A HYBRID APPROACH FOR DRIVER'S DROWSINESS DETECTION USING RELATIVE CAMERA-BASED DETECTION AND EEG-BASED DETECTION

A project submitted in partial fulfillment of the required for the Degree of

BACHELOR OF TECHNOLOGY

IN

POWER ELECTRONICS & INSTRUMENTATION ENGINEERING

Submitted by

Kirtymoye Sonowal (Roll No.: 190810029013)

Kukil Kumar Borah (Roll No.: 190810029014)

Rajneesh Chetia (Roll No.: 190810029018)

Roktim Probal Gogoi (Roll No.: 190810029022)

Mainamati Tayung (Roll No.: 200850029002)

Submitted to

Department Of Power Electronics and Instrumentation Engineering

JORHAT INSTITUTE OF SCIENCE & TECHNOLOGY, JORHAT-10

AFFILIATED TO

ASSAM SCIENCE & TECHNOLOGY UNIVERSITY, GUWAHATI

JUNE, 2023

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[Code No.: PI181821]

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Mainamati Tayung (Roll No.: 200850029002)

Under the supervision of

Dr. Rakcinpha Hatibaruah

Assistant professor, Department of Power Electronics & Instrumentation Engineering

&

Sri Gautam Talukdar

Head of the Department, Department of Power Electronics & Instrumentation Engineering

Submitted to

Department of Power Electronics and Instrumentation Engineering

Jorhat Institute of Science & Technology, Jorhat-10

Certificate of Approval from Department of

Power Electronics& Instrumentation Engineering

Jorhat Institute of Science & Technology

The undersigned certify that the project report entitled “A Hybrid Approach for Driver’s Drowsiness Detection” have been read and recommended to the Department of Power Electronics & Instrumentation Engineering for acceptance, submitted by

Kirtymoye Sonowal (Roll No.: 190810029013)

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……………………………….

Dr. Rakcinpha Hatibaruah

Assistant professor, Department of Power Electronics & Instrumentation Engineering

Jorhat Institute of Science and Technology, Jorhat-10

…………………………..

Sri Gautam Talukdar

Head of the Department, Department of Power Electronic & Instrumentation Engineering

Jorhat Institute of Science and Technology, Jorhat-10

Certificate of Approval from

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Report

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External Examiner

ACKNOWLEDGEMENT

It gives us immense pleasure to express our deepest sense of gratitude and sincere thanks to our highly respected and esteemed guide and Dr. Rakcinpha Hatibaruah (Assistant professor, Department of Power Electronics & Instrumentation Engineering) and Co-Guide Sri Gautam Talukdar (Head of the Department, Department of Power Electronics & Instrumentation Engineering), for their valuable guidance, encouragement and help for completing this work. Their useful suggestions for this whole work and co-operative behavior are sincerely acknowledged.

We would like to express our sincere thanks to all the respected professors of Power Electronics & Instrumentation Engineering Department, for giving us this opportunity to undertake this project.

We are also grateful to our Lab Teachers for their constant support and guidance.

At the end we would like to express our sincere thanks to all our friends and others who helped us directly or indirectly during this project work.

ABSTRACT

The amount of road accidents caused by driver drowsiness is one of the world's major challenges. These accidents lead to numerous fatal and non-fatal injuries which impose substantial financial strain on individuals and governments every year. There are several causes of drowsiness. Sleep deprivation, excessive sleepiness, fatigue, medication due to sedatives, alcohol consumption etc. are the most notable ones. Controlling of these causes in order to prevent accidents is a tricky problem which needs special attention. However, an easier solution to this problem is to detect/sense the drowsiness of drivers early and subsequently alerts them before any serious scenario emerges. In this project work we are attempting to address this problem. Herein a drowsiness detection system is presented which integrates two modes of approaches to identify driver drowsiness: intrusive and non-intrusive. The intrusive approach includes physiological measures, and the non-intrusive approach includes vehicle-based and behavioral measures. In the intrusive approach, sensors are used to detect driver drowsiness by placing them on the driver's body, whereas in the non-intrusive approach, a camera is used for drowsiness detection by identifying yawning patterns and eyelid movement. Most research has been conducted in driver drowsiness detection methods using only single measures that failed to produce good outcomes. This project proposes a hybrid model that combines the two approaches, non-intrusive and intrusive, to detect driver drowsiness. The proposed hybrid model uses 68 facial landmarks as a behavioral measure (non-intrusive) to get eye aspect ratio (EAR) which depends on movements of eyelids and mouth, and the Galvanic Skin Response (GSR) sensor as a physiological measure (intrusive) to collect the skin conductance of the driver. The EAR and GSR values are used as features and by analyzing these features separately, the model infers that whether the driver is in drowsy state or not. The inferences of both intrusive and nonintrusive approaches are independently computed. Both these inferences are at last passed through an AND gate in order to come to a final decision on drowsiness. The technique is accurate, robust and can be used in real time, which can be observed from the experimental results.

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SYMBOLS	REPRESENTATIONS
R	Eye aspect ratio
d1	Shorter diagonal distance
d2	Shorter diagonal distance
d3	Longer diagonal distance
d	Distance between two points (X1, Y1) and (X2, Y2)
C	Screen conductance
r	Resistance
µs	Micro siemens

ABBREVIATIONS

ABBREVIATIONS	REPRESENTATIONS
DDD	Driver's Drowsiness Detection
ECG	Electrocardiogram
EOG	Electrooculogram
NHTSA	National Highway Traffic Safety Administration
KSS	Karolinska sleepiness scale
ROI	Region of Interest
SM	Subjective measures
VBM	Vehicle-based measures
BM	Behavioral measures
PM	Hybrid measures
HM	Physiological measures
SSS	Stanford Sleeping Scale
SDLP	are Standard Deviation of Lane Positioning
SWM	Steering Wheel Movement
PERCLOS	percentage of eye closure
ML	machine learning
DL	Deep learning
EEG	electroencephalogram
EMG	electromyograms
GSR	Galvanic Skin Response
SVM	Support Vector Machines
CNN	Convolutional Neural Network
HMM	Hidden Markov Model
SDA	Serial Data Line
SCL	Serial Clock Line

CHAPTER 1: INTRODUCTION

1. Introduction

A Driver who does not take regular breaks when driving long distances run a high risk of becoming drowsy, a state which they often fail to recognize early enough according to the experts. Studies show that around one quarter of all serious motorway accidents attributable to sleepy drivers in need of a rest, meaning that drowsiness causes more road accidents than drink-driving.

Based on 2017 police and hospital reports, the National Highway Traffic Safety Administration (NHTSA) identified 91,000 car accidents as being caused by drowsy drivers. These accidents resulted in 50,000 injuries. In 2019, 697 fatalities involved a drowsy driver. However, NHTSA admits that it is hard to determine the precise number of drowsy-driving accidents, injuries, or deaths and that the reported numbers are underestimates. A study by the American Automobile Association's foundation for traffic safety estimated that more than 320,000 drowsy driving accidents happen each year, including 6400 fatal crashes [1]. The alarming statistics show that drowsy driving is a major issue that requires urgent attention to reduce its effects.

Driver drowsiness detection is a car safety technology which prevents accidents when the driver is getting drowsy. Various studies have suggested that around 20% of all road accidents are fatigue-related, up to 50% on certain roads. Driver fatigue is a significant factor in a large number of vehicle accidents. Recent statistics estimate that annually 1,200 deaths and 76,000 injuries can be attributed to fatigue related crashes [2]. The development of technologies for detecting or preventing drowsiness at the wheel is a major challenge in the field of accident-avoidance systems. Because of the hazard that drowsiness presents on the road, methods need to be developed for counteracting its effects. Driver inattention might be the result of a lack of alertness when driving due to driver drowsiness and distraction. Driver distraction occurs when an object or event draws a person's attention away from the driving task. Unlike driver distraction, driver drowsiness involves no triggering event but, instead, is characterized by a progressive withdrawal of attention from the road and traffic demands. Both driver drowsiness and distraction, however, might have the same effects, i.e., decreased driving performance, longer reaction time, and an increased risk of crash involvement.

According to statistics on traffic accidents 40 percent of crashes occurred from 6 pm to

12 am when drivers felt tired after working all day.

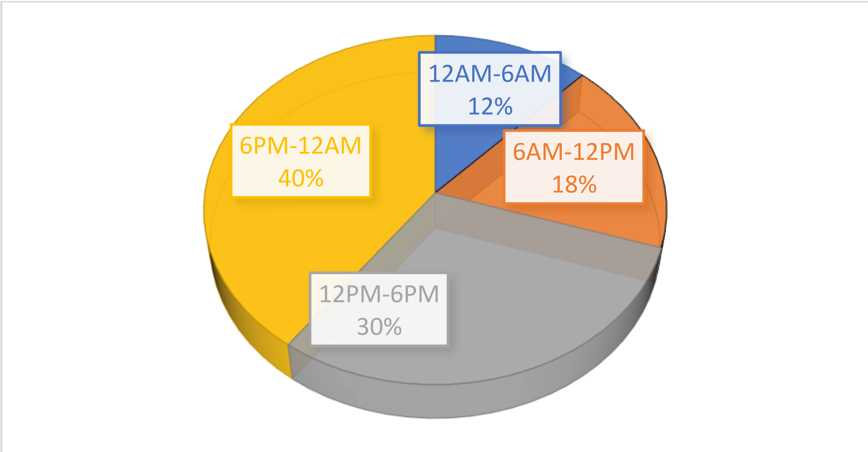

Figure 1.1: Occurrence of accidents at different time of a day [2]

Fortunately, it is possible to detect driver drowsiness in its early stages and alarm the driver to avoid any potential accident. Drowsy drivers exhibit various signs, which include repeated yawning, frequent eye closure, and repeatedly departing street lanes. In fact, driver drowsiness detection (DDD) techniques have been researched intensively in recent years. Researchers have proposed various measures to detect these drowsiness signs as early as possible, in order to avoid accidents.

1.2 Factors causing driving Drowsiness

Factors associated with drowsiness are the quality of sleep, the biological clock known as circadian rhythm, age, fitness, and liquor consumption, work circumstances such as noise, in car temperature and driving schedule, road environments such as monotony, car density and number of lanes. It has been reported that people who are harmonized with circadian rhythm, often found themselves in a drowsy state during 13:00-15:00 h and 1:00-6:00 h in a day. Besides, driving at night increases the risk factor to about 3 to 6 times than day time driving as the propensity to fall asleep increases with reduced vision at night. It is observed that monotonous driving severely impacts the driver's attention stimulation and it rapidly induces drowsiness when compared to any other contextual features. Drivers often fail to assess their state of drowsiness, leading to fatality. Falling asleep at the wheel reduces drivers' awareness to their surroundings and affects their response time. Furthermore, drowsiness diminishes the decision-making capability of the drivers.

Driver Fatigue is often caused by four main factors: sleep, work, time of day, and physical. Often people try to do much in a day and they lose precious sleep due to this. Often by taking caffeine or other stimulants people continue to stay awake. The lack of sleep builds up over a number of days and the next thing that happens is the body finally collapses and the person falls asleep. Time of day factors can often affect the body. The human brain is trained to think there are times the body should be asleep. These are often associated with seeing the sunrise and sunset. Between the hours of 2 AM and 6 AM, the brain tells the body it should be asleep. Extending the time awake will eventually lead to the body crashing. The final factor is a person's physical condition. People sometimes are on medications that create drowsiness or have physical ailments that cause these issues. Being physically unfit, by being either under or overweight, will cause fatigue. Additionally, being emotionally stressed will cause the body to get fatigued quicker.

A driver does not become drowsy suddenly, without showing some signs. Examples of such signs include: Difficulty keeping eyes open, Yawning, Frequent blinking, Difficulty concentrating, Swerving out of the lane and delayed reaction to traffic, Nodding, Unjustifiable variations in speed [3]. These signs gradually become more apparent as drowsiness deepens and, as such, can serve as indicators for the level of driver drowsiness.

1.3 Types of Drowsiness Detection

There are two approaches, intrusive and non-intrusive, to identify drowsy driving. In an intrusive approach, the drowsy condition of a person is identified using physiological parameters, but in a non-intrusive approach, this is identified by installing devices and sensors on the vehicle. Based on intrusive and non-intrusive approaches, five different Sensors measures are utilized to identify driver drowsiness at an early stage. These measures are as follows:

1. Subjective measures (SM)
2. Vehicle-based measures (VBM)
3. Behavioral measures (BM)
4. Physiological measures (PM)
5. Hybrid measures (HM)

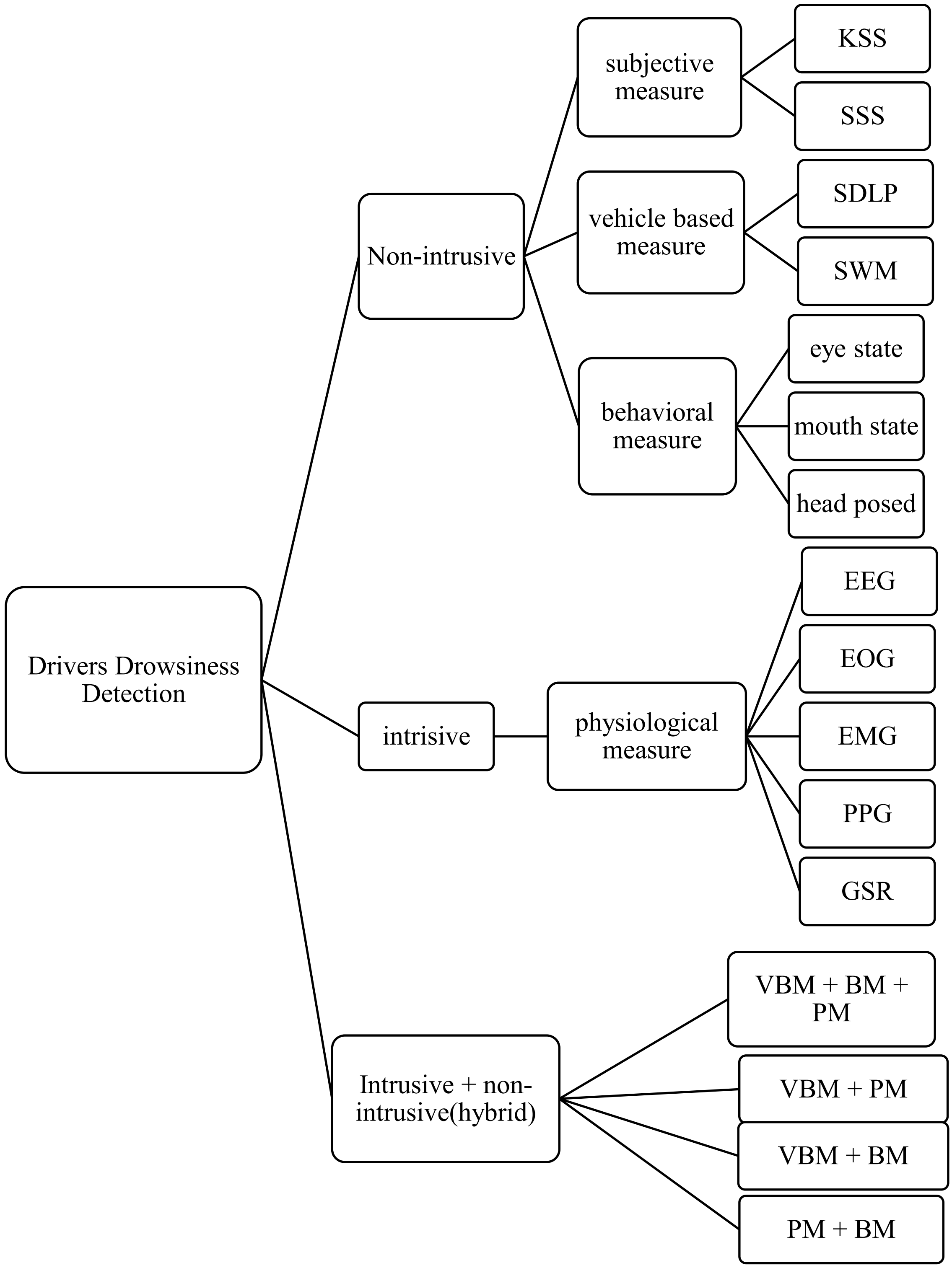

Figure 1.2: Driver drowsiness detection measures techniques

Physiological measures considered intrusive, whereas subjective, vehicle-based and behavioral measures are considered non-intrusive. Hybrid measures are a combination of two or more measures [4]. Figure 1.4 depicts the various measures for driver drowsiness detection and their respective techniques.

1.3.1 Subjective measures (SM)

Subjective measures are used to detect driver drowsiness by gathering data from the driver in a simulated environment. The Stanford Sleeping Scale (SSS) and Karolinska Sleeping Scale (KSS) approaches help to gather the driver's observations while operating the vehicle to assess the driver's state. In SSS, seven levels of the Likert scale (1-feeling active to 7-extremely sleepy), and in KSS, nine levels of the Likert scale (1-extremely alert to 9-extremely sleepy) help to evaluate the different levels of drowsiness at a particular time [4]. The drawback of a subjective measure is that it is impractical and produces biased results, making it impossible to utilize in real driving conditions.

1.3.2 Vehicle-based measures (VBM)

By installing several types of sensors in various places in the vehicle, such as the driver's seat and steering wheel, it is possible to apply vehicle-based measures. The two most common vehicle-based measures for driver drowsiness detection are Standard Deviation of Lane Positioning (SDLP) and Steering Wheel Movement (SWM). In Standard Deviation of Lateral Position (SDLP), a camera is mounted on the front of the vehicle to track the lane position, which helps to identify the alert or drowsy state. The SDLP represents the change in lateral position. It is an indicator of stability of path control. Its calculation requires the use of a front camera to measure the lateral position of the vehicle. Its biggest drawback is that it needs to rely on external variables like road markings, lighting and weather conditions. In Steering Wheel Movement (SWM), various sensors positioned on the vehicle's steering wheel gather information to aid in the detection of driver drowsiness [4]. The primary issue associated with SWM is that it is expensive and has a high false positive detection rate, making it ineffective in real driving conditions.

1.3.3 Behavioral measures (BM)

The behavior of the driver, including yawning, eye closure, eye blinking, head pose, etc. is monitored through a camera and the driver is alerted if any of these drowsiness symptoms are detected. Behavioral measures are based on the driver's features, such as eyes, mouth and head inclination. To identify drowsy driving, the researcher primarily focuses on eye blink rate and percentage of eye closure (PERCLOS), which are further examined by machine learning

(ML) and deep learning (DL) algorithms. Other signs that can aid in detecting drowsiness in a driver include yawning and head movement [4]. Due to their non-intrusive characteristics, these behavioral measurement techniques are frequently used in simulated and real driving conditions. The present state of the art reveals that behavioral measures are more accurate than vehicle-based measures. Due to its non-intrusiveness, the behavioral measure is one of the most widely used drowsiness detection techniques. A camera is mounted on the dashboard of the vehicle to capture the driver's facial features. Behavioral measures also show promising results for driver drowsiness detection with higher accuracy in normal conditions, but the accuracy decreases drastically in certain conditions such as low light and drivers with eyeglasses.

1.3.4 Physiological measures (PM)

Using physiological measures to identify driver drowsiness at an early stage provides promising results. A number of devices are directly attached to the driver to capture the relevant physiological parameters, such as electroencephalograms (EEG), electrocardiograms (ECG), electromyograms (EMG) and electrooculograms (EOG) [13]. Although physiological measures have a high level of accuracy, they are very intrusive. Using these highly intrusive devices in real driving conditions is challenging. Therefore, small and lightweight physiologically based sensors that are less intrusive, such as a Galvanic Skin Response (GSR) sensor, can be used to record the physiological parameters. A GSR sensor is a physiologically based sensor that is placed on the skin to capture the body's skin conductance. Using a GSR sensor is possible and can play a supportive role when the behavioral measures are ineffective. The unit of GSR is micro siemens (μs). The GSR sensor is first attached to the driver to collect bioelectric signals. Following data acquisition, it transmits the signals to the next phase for feature extraction [4]. Based on the processed data, further raw data are converted into meaningful data by removing anomalies/missing frequencies and duplicate values. These data are transmitted again for classification after analysis. The binary classification technique efficiently classifies the drowsy or non-drowsy state.

There are several graphs shown below which are created in using GSR data at different stages:

1.3.5 Hybrid measures (HM)

The limitations of individual measures can be overcome by combining two or more measures in such a way that one technique can reduce the limitations of the others to improve the system's overall accuracy [4]. Hybrid measures combine two or more measures that help to develop a highly accurate and reliable driver drowsiness detection system. [13]

1.4 Project Features

In this work, we are integrating an image processing-based approach and a GSR based approach to design a more efficient hybrid model for real time drowsiness detection. Here we measure the eye aspect ratio from ROI (region of interest) and skin conductance of the driver to make an appropriate decision in the computer about the driver's state. A number of road accidents could be avoided by connecting an alarm system to the hybrid model.

CHAPTER 2: LITERATURE REVIEW

2. Literature Review

In concerning the design of drowsiness detection systems, different terms of reference are used. Although “drowsiness” is the commonly mentioned term, “fatigue” is also used. Fatigue refers to “the reluctance to continue a task as a result of physical or mental exertion or a prolonged period of performing the same task”. Although they are different concepts, some researchers considered drowsiness and fatigue alike, due to their similar consequences.

2.2 Different studies on Drowsiness detection

A discussion on previous studies is presented below.

Deng et al. conducted a study on “Real-Time Driver-Drowsiness Detection System Using Facial Features” in 2016. The paper proposes a system called DriCare, which detects the drivers’ fatigue status, such as yawning, blinking, and duration of eye closure, using video images, without equipping their bodies with devices. By combining the features of the eyes and mouth, DriCare can alert the driver using a fatigue warning. The experimental results showed that DriCare achieved around 92% accuracy [5].

Ngxande et al. conducted a study on “Driver drowsiness detection using Behavioral measures and machine learning techniques: A review of state-of-art techniques” in 2017. According to the study faces contain information that can be used to interpret levels of drowsiness. Machine learning techniques such as SVM (Support Vector Machines), CNN (Convolutional Neural Network), and HMM (Hidden Markov Model) are reviewed in this paper. It is extremely difficult to compare these approaches. This analysis highlighted the performance of CNNs, which outperformed other approaches [6].

Gabhane et al. Conducted a study on **“**Drowsiness Detection and Alert System: A Review” in 2018. According to the study the most at risk of falling asleep while driving are the truck drivers, company car drivers and shift workers. The main objective of the project was to reduce the accident ratio of the truck driver. It helps solving real life problem in very cost effect way. It warns the driver and also the owner of the truck driver by sending him text messages [7].

Chowdhury et al. conducted a study on “Sensor Applications and Physiological Features in Drivers’ Drowsiness Detection: A Review” in 2018. According to the study wake-sleep is an intermediate state between two physiologically dissimilar states. Physiological signals can define this transition more accurately when compared with approaches that fall in other categories [8].

Albadawi et al. conducted a study on "A Review of Recent Developments in Driver Drowsiness Detection Systems" in 2022. The study illustrates and reviews recent systems using different measures to track and detect drowsiness. The study emphasizes that DDD technology has enormous market potential. Many car manufacturers, such as Toyota and Nissan, have recently installed driver assistance devices in their products. The artificial intelligence and deep learning fields are developing tremendously. Soon, the DDD systems will most likely evolve, enabling the formation of smart cities [9].

Nasri et al. conducted a study on "A Review of Driver Drowsiness Detection Systems: Techniques, Advantages and Limitations" in 2022. The study focused on advantages and limitations of physiological signals, facial features, and driving patterns. The result is shown in following table. [10]

class	hardware	Advantages	Limitations
Physiological Signals	Electroencephalogram (EEG) and Electrocardiogram (ECG) Sensors	Accurate, reliable	Intrusive
Facial Features	External camera	Non-intrusive	Not possible in low brightness and all very light condition
Driving Patterns	Steering angle sensor for (SWM) External camera for (SDLP) OBD-2 for Acceleration, Speed, Gravity, and RPM	Non-intrusive	Unreliable, less accurate

Table 2.1: Advantages and limitations of each class [10]

Bajaj et al. conducted a study on "System and Method for Driver Drowsiness Detection Using Behavioral and Sensor-Based Physiological Measures" in 2023. The study shows various hybrid models and their accuracy [11]. The accuracy of different hybrid models is shown below.

Hybrid Measures	Accuracy	Advantages	Limitation
Behavioral +Vehicle based	91%	Ease of use	High false positive detection rate and dependent on geographical conditions
Behavioral +Physiological	98%	High accuracy	Highly intrusive
Vehicle-based +Physiological	93%	High accuracy	Extremely intrusive and geographically dependent
Vehicle-based +Physiological + Behavioral	81%	High accuracy and ease of use	Expensive and more challenging to implement in real driving conditions

Table2.2: Various hybrid measures [11]

Among all possible combinations, the behavioral and physiological measures produce promising results. The physiological measures are extremely intrusive and thus challenging for the driver to wear them and drive the vehicle. Due to technological advancements in the area of biological sensors hybrid measures can be used for driver drowsiness detection at an early stage. The features based on hybrid model are capable of identifying a drowsy state in the driver with the efficacy of 91%.

CHAPTER 3: OBJECTIVES

3. Objectives

1. To design and develop a hybrid driver drowsiness detection system by:

    (i) Integrating both intrusive (physiological) and non-intrusive (behavioural) approaches to achieve improved accuracy and reliability.

    (ii) Testing physiological responses separately for both male and female subjects.

2. To implement a decision-making mechanism that combines the independent inferences from both approaches using a logical gate, ensuring the real-time detection of driver drowsiness.

CHAPTER 4: METHODOLOGY

4. Methodology of Drowsiness Detection System

4.1 Block diagram of the Proposed Model

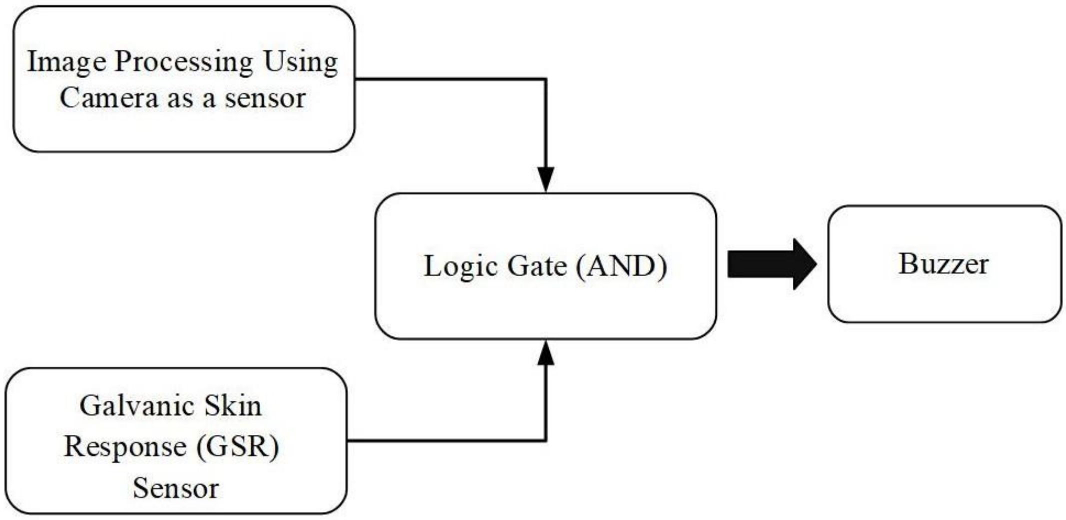

Fig 4.1: Block Diagram of the Proposed Model

In the proposed hybrid model, we use eye and mouth ratio detection via a camera sensor under the behavioural measurement system, and a Galvanic Skin Response (GSR) sensor under the physiological measurement system.

When a person becomes drowsy, facial posture changes significantly, particularly in the eyes and mouth. By analysing these changes using a camera sensor, we can detect whether the person is sleepy or alert. Similarly, in a drowsy state, the skin's electrical response also changes. This variation can be measured using the GSR sensor.

The outputs from both systems are combined using an AND gate to make a final decision about the person's alertness.

This system will be especially useful for drivers, whether driving at night or during the day, to detect signs of sleepiness early. By timely alerting the driver, it can help reduce the risk of accidents and improve road safety.

4.2 Image processing-based detection

We will make a drowsiness detection system using 68 facial landmark points.

4.2.1 68 Facial landmark detection

The 68 Facial landmarks were created by Brandon Amos. The facial landmarks are used for localizing and representing salient regions or facial parts of the person's face, such as: Eyebrows, Eyes, Jaws, Nose, and Mouth etc. Facial landmarks is a technique which can be applied to applications like face alignment, head pose estimation, face swapping, blink detection, drowsiness detection, etc. In this context of facial landmarks, our vital aim is to detect facial structures on the person's face using a method called shape prediction [1]. There are mostly two steps to detect face landmarks in an image which are given below:

1. Face detection: Face detection is the first methods which locate a human face and return a value in x, y, w, h which is a rectangle.
2. Face landmark: After getting the location of a face in an image, then we have to through points inside of that rectangle.

There are varieties of facial landmark detectors, but every method will essentially be trying to localize and also labeling the following facial regions: Nose, Jaws, left eye, Right eye, left eyebrow, Mouth, Right eyebrow [14]. The below image is an example of a Dib's 68 points model where we can see points from 1 to 68.

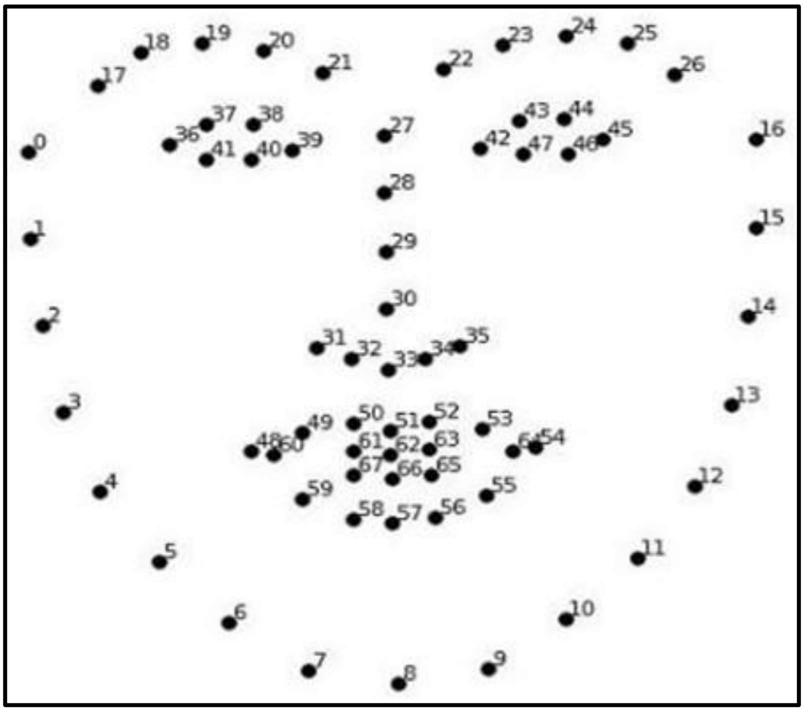

Fig 4.2: 68 landmark points on human face [1]

The Locations of the Facial Parts are as follows:

- The left eye is accessed with points: 42, 43, 44, 45, 46 and 47
- The right eye is accessed with points: 36, 37, 38, 39, 40, and 41
- The mouth is accessed through points: 48 to 67
- The nose is accessed using points: 27 to 34
- The left eyebrow is accessed through points: 22, 23, 24, 25 and 26.
- The right eyebrow is accessed through points: 17 to 21
- The jaw is accessed via points: 0 to 16

4.2.2 Requirements for Image processing-based detection

The requirements for the image processing model are shown below:

- Software: Python Interpreter, Visual Studio Code (Code Editor)
- Libraries: OpenCV, NumPy, Dlib, imutils (including face_utils), pySerial
- Hardware: ARDUINO UNO, Buzzer, Jumper wire

4.2.2.1 Software

Python Interpreter is a high-level, general-purpose programming language. It designs philosophy emphasizes code readability with the use of significant indentation via the off-side rule. Python is dynamically typed and garbage-collected. It supports multiple programing paradigms, including structured, object oriented and functional programming. It is often described as a "batteries-oriented" language due to its comprehensive standard library. [9]

Visual Studio Code (famously known as VS Code) is a free open-source text editor by Microsoft. VS Code is available for Windows, Linux, and macOS. Although the editor is relatively lightweight, it includes some powerful features that have made VS Code one of the most popular development environment tools in recent times.

4.2.2.2 Libraries

OpenCV is an open-source software library for computer vision and machine learning. The OpenCV full form is Open-Source Computer Vision Library. It was created to provide a shared infrastructure for applications for computer vision and to speed up the use of machine perception in consumer products. OpenCV, as BSD-licensed software, makes it simple for companies to use and change the code [16]. There are some predefined packages and libraries that make our life simple and OpenCV is one of them. OpenCV supports a wide variety of programming languages like Python, C++, Java, etc. It can process images and videos to identify objects, faces and handwritings. It is integrated with various libraries, such as NumPy which is a highly optimized library for numerical operations.

NumPy is a Python library used for working with arrays. It also has functions for working in domain of linear algebra, Fourier transform, and matrices. NumPy aims to provide an array object that is up to 50 times faster than traditional Python lists. NumPy arrays are stored at one continuous place in memory unlike lists, so processes can access and manipulate them very efficiently. This behaviour is called locality of reference in computer science. This is the main reason why NumPy is faster than lists. Also, it is optimized to work with latest CPU architectures. NumPy is a Python library and is written partially in Python, but most of the parts that require fast computation are written in C or C++.[9]

Dlib is a modern C++ toolkit containing machine learning algorithms and tools for creating complex software in C++ to solve real world problems. It is used in both industry and academia in a wide range of domains including robotics, embedded devices, mobile phones, and large high performance computing environments. Dlib's open-source licensing allows you to use it in any application, free of charge. We can use a number of its tools from python applications [16]. Dlib is one of the most powerful and easy-to-go open-source libraries consisting of machine learning library/algorithms and various tools for creating software**.** Unlike a lot of open-source projects, it provides complete and precise documentation for every class and function. There are also debugging modes that check the documented preconditions for functions. When this is enabled, it will catch the vast majority of bugs caused by calling functions incorrectly or using objects in an incorrect manner.

imutils face_utils this is an open-source wrapper library for the most common face detection models. It also provides multiple face utilities such as face cropping [16]. A series of convenience functions to make basic image processing functions such as translation, rotation, resizing, skeletonization, displaying Matplotlib images, sorting contours, detecting edges, and much easier with OpenCV.

pySerial: This module encapsulates the access for the serial port. It provides backends for Python running on Windows, OSX, Linux, BSD (possibly any POSIX compliant system) and Iron Python. The module named "serial" automatically selects the appropriate backend.

4.2.2.3 Hardware

Arduino Uno

It is a microcontroller board based on the **ATmega328P**. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; the board should connect to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

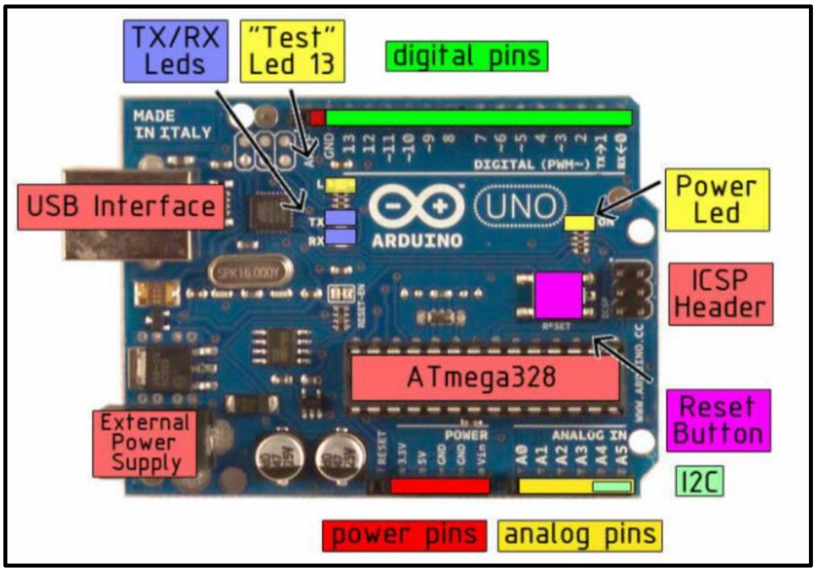

Figure 4.3: ARDUINO UNO

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Ground and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- VIN: The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V: The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- 3V3: A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND: Ground pins.

The Atmega328 has 32 KB of flash memory for storing code. It has also 2 KB of SRAM and 1 KB of EEPROM. Each of the 14 digital pins on the Uno can be used as an input or output. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor of 20-50 k ohms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, each of which provides 10 bits of resolution (i.e. 1024 different values). By default, they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin. Additionally, some pins have specialized functionality:

- I^2C : 4 (SDA) and 5 (SCL). There are a couple of other pins on the board:
- AREF: Reference voltage for the analog inputs.
- Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Buzzer

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

Figure 4.4: TMB12A05 Buzzer [9]

The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

TMB12A05 buzzer is a small 12mm round speaker that operates around the audible 2 kHz range. You can use these speakers to create simple music or user interfaces. This is not a true piezoelectric speaker but behaves similarly. Instead of a piezoelectric crystal that vibrates with an electric current, this tiny speaker uses an electromagnet to drive a thin metal sheet. That means we need to use some form of alternating current to get sound. This speaker is tuned to respond best with a square wave (e.g. from a microcontroller).

Jumper wires

A jump wire (also known as jumper, jumper wire, DuPont wire) is an electrical wire, or group of them in a cable, with a connector or pin at each end, which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering. Though jumper wires come in a variety of colors, but the colors don't actually mean anything. This means that a red jumper wire is technically the same as a black one. But the colors can be used to your advantage in order to differentiate between types of connections, such as ground or power. Jumper wires typically come in three versions: male-to-male, male-to-female and female-to-female. The difference between each is in the end point of the wire. Male ends have a pin protruding and can plug into things, while female ends do not and are used to plug things into. Male-to-male jumper wires are the most.

Figure 4.5: Three types of Jumper wires

4.2.3 Measurement of Image Processing-Based Detection

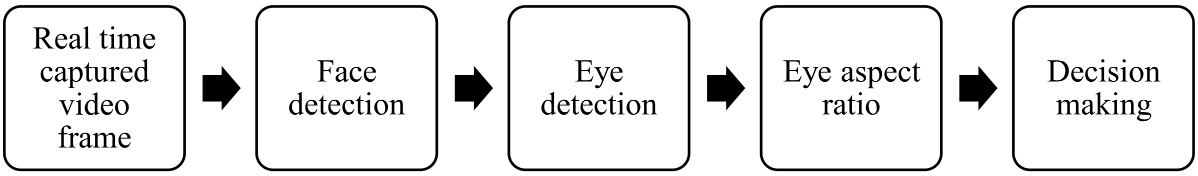

Figure 4.6: Block diagram image processing-based detection

Step1. Installing and importing all the modules needed for the python code.

- pip install NumPy
- pip install OpenCV-python
- pip install dlib
- face_utils
- shape_predictor_68_face_landmarks1

Step2. Determining ROI (Region of Interest) from the image using python libraries.

Step3. Accessing the camera and marking the landmarks to predict the location of the eyes with the help of 68 facial landmarks. The right eye locates from point number 36 to 41 and the left eye locates from point number 42 to 47.

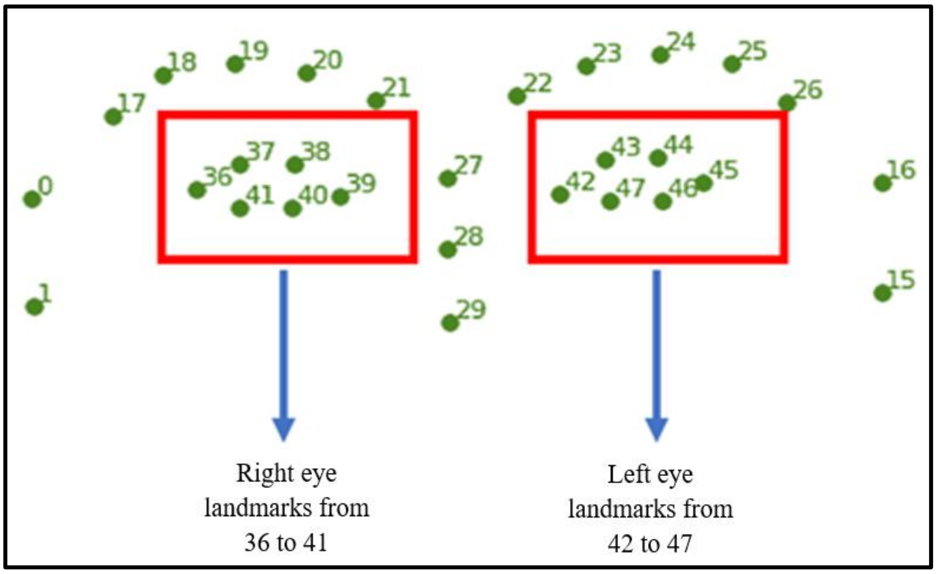

Figure 4.7: Right eye and left eye landmarks [9]

Step4. Calculating the eye aspect ratio for left and right eye using the formula given below

$$R = \frac{Sum\ of\ shorter\ diagonal\ distances}{2 \times longer\ diagonal\ distance}$$

Or

$$\mathbf{R}=\frac{d1+d2}{2d3}$$

which is equation number (1)

Where, R= Eye aspect ratio; d1 and d2 are the shorter diagonal distances, whereas d3 is the longer diagonal distance

d1 (right eye) = diagonal distance between point number 37 to 41

d1 (right eye) = diagonal distance between point number 43 to 47

d2 (right eye) = diagonal distance between point number 38 to 40

d2 (right eye) = diagonal distance between point number 44 to 46

d3 (right eye) = diagonal distance between point number 36 to 39

d3 (right eye) = diagonal distance between point number 42 to 45

Distance between two points (X1, Y1) and (X2, Y2) is calculated using Euclidean distance formula given below

Euclidean distance formula

$$\mathbf{d}=\sqrt{(X2-X1)^2+(Y2-Y1)^2} \qquad \ldots\ldots(1)$$

Step4. Decision making on the basis of eye aspect ratio(R), if a person is in Active state, then 'R' is greater than 0.25 and if the person is in sleepy state R is equal to zero. If the person is in drowsy state, then 'R' is in between 0.21 and 0.25.

State	Value of 'R'
Active	R>0.25
Drowsy	0.25 ≥R>0.21
Sleepy	R=0

Table 3.1: Value of 'R' at differently stages

Step5. Installing a buzzer by connecting the buzzer positive pin to Arduino pin 10 and the buzzer negative to Arduino GND. The buzzer will give alarm when the driver is Drowsy.

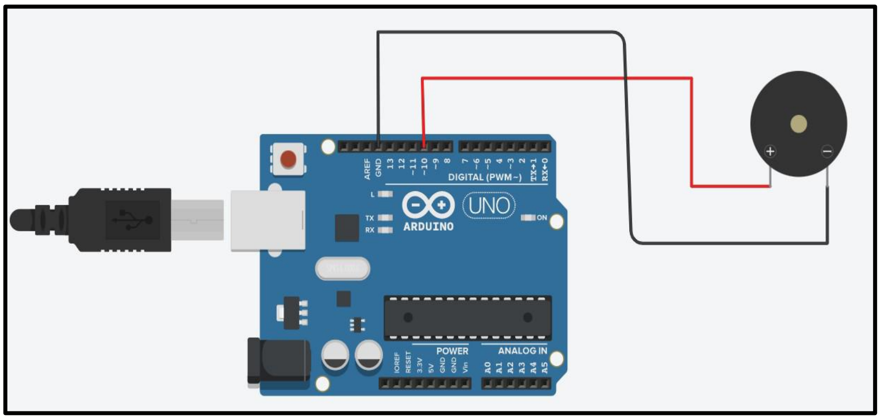

Figure 4.8: Connection of buzzer with Arduino

4.3 GSR based detection

During drowsiness, it is observed that the GSR value tends to decrease. The conductivity of the skin is used to calculate the GSR value. The equation to measure skin response is $C = \frac{1}{R}$, where C represents the skin conductance, which is inversely proportional to resistance (R). The skin conductance can be measured in micro-Siemens (µs), where the normal range lies between 250 µs to 450 µs for a normal person. The GSR value, often between 128 µs and 250 µs, indicates the driver's drowsy state. Driver's state can be determined by calculating the slope of the GSR, which provides the average rate of absolute change from a group of data observed over a period of time. It is determined by averaging the initial difference of the skin conductance signal's absolute value.

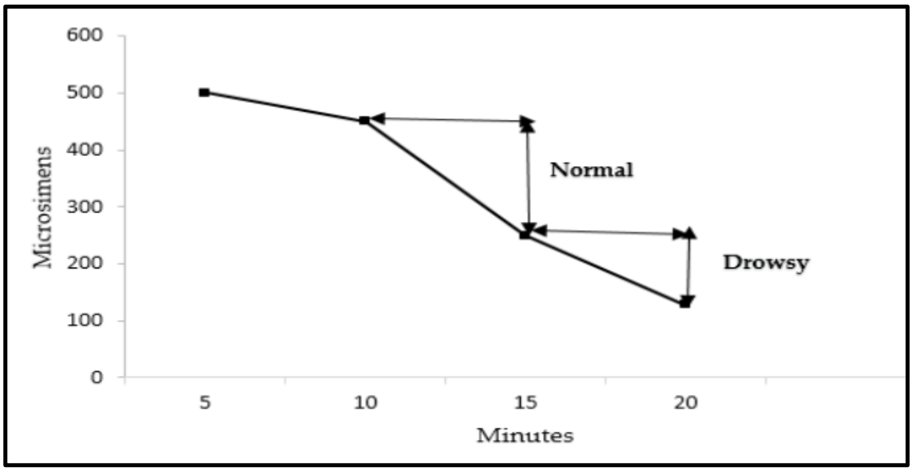

Figure 4.9: GSR skin conductance value [4]

4.3.1 Requirements for GSR based detection

The requirements for the GSR based detection are:

- GSR Sensor Kit
- LCD Display with I2C Module

4.3.1.1 GSR Sensor Kit

It is a method of measuring the electrical conductance of the skin. Strong emotion can cause stimulus to human sympathetic nervous system, resulting more sweat being secreted by the sweat glands.

Human body sweating is regulated by the autonomic nervous system. In particular, if the sympathetic branch of the autonomic nervous system is highly aroused, then sweat gland activity also increases, which in turn raises the skin conductance, and vice versa. A GSR sensor allows us to measure sweat gland activity, which is related to emotional arousal. So, to measure GSR, we take advantage of the electrical properties of the skin. Specifically, how the skin resistance changes with sweat gland activity, i.e., the greater sweat gland activity, the more perspiration, and thus, less skin resistance. Also, it depending on the sex difference the skin response is different [15].

The GSR signal is very easy to record. In principle, just two electrodes put at the second and third finger of one hand are necessary. The most common method to measure a GSR signal for psych galvanic-response studies is grounded on the exosmotic method in which skin resistance to a small electric current from an external source is measured. The most common measure of a GSR signal is not resistance, but conductance measured in Siemens, which is the reciprocal of resistance in ohms. The conductance makes the signal interpretation easier, since the greater the sweat gland activity, the higher the skin conductance.

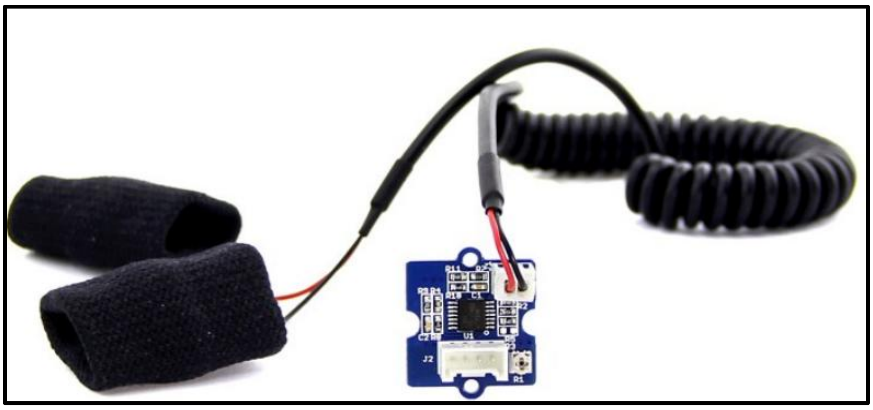

Figure 4.10: GSR sensor kit

4.3.1.2 LCD Display with I2C Module

The I2C 16x2 Arduino LCD Screen is using an I2C communication interface. It is able to display 16×2 characters on 2 lines, white characters on a blue background. This display overcomes the drawback of LCD 1602 Parallel LCD Display in which there will waste about 8 Pins on the Arduino for the display to get working. The I2C is a type of serial bus developed by Philips, which uses two bidirectional lines, called SDA (Serial Data Line) and SCL (Serial Clock Line). Both must be connected via pulled-up resistors. The usage voltages are standard as 5V and 3.3V.

If the I2C adapter soldered onto the board the wiring is quite easy. We need only four pins. The 4 pins for the LCD display are

1) VCC
2) GND
3) SDA
4) SCL

By using I2c protocol we can easily interface LCD with Arduino and display the character with short commands. Below figure showed 4 l=pins of I2c module and 1

Figure 4.11: LCD Display with I2C Module [13]

4.3.1 Measurement of GSR based detection

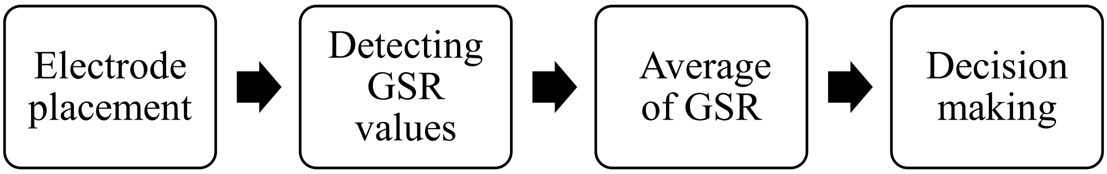

Figure 4.12: Block diagram of GSR based drowsiness detection

Step 1: Electrodes are placed in any two fingers of the driver which is connected to the GSR sensor, to measure the skin conductance. The electrical conductance value of skin of the human body is being read by the GSR sensor.

Step 2: The skin conductance value that is GRS value is determined using GSR sensor kit. These values are sent to the Arduino UNO module in 1 sec interval of time repeatedly.

Step 3: Determining average GSR from 10 GSR reading to get a stable GSR for interval of 10 second.

Step 4: Decision making on the basis of average GSR value, whether the driver is drowsy or active. It the average GSR value is less than a threshold value of 250µs then the person is in drowsy state and if the GSR average is greater than the threshold of 250µs then the person is in active mode. The buzzer will be on if the person is in drowsy state.

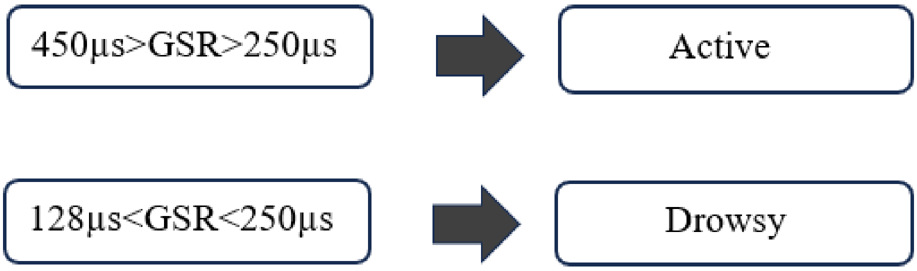

Figure 4.13: Decision making on the basis of skin conductance

4.4 Hybrid Model

The hybrid model is shown in figure 3.13 which is the combination of image processing-based detection and GSR based detection. The combination done by using an AND gate. The truth table is shown below.

Image processing input	GSR input	Buzzer output
0	0	0
0	1	0
1	0	0
1	1	1

Table 3.2: Truth table of AND gate

4.4.1 Process of Proposed drowsiness detection Hybrid Model

The schematic diagram of the proposed driver drowsiness detection system is shown in the figure below.

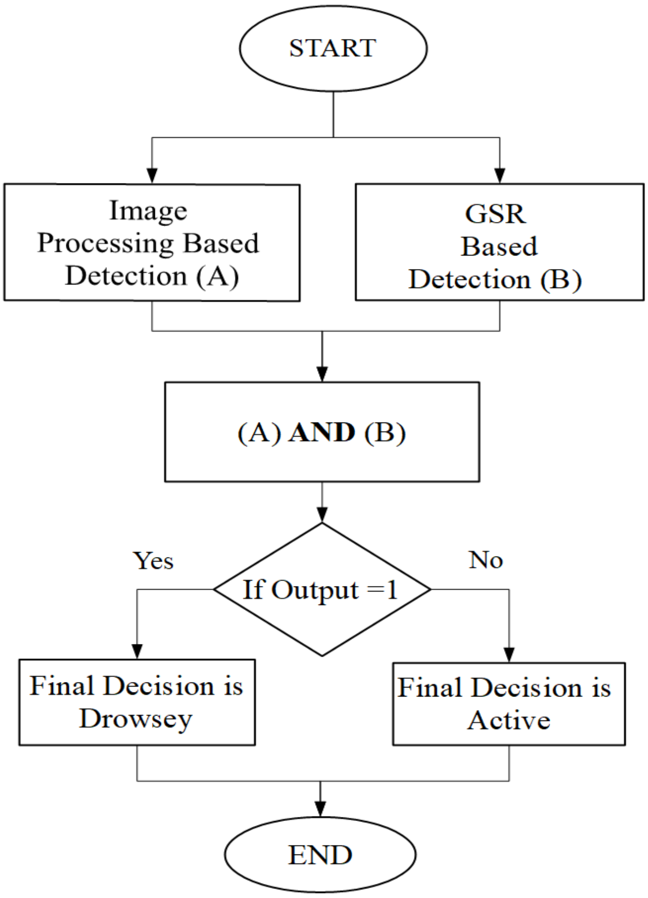

Figure 4.14: Schematic Diagram of the proposed driver drowsiness detection System

Step 1: The image processing unit takes the real time video input from the camera and detects the drowsiness of the person using a deep learning module as discussed in 3.2. The python script then sends the value: "SLEEP" or "NO SLEEP" to the Arduino via serial connection.

Step 2: The GSR sensor also sends the reading to the Arduino UNO in every 1 second of interval. The average of the 10 values read from the GSR module is calculated and conditioned with the following way:

GSR value > 250µs: Not Sleeping

GRS value < 250µs: Sleeping

Step 3: According to the conditions above, if the GSR value is less than 250 and the value from the Image processing unit is indication of "SLEEP", then the buzzer is triggered. If the condition goes to normal, the buzzer will stop. These values are displayed in the LCD module every 2 seconds interval. The other function of the GSR module is that if the person puts their hands away from the GSR sensor for 10 seconds, the buzzer is again triggered in every 2 seconds interval. The message "Hand Away" is also displayed in the LCD display when the hands are away from the GSR sensor for 10 seconds.

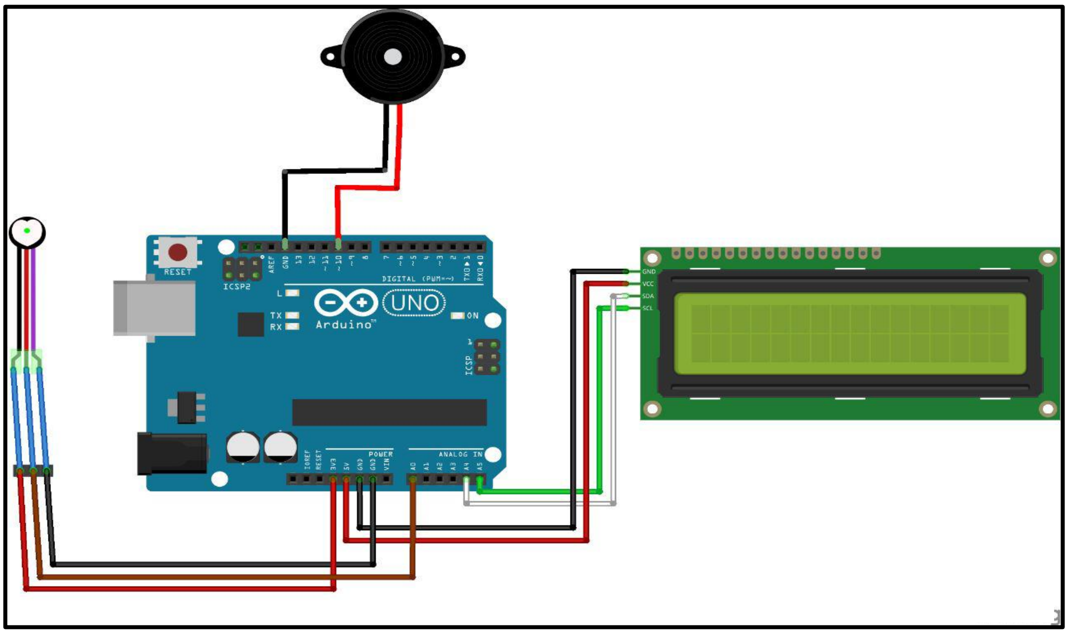

Figure 4.15: Connection of LCD and I2C with ARDUINO

The complete monitoring setup is shown in the figure below.

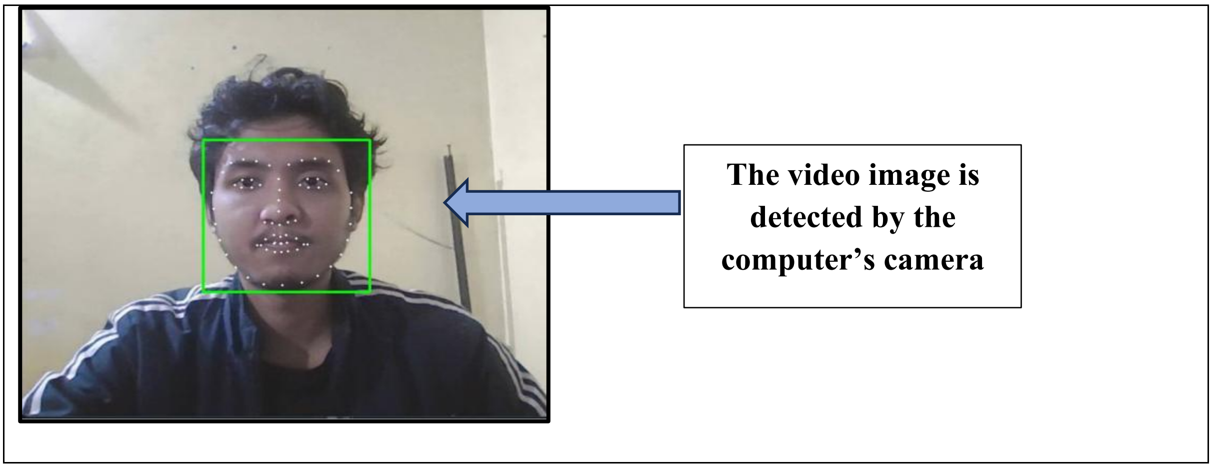

Fig: 4.16: Image processing-based drowsiness detection system

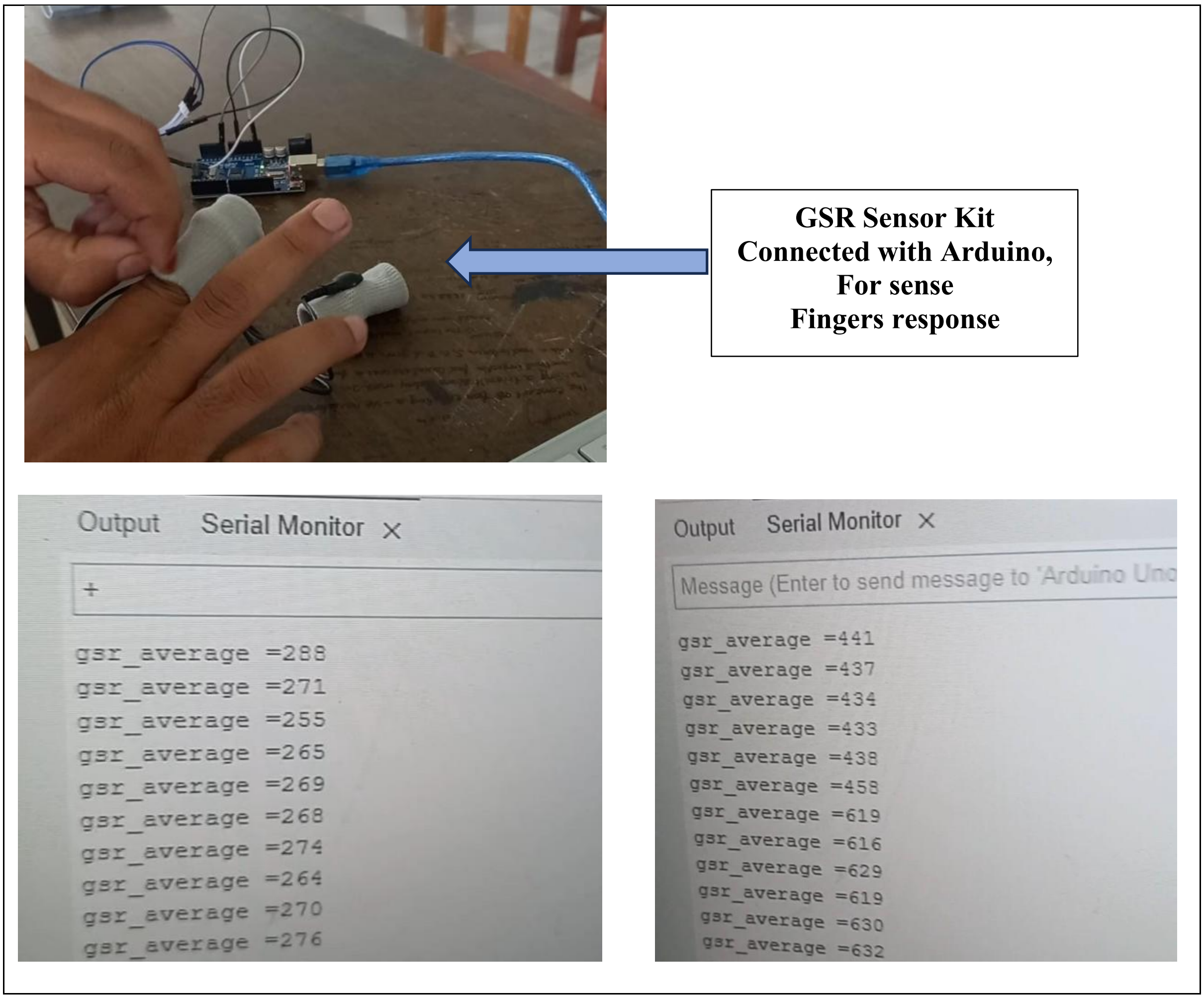

Fig: 4.17: GSR- Based drowsineess detection system

CHAPTER 5: RESULT AND DISCUSSIONS

5.1 Output of Image processing-based drowsiness detection system

The output of the image processing-based drowsiness detection system is shown below. The video image was detected by the camera and the system starts processing. It gives the output as active, drowsy or sleeping can be seen in the output image.

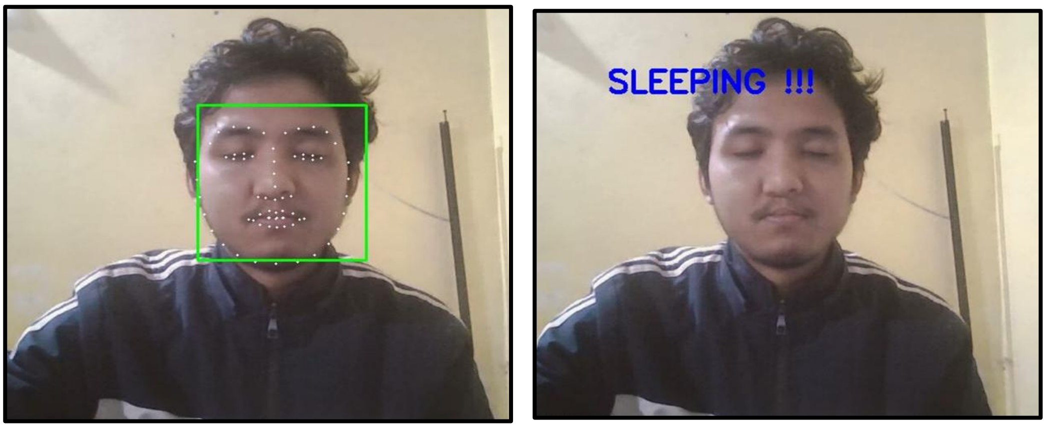

Figure 5.1(A): Sleeping state (without Spectacle)

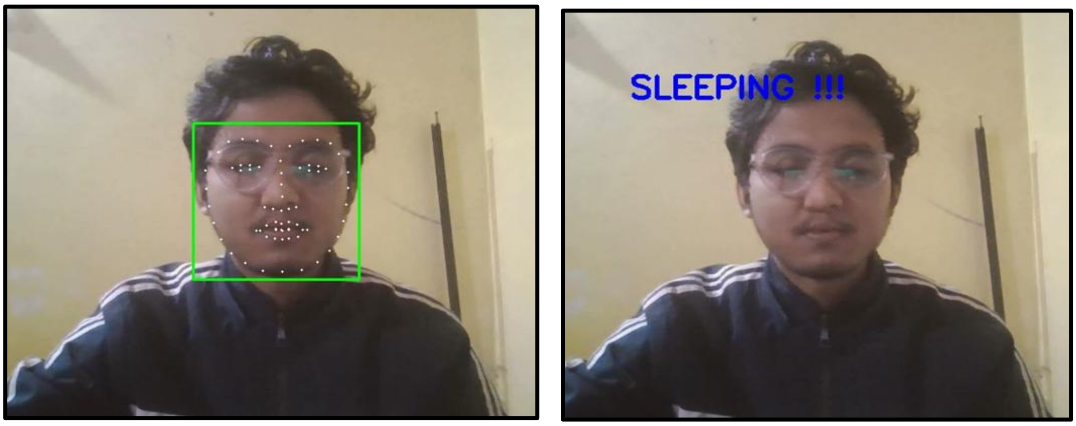

Figure 5.1(B): Sleeping state (with Spectacle)

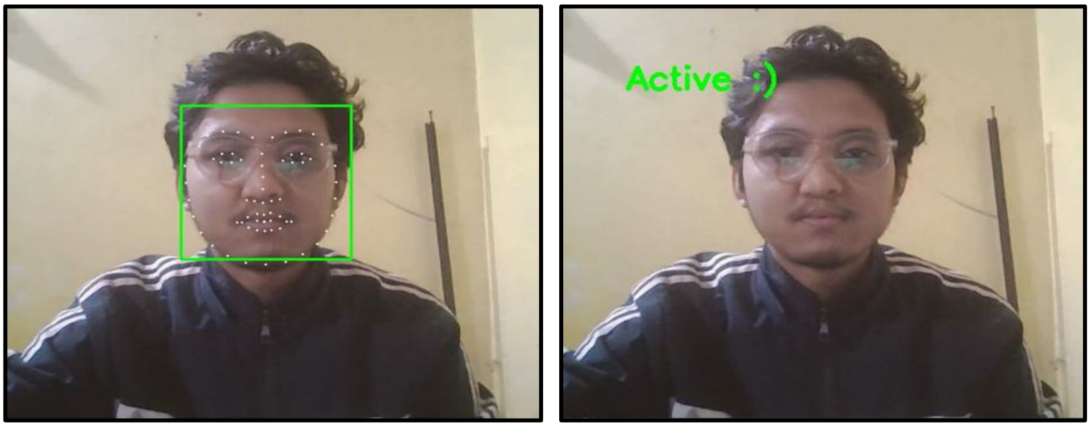

Figure 5.1(C): Active state (with Spectacle)

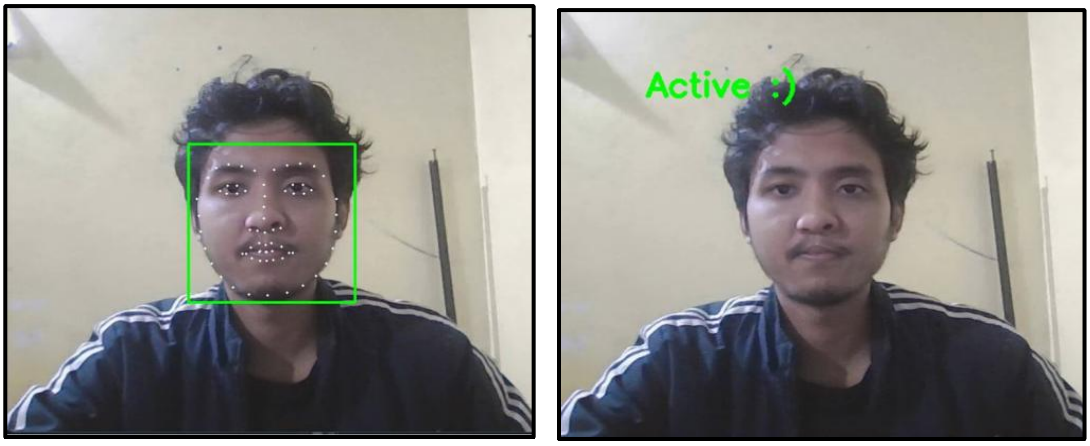

Figure 5.1(D): Active state (without Spectacle)

Figure 5.1(E): Drowsy state (with spectacle)

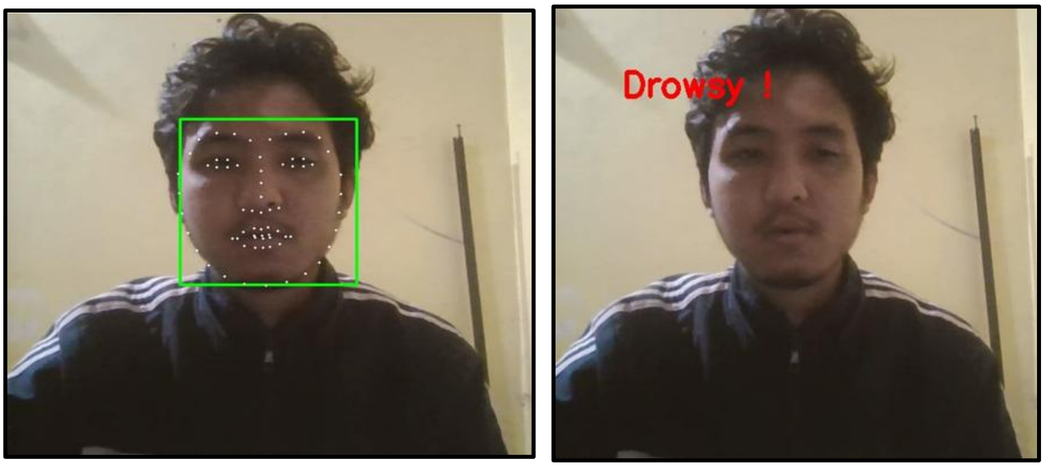

Figure 5.1(F): Drowsy state (without spectacle)

Using the image processing-based drowsiness detection system ROI is determined and also with the 68 facial landmarks can be seen in green color. The right eye landmarks from 36 to 41 and the left eye landmarks from 42 to 47 with green colored dots. The system follows the process as mention in figure 3.6 and uses equation number (1) to detect eye aspect ratio.

- Figure 4.1(A) represents sleeping state of the person when system gives 0 value of R.
- Figure 4.1(B) represents sleeping state of the person with Spectacle, to determine how efficiently the system works. The landmarks are detected clearly with green dots and perfectly measures R then give decision as sleeping state.
- Figure 4.1(C) represents active state of the person with spectacle, when value of R is greater than 0.25
- Figure 4.1(D) represents active state of the person without spectacle($R>0.25$).
- Figure 4.1(E) represents drowsy state of the person with spectacle when value of R is calculated in between 0.21 and 0.25
- Figure 4.1(F) represents the drowsy state of the person without spectacle ($0.25>R>0.21$)

5.2 Output of GSR based drowsiness detection system

The output of GSR based detection system is shown below:

Figure 5.2(A): Active state GSR value of a male

Figure 5.2(B): Drowsy state GSR value of a male

Figure 5.2(C): Active state GSR value of a female

Figure 5.2(D): Drowsy state GSR value of a female

Using GSR based drowsiness detection two state of person can be defined for both male and female. From our study it can be seen that the skin conductance value for female is slightly high as compare to male. So, there may be variation of threshold value rather than 250µs for some cases. But for most of the cases the threshold is 250µs.

5.3 Output of the Hybrid model

For male subject the different situations can be shown below:

Figure 5.3(A): High R with high GSR and buzzer off(male)

Figure 5.3(B): High R with low GSR and buzzer off(male)

Figure 5.3(C): Low R with high GSR and buzzer off (male)

Figure 5.3(D): Low R with low GSR and buzzer on(male)

Using hybrid-based drowsiness detection system we get the most accurate result about the persons state of active or sleepy, as we combine both the digital result of image processing and GSR value through an AND gate, which result only when both the inputs are 1 in digital. The buzzer will on only when both the result shows the subject to be in sleepy state.

- Figure 4.3(A) represents active state of male subject i.e. buzzer is off when both the values R and GSR shows active.
- Figure 4.3(B) represents active state of male subject with R shows sleepy and GSR shows active.
- Figure 4.3(C) represents active state of male subject with R shows active and GSR shows sleepy.
- Figure 4.3(D) represent the sleepy state of male subject with both the values R and GSR shows sleepy.

For female subject the different situations can be shown below:

Figure 5.4(A): High R with high GSR and buzzer off(female)

Figure 5.4(B): High R with low GSR and buzzer off(female)

Figure 5.4(C): Low R with high GSR and buzzer off(female)

Figure 5.4(D): Low R with low GSR and buzzer on(female)

We can see that the threshold values are different for male and female as females displayed greater phasic reactivity (GSR magnitude) and a larger number of nonspecific GSRs.

CHAPTER 6: CONCLUSION

CONCLUSION

Drowsiness detection is vital to save precious human life and monetary losses. From this Drowsiness Detection System, we get an accurate result about the driver's conditions active or drowsy. Our proposed hybrid drowsiness detection model using multiple measures to detect driver drowsiness in all conditions that also reduces the false positive rate. No distinct measures can ensure accuracy. Each measure has limitations in different contexts and is ineffective in detecting drowsiness. These limitations can be eliminated by combining two or more measures to detect driver drowsiness and making the system work under all conditions. Additionally, the proposed hybrid model is also cost-effective and easy to implement. The efficacy of the proposed model may be improved by integrating other sensors, such as the PPG, pulse rate sensor and IR-UWB radar.

We conclude by emphasizing that DDD technology has enormous market potential. Many car manufacturers, such as Toyota and Nissan, have recently installed or upgraded driver assistance devices in their products. The artificial intelligence and deep learning fields are developing tremendously. Soon, the DDD systems will most likely evolve, enabling the formation of smart cities.

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