsy Message In LCD Display**

Figure.16 illustrates the DC motor gradually slowing and stopping, simulating the bus safely halting as part of the autonomous intervention protocol.

A yellow wheel with a black tire and a red and blue circuit

AI-generated content may be incorrect.

**Figure.16 The DC Motor Gradually Slowing And Stopping**

Figure.17 presents the activation of emergency warning lights. Once the system detects critical drowsiness, emergency LEDs are turned on to alert nearby vehicles and road users, enhancing situational awareness and preventing accidents.

A close-up of a circuit board

AI-generated content may be incorrect.

**Figure.17 The Activation Of Emergency Warning Lights**

**CHAPTER 8**

**CONCLUSION AND FUTURE SCOPE**

**8.1 CONCLUSION:**

This project presents an innovative and practical approach to enhancing road safety in public transportation through the use of Continuous Rapid Eye Motion (CREM) technology. By combining real-time facial landmark detection, the Eye Aspect Ratio (EAR) algorithm, and fuzzy logic-based hardware response, the system effectively monitors the driver’s alertness and initiates timely interventions. Short eye closures trigger a buzzer alert, while prolonged eye closures activate an autonomous driving mode and emergency signalling, ensuring safety not only for passengers but also for other road users.

The integration of Python programming, OpenCV, Dlib, and Arduino hardware has resulted in a robust proof of concept capable of detecting drowsiness accurately and responding in real-time. This dual-module (software + hardware) system represents a step forward in intelligent transport safety solutions and demonstrates how artificial intelligence and embedded systems can work hand-in-hand to reduce human error and save lives.

**8.2 FUTURE SCOPE:**

* **Enhanced Detection Accuracy:** Optimize algorithms and thresholds for better performance across diverse drivers and lighting conditions.
* **Voice Alert Integration:** Add voice notifications alongside the buzzer to effectively alert the driver.
* **Real-Time Data Logging:** Implement data recording for analysing driver behaviour and system performance over time.

**CHAPTER 9**

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**APPENDIX A: SOURCE CODE**

**A.1 PYTHON SOURCE CODE:**

**Initialization and Setup:**

import numpy as np

import imutils

import dlib

import cv2

from imutils import face\_utils

import time

import serial

import threading

def euclidean\_dist(ptA, ptB):

return np.linalg.norm(ptA - ptB)

def eye\_aspect\_ratio(eye):

A = euclidean\_dist(eye[1], eye[5])

B = euclidean\_dist(eye[2], eye[4])

C = euclidean\_dist(eye[0], eye[3])

ear = (A + B) / (2.0 \* C)

return ear

CASCADE\_PATH = "haarcascade\_frontalface\_default.xml"

PREDICTOR\_PATH = "shape\_predictor\_68\_face\_landmarks.dat"

EYE\_AR\_THRESH = 0.31

CLOSED\_EYES\_DURATION\_THRESHOLD = 10

Eyes\_Blink\_DURATION\_THRESHOLD = 2

RESET\_INTERVAL = 3 # seconds

print("[INFO] loading facial landmark predictor...")

detector = cv2.CascadeClassifier(cv2.data.haarcascades + CASCADE\_PATH)

predictor = dlib.shape\_predictor(PREDICTOR\_PATH)

(LANDMARKS\_LEFT\_START, LANDMARKS\_LEFT\_END) = face\_utils.FACIAL\_LANDMARKS\_IDXS["left\_eye"]

(LANDMARKS\_RIGHT\_START, LANDMARKS\_RIGHT\_END) = face\_utils.FACIAL\_LANDMARKS\_IDXS["right\_eye"]

print("[INFO] starting video capture...")

video\_capture = cv2.VideoCapture(0)

closed\_start\_time = None

prev\_state = None # Variable to store the previous state

last\_reset\_time = time.time()

# Open the serial port (adjust the port and baudrate accordingly)

ser = serial.Serial('COM6', 115200)

# Flag to indicate whether the program should exit

exit\_program = False

# Function to receive data from Arduino in a separate thread

def receive\_data\_from\_arduino():

global exit\_program

try:

while not exit\_program:

if ser.in\_waiting > 0:

received\_data = ser.readline().decode('utf-8').rstrip()

print(f"Received data from Arduino: {received\_data}")

except serial.SerialException as e:

print(f"SerialException in receive\_data\_from\_arduino: {e}")

# Create a thread for receiving data

arduino\_thread = threading.Thread(target=receive\_data\_from\_arduino)

arduino\_thread.daemon = True # Allow the program to exit even if this thread is still running

arduino\_thread.start()

**Real-Time Eye Detection and EAR Calculation Loop:**

while True:

ret, frame = video\_capture.read()

if not ret:

break

frame = imutils.resize(frame, width=600)

frame = cv2.flip(frame, 1)

gray = cv2.cvtColor(frame, cv2.COLOR\_BGR2GRAY)

rects = detector.detectMultiScale(gray, scaleFactor=1.1, minNeighbors=5, minSize=(30, 30), flags=cv2.CASCADE\_SCALE\_IMAGE)

for (x, y, w, h) in rects:

rect = dlib.rectangle(int(x), int(y), int(x + w), int(y + h))

shape = predictor(gray, rect)

shape = face\_utils.shape\_to\_np(shape)

left\_eye = shape[LANDMARKS\_LEFT\_START:LANDMARKS\_LEFT\_END]

right\_eye = shape[LANDMARKS\_RIGHT\_START:LANDMARKS\_RIGHT\_END]

left\_ear = eye\_aspect\_ratio(left\_eye)

right\_ear = eye\_aspect\_ratio(right\_eye)

ear = (left\_ear + right\_ear) / 2.0

for i in range(1, len(left\_eye) + 1):

if i == len(left\_eye):

cv2.line(frame, tuple(left\_eye[i - 1]), tuple(left\_eye[0]), (0, 255, 0), 1)

else:

cv2.line(frame, tuple(left\_eye[i - 1]), tuple(left\_eye[i]), (0, 255, 0), 1)

for i in range(1, len(right\_eye) + 1):

if i == len(right\_eye):

cv2.line(frame, tuple(right\_eye[i - 1]), tuple(right\_eye[0]), (0, 255, 0),1)

else:

cv2.line(frame, tuple(right\_eye[i - 1]), tuple(right\_eye[i]), (0, 255, 0), 1)

**Eye State Evaluation, Serial Communication and Cleanup:**

if ear < EYE\_AR\_THRESH:

if closed\_start\_time is None:

closed\_start\_time = time.time()

else:

elapsed\_time = time.time() - closed\_start\_time

if elapsed\_time >= CLOSED\_EYES\_DURATION\_THRESHOLD:

cv2.putText(frame, "DROWSINESS ALERT!", (10, 30), cv2.FONT\_HERSHEY\_SIMPLEX, 0.7, (0, 0, 255), 2)

print('Drowsiness alert - Eyes closed for {:.2f} seconds'.format(elapsed\_time))

current\_state = "drowsy"

if current\_state != prev\_state:

print('Drowsiness alert')

ser.write(current\_state.encode())

prev\_state = current\_state

elif elapsed\_time >= Eyes\_Blink\_DURATION\_THRESHOLD:

cv2.putText(frame, "Eyes Closed", (10, 30), cv2.FONT\_HERSHEY\_SIMPLEX, 0.7, (0, 0, 255), 2)

current\_state = "alert"

print('Drowsiness alert - Eyes closed for {:.2f} seconds'.format(elapsed\_time))

if current\_state != prev\_state:

ser.write(current\_state.encode())

prev\_state = prev\_state

elif ear > (EYE\_AR\_THRESH + 0.03):

current\_state = "run"

if current\_state != prev\_state:

print('Running')

ser.write(current\_state.encode())

prev\_state = current\_state

closed\_start\_time = None

else:

closed\_start\_time = None

cv2.putText(frame, "VAL: {:.3f}".format(ear), (300, 30), cv2.FONT\_HERSHEY\_SIMPLEX, 0.7, (0, 0, 255), 2)

if time.time() - last\_reset\_time >= RESET\_INTERVAL:

prev\_state = None

last\_reset\_time = time.time()

cv2.putText(frame, "Press 'Esc' to exit", (10, 550), cv2.FONT\_HERSHEY\_SIMPLEX, 0.7, (255, 255, 255), 2)

cv2.imshow("Frame", frame)

key = cv2.waitKey(1) & 0xFF

if key == 27: # 'Esc' key

exit\_program = True

break

cv2.destroyAllWindows()

video\_capture.release()

ser.write("rst".encode())

ser.close()

arduino\_thread.join()

**A.2 ARDUINO SOURCE CODE:**

#include <SoftwareSerial.h>

#include <LiquidCrystal.h>

LiquidCrystal lcd(8, 9, 10, 11, 12, 13);

int buz\_status;

int trans\_dat;

#define m1 3

#define m2 4

#define en1 5

#define BUZZER\_PIN 6

#define BUZZER\_OFF\_PIN 7

#define LED1 2

#define LED2 7

long BUZZER\_OFF\_DELAY = 5000; // Time in milliseconds (adjust as needed)

unsigned long buzzerOffTime = 0;

unsigned long sendInterval = 10000; // Send data every 10 seconds

unsigned long lastSendTime = 0;

#define python Serial

#define splash splash1

void setup() {

Serial.begin(115200);

LcDSet();

pinMode(BUZZER\_PIN, OUTPUT);

pinMode(BUZZER\_OFF\_PIN, OUTPUT);

pinMode(LED1, OUTPUT);

pinMode(LED2, OUTPUT);

pinMode(m1, OUTPUT);

pinMode(m2, OUTPUT);

analogWrite(en1, 0);

digitalWrite(m1, LOW);

digitalWrite(m2, LOW);

// Initially, turn off both the buzzer and the buzzer off pin

digitalWrite(BUZZER\_PIN, LOW);

digitalWrite(BUZZER\_OFF\_PIN, LOW);

digitalWrite(LED1, LOW);

digitalWrite(LED2, LOW);

}

void LcDSet() {

lcd.begin(16, 2);

splash(0, "EYE MOTION");

splash(1, "");

delay(2000);

lcd.clear();

}

void loop() {

delay(100);

// Check if it's time to send trans\_data

if (millis() - lastSendTime >= sendInterval) {

// Perform actions to update trans\_data as needed

if (trans\_dat == 1) {

analogWrite(en1, 100);

}

if (trans\_dat == 2) {

analogWrite(en1, 0);

digitalWrite(m1, LOW);

digitalWrite(m2, LOW);

}

if (trans\_dat == 3) {

analogWrite(en1, 255);

digitalWrite(m1, HIGH);

digitalWrite(m2, LOW);

}

lastSendTime = millis();

}

if (trans\_dat == 1) {

analogWrite(en1, 100);

}

if (trans\_dat == 2) {

analogWrite(en1, 0);

digitalWrite(m1, LOW);

digitalWrite(m2, LOW);

}

if (trans\_dat == 3) {

analogWrite(en1, 255);

digitalWrite(m1, HIGH);

digitalWrite(m2, LOW);

}

while (python.available() > 0) {

String receivedData = python.readStringUntil('\n');

processMessage(receivedData);

splash(1, receivedData);

}

// Check if it's time to turn off the buzzer

if (millis() - buzzerOffTime >= BUZZER\_OFF\_DELAY) {

if (trans\_dat == 1 && buz\_status == 0) {

digitalWrite(BUZZER\_PIN, HIGH);

digitalWrite(LED1, HIGH);

digitalWrite(LED2, HIGH);

buz\_status = 1;

BUZZER\_OFF\_DELAY = 50;

} else if (trans\_dat == 2 && buz\_status == 0) {

digitalWrite(BUZZER\_PIN, HIGH);

digitalWrite(LED1, HIGH);

delay(10);

digitalWrite(LED1, LOW);

digitalWrite(LED2, HIGH);

delay(10);

digitalWrite(LED2, LOW);

buz\_status = 1;

trans\_dat = 2;

BUZZER\_OFF\_DELAY = 5000000;

} else if (buz\_status) {

digitalWrite(BUZZER\_PIN, LOW);

digitalWrite(LED1, LOW);

digitalWrite(LED2, LOW);

buz\_status = 0;

}

buzzerOffTime = millis();

}

}

void processMessage(String data) {

data.trim();

if (data != "drowsy" && data != "alert" && data != "rst" && data != "run") {

return;

}

python.println("Received: " + data);

if (data == "run") {

digitalWrite(BUZZER\_PIN, LOW);

digitalWrite(LED1, LOW);

digitalWrite(LED2, LOW);

trans\_dat = 3;

buz\_status = 0;

BUZZER\_OFF\_DELAY = 100;

buzzerOffTime = millis();

} else if (data == "drowsy") {

digitalWrite(BUZZER\_PIN, HIGH);

digitalWrite(LED1, HIGH);

digitalWrite(LED2, HIGH);

trans\_dat = 2;

buz\_status = 1;

BUZZER\_OFF\_DELAY = 5000000;

buzzerOffTime = millis();

} else if (data == "alert") {

digitalWrite(BUZZER\_PIN, HIGH);

digitalWrite(LED1, HIGH);

digitalWrite(LED2, HIGH);

trans\_dat = 1;

buz\_status = 1;

BUZZER\_OFF\_DELAY = 100;

buzzerOffTime = millis();

} else if (data == "rst") {

python.println("Resetting...");

delay(1000);

asm volatile(" jmp 0");

}

}