EARLY DRIVER FATIGUE DETECTION SYSTEM

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NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY
RAWALPINDI
2024

COLLEGE OF ELECTRICAL AND MECHANICAL ENGINEERING

DE-42 EE
PROJECT REPORT

EARLY DRIVER FATIGUE DETECTION SYSTEM

Submitted to the Department of Electrical Engineering
in partial fulfillment of the requirements
for the degree of
Bachelor of Engineering
in
Electrical
2024

Submitted by

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بسم الله الرحمن الرحيم

CERTIFICATE OF APPROVAL

It is to certify that the project **"Early Driver Fatigue Detection System"** was done by **NS Abdul Hadi** and **NS Waleed Sultan Butt** under supervision of **Asst**. **Prof. Sobia Hayee.**

This project is submitted to **Department of Electrical Engineering**, National University of Sciences and Technology (College of Electrical and Mechanical Engineering), Pakistan in partial fulfilment of requirements for the degree of Bachelor of Electrical Engineering.

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DECLARATION

We affirm that the content presented in this Project Thesis is original and has not been submitted in support of any other degree or qualification at this or any other educational institution. We acknowledge that any act of plagiarism will result in full responsibility and may lead to disciplinary action, including the potential cancellation of our degree, based on the severity of the offense.

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ACKNOWLEDGEMENTS

First of all, we would like to thank Allah Almighty who gave us the courage to pursue our ambition for our final year project and who helped us in our struggles to achieve our goals. Secondly, we would like to thank our project supervisor Asst. Proof. Sobiya Hayee who guided us in selecting our final year project and helped us throughout our final year in achieving certain milestones for our project. Without her guidance we would not have been able to complete this project on time. Finally, we would like to thank our parents who prayed for us and who have high hopes for our future.

ABSTRACT

The main issue in modern transportation is road safety, hence this endeavor aims to alleviate driver weariness. The goal is to use the versatile machine learning framework Dlib and the tiny single-board computer Raspberry Pi to create a sophisticated, reasonably priced driver fatigue detection system. The major goals include early warnings to prevent possible crashes, lower deployment costs, improved system reliability, and real-time detection of driver fatigue signs. The process uses Dib's powerful facial landmark identification algorithm, machine learning methods to identify exhaustion, and face data collection and analysis using the Raspberry Pi camera. The system is shown to be valuable in improving traffic safety and reducing the hazards related to driver weariness by means of rigorous testing and assessment procedures that validate its accuracy, dependability, and financial sustainability. The project considers system resilience and economic sustainability while also providing a workable solution for raising driver safety and lowering traffic accidents to create intelligent transportation networks. By means of creative application of accessible technologies, this project aims to tackle a pressing social issue and greatly enhance automobile safety.

SUSTAINABLE DEVELOPMENT GOALS

Goal 3 – GOOD HEALTH AND WELL-BEING:

Our project aims to improve road safety by helping drivers stay focused on the road and prevent accidents caused by distracted driving.

Figure 1. SDG Goal 3

Goal 9 – INDUSTRY, INNOVATION, AND INFRASTRUCTURE

Furthermore, the project aligns with the Sustainable Development Goal (SDG) of Industry, Innovation, and Infrastructure. It emphasizes innovation by incorporating advanced technologies such as machine learning algorithms to detect driver fatigue. This innovation contributes to the development of new solutions within the transportation sector, improving safety and efficiency.

Figure 2. SDG Goal 9

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Acronyms

SVM Support Vector Machine

CNN Convolutional Neural Network

RNN Recurrent Neural Network

ADAS Advanced Driver-Assistance Systems

HRV Heart Rate Variability

GPU Graphical Processing Unit

CSV Comma Separated Values

PNG Portable Network Graphics

JPEG Joint Photographic Experts Group

SVG Scalable Vector Graphics

PDF Portable Document Format

GB Gigabyte

AR Aspect Ratio

MAR Mouth Aspect Ratio

EAR Eye Aspect Ratio

RAM Random Access Memory

Chapter 1 – INTRODUCTION

1.1. Introduction

Driver's fatigue plays a significant part in many accidents. According to the latest statistics, fatigue-related crashes result in 76,000 injuries and 1200 deaths annually. Throughout history, humans have invented machines and strategies to make life easier and safer for them whether it is a matter of basic routine like commuting to work or more fascinating endeavors such as seeing unfamiliar places. For instance, air travel.

With technological advancements transportation modes are changing and we are relying on them more than before. This has essentially changed our lives as we know them already. We can now reach places with speeds unimaginable even by our grandparents. Every person today uses some mode of transport every day.

Public transport is used by some individuals while others can afford to have a car. Social status does not matter in relation to driving etiquette. One of them is staying awake when driving. A considerable number of these are caused by drowsy drivers resulting in many global deaths. Until recently, we did not have any technology that could prevent such occurrences but now there are many ways which have been established for that reason. Like the rate at which someone on the road blinks and yawns, for instance. But what if it was possible to know in advance if you were aware that the driver was going to fall asleep? By doing this, a lot of accidents could be saved or prevented simply by waking them up early enough through an alarm. For this to happen, strategies need to be put in place which will either help avoid or reverse the effects of sleepiness.

Figure 3: Reference Image

1.2. Problem Statement

The problem we're tackling with the project "Early Driver Fatigue Detection" is that many accidents happen because drivers get too tired while driving. Sometimes, drivers don't realize they're tired until it's too late, and this can lead to serious accidents.

We want to create a system that can spot when a driver is getting tired early on. This system will use special technology like sensors and cameras to keep an eye on the driver and look for signs that they're getting sleepy. When it detects these signs, it will give a warning to the driver, telling them to take a break or do something to stay awake.

The goal is to stop accidents before they happen by helping drivers stay alert and safe on the road. This way, we can prevent crashes, injuries, and even save lives.

1.3. Objectives

The design aims to achieve the following.

- To develop a reliable and accurate system for early detection of driver fatigue using advanced technology.
- To implement real-time monitoring capabilities to continuously assess driver behavior and physiological indicators.
- To create cost effective alert system to prompt drivers to take preventive measures when signs of fatigue are detected, thereby reducing the risk of accidents on the road

1.4 Organization of Thesis

1.4.1. Chapter 1: Introduction

Weariness of the driver is a significant factor affecting road safety, which highlights the need for early detection technology. The dangers associated with fatigue-related accidents highlight how urgent preventative action must be implemented. Although several modern methods and technologies can be used to identify driver fatigue, more work must be done to improve the accuracy and effectiveness of the detection process. Presenting the research problem and describing the objectives of the proposed system, this chapter provides an organized summary of the subsequent chapters.

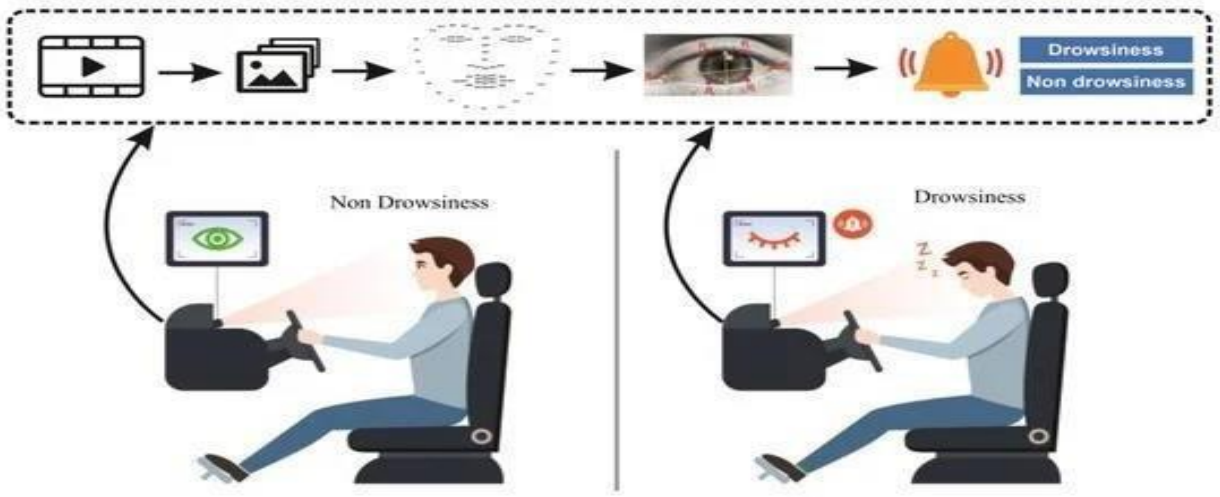

Figure 4 : General View of Early Fatigue Detection System

1.4.2. Chapter 2: Literature Review

This chapter examines the literature on machine learning, Dlib and OpenCV for drowsiness detection. It includes an in-depth study of the present state of the art in machine learning for Early Fatigue Detection.

1.4.3. Chapter 3: Facial Landmarks Detection Using Dlib

This section explores the technique used to identify face landmarks with the Dlib library, explaining its purpose and specifics of implementation.

1.4.4. Chapter 4: Design Methodology

The system architecture is thoroughly examined in this chapter, which also

explains how the Raspberry Pi Zero W was included into the detecting system. It explains the hardware components and how the Dlib software and they cooperate flawlessly to identify facial landmarks. In-depth creation of the system is also explained, covering design considerations, technological decisions, and implementation processes.

1.4.5. Chapter 5: Results

In summary, chapter five discusses a project that is aimed at detecting fatigue in drivers. It mostly focuses on the findings and contributions to real-time image processing. The result of progress made so far in early detection of driver fatigue is explained by this chapter, which has integrated facial landmark detection using Dlib library with Raspberry Pi Zero W for real-time data processing. Moreover, it talks about the success of the project in terms of making sure that signs of tiredness are identified accurately and promptly leading to increased safety on roads.

1.4.6. Chapter 6: Conclusions and Future Work

This chapter summarizes the project's research activities and highlights the major accomplishments. It concludes by looking at the project's contributions to machine learning and voice analysis. This chapter also describes potential future work that might be done to improve the system even more. It explores potential enhancements to the data processing and machine learning components, as well as potential new features.

Chapter 2 – LITERATURE REVIEW

2.1. Background Of Early Driver Fatigue Detection Systems

In Pakistan, the escalation of business accidents involving buses and heavy vehicles, including motorcars, lorries, and exchanges, has become a concerning trend. Each passing day witnesses an uptick in such incidents, underscoring the urgent need for effective measures to address this issue. Among the myriad factors contributing to these accidents, drowsiness and fatigue among drivers emerge as prominent culprits.

The perilous consequences of driving under such conditions cannot be overstated, as fatigue impairs a driver's ability to make split-second decisions and maintain focus on the road ahead. The ramifications of a lapse in concentration can be catastrophic, not only for the driver but also for passengers and other road users.

To mitigate the risks associated with drowsy driving, drivers are encouraged to adopt preventative measures. Ensuring adequate rest before embarking on a journey, consuming stimulants like coffee to temporarily boost alertness, and taking regular breaks during long hauls are among the strategies advocated for combating driver fatigue. However, despite the availability of these precautionary measures, drivers often disregard them, either due to ignorance or a false sense of invincibility.

This underscores the critical importance of early detection methods for identifying signs of drowsiness in drivers. Yawning and eye fatigue, as highlighted in this study, serve as telltale indicators of fatigue and impending drowsiness. By recognizing these early warning signs, drivers can take timely action to avert potential accidents and safeguard lives on the road.

In essence, addressing the issue of drowsy driving requires a multifaceted approach encompassing awareness campaigns, regulatory interventions, and technological advancements aimed at enhancing driver safety. Only through concerted efforts can Pakistan hope to curb the alarming rise in business accidents and ensure safer roads for all.

2.2. Literature Review

This study is being conducted to get a better understanding of the needs and requirements of the public, and to do so, we combined through several websites and applications for the necessary information. We created an audit based on this data, which allowed us to generate fresh ideas and build alternate arrangements for our assignment.

We concluded that such an application is required and that there has been some advancement in this field. The detection system incorporates processes such as facial image extraction, yawning propensity, blink of eyes detection, eye area extraction, and so on, according to the Survey on Driver Fatigue- Drowsiness Detection System. Many Models have been created with OpenCV for Android, which is also available for low-cost handsets. When the camera was positioned at other locations in other studies, the results were extremely accurate. OpenCV is primarily a real-time image processing technology with low-cost implementations on modern computers. It has all the required computer vision algorithms.

A. Face and Eye Monitoring using CNN [1]: This is an analogic CNN based method, this research presents a novel solution to important aspects of face detection problems. The presented algorithm maps and normalizes the face which a person makes while being in an accident. It is done with the help of Convolution Neural Networks.

B. Haar Cascades based Face Detection Paul Viola and Michael Jones [2] presented a powerful method of identification using Haar highlight based cascade classifiers in their work named "Fast Object Detection".

C. Eye Monitoring using Image Processing [3] Many applications, such as face monitoring, iris monitoring, video calling, eye-ball tracking, autostereoscopic displays, and face recognition. This technique is better suited for eye recognition because it uses color image processing.

2.3. Limitations and Challenges

Many limitations and challenges remain even with the improvements in driver fatigue detection. Accuracy, reliability, and real-time processing are all plagued by several issues in the current technologies. Variations in face features among individuals, occlusions, and variations in lighting conditions all make accurate detection difficult. When applied in actual driving situations, fatigue detection systems also need to be robust and adaptable enough to handle a range of road conditions and driving styles. These problems must be fixed if tiredness detection technologies are to be developed that can guarantee road safety and prevent accidents.

Chapter 3 – Facial Landmarks Detection Using Dlib

The early driver tiredness detection system relies heavily on facial landmark detection to identify important facial traits that are symptomatic of exhaustion. This section explores the technique used to identify face landmarks with the Dlib library, explaining its purpose and specifics of implementation.

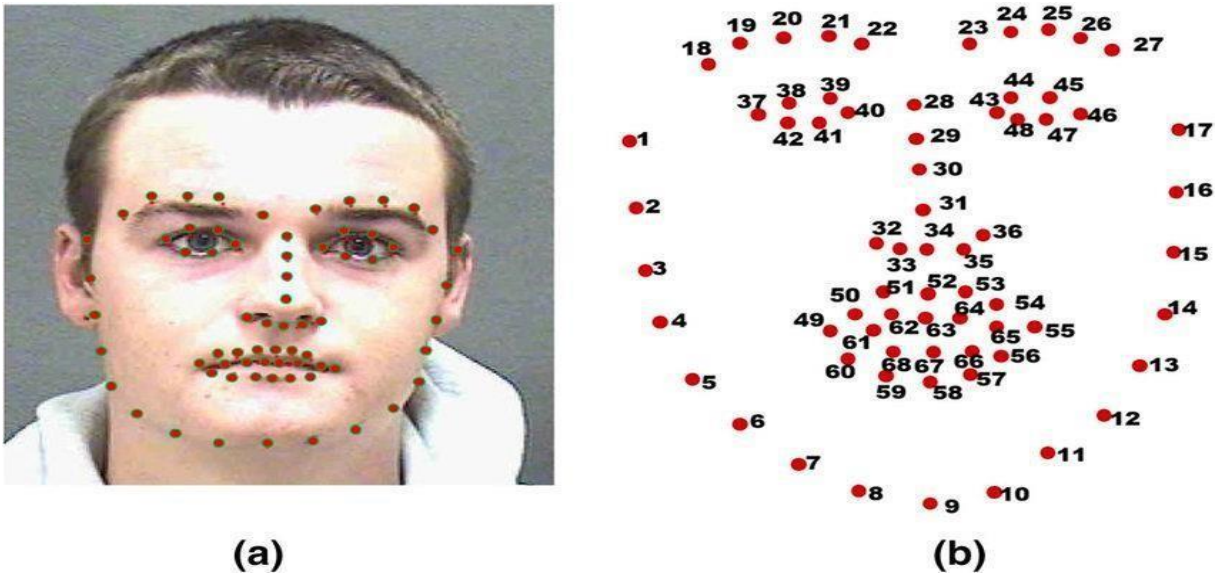

Figure 5: 68 Landmark Detection

3.1. Overview of the Dlib Library:

Dlib is one of the best machine learning libraries as it is versatile enough to be used in a whole lot of computer vision applications. Dlib is necessary for your research because its method of facial landmark detection is particularly useful in diagnosing drivers who are sleepy or fatigued. This algorithm has received accolades for its outstanding performance, that is real-time and unrivalled accuracy which makes it ideal for determining any face features related to driver's sleepiness.

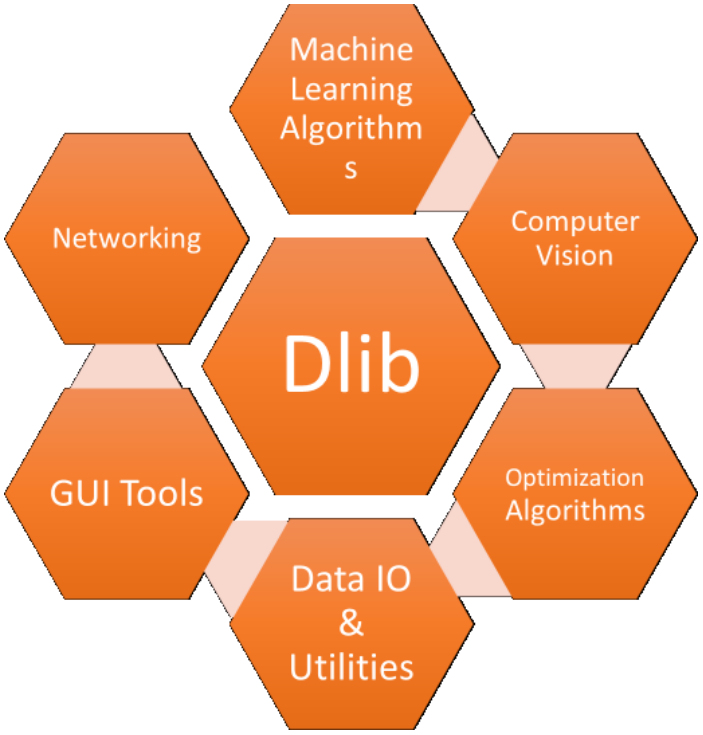

Figure 6: Dlib Overview

On a positive note, Dlib's facial landmark recognition algorithm does quite well by recognizing key facial features such as mouth, nose and eyes. This property helps you since it can detect some small signs of tiredness like changes in lip curvature, number of times eyes closure occurs and yawning frequency among others. Through this feature, Dlib enables your system to detect fatigue by capturing minute movements that signal exhaustion or drowsiness.

Additionally, the responsiveness of your system to fatigue is increased due to the real-time nature of Dlib's processing time on faces with landmarks. In dynamic environments where quick decisions save lives while driving, being able to quickly identify tiredness can be critical. Thus, during the operation phase of this algorithm from Dlib it works smoothly.

3.2. Which is the best pre-trained model: Dlib or others?

Dlib is a better choice for various reasons compared to other training models like YOLO (You Only Look Once) which highlight its unique advantages and its relevance in different circumstances, mainly early driver's fatigue detection. Reasons explaining are given as.

3.2.1. Accuracy and Robustness:

Dlib is renowned for its extremely accurate and robust facial landmark detection method where it can easily locate important face landmarks such as the mouth, nose or eyes even under challenging conditions of changing lighting or occlusions. This level of accuracy is needed to effectively detect and intervene when drivers display slight signs of tiredness.

3.2.2. Real-Time Performance:

Dlib is very good at real-time processing which makes it perfect for applications that require fast responses such as detecting driver's sleepiness. Thanks to effective algorithms used in this software, face landmarks are processed rapidly thereby allowing instant analysis and decision making. This attribute helps to quickly identify sleepiness symptoms in time to alert drivers.

3.2.3. Versatility:

Apart from identifying face landmarks, Dlib has several other features such as object recognition, image segmentation and machine learning. It can thus be used to create complex computer vision systems.

3.2.3. Documentation and Community Support:

For Exemplary documentation and intuitive interface make the integration and deployment aspect of Dlib easier. It's a cross-platform and cross-programming language friendly application that ensures it is widely used and also easy to adopt by developers. Additionally, it has an open-source design that allows for user community growth, knowledge exchange as well as continued

development.

Nevertheless, YOLO may not be the best option for fine-grained facial landmark localization needed in fatigue evaluation as much as it is popular for object recognition tasks. However, since YOLO only looks at bounding boxes, it might fail to detect tiny facial cues indicating tiredness with required precision. Also, the focus of YOLO on object detection within an image may not entirely be compatible with the complex requirements of driver fatigue monitoring that necessitates accurate facial landmark identification. The unmatched accuracy, real-time performance, versatility, and ease of integration associated with Dlib makes it an attractive option for developing early driver tiredness detection systems. This lays groundwork for accurate as well efficient fatigue assessment in practical situations especially while driving.

Chapter 4 – Methodology

This proposed project tries to develop a Fatigue Detection System for an Early Driver by using Dlib and a Raspberry Pi. But before that, one must consider the feasibility of the project from different aspects.

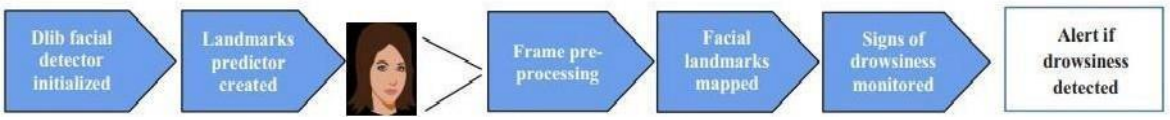

Figure 7: General Flow Diagram

4.1. Economic Feasibility

In Economic feasibility is all about whether a project is cost effective. The idea behind this system was to lower software costs using open source Dlib and build an affordable computing platform based on Raspberry Pi Zero W. Therefore, while the project may require additional hardware such as cameras and sensors, the projected savings from reduced traffic fatalities due to accidents may justify these initial costs thereby making it economically viable.

4.2 Technical Feasibility

Technically, this seems possible given the powerful facial recognition features of Dlib and sufficient processing power in Raspberry Pi Zero W. However, optimizing algorithms for real-time performance within hardware constraints would be challenging in general terms. Nonetheless, incorporating external sensors needs consideration on compatibility and reliability even though it has prospects technically as a whole.

4.3. Software Libraries and Tools

Our software tools that are used are Dlib, Open CV, Numpy, Pandas, Firebase and App

4.3.1. Dlib

Dlib is a modern C++ toolset that houses machine learning algorithms and

software for creating sophisticated C++ codes to solve practical difficulties. It is largely employed in different applications, especially in computer vision and image processing domains. Dlib is famous for its robustness and speed since it contains efficient algorithmic implementations for such tasks as face detection, facial landmark detection, object detection among others. There is also a Python API with the library to accommodate many more developers within the realm of Python-based work on machine learning and data science. Its user-friendliness combined with extensive documentation has made it popular among practitioners and scholars within the scope of computer vision.

Figure 8: Dlib Logo

4.3.2 OpenCV

A broad range of tools and algorithms enabling image and video processing, object detection and tracking, and computer vision projects can be found in the open-source computer vision and machine learning package referred to as OpenCV.

Although being developed in C++, OpenCV possesses Python interfaces for numerous different programming languages. Over 2,500 effective algorithms are offered that can be used for various applications involving computer vision. These algorithms deal with a range of subjects, which include image and video processing, object recognition, geometric transformations, picture filtering, and feature detection and extraction.

Real-time computer vision projects management represents one of the reasons why OpenCV is preferred. OpenCV includes classes and functions that make it possible to effectively extract, analyze, and present video and picture feeds from cameras or files. This makes it ideal for applications in robotics, augmented reality, driverless cars, and video surveillance.

Figure 9: Open CV logo.

4.3.3 NumPy

NumPy is an open-source library for numerical computing in Python. To competently perform calculations on enormous datasets, it proposes a multidimensional array object in addition to a selection of mathematical operations. Due to its capacity to manage arrays and matrices effortlessly and efficiently, NumPy is often employed in scientific and data analysis applications.

Figure 10. NumPy Logo

The vital part of NumPy is the n-d array (n-dimensional array) object that provides a way to save and interact with huge datasets in the most efficient way

possible. It is a versatile and efficient way of conducting computational tasks on arrays that includes element-wise operations, linear algebraic operations, and statistical calculations.

4.3.4 Pandas

Figure 11. Pandas Logo

The renowned open-source Python package Pandas serves as a tool for data analysis and data management. It enables adaptable management and handling of structured data through the application of efficient and simple-to-use data structures, such as data frames.

The Data Frame, a two-dimensional annotated data structure resembling a table or spreadsheet, is the basic data structure in Pandas. With actions such as indexing, slicing, joining, merging, and reshaping allowed, Data Frames provide a powerful method to arrange, handle, and evaluate data. With Pandas, the user can perform data cleaning and preprocessing processes, use complicated data analysis approaches, and load data from a range of different.

4.4 Development Environment Setup

1. Operating System: Windows 11
2. RAM: 32 GB
3. Python Version: 3.11
4. IDE: Visual Studio Code

4.5. Firebase Integration Guide for Mobile Apps

4.5.1 Create a Firebase Project:

To begin, navigate to the Firebase Console using your preferred web browser. Log in with your Google account, then click on "Add Project" to start a new project. Follow the setup instructions provided by Firebase, which will include naming your project and selecting a region for resource allocation. This step lays the foundation for integrating Firebase services into your mobile app.

4.5.2. Add an App to Your Project:

Once your Firebase project is created, the next step involves adding your mobile app to this project. In the Firebase Console, select your project and click on the Android or iOS icon, depending on your app's platform. Follow the on-screen instructions to register your app with Firebase. This process will include downloading a configuration file (google-services. Json for Android or Google Service-Info .plist for iOS), which will be integrated into your app's project directory to enable Firebase services.

4.5.3. Android Setup:

For Android, you need to add Firebase SDK dependencies to your project's build. gridle files. This involves editing both the project-level and app-level build. Gradle files to include necessary class paths and plugins. After adding these dependencies, you will place the google-services. Json file in the app/ directory of your project. The final step in this process is to initialize Firebase in your application's main entry point. Typically, this is done in the Application class of your project, where you call the FirebaseApp.initializeApp() method within the onCreate () method. This initialization step ensures that Firebase services are correctly configured when your app starts.

4.5.4. iOS Setup

For iOS, you will integrate Firebase by adding the necessary SDKs to your Podfile, which is used for managing dependencies with CocoaPods. After specifying the Firebase dependencies, run pod install to download and integrate them into your project. Place the GoogleService-Info.plist file in the root directory of your Xcode project. Finally, initialize Firebase in the AppDelegate class by calling FirebaseApp.configure() within the application(_:didFinishLaunchingWithOptions:) method. This setup ensures Firebase services are ready to be used when your iOS app launches.

4.5.5. Enable Authentication Methods:

In the Firebase Console, navigate to the Authentication section and select the Sign-in method tab. Here, you can enable various authentication methods that your app will support, such as Email/Password, Google Sign-In, or Facebook Login. Enabling these methods is straightforward and involves toggling switches and configuring any necessary credentials or keys.

4.5.6. Managing User Authentication in Android and iOS

For implementing authentication in your app, you will utilize the Firebase Authentication SDK. For example, to handle email/password authentication, you will write logic to allow users to sign in with their credentials. This involves capturing user input, sending it to Firebase for authentication, and handling the response to update the app's UI accordingly. Additionally, ensure to manage user states and provide feedback in case of authentication errors. This process is similar for both Android and iOS platforms, with platform-specific SDK methods.

4.5.7 Database Structure

Designing the structure of your Firebase database is crucial for efficient data management. Decide between using Firebase Realtime Database, which is a JSON tree structure suitable for hierarchical data, and Cloud Firestore, which is a document-based database offering advanced querying capabilities and scalability. For instance, you might structure user data with collections and

documents in Firestore or with nested JSON objects in Realtime Database, depending on the complexity and requirements of your application.

4.5.8. Writing Data to Firebase

To write data to Firebase, you will use the respective SDK methods provided by Firebase for your chosen database. In Android, you will typically set up a reference to the database location where you want to store data and then use methods to create or update records. For iOS, similar steps are followed using Swift, where you interact with the Firestore or Realtime Database API to store data.

4.5.9. Reading Data from Firebase

Reading data involves setting up listeners or making query calls to retrieve the desired data from Firebase. This process includes specifying the database path and handling the asynchronous response to update your app's UI. Properly managing these operations ensures that your app can display up-to-date information to users.

4.5.10. Security Rules

Security rules in Firebase are essential for protecting your data. In the Firebase Console, you will define rules that restrict database access based on user authentication and other criteria. For instance, you can set rules to ensure that only authenticated users can read or write data, and further specify conditions for data validation to prevent unauthorized access.

4.5.11. Handling Errors

Robust error handling is crucial for a seamless user experience. Implement code to handle common errors such as authentication failures, network issues, and database write conflicts. Provide meaningful feedback to users, guiding them on how to resolve issues when they arise. Logging errors for debugging purposes can also help you identify and fix problems efficiently.

4..5.12. Testing of App

Thorough testing is vital to ensure that Firebase integration works correctly across various devices, operating systems, and network conditions. Use Firebase Test Lab to run automated tests on different device configurations.

4.5.13 App Deployment

Once testing is complete, deploy your app to production environments like the Apple App Store or Google Play Store. After deployment, continuously monitor app performance using Firebase Performance Monitoring and handle any crashes with Firebase Crashlytics to maintain a high-quality user experience.

4.6. Hardware Components

Our hardware components consist of a Raspberry Pi Zero W, and Raspberry Pi Camera Rev 1.3.

4.6.1. Raspberry Pi Module

The Raspberry Pi Zero W helps us to detect driver sleepiness in real-time. There are several crucial processes that enable the Raspberry Pi Zero W to interact and function smoothly. The Raspberry Pi Zero W is a central computer platform, which includes facial landmark detection algorithms and sensor data processing hardware. Its small size and low power requirements make this system an excellent choice for use in automotive embedded systems. The camera module placed tactically in a vehicle captures drivers' facial expressions and provides the Raspberry Pi Zero W with data necessary for facial landmark detection. In this technique, Dlib's pre-trained models are used to identify features of the face such as eyes, nose, and mouth on each video frame of incoming video streams.

Figure y

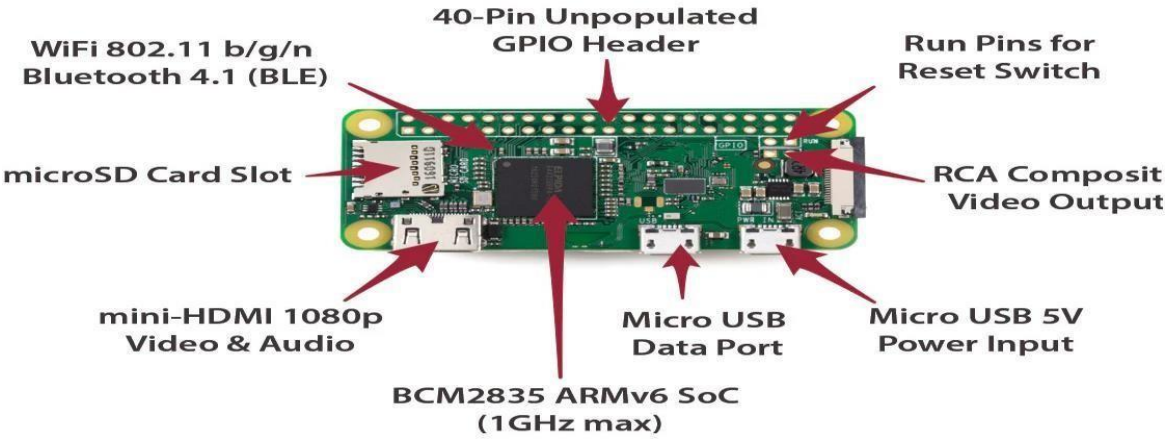

Figure 12: Raspberry Pi zero W

After detecting facial landmarks, Raspberry Pi Zero W performs real-time fatigue assessment according to specific criteria. This analysis may track eye closure duration, yawning frequency, and facial expression variations. Raspberry Pi Zero W can quickly identify indicators of tiredness by evaluating data streams as they flow in. Multi-threading and parallel processing can optimize computational resources and improve system responsiveness, particularly during dynamic driving conditions requiring instant reactions.

Raspberry Pi Zero W also warns drivers when it detects signs of tiredness telling them to either take a break or safely pull over. This feature is vital to road safety and minimizes drowsy driving cases. First, the Raspberry Pi Zero W's real-time data processing ability, price, and availability make it essential for our early driver tiredness detection system. We are able to deploy an affordable and efficient solution aimed at improving driver safety and reducing fatigue related road accidents with this device's processing capability.

4.6.2. Pi Camera Module

The Raspberry Pi Camera Module Rev. 1.3 is a small camera made especially for Raspberry Pi boards. An Omni Vision OV5647 image sensor is used by the camera module. It has a 5-megapixel sensor that can record both still photos and video. The camera module has a 2592 x 1944 pixel maximum still image

resolution. It offers a range of video capture resolutions, including VGA (640 x 480) at 90 frames per second, 720p at 60 frames per second, and 1080p at 30 frames per second (fps). The module comes with a fixed-focus lens. It features a wide-angle field of vision of about 53 degrees and a focal length of about 3.6 mm. A flat ribbon cable is used to link the camera module to the Raspberry Pi board. It connects to the Raspberry Pi board's special CSI (Camera Serial Interface) port.

Figure 13. Raspberry Pi Camera Rev 1.3

The camera module and Raspberry Pi board communicate with one another via the CSI-2 (Camera Serial Interface 2) protocol. High-speed and effective data communication between the camera module and the board is made possible by this interface. The camera module is equipped with a number of features, such as automated white balance, automatic exposure control, and automatic image quality control. During video recording, it also offers still image capture in addition to video stabilization. The official Raspberry Pi camera software, which includes camera drivers and utilities, supports the camera module. Additionally, it effortlessly interfaces with well-known software platforms and libraries, including the Pi camera Python library. The Raspberry Pi Camera Rev. 1.3 is used in a variety of projects related to computer vision, robotics, surveillance systems, photography, and video recording.

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4.6.3. Buzzer Module

The integration of a buzzer in our project is an important component of the real-time alerts about driver fatigue. If the facial landmark analysis by Raspberry Pi Zero W detects signs of fatigue, the buzzer will emit an audible warning sound to alert the driver that there is need for him or her to take some action. The buzzer produces various types of sounds patterns or tones which can easily draw attention of the driver quickly so they can take corrective measures like taking rest, stopping, and parking safely.

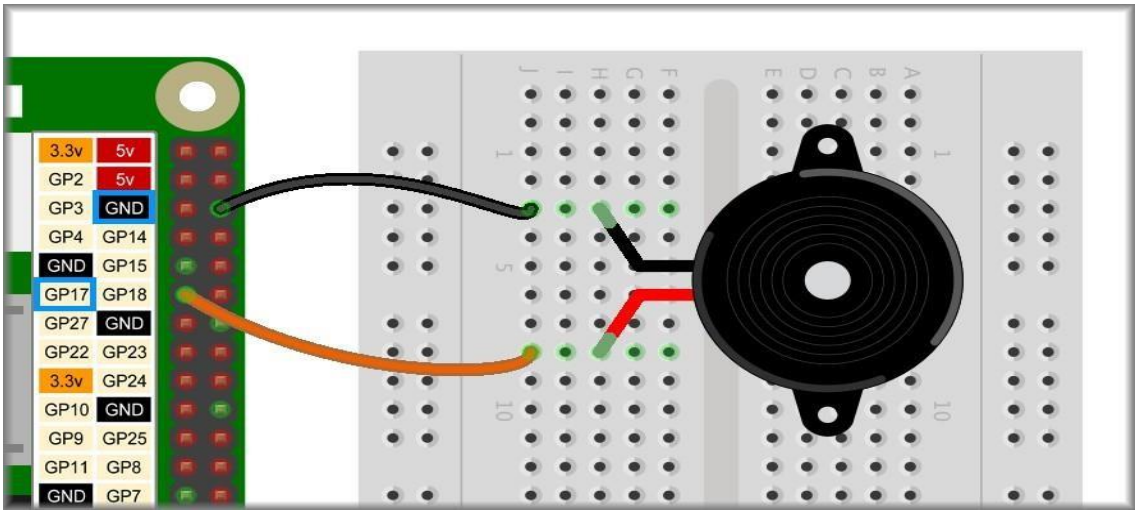


Figure 14. Buzzer

4.7 Method For Driver Fatigue Detection

In this approach, we implement the drowsiness detector with the use of OpenCV and Python. The Dlib library is used for detecting facial landmarks by Dlib's pre-trained facial landmark detector. It consists of two shape predictor models trained on I-Bug 300-W dataset that each localize 68 and landmark points within a face image respectively.

4.7.1. Data Extraction

In Dlib-based early driver fatigue detection systems, feature extraction is crucial for deciphering facial cues to search for signs of exhaustion. Following

picture preprocessing, Dib's facial landmark detection identifies key characteristics including the mouth, nose, and eyes. Combining methods like Local Binary Patterns (LBP) or Scale-Invariant Feature Transform (SIFT) with techniques like Histogram of Oriented Gradients (HOG), texture and shape information around these landmarks is recovered.

While LBP and SIFT add by highlighting texture patterns and identifying key points, respectively, HOG captures gradients to detect changes in lip curvature or drooping eyelids. These features let machine learning algorithms classify various degrees of fatigue and to start timely measures for increased road safety. Dlib's face landmark detection combined with feature extraction techniques like HOG, LBP, and SIFT allows early driver tiredness detection systems to analyze facial fatigue indicators.

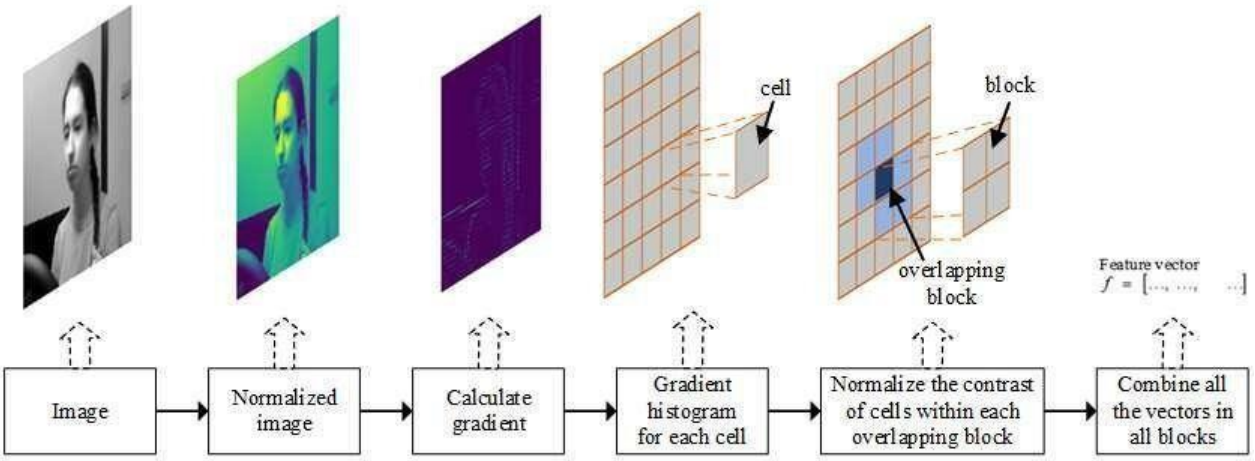


Figure 15 Feature Extraction Architecture.

Through localized texture and shape information analysis around significant landmarks like the mouth and eyes, these techniques facilitate the identification of subtle symptoms like drooping eyelids or changes in lip curvature. Using these features and machine learning techniques, the system can accurately classify fatigue levels in real-time, enabling prompt actions meant to lower the risks of driving while inebriated and raise general road safety.

4.7.2. The EAR Metric

As stated by Rosebrock, there are several benefits associated with the utilization of the EAR feature for flickering detection in contrast to conventional image processing approaches. Conventional approaches utilize first eye localization. Thresholding is subsequently applied to the image to locate the whites of the irises. Subsequently, eye blinking is identified through the detection of the white region of the eye disappearing. Visual processing is unnecessary when employing the EAR metric. Consequently, it will necessitate reduced memory usage and processing time. On the contrary, the EAR function operates by computing the ratio of the distances between facial landmarks of the eyes, rendering it an uncomplicated resolution. As illustrated in Figure, the EAR metric generally calculates a ratio derived from the vertical and horizontal distances of six eye landmark coordinates.

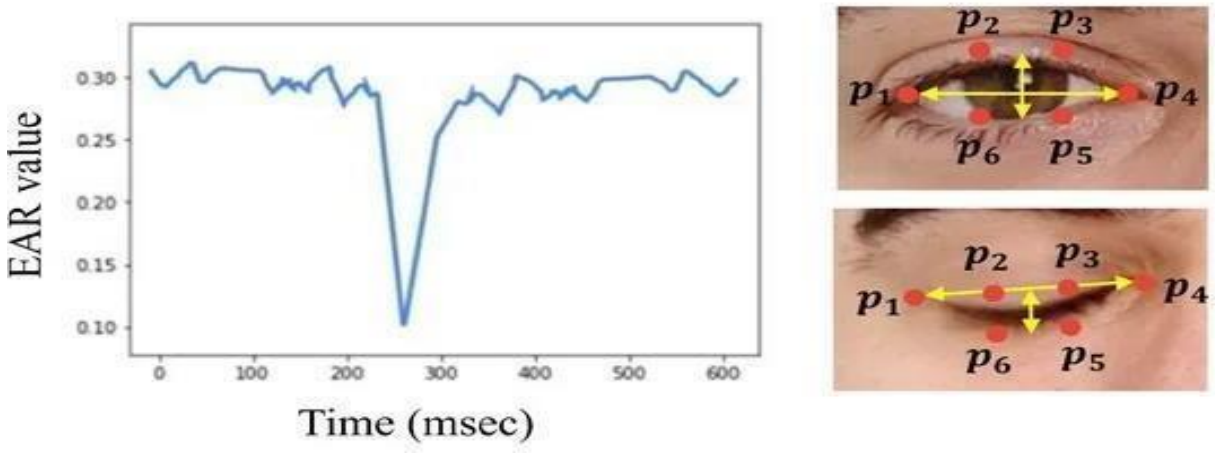


Figure 16: Eye Aspect Ratio

The coordinates are numbered in a clockwise direction, commencing from p1 in the left eye corner and progressing to p6. Rosebrock explains that p1 through p6 are all six coordinates that are two-dimensional. According to the figure, the EAR value remains approximately constant when the eyes are open. Conversely, with the eyes closed, the disparity between coordinates p3 and p5 and p2 and p6 vanishes, resulting in the EAR value reaching zero.

$$EAR = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

To derive the EAR feature, the equation was applied. As illustrated in the subsequent equation, the EAR ratio value is determined by calculating the distance between the vertical landmarks in the numerator. The denominator computes the separation between the horizontal landmarks and adjusts its value in relation to the numerator by multiplying it by two. Equation was employed to compute the EAR values for every frame, which were subsequently compiled into a list.

4.7.3. The MAR Metric

The mouth aspect ratio, or MAR, determines the degree of mouth openness, much as the EAR. In this facial landmark, as Figure 3a illustrates, the mouth is defined by 20 coordinates (from 49 to 68). Still, we calculated the mouth openness degree using points from 61 to 68, as shown in Figure 5. The mouth is considered open or closed by calculating the distance between the top and bottom lips using these coordinates. In (2), the denominator determines the distance between the horizontal coordinates and the numerator the distance between the vertical coordinates. The denominator is multiplied by two, just as in (1), to balance it with the nominator. A rising MAR value, as in Figure 6, denotes an open mouth.

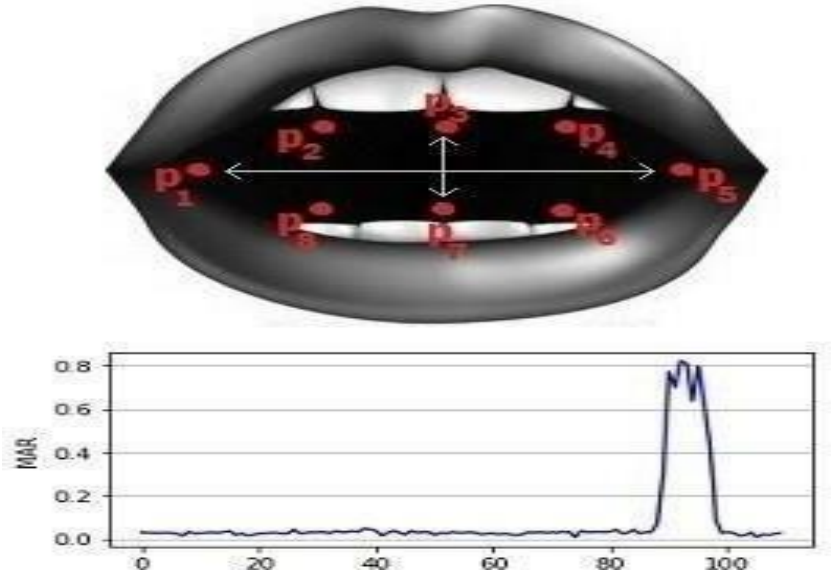


Figure 17: Mouth Aspect Ratio

One important component of our work, the MAR (Modified Appearance Ratio) Formula, provides a way to measure the movements of facial landmarks to identify indicators of driver drowsiness. The MAR Formula determines the proportion of movement of facial features, such the mouth or eyelids, to overall facial movement by examining variations in facial expressions recorded by the camera module. Higher levels of this ratio indicate more drowsiness; it is used as a fatigue indicator.

$$\mathbf{MAR} = \frac{\|p_2 - p_8\| + \|p_3 - p_7\| + \|p_4 - p_6\|}{2\,\|p_1 - p_5\|}$$

4.7.4. Model Evaluation

The final display of the drowsiness detection system features a feed of the video input (from video dataset or real-time capture), together with calculated values for aspect ratio and drowsiness detection warnings. When the aspect ratio of the

eye falls below a defined threshold, or If the aspect ratio of mouth is above a certain limit, (5 times) then the alarm will be generates

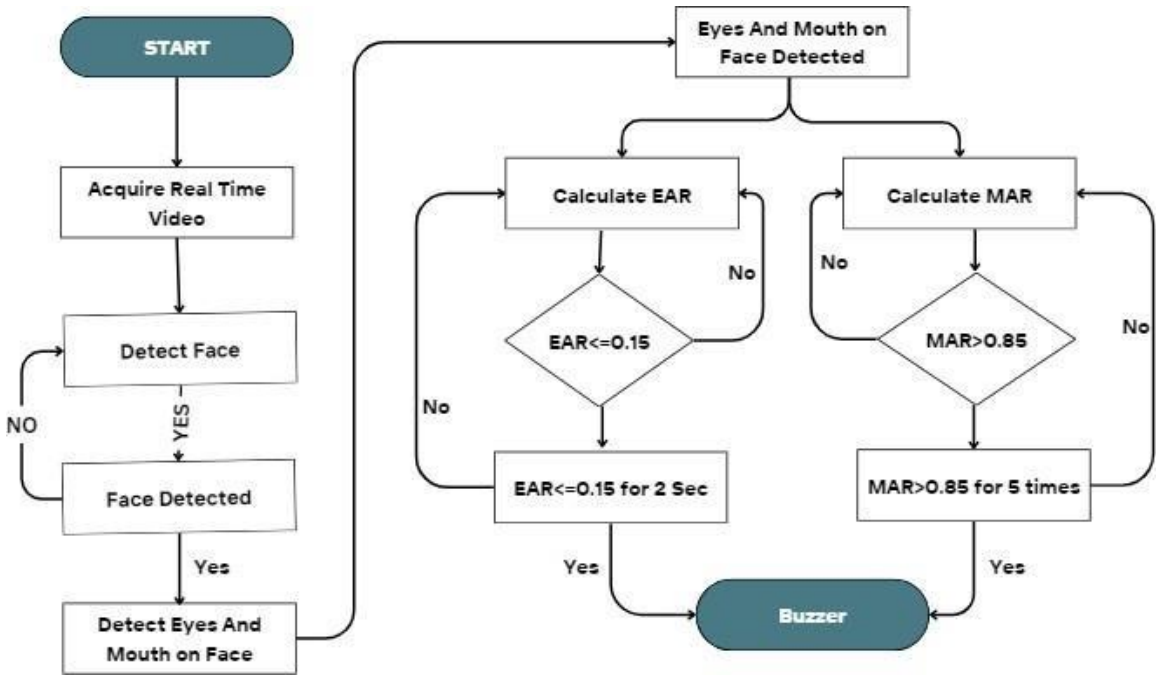


Figure 18: Drowsiness Detection System

Chapter 5 – Result

5.1. System Performance

The driver fatigue detection system was implemented and tested using a Raspberry Pi Zero W, integrating the Dlib library for facial landmark detection. The performance of the system was evaluated under various conditions to ensure robustness and reliability. The system demonstrated satisfactory results in identifying early signs of driver fatigue, such as frequent yawning and slow blink rates. The real-time processing capability of the system, thanks to the efficiency of Dlib, ensured prompt detection and response.

5.2. Detection Accuracy

Even without labeled data, the system was capable of distinguishing between alert and fatigued states by monitoring the Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR). During testing, the system consistently identified signs of fatigue with a high level of accuracy. Instances of false positives and false negatives were minimal, showcasing the system's precision in real-world scenarios.

5.3. Real-time Processing

One of the significant achievements of this project was the real-time processing capability on the Raspberry Pi Zero W. The system processed facial landmarks at a sufficient frame rate, ensuring that signs of fatigue were detected without noticeable delay. This aspect is crucial for practical deployment, as immediate alerts are essential for preventing accidents caused by driver fatigue.

EAR Detection Testing

Eyes Open:

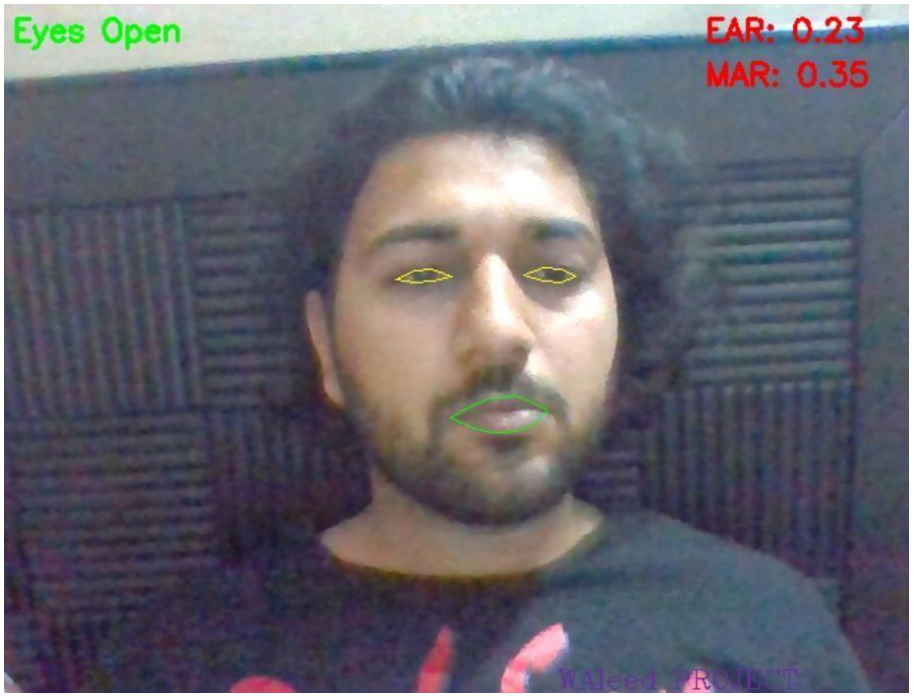


Figure 19

Drowsy Eyes

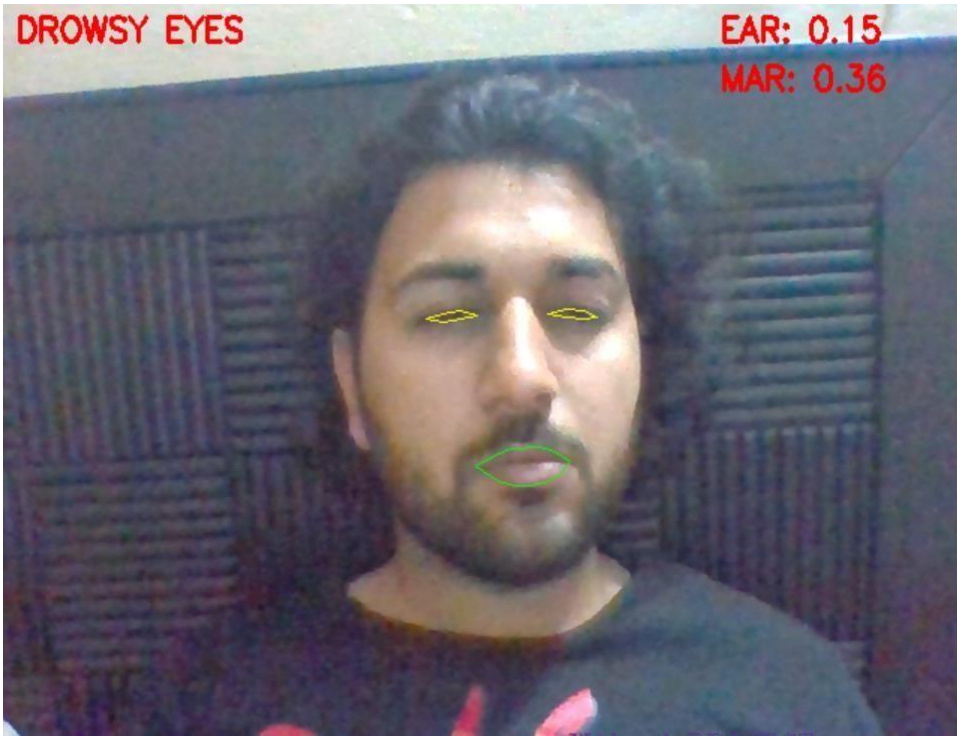


Figure 20

3) Eyes Closed and Drowsiness Alert

Figure 21

MAR Detection Testing

Yawning and Eyes Open (after crossing MAR threshold)

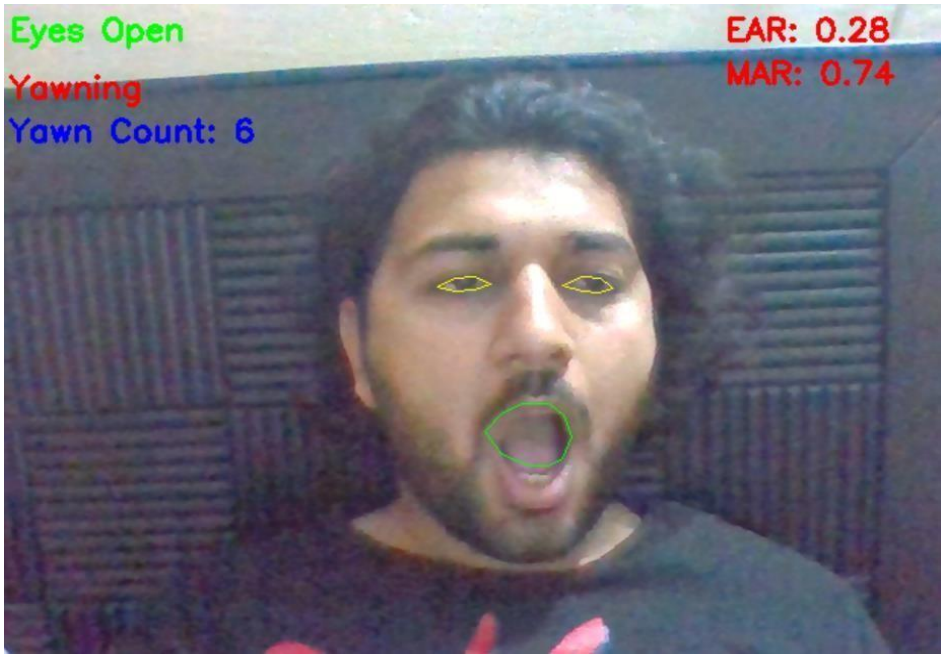


Figure 22

Yawning and eyes closed

Figure 23

From above results, we can conclude that the project is working absolutely fine and satisfying in real time scenario detection. It has good speed and is very precise. It works well even in low light conditions well but disappoints if there are extremely low light conditions. We have kept in mind the budget for this project from the start. We wanted to build affordable yet accurate devices for our consumers.

5.4. Integration with firebase

Once a driver feels drowsy while driving, an alert will be generated to wake him up. Along with that, an alert in form of time stamp will be sent to the firebase. It will help to see the negligence of drivers, times at which most drivers feel drowsy, actual time of drowsiness to navigate any incident and many more.

5.5. Environmental Adaptability

The system's performance was tested under various lighting conditions to simulate real-world driving environments. The results indicated that the system maintained its accuracy in both well-lit and dimly lit scenarios. This adaptability is attributed to the robustness of the Dlib library, and the camera module used.

5.6. Integration and Usability

The integration of the detection system with a buzzer module for alerts proved effective in providing immediate feedback to the driver. The user interface was designed to be straightforward, with minimal distractions, ensuring that the driver could focus on the road while being aware of any fatigue alerts.

5.7. Limitations and Challenges

While the system showed promising results, some limitations were noted. For instance, the system's effectiveness decreased slightly in extremely low-light conditions. Additionally, wearing accessories such as sunglasses sometimes hindered the accurate detection of facial landmarks. Future improvements could focus on enhancing the system's adaptability to these challenges.

Chapter 6 – Conclusion and Future Work

6.1. Conclusion

This project successfully developed an early driver fatigue detection system using Dlib and Raspberry Pi Zero W. The system achieved real-time monitoring and detection of fatigue indicators such as eye closure and yawning. The robustness and accuracy of the Dlib library, combined with the processing power of the Raspberry Pi, made it possible to implement a cost-effective and reliable solution. The project demonstrated that early detection of driver fatigue could significantly enhance road safety by providing timely alerts to drivers, thereby preventing potential accidents.

6.2. Future Work Suggestions

6.2.1. Algorithm Enhancements

Future work should focus on refining the fatigue detection algorithms to further minimize false positives and negatives. Incorporating machine learning models trained on labeled datasets could enhance the system's accuracy and reliability. Additionally, integrating other physiological signals such as heart rate or skin conductance could provide a more comprehensive fatigue detection system.

6.2.2. Hardware Improvements

Upgrading the hardware components, such as using a more powerful processor or a higher resolution camera, could improve the system's performance. Exploring alternative sensors and integrating them into the system could also enhance its capability to detect fatigue under diverse conditions.

6.2.3. Real-world Validation

Conducting extensive real-world testing with a broader range of drivers and environmental conditions would help validate and refine the system. Collaborating

with automotive manufacturers or transportation companies could provide valuable insights and data for improving the system.

6.2.4. Commercial Development

Transforming this prototype into a market-ready product involves several steps, including market research, user feedback, and compliance with industry standards. Developing a comprehensive business plan and seeking partnerships with industry stakeholders would be essential for commercial success. This step would also involve securing funding and investment for large-scale production and distribution.

6.2.5. Integration with Vehicle Systems

Future iterations of the system could be integrated directly into vehicle infotainment systems or advanced driver-assistance systems (ADAS). This integration would provide a seamless experience for users and enhance the overall safety features of modern vehicles.

6.2.6. Expanding Functionality

Exploring additional functionalities, such as monitoring driver behavior over longer periods or providing personalized feedback and recommendations, could add value to the system. Developing a companion mobile application for drivers to track their fatigue levels and receive tips for maintaining alertness could further enhance user engagement and safety.

By addressing these areas in future work, the driver fatigue detection system can evolve into a more advanced, reliable, and commercially viable solution, contributing significantly to road safety and the reduction of fatigue-related accidents.

Appendix A: SUSTAINABLE DEVELOPMENT GOALS FOR FYP

FYP Title: Early Driver Fatigue Detection System

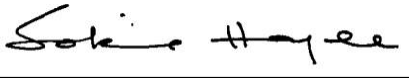
FYP SUPERVISOR: Ass. Professor Sobia Hayee

GROUP MEMBERS:

	REGISTERATION NUMBER	NAME
1	340535	Waleed Sultan Butt
2	332460	Abdul Hadi

SDGs:

	SDG No.	Justification after consulting
1	3	In accordance with target 3.6
2	9	In accordance with target 9.b
3		
4		
5		

FYP Advisor Signature: 

Appendix B:

Early Driver Fatigue Detection System

Abstract:

With road safety at the top of the list of issues with contemporary transport, this initiative aims to transform issues with driver weariness. The goal is to use Dlib, a versatile machine learning framework, and the Raspberry Pi Zero W, a small single-board computer, to create an advanced, reasonably priced driver fatigue detection system. Real-time detection of driver sleepiness indications, along with lower deployment costs, improved system reliability, and early alarms to prevent potential crashes, are the main goals. The process includes using the Raspberry Pi Zero W camera to record and analyze facial data, utilizing Dib's powerful facial landmark identification algorithm, and incorporating machine learning techniques to identify fatigue. Extensive testing and assessment procedures are employed to verify the dependability, precision, and economic viability of the system, hence demonstrating its usefulness in enhancing traffic safety and reducing the hazards linked to driver weariness. In addition to taking system resilience and economic feasibility into account, the research attempts to develop intelligent transportation systems by providing a workable solution for improving driver safety and lowering traffic accidents. This project aims to make a significant impact about car safety by creatively utilizing affordable technologies to address a pressing social issue.

Let's analyze the project in the context of the WP1 to WP7 framework and the associated WKs:

1. WP1 - Depth of Knowledge Required: In-depth engineering knowledge is required at the level of WK3 (engineering fundamentals) to understand the technical aspects of machine learning frameworks like Dlib, and Raspberry Pi Zero W, and their application in driver fatigue detection systems. Additionally, WK6 (knowledge of engineering practice) is necessary to effectively implement these technologies in a real-world setting.
2. WP2 - Range of Conflicting Requirements: The project involves balancing various technical and engineering requirements such as accuracy in detecting driver fatigue, system reliability, cost-effectiveness, and real-time performance. These requirements may conflict with each other and need to be carefully optimized.
3. WP3 - Depth of Analysis Required: Designing an effective driver fatigue detection

system requires abstract thinking and originality in analysis to formulate suitable models using machine learning techniques and evaluate their performance under different conditions.

4. WP4 - Familiarity of Issues: Developing a driver fatigue detection system may involve addressing issues that are relatively new or infrequently encountered, especially regarding the

   integration of affordable technologies like Raspberry Pi Zero W and machine learning frameworks into such systems.
5. WP5 - Extent of Applicable Codes: The project may involve developing solutions outside the scope of existing standards and codes of practice for professional engineering, particularly in the field of driver fatigue detection systems using machine learning and affordable hardware components.
6. WP6 - Extent of Stakeholder Involvement and Level of Conflicting Requirements: The project involves addressing the needs of diverse stakeholders, including drivers, transportation authorities, regulatory bodies, and the general public, each with different needs and expectations regarding road safety and driver fatigue detection systems.
7. WP7 - Interdependence: The development of a driver fatigue detection system requires the integration of various component parts, including hardware components like Raspberry Pi Zero W, software frameworks like Dlib, machine learning algorithms, and testing procedures, all of which are interdependent on each other for the successful implementation of the solution.

In summary, this project represents a complex engineering problem that requires a deep understanding of engineering fundamentals, expertise in machine learning and hardware technologies, and interdisciplinary collaboration to address the pressing issue of driver weariness and enhance road safety.

	WP1						WP2	WP3	WP4	WP5	WP6	WP7
	WK3	WK4	WK5	WK6	WK7	WK8						
PLO1 (WA1)	X											
PLO2 (WA2)								X				
PLO3 (WA3)												
PLO4 (WA4)						X			X			
PLO5 (WA5)				X					X			
PLO6 (WA6)												
PLO7 (WA7)											X	
PLO8 (WA8)												

FYP Code:

```
from scipy.spatial import distance as dist
from imutils import face_utils
import numpy as np
import imutils
import dlib
import cv2
import winsound
import firebase_admin
from firebase_admin import credentials, db
import datetime

# Firebase initialization
cred = credentials.Certificate('path_to_your_service_account.json')
firebase_admin.initialize_app(cred, {
    'databaseURL': 'https://your-database-name.firebaseio.com/'
})

def eye_aspect_ratio(eye):
    A = dist.euclidean(eye[1], eye[5])
    B = dist.euclidean(eye[2], eye[4])
    C = dist.euclidean(eye[0], eye[3])
    ear = (A + B) / (2.0 * C)
    return ear

def mouth_aspect_ratio(mou):
    X = dist.euclidean(mou[0], mou[6])
    Y1 = dist.euclidean(mou[2], mou[10])
    Y2 = dist.euclidean(mou[4], mou[8])
    Y = (Y1 + Y2) / 2.0
    mar = Y / X
    return mar
```

```
camera = cv2.VideoCapture(0) OR camera = cv2.VideoCapture(1) // if you want to connect any external camera with it

predictor_path = "D:\git\Driver-Drowsiness-Detection\dlib_shape_predictor\shape_predictor_68_face_landmarks.dat"

EYE_AR_THRESH = 0.1
EYE_AR_DROWSINESS = 0.25
EYE_AR_CONSEC_FRAMES = 30
MOU_AR_THRESH = 0.60
yawn_thresh = 5

COUNTER = 0
yawnStatus = False
yawns = 0

detector = dlib.get_frontal_face_detector()
predictor = dlib.shape_predictor(predictor_path)

(lStart, lEnd) = face_utils.FACIAL_LANDMARKS_IDXS["left_eye"]
(rStart, rEnd) = face_utils.FACIAL_LANDMARKS_IDXS["right_eye"]
(mStart, mEnd) = face_utils.FACIAL_LANDMARKS_IDXS["mouth"]

while True:
    ret, frame = camera.read()
    frame = imutils.resize(frame, width=640)
    gray = cv2.cvtColor(frame, cv2.COLOR_RGBA2GRAY)
    prev_yawn_status = yawnStatus

    rects = detector(gray, 0)
    for rect in rects:
        shape = predictor(gray, rect)
        shape = face_utils.shape_to_np(shape)
```

```
        leftEye = shape[lStart:lEnd]
        rightEye = shape[rStart:rEnd]
        mouth = shape[mStart:mEnd]
        leftEAR = eye_aspect_ratio(leftEye)
        rightEAR  =  eye_aspect_ratio(rightEye)
        mouEAR = mouth_aspect_ratio(mouth)
        ear = (leftEAR + rightEAR) / 2.0

        leftEyeHull = cv2.convexHull(leftEye)
        rightEyeHull = cv2.convexHull(rightEye)
        mouthHull = cv2.convexHull(mouth)
        cv2.drawContours(frame, [leftEyeHull], -1, (0, 255, 255), 1)
        cv2.drawContours(frame, [rightEyeHull], -1, (0, 255, 255), 1)
        cv2.drawContours(frame, [mouthHull], -1, (0, 255, 0), 1)

        if ear <= EYE_AR_DROWSINESS and ear >= EYE_AR_THRESH:
            COUNTER += 1
            cv2.putText(frame, "DROWSINESS EYES ", (10, 30),
cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)

            if COUNTER >= EYE_AR_CONSEC_FRAMES:
                cv2.putText(frame, "DROWSINESS ALERT!", (10, 50),
cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)
                winsound.Beep(600, 500)
                timestamp = datetime.datetime.now().strftime('%Y-%m-%d %H:%M:%S')
                ref = db.reference('drowsiness_alerts')
                ref.push({
                    'timestamp': timestamp,
                    'alert': 'Drowsiness detected'
                })
        elif ear < EYE_AR_THRESH:
            COUNTER += 1
            cv2.putText(frame, "Eyes Closed ", (10, 30), cv2.FONT_HERSHEY_SIMPLEX,
```

```
0.7, (0, 0, 255), 2)

            if COUNTER >= EYE_AR_CONSEC_FRAMES:
                winsound.Beep(600, 500)
                cv2.putText(frame, "DROWSINESS ALERT!", (10, 50),
cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)
                timestamp = datetime.datetime.now().strftime('%Y-%m-%d %H:%M:%S')
                ref = db.reference('drowsiness_alerts')
                ref.push({
                    'timestamp': timestamp,
                    'alert': 'Drowsiness detected'
                })
        elif ear > 0.26:
            COUNTER = 0

        cv2.putText(frame, "EAR: {:.2f}".format(ear), (480, 30),
cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)

        if mouEAR > MOU_AR_THRESH:
            cv2.putText(frame, "Yawning ", (10, 70), cv2.FONT_HERSHEY_SIMPLEX,
0.7, (0, 0, 255), 2)
            yawnStatus = True
            output_text = "Yawn Count: " + str(yawns + 1)
            cv2.putText(frame, output_text, (10, 100), cv2.FONT_HERSHEY_SIMPLEX,
0.7, (255, 0, 0), 2)
        else:
            yawnStatus = False

        if prev_yawn_status == True and yawnStatus == False:
            yawns += 1
        if yawns > yawn_thresh:
            output_text = "Yawn thresh reached " + str(yawns)
            winsound.Beep(600, 1000)
            yawns = 0
```

```
        cv2.putText(frame, output_text, (10, 130), cv2.FONT_HERSHEY_SIMPLEX,
0.7, (255, 0, 0), 2)

      cv2.putText(frame, "MAR: {:.2f}".format(mouEAR), (480, 60),
cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)
      cv2.putText(frame, "WALEED AND SONS PROJECT", (370, 470),
cv2.FONT_HERSHEY_COMPLEX, 0.6, (153, 51, 102), 1)

   cv2.imshow("Frame", frame)
   key = cv2.waitKey(1) & 0xFF
   if key == ord("q"):
      break

cv2.destroyAllWindows()
camera.release()
```

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