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# AI Powered Real - Time Fatigue Detection for Road Safety Using Edge Computing

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**ABSTRACT:**

Drowsiness and fatigue are one of the main causes leading to road accidents. They can be prevented by taking effort to get enough sleep before driving, drink coffee or energy drink, or have a rest when the signs of drowsiness occur. The popular drowsiness detection method uses complex methods, such as EEG and ECG. This method has high accuracy for its measurement, but it needs to use contact measurement and it has many limitations on driver fatigue and drowsiness monitor. Thus, it is not comfortable to be used in real time driving. This paper proposes a way to detect the drowsiness signs among drivers by measuring the eye closing rate and yawning. We proposed an end-to-end non-intrusive AI-based automated framework to monitor driver behaviors, designed specifically for logistic and public transport applications. It consists of an embedded system, edge computing and cloud computing modules, and a mobile phone application, in an attempt to provide a holistic unified solution for drowsiness detection, monitoring, as well as evaluation of drivers. Drowsiness detection is based on detecting sleeping, yawning, and distraction behaviors using an image processing-based technique. To minimize the effects of latency, throughput, and packet losses, edge computing is performed using

## 1. INTRODUCTION

The Importance of driver drowsiness detection has inevitably led to an enhanced focus of research in this domain. It is particularly critical for drivers of buses and heavy trucks, as they may have to work over a prolonged durations during the peak drowsiness periods (i.e., 2:00 am. to 6:00 am. and 2:00 pm. to 4:00 pm) and under monotonous or boredom working conditions which can lead to accidents. Therefore, the need remains for an intelligent system that can efficiently and effectively detect drowsiness.

## 2. OBJECTIVES

The primary objective of non-intrusive AI-based drowsiness detection systems is to enhance safety across various domains, particularly in transportation and critical operations. By employing advanced algorithms and sensor technologies, these systems can monitor physiological and behavioral indicators of drowsiness without requiring intrusive measures like attaching sensors to the body.

These systems aim to detect signs of drowsiness such as eye closure, eyelid drooping, changes in head position, and Micro - sleep episodes. By continuously analyzing these indicators in real-time, AI algorithms can accurately assess an individual's level of alertness. When signs of drowsiness are detected, the system can issue timely alerts to the individual, prompting them to take necessary breaks or corrective actions to avoid accidents.

In transportation, such as in automotive vehicles, trucks, trains, and aircraft, non-intrusive drowsiness detection systems play a crucial role in preventing accidents caused by driver fatigue. Similarly, in critical operations such as control rooms or medical facilities, these systems help ensure that operators remain vigilant and responsive, reducing the risk of errors and accidents due to drowsiness-induced impairment. Overall, the objective of non-intrusive AI-based drowsiness detection is to enhance safety, prevent accidents, and mitigate risks associated with human fatigue in various operational environments.

## 3. DESCRIPTION ON PROPOSED TECHNOLOGY

We used same sensors in addition we added AI technology. Here the sensors detect the status of the driver and it itself activates the alarm system, vibration sensor, and push button one by one. Here the accelerometer sensor detects the speed of vehicle and slows down until the driver wakes up. Also, it sends the acknowledgement to the admin

### 3.1 EMBEDDED ANALYSIS

Embedded systems enable real-time processing of sensor data, such as eye movement or facial expressions, to detect signs of drowsiness and alert the user before a potential accident. These systems typically involve integrating sensors, like cameras or wearables, with microcontrollers for processing and decision-making. They can sound alarms, vibrate seats, or even trigger autonomous driving features to prevent accidents. Drowsiness detection using embedded systems is crucial for applications like driver monitoring systems in vehicles or monitoring operators in critical industries.

### 3.2 MACHINE LEARINING ANALYSIS

Drowsiness detection using machine learning typically involves collecting data on various physiological signals such as eye movements, head position, facial expressions, and even physiological signals. This data is then used to train a machine learning model, often a classifier, to distinguish between states of alertness and drowsiness. Once trained, the model can analyze real-time data from sensors such as cameras or wearables to detect signs of drowsiness and trigger alerts or interventions to prevent accidents, particularly in scenarios like driving.

### 3.3 HARDWARE DESCRIPTION

#### 3.3.1 Embedded

An embedded board for drowsiness detection is a compact electronic device designed to monitor and analyze a person's level of alertness to prevent accidents, particularly while driving. It typically incorporates sensors such as cameras and accelerometers to detect physical and cognitive indicators of drowsiness, such as eyelid closure, head nodding, and brainwave patterns associated with fatigue. Through real-time data processing and machine learning algorithms, the board assesses the user's state of alertness and triggers alerts or interventions when signs of drowsiness are detected, such as sounding an alarm, vibrating the steering wheel, or sending alerts to a connected mobile device. The compact nature of the board makes it suitable for integration into vehicles, wearable devices, or other systems where continuous monitoring of drowsiness is essential for safety. Additionally, it can be customizable and scalable to accommodate various environments and user preferences, enhancing its effectiveness and usability.

#### 3.3.2 Sound Buzzer 12V

The sound buzzer work as an alert mechanism which is categorized into onboard alert for a driver.Where on-board alert triggers when any of the three facial actions (eyes closed, yawning, and distraction) are detected as abnormal to get the driver's attention back to avoid an accident. If a driver falls asleep (i.e. his/her eyes are continuously closed for more than 3 seconds), an alert notification is received on the admin mobile application along with the driver's drowsiness images, timestamp, and location for tracking. We tested the alert system for all three scenarios (eyes closed, yawning, and distraction) on different subjects,on detecting a person in which it calculates EAR, MAR, and ENED. It took overall 3.07 seconds to detect drowsiness, capture an image to store in a local drive, and send that image to the firebase cloud database.

#### 3.3.3 Vibration Motor 4.2V

Drowsiness detection systems often employ vibration motors to alert drivers when they show signs of fatigue. These motors are strategically placed in the vehicle, typically embedded within the driver's seat or worn as a wearable device. When the system detects drowsiness based on factors like eye movement, head position, or steering behaviour. It triggers the vibration motor to produce a tactile alert. The vibrations serve as a non-intrusive method to awaken the driver, prompting them to become more alert and attentive to the road. By utilizing vibrations, these systems offer a subtle yet effective means of preventing accidents caused by driver fatigue. Moreover, vibration alerts can be customized based on the severity of drowsiness detected, ensuring that drivers are promptly notified without causing unnecessary distraction. Overall, integrating vibration motors into drowsiness detection systems enhances safety on the roads by providing timely warnings to drivers, potentially preventing accidents, and saving lives.

#### 3.3.4 DC Motor 12V

A 12-volt DC motor is an electrical device that converts direct current electrical energy into mechanical motion. It consists of several key components, including a rotor, a stator, and a commutator. When voltage is applied across the motor terminals, a magnetic field is created within the stator, which interacts with the magnetic field of the rotor, causing it to rotate. The direction of rotation can be controlled by reversing the polarity of the applied voltage.

These motors are commonly used in a variety of applications such as automotive systems, robotics, industrial machinery, and household appliances due to their simplicity, reliability, and ease of control. They come in various sizes and configurations to suit different power requirements and mechanical loads. Additionally, they can be coupled with gears or other mechanisms to adjust the speed and torque output as needed.

#### 3.3.5 Power Supply

Lithium polymer battery usually consists of several identical parallel secondary cells to increase the discharge current, or several battery packs in series to increase the available voltage.We have been producing and selling Lithium Polymer Batteries for more than 10 years. The Lithium ion LP18650 A+ 3.7V 3500mAh battery is one of our most popular 3.7V li polymer batteries. Buy some batteries for you device or prototyping. Our MOQ is only 5pcs, kind to the all of start-up companies in the world.
As we all know, today this new type of our lithium polymer batteries are mainly used in portable devices, radio controlled devices, personal electronics, Smart wearable devices, Bluetooth headset/speakers, GPS tracker, E-book, laptops, mobile phones, digital cameras, digital camcorders, and gaming types of equipment. Set of four high-quality 1.5V batteries, perfect for powering a wide range of devices such as remote controls, flashlights, toys, and more. These batteries are long-lasting and reliable, providing consistent power for your electronics whenever you need it.

#### 3.3.6 Microcontroller – ESP32s CAM

The ESP32-CAM is a compact, yet powerful development board designed around the ESP32 microcontroller and featuring a camera module, making i.e., deal for projects involving image capture and processing. Its compact form factor makes it suitable for various applications, including surveillance, home automation, and IoT projects. The ESP32-CAM comes with built-in Wi-Fi and Bluetooth connectivity, allowing it to communicate wirelessly with other devices and networks, making it versatile for a wide range of applications.Additionally, the ESP32-CAM features GPIO pins and interfaces for connecting peripherals and sensors, expanding its functionality, and allowing developers to create custom solutions tailored to their specific needs. With its combination of powerful processing capabilities, wireless connectivity, and camera functionality, the ESP32-CAM is a versatile platform for building innovative and feature-rich projects.

#### WIFI MODULE (ESP32)

The ESP32 Wi-Fi module, developed by Espressif Systems,

is a versatile and powerful solution for wireless communication in IoT applications. Featuring dual-core processing capabilities, it offers robust connectivity over both 2.4 GHz and 5 GHz Wi-Fi bands, complying with IEEE 802.11 standards. In addition to Wi-Fi, the ESP32 integrates Bluetooth functionality, including Bluetooth Low Energy (BLE), expanding its applicability across various IoT scenarios. Despite its processing power, the ESP32 is designed with energy efficiency in mind, making it suitable for battery-operated devices through various power-saving modes. With a rich set of peripherals, including GPIO, UART, SPI, I2C, ADC, and DAC, it facilitates seamless interfacing with external sensors and actuators. Security is paramount, and the ESP32 incorporates features like SSL/TLS encryption and secure boot to ensure secure communication. Supported by a diverse development ecosystem, including the Arduino IDE and ESP-IDF, the ESP32 offers flexibility in programming environments. Furthermore, its competitive pricing makes it an attractive choice for both hobbyists and professional developers working on IoT projects of any scale. Overall, the ESP32 stands as a comprehensive solution, combining Wi-Fi and Bluetooth connectivity with advanced features and a flexible development environment, making it an ideal choice for a wide range of IoT applications.

### 3.3.7 MALE AND FEMALE JUMPER WIRES

Male to female jumper wires are an essential component for any electronic prototyping and testing project. They allow for easy and convenient interconnection between components without the need for soldering. These jumper wires male to female come in groups or cables with connectors or pins at each end and are commonly used for connecting FRC pins, Header pins, Berg pins, and other components.

The male to female jumper wires, in particular, have a male pin on one end and a female connector on the other, making them suitable for a wide range of projects that require connecting components with different types of pins or connectors. One popular use for these jumper wire is with microcontrollers such as the Arduino. These boards have a series of pins that control various components and sensors, and with the help of male to female jumper wires, these pins can easily be connected to other components on a breadboard or in a circuit.
In addition to Arduino projects, male to female jumper wires are also useful for connecting components on a PCB project or a PC motherboard. Their easy plug-and-play design makes it possible to test different component configurations quickly without the need for permanent connections. This male to female wire allows for efficient troubleshooting and design refinement before making a final, permanent connection.Say goodbye to messy wires and complex setups. Switch to Robocraze's jumper wires male to female today and open up endless possibilities for prototyping.

### 3.3.8 ARDUINO Uno R3 BOARD

The Arduino UNO is a popular microcontroller board renowned for its simplicity and versatility. Developed by Arduino LLC, it's based on the ATmega328P microcontroller, featuring digital and analog input/output pins, making it ideal for prototyping various electronics projects. With its user-friendly interface and open-source nature, it's widely adopted by hobbyists, educators, and professionals alike. The UNO board includes onboard components such as LEDs, a reset button, and a USB interface for programming and power supply. It supports a wide range of sensors and actuators, enabling users to create interactive projects easily. Its compatibility with the Arduino Software (IDE) simplifies programming, allowing users to write and upload code effortlessly. Whether you're a beginner learning the basics of electronics or an experienced developer building advanced projects, the Arduino UNO provides a reliable platform for innovation and experimentation in the world of embedded systems and IoT applications.

### 3.3.9 L298N MOTOR DRIVER MODULE

The L298N is a popular dual H-bridge motor driver integrated circuit (IC) used in robotics and automation projects. It can control the speed and direction of two DC motors or one stepper motor. With its built-in H-bridges, it enables bidirectional control of motors, allowing them to rotate clockwise or counterclockwise. The L298N operates at voltages up to 46V and can deliver a maximum current of 2A per channel, making it suitable for a wide range of motor applications. It has built-in flyback diodes for protection against back electromotive force (EMF) generated by the motors. The module typically includes heat sinks to dissipate heat generated during operation. It is commonly interfaced with microcontrollers like Arduino for motor control in various projects such as robots, CNC machines, and remote-controlled vehicles. Overall, the L298N is a versatile and reliable motor driver IC widely used in the maker and hobbyist communities.

### 3. 4 SOFTWARE DESCRIPTION

**Arduino IDE** is an open-source software, designed by Arduino.cc and mainly used for writing, compiling & uploading code to almost all Arduino Modules. It is an official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.
It is available for all operating systems i.e. MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role in debugging, editing and compiling the code.

A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro and many more.

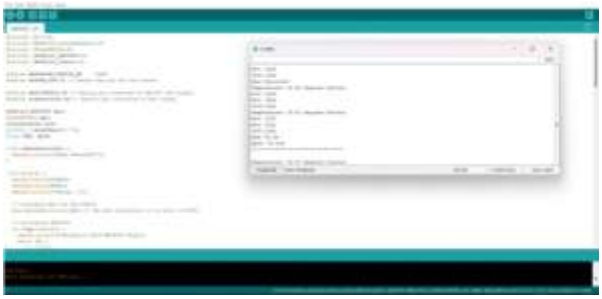
**OPEN NEW SKETCH.**

WRITE THE CODE.

**4**. INCLUDE THE LIBRARIES.

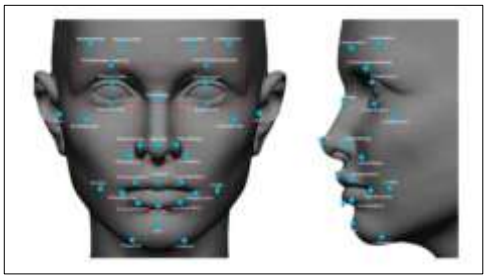
**5**. SELECT THE BOARD AND PORT.

**6**. SAVE AND COMPILE THE SKETCH.



**7**. UPLOAD THE CODE AND SEE THE OUTPUT IN THE SERIAL MONITOR.

### 3.5. EDGE COMPUTING – EAR, MAR, ENED



Edge computing is followed by an embedded block that consists of pre-processing and processing layers. This block captures a live video stream to pass frames for further processing that includes, RGB into a greyscale image, ROI detection, and facial landmarks detection. To determine the drowsiness, the suggested work implements a pre-trained library for the detection of facial landmarks. The 68 facial landmarks (preset indexed landmarks) aid in shape prediction to distinguish between different facial parts such as the eyebrows, mouth area, jaw points, etc.,
Based on facial landmarks, we have calculated Eye Aspect Ratio (EAR), Mouth Aspect Ratio (MAR), and Ear to Nose Euclidean Distance (ENED) for drowsiness and distraction detection

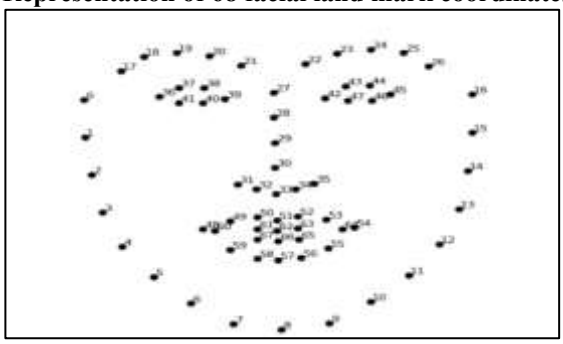
EYE ASPECT RATIO (EAR) Drowsiness can be detected from the eyes based on blink pattern and blink duration. Human adults blink on average 12 times per minute, where the duration of one blink is approximately 1/3 seconds. The library gives us 6 points of an eye

MOUTH ASPECT RATIO (MAR) Yawning is an early sign

of a person getting possibly drowsy. Frequent yawning enhances the possibility of drowsiness. To detect yawning, Equation (3) is used in which 8 points of lips from 68 facial landmarks

EAR TO NOSE EUCLIDEAN DISTANCE (ENED)
A related important behavior to detect is 'distraction', as it could potentially cause an accident. It normally involves the driver looking sideways, i.e. to the left or right side, for a certain duration of time due to (or without) being drowsy. Here, we define 'distraction' as looking sideways for more than 3 seconds, which could be considered as a reasonably longer enough time to stay distracted while driving. To detect this behavior, we use p1, p2, and p3 points from the 68 facial landmarks

**Representation of 68 facial land mark coordinates**



### 3.5.1 CLOUD COMPUTING

This block consists of a network layer and a storage layer. The network layer allows connecting edge devices with the Internet, which enables access to the cloud-hosted real-time database for storing media, real-time data, and authentication. It allows real-time data streaming and storage in the storage layer. Firebase cloud-hosted real-time database is used to achieve the aforementioned functionality in this layer. It is a hybrid cloud-hosted real-time database that can be configured with a cross-platform embedded system, mobile application, and websites, where data is stored and synchronized among all the nodes and remains available when an application goes offline. Firebase provides various features but we used: (a) authentication to authenticate legitimate users; (b) a realtime database for real-time data streaming; and (c) storage to save media. Our database is synced with three nodes such as an embedded device, admin, and driver mobile applications.
Authentication is an important feature of the Android application that allows only legitimate users to access the application. A new user needs to register on the Android application and the registration data is stored on the Firebase database.
After successful registration, the user needs to use the same credentials (email, password) to sign into the application, where input credentials are authenticated with Firebase authentication. Moreover, the user can recover a forgotten password through the email address he entered at the time of registration.

VERIFY, SAVE AND UPLOAD THE CODE.

### 3.6 MACHINE LEARNING LIBRARIES AND ALGORITHMS

### LIBRARIES

Detecting Drowsiness with dlib
Dlib is a popular libraries in the field of computer vision and machine learning. They provide a robust toolkit for building applications that involve facial detection and tracking. By utilizing these libraries, we can create a drowsiness detection system that monitors a person's facial features and alerts them when signs of drowsiness are detected

**Face Detection**: Use OpenCV's pre-trained Haar cascade classifier or deep learning-based face detection models like Dlib or MTCNN to detect faces in the video stream.

**Eye Detection**: Once a face is detected, use another Haar

cascade classifier or deep learning-based model to detect eyes within the detected face regions.
**Eye Aspect Ratio (EAR) Calculation**: Calculate the Eye Aspect Ratio (EAR) for each eye to determine if they are open or closed. EAR is calculated based on the distances between landmarks of the eye (e.g., inner and outer corners).

**Drowsiness Detection Logic**: Define thresholds for the EAR values to classify the eyes as open, closed, or in a drowsy state. For example, if the EAR falls below a certain threshold for a certain duration, it indicates drowsiness.

**Alert Mechanism**: Implement a mechanism to alert the driver when drowsiness is detected. This could be a sound alert, visual alert on the screen, or a vibration alert.

**Continuous Monitoring**: Continuously monitor the EAR values and update the drowsiness state in real-time.

**Testing and Fine-Tuning**: Test the algorithm with various lighting conditions, different individuals, and different levels of drowsiness to fine-tune the thresholds and improve the accuracy of the detection

**Applications of Drowsiness Detection with dlib**

1. Driver Monitoring Systems:
The most obvious application is in vehicles, especially long-haul trucks and buses. Drowsiness detection systems can help prevent accidents by alerting fatigued drivers to take a break or rest.
2. Aviation:
Pilots are responsible for the lives of hundreds of passengers. Drowsiness detection can play a crucial role in aviation safety, ensuring that pilots remain alert during long flights.
3. Healthcare:
Drowsiness detection is not limited to transportation. It can also be applied in healthcare settings to monitor patients' alertness, especially those recovering from surgery or under the influence of sedatives.

4. Workplace Safety:
Industries that require employees to operate heavy machinery or perform safety-critical tasks can benefit from drowsiness detection systems to reduce the risk of accidents caused by fatigue.
5. Consumer Electronics:
Drowsiness detection can be integrated into consumer devices like smartphones and wearables. This feature could help users manage their sleep patterns and avoid accidents while using machinery.

**ALGORITHMS**

**Viola-Jones Algorithm**

It is a machine-learning technique for object detection proposed in 2001 by Paul Viola and Michael Jones in their paper "Rapid object detection using a boosted cascade of simple features". The algorithm was primarily conceived for face detection.
If the eyes are found closed for 6 or more consecutive frames, then the system finds the inactiveness of the driver and concludes that the driver is falling asleep and issues a warning signal or generate and alarm signal to wake him up
**1. Data Collection:** Various sensors, such as cameras, steering angle sensors, and vehicle speed sensors, collect data on the driver's behavior and vehicle dynamics.

**2.Feature Extraction:** Relevant features are extracted from the collected data. For example, from camera data, features like eye closure duration, blink frequency, and facial expressions are extracted. From vehicle data, features like steering wheel deviation and speed variations are extracted.

**3. Data Labeling:** Data points are labeled as either drowsy or alert based on ground truth
annotations or physiological indicators (e.g., yawning, head nodding).

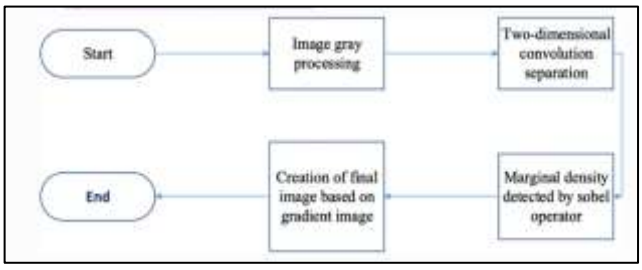
**4. Model Training:** Machine learning models, such as support vector machines, random forests, or deep neural networks, are trained using the labeled data. The models learn to recognize patterns indicative of drowsiness based on the extracted features.

**5. Model Evaluation:** The trained model is evaluated using validation datasets to assess its performance in accurately predicting drowsiness.

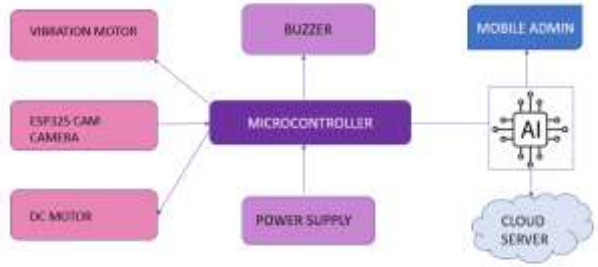
**6. Real-timePrediction:** During deployment, the trained model processes real-time sensor data to predict the driver's state (drowsy or alert) continuously.

**7. Alert Generation:** When signs of drowsiness are detected, alerts are generated to prompt interventions, such as auditory warnings or seat vibrations, to alert the driver or autonomous vehicle systems.

**8. Feedback Loop:** The algorithm is continuously refined and validated using feedback from real-world deployments to improve its accuracy and adaptability across different driving conditions and individual characteristics.




**3.7 BLOCK DIAGRAM**

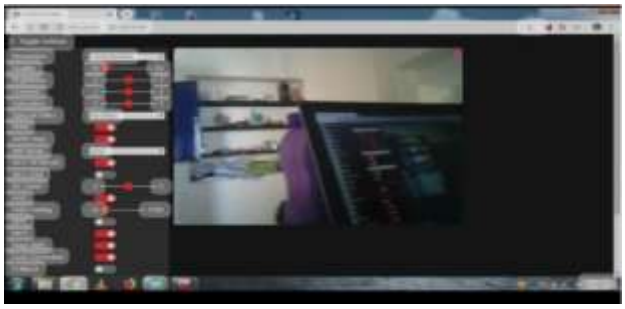



## 4. CONCLUSION

We propose a non-intrusive AI-based automation framework for drowsiness detection using the ESP32-CAM involves integrating Arduino Cloud and machine learning algorithms to analyze facial features and movements captured by the camera. By leveraging computer vision techniques, the system can monitor the driver's facial expressions, eye movements, and head nods in real-time. Upon detecting signs of drowsiness, such as drooping eyelids or prolonged eye closure, the system triggers alerts to prompt the driver to take action, such as stopping the vehicle. This framework enhances road safety by providing timely interventions to prevent accidents caused by driver fatigue.

### 4.1.1 Results on Arduino IDE

### 4.1.2 Results on Facial recognition in ESP32 – Arduino Cloud



### 4.2 Conclusion and Future scope

In conclusion, a non-intrusive AI-based automatic framework for drowsiness detection offers a promising solution for enhancing safety in various settings, such as transportation and industrial operations. By leveraging advanced machine learning algorithms and computer vision techniques, this framework can accurately identify signs of drowsiness in individuals without requiring intrusive sensors or devices. Its ability to analyze facial expressions, eye movements, and other physiological indicators in real-time allows for timely intervention, potentially preventing accidents and improving overall productivity. However, further research and development are needed to optimize its accuracy, reliability, and adaptability across different environments and demographics. Overall, this technology holds great potential for mitigating the risks associated with drowsiness-related incidents, contributing to safer and more efficient operations in diverse industries.

### 4.2.1 Future Works on following project

Future works for AI-based drowsiness detection may involve enhancing real-time monitoring accuracy by integrating biometric data such as heart rate variability and facial recognition. Deep learning algorithms could be refined to detect subtle signs of fatigue, like micro-expressions or changes in speech patterns. Collaborations with automotive companies may lead to embedding drowsiness detection systems directly into vehicles, ensuring safer roads. Furthermore, advancements in wearable technology could enable continuous monitoring outside of controlled environments, offering personalized alerts and interventions. Ethical considerations regarding privacy and data security will also be paramount in the development and deployment of these technologies.

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