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IoT Based Smart Alert System for Driver Drowsiness Detection

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A B S T R A C T

More and more vocations today demand long-term focus. Drivers need to pay full attention to the road so they can respond quickly to unexpected incidents. Many road incidents frequently have driver weariness as a primary contributing factor. As a result, methods that can identify and alert drivers of their poor psychophysical condition are needed, which might greatly minimize the occurrence of incidents involving exhaustion. However, there are numerous challenges in the development of such systems that are related to the quick and accurate identification of a driver's fatigue symptoms. The deployment of a vision-based method is one among many of the technical options for enacting driver drowsiness detection systems. The systems used to detect driver drowsiness are discussed in this article. By assessing the driver's vision system, we can here identify tiredness. The IoT module sends a warning message together with collision impact and location information when the driver's weariness is recognized, notifying by an alarm sound over the monitoring system.

Keywords: Drowsiness Detection System, NodeMCU, Crash Sensor, GPS Module, Facial Landmark Algorithm, Eye Aspect Ratio (EAR), OpenCV, Dlib.

1. Introduction

Numerous accidents have been caused by tired drivers, tiresome road conditions, and unfavorable weather conditions. The National Highway Traffic Safety Administration (NHTSA) and World Health Organization (WHO) estimate that 1.35 million individuals worldwide lose their lives in car accidents each year. In general, poor driving practices are the main cause of traffic accidents. These scenarios occur when a driver is intoxicated or sleepy. The maximum type of fatal accidents has driver fatigue as a major contributing element.

Drivers lose control of their vehicles when they nod off. Using cutting-edge technology, smart or intelligent vehicle systems must be designed. The method used in this project warns the driver if he is falling asleep or daydreaming. In a behavioral-based approach, a webcam tracks the driver's eye blinking, eye closure, facial detection, head posture, etc. using a face landmark algorithm and Euclidean distance. These traits make it easier to detect driver fatigue, inform him right away by voice speaker, and send an alert to the vehicle owner who can awake him. IoT modules, which rely on wireless transmission, are used to send alerts to their destinations.

However, the proposed system incorporates an open-source development kit known as NodeMCU and a webcam that can track eye movements in order to monitor the intensity of collision effects that occur at the time of an accident and provide GPS location in case of collision.

2. Literature Review

2.1 Drivers' attention detection: a systematic literature review.

Countless traffic accidents often occur because of the inattention of the drivers. Many factors can contribute to distractions while driving, since objects or events to physiological conditions, as drowsiness and fatigue, do not allow the driver to stay attentive. The technological progress allowed the development and application of many solutions to detect the attention in real situations, promoting the interest of the scientific community in these last years. Commonly, these solutions identify the lack of attention and alert the driver, in order to help her/him to recover the attention, avoiding serious accidents and preserving lives. This work presents a Systematic Literature Review (SLR) of the methods and criteria used to detect attention of drivers at the wheel, focusing on those methods based on images. As results, 50 studies were selected from the literature on drivers' attention detection, in which 22 contain solutions in the desired context. The results of SLR can be used as a resource in the preparation of new research projects in drivers' attention detection.

2.2 Sensor and Sensor Fusion Technology in Autonomous Vehicles: A Review.

With the significant advancement of sensor and communication technology and the reliable application of obstacle detection techniques and algorithms, automated driving is becoming a pivotal technology that can revolutionize the future of transportation and mobility. Sensors are fundamental to the perception of vehicle surroundings in an automated driving system, and the use and performance of multiple integrated sensors can directly determine the safety and feasibility of automated driving vehicles. Sensor calibration is the foundation block of any autonomous system and its constituent sensors and must be performed correctly before sensor fusion and obstacle detection processes may be implemented. This paper evaluates the capabilities and the technical performance of sensors which are commonly employed in autonomous vehicles, primarily focusing on a large selection of vision cameras, LiDAR sensors, and radar sensors and the various conditions in which such sensors may operate in practice. The authors present an overview of the three primary categories of sensor calibration and review existing open-source calibration packages for multi-sensor calibration and their compatibility with numerous commercial sensors. They also summarize the three main approaches to sensor fusion and review current state-of-the-art multi-sensor fusion techniques and algorithms for object detection in autonomous driving applications. The current paper, therefore, provides an end-to-end review of the hardware and software methods required for sensor fusion object detection. The authors conclude by highlighting some of the challenges in the sensor fusion field and propose possible future research directions for automated driving systems.

2.3 Fundamental Concepts of Driver Drowsiness Detection.

According to the authors of this publication, the biggest difficulty with modern technology is to rapidly identify the driver's tiredness; otherwise, a dangerous road collision is always a possibility. As a result, establishing a new method to cope with such an unfortunate catastrophe and its aftermath becomes necessary. The goal of this research is to create a pattern for a sleepiness recognition system that aids in the widespread prevention of traffic accidents.

The technology measures the driver's level of weariness while they are operating the car. It uses online and in-vehicle categorisation systems. Many bio-behavioural characteristics, including the face, eyes, heart, reaction time in the head, etc., are employed in categories, and information is recorded and exploited. Many researchers today have created driving assistance systems that can gauge a motorist's level of weariness. To discover the driver's inattention, a variety of methodologies are applied, with the major focus being on the driver's level of weariness**.**

2.4 Driver Drowsiness Detection Methods: A Comprehensive survey.

Drowsy driving is one of the main causes for accidents on roads which leads to death. So, detection of fatigue of the driver and indicating it is an active research area. Most of the traditional methods followed either physiological, vehicle or behavioral based methods for drowsiness detection techniques. It is observed that some methods require sensors which are expensive while others are intrusive to the driver which distract the driving. Therefore, a real time driver’s drowsiness detection system with low cost and high accuracy is an essential need. This paper presents different traditional methods used in drowsiness detection for over a decade. This study analyses different machine learning methods in drowsiness detection. It also reviews related studies in the period between 2008 and 2018 focusing on different methods used including latest machine learning techniques.

2.5 Real time sleep/drowsiness detection.

The major goal of this research is to create a non-intrusive system that can recognise human weariness and send an alert when it occurs. Long-distance drivers who do not take frequent rests have a greater risk of becoming sleepy, a condition that they frequently fail to identify in time. According to the expert's studies, drowsy driving causes more traffic accidents than drunk driving, with almost one-fourth of all serious motorway accidents being caused by sleepy drivers who need to rest. The technology will use a camera to track the driver's eyes, and by creating an algorithm, we can identify signs of driver fatigue early enough to prevent the individual from falling asleep. So, this project will aid in anticipating driver weariness and provide warning output in the form of alert and pop-ups. Additionally, rather than being turned off automatically, the warning will be turned off manually. To accomplish this, a deactivation dialogue will be created, which will include a few straightforward mathematical operations that, when correctly completed, will turn off the alert. Also, if the driver is sleepy, it is possible that they will respond to the dialogue incorrectly. By creating a time-domain graph, we can evaluate this. A Warning signal is issued in the form of text and sound if all three input variables point to the likelihood of weariness simultaneously. This will immediately indicate drowsiness or exhaustion and serve as a record of the driver's performance.

2.6 Facial landmarks, real-time detection with dlib, OpenCV, and Python; Detect eyes and other facial features & Eye blink detection.

This paper presents a blink detector implementation utilising OpenCV, Python, and dlib. To locate the eyes in a particular frame from a video stream, facial landmark detection is the first stage in creating a blink detector. After we know the face landmarks for both eyes, we can compute the eye aspect ratio for each eye, which provides us a single value that connects the vertical and horizontal landmark distances for the eyes. Once we know the eye aspect ratio, we can threshold it to see if someone is blinking. The eye aspect ratio will be roughly constant when the eyes are open, quickly decrease during a blink, then rise again when the eye opens.

2.7 Eye tracking based driver fatigue monitoring and warning system.

The major goal of this research is to create a non-intrusive system that can recognise driver weariness and deliver a prompt warning because driver fatigue is a major factor in many traffic incidents. As a result, this approach will help avoid numerous accidents, which will save money and lessen personal suffering. With the help of a camera, this system will keep track on the driver's eyes, and by creating an algorithm, we can identify signs of driver drowsiness early enough to prevent accidents. So, this project will be useful in anticipating driver fatigue and will provide warning output information by sound and seat belt vibration, whose frequency will range from 100 to 300 Hzs. Additionally, if the driver is feeling sleepy, there is a chance of sudden acceleration or deceleration. We can determine this by plotting a time-domain graph, and when all three input variables indicate that the driver may be feeling tired at once, a warning signal is displayed in the form of text or a red circle. This will immediately indicate drowsiness or exhaustion, which can then be used as a record of the driver's performance.

2.8 Review of on-road driver fatigue monitoring devices.

We are becoming more and more aware that driving while fatigued may be a factor in a sizable number of crashes on NSW roadways. According to current statistics, fatigue is thought to be a significant contributing factor in about 20% of fatal fatalities on NSW roads, but experts agree that this figure likely underestimates the impact of fatigue because many accidents with other causes may also have fatigue as a contributing element. The creation of tiredness detection tools has gained popularity over the past ten years, and some automakers are now integrating tools in their vehicles that are promoted as fatigue warning systems (e.g., Citroen). A variety of methods are being used to combat the issue of fatigue detection. This paper provides a concise summary of the research on tiredness monitoring systems and discusses their potential utility in reducing driver weariness.

2.9 New Automotive Electronics Technologies.

Nowadays, a growing variety of professions demand long-term focus. Drivers need to be aware of the road so they can react quickly to unforeseen events. Certain auto incidents frequently have driver fatigue as the immediate cause. In order to reduce the number of accidents involving fatigue, it is necessary to develop the frameworks that will recognise and alert drivers to their terrible psychophysical conditions. Yet, there are many obstacles to the development of such frameworks that are related to the prompt and suitable identification of a driver's weakening effects. Adapting the vision-based approach is one of the technical options for implementing driver sleepiness detection systems. The systems used to detect driver drowsiness are discussed in this article. By assessing the driver's vision system, we can here identify tiredness.

2.10 Driver Alertness Monitoring Using Fusion of Facial Features and Bio-Signals.

One of the main contributing causes of traffic accidents that happen everywhere is driver intoxication. The system described in this research uses two independent techniques—eye movement monitoring and bio-signal processing—to analyse data on fatigue and monitor driver safety. A monitoring system is built into Android-based smartphones, which uses a wireless sensor network to collect sensory data and further process it to determine the driver's current level of driving skill. In order to assess the behaviour of the driver in a way that is more realistically, it is essential that several sensors be combined and timed. A video sensor and a bio-signal sensor have been used to collect the driver's photoplethysmography signal and image, respectively. The framework for evaluating driver weariness is a dynamic Bayesian network. If a certain level of driver weariness is thought to have been reached, a warning alarm is activated. The system's extensive testing proves the usefulness of various aspects, especially when combined with discrete approaches, and their integration makes fatigue detection more accurate and comprehensive.

2.11 Development of a Drowsiness Warning System based on the Fuzzy Logic.

In this paper, the authors stress on the fact that driving assistance systems, including automotive navigation systems, are becoming more popular in modern times and help drivers in a variety of ways. The ability to gauge the driver's level of consciousness is crucial for driving support systems. In particular, drowsy driving collisions may be avoided if drivers' tiredness was detected. In this research, we discuss a system and a technique for detecting driver drowsiness that makes use of fuzzy logic and image processing.

3. Methodology

3.1 Existing Methodology

The existing system uses eye or facial movements, deep learning, heart rate variability (HRV), steering-wheel grip pressure, vehicle steering movement, etc. to calculate the driver's level of weariness.

- The various deep learning algorithms such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Convolutional Recurrent Neural Networks (CRNNs), Deep Belief Networks (DBNs), etc., are used for face and eye detection to monitor a driver's drowsiness.

- A hardware device has been designed to collect and process variables such as heart rate variability (HRV), steering-wheel grip pressure, and temperature differences between the inside and outside of the car, and an algorithm has been created to find beats and compute the HRV while accounting for the other previously mentioned factors.
- Vehicle steering movement technique primarily uses steering input from electric power steering system. Monitoring a driver this way only works as long as a driver actually steers a vehicle actively instead of using an automatic lane-keeping system.

3.2 Demerits of Existing System

The main demerits of the existing system are:

- The existing system relies on the active participation and cooperation of the driver to provide accurate measurements. For example, monitoring the driver's level of weariness through steering wheel grip pressure or vehicle steering movement is contingent upon the driver actively engaging with the steering input. This limitation can lead to inaccurate or incomplete data if the driver is using an automatic lane-keeping system or not actively steering the vehicle.
- While the existing system incorporates various data sources such as facial and eye movements, HRV, steering-wheel grip pressure, and temperature differences, it may still have limitations in capturing a comprehensive understanding of the driver's level of weariness. It does not account for factors such as cognitive load, external distractions, or emotional state, which can also contribute to driver fatigue or inattention.
- The hardware device designed to collect and process variables like HRV, grip pressure, and temperature differences may add complexity and cost to the system. Integration and installation of the hardware device in vehicles may require additional effort and resources, potentially limiting its scalability and widespread adoption.
- While deep learning algorithms, such as CNNs, RNNs, CRNNs, and DBNs, can effectively detect facial and eye movements, they often require large amounts of labeled training data and computational resources for training and inference. This can pose challenges in terms of data collection, model training, and real-time performance, especially in resource-constrained environments or devices.

3.3 Proposed Methodology

3.3.1 Drowsiness Detection

The image analysis techniques have been greatly accepted and applied. In the proposed method, A Web camera is for taking consecutive facial images of the driver. It then uses program which is written in python code to detect the position of eyes based on the images taken. The algorithm for this system is as shown below:

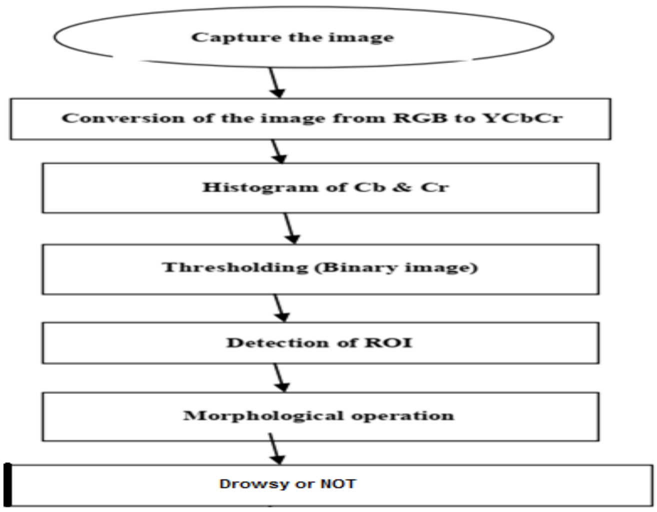

Figure 1 Flow Diagram

3.3.1.1 Image Processing for the Detection of the Eye

This section explains the various steps involved in the detection of ROI implementing the image processing.

1. Capturing the Image

An image which taken inside a vehicle includes the driver driver's face. Typically, a camera takes images within the RGB model (Red, Green and Blue). However, the RGB model includes brightness in addition to the colours. When it comes to human's eyes, different brightness for the same colour means different colour. When analysing a human face, RGB model is very sensitive in image brightness. Therefore, to remove the brightness from the images is second step. We use the YCbCr space since it is widely used in video compression standards. Since the skin-tone colour depends on luminance, we nonlinearly transform the YCbCr colour space to make the skin cluster luma-independent. This also enables robust detection of dark and light skin tone colours. The main advantage of converting the image to the YCbCr domain is that influence of luminosity can be removed during our image processing. In the RGB domain, each component of the picture (red, green and blue) has a different brightness. However, in the YCbCr domain all information about the brightness is given by the Y component, since the Cb (blue) and Cr (red) components are independent from the luminosity. The following conversions are used to segment the RGB image into Y, Cb and Cr components:

Cr=0.439 *R-0.368*G-0.071*B+ 128

Cb=0.148*R- 0.291*G- 0.439*B+128

2. Binary Image Processing and Segmentation of the Image

The Cb and Cr components provide a good indication of whether a pixel is part of the skin or not. To reject regions in the image that are not faces, the next step is to use binary image processing to create clearer delineations in these regions. The algorithm has been implemented in Python. Faces can be distinguished by applying maximum and minimum threshold values for both the Cb and Cr components. The thresholds chosen based on the histograms are as follows: 130 <= Cr <= 155 and 159 <= Cb <= 230. Narrowing down these thresholds increases the probability that the accepted pixels are part of the skin. Based on the Cb and Cr thresholding, a resulting black and white "mask" is obtained.

3. Eye Region Detection

Since we are focusing solely on the face area, we can identify the region of interest as the area encompassing the eyes. To facilitate this, we divide the face into four quadrants, with the upper two quadrants containing the eye region. Given that eye blinking typically occurs simultaneously, we can assume that the right eye will be situated in the upper left-hand side of the face. Consequently, our calculations will be based on detecting just one eye. By employing these assumptions, the search for the eye will be confined to this limited area, thereby enhancing search efficiency. The computer vision system, developed with the assistance of OpenCV, is capable of automatically detecting driver drowsiness in real-time video streams and activating an alarm if the driver appears to be drowsy.

3.3.1.2 Algorithm

- We utilized a pre trained frontal face detector from Dlib's library which is based on a modification to the Histogram of Oriented Gradients in combination with Linear SVM for classification.
- The pre-trained facial landmark detector inside the dlib library is used to estimate the location of 68 (x, y)-coordinates that map to facial structures on the face. The indexes of the 68 coordinates can be visualized on the image below.

Figure 2 Face Landmarks

- These annotations are part of the 68 point iBUG 300-W dataset which the dlib facial landmark predictor was trained on.
- We then calculate the aspect ratio to check whether eyes are opened or closed.
- Each eye is represented by 6 (x, y)-coordinates, starting at the left-corner of the eye (as if you were looking at the person), and then working clockwise around the remainder of the region.

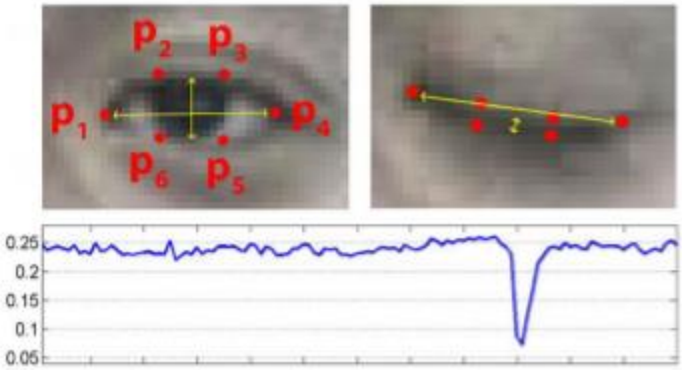

Figure 3 Six facial landmarks associated with the eye

- There is a relation between the width and the height of these coordinates.
- An equation reflects this relation called the eye aspect ratio (EAR).

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

Figure 4 The eye aspect ratio equation

- The numerator of this equation computes the distance between the vertical eye landmarks while the denominator computes the distance between horizontal eye landmarks, weighting the denominator appropriately since there is only one set of horizontal points but two sets of vertical points.
- The eye aspect ratio is approximately constant while the eye is open, but will rapidly fall to zero when a blink is taking place.
- Using this simple equation, we can avoid image processing techniques and simply rely on the ratio of eye landmark distances to determine if a person is blinking.
- To make this more clear, we consider the following figure.

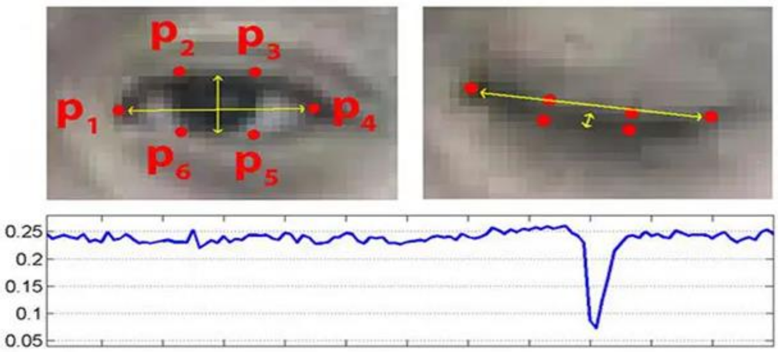

Figure 5 Eye Measurements

- On the top-left we have an eye that is fully open — the eye aspect ratio here would be large(r) and relatively constant over time.
- However, once the person blinks (top-right) the eye aspect ratio decreases dramatically, approaching zero.
- The bottom figure plots a graph of the eye aspect ratio over time for a video clip. As we can see, the eye aspect ratio is constant, then rapidly drops close to zero, then increases again, indicating a single blink has taken place.
- A blink is supposed to last 100-200 milliseconds.
- A drowsy blink would last for 800-900 milliseconds.

3.3.2 Collision Detection

The proposed system also includes a collision detection system. In case a collision is detected our system is able to send the coordinates of the accident location via an application called ‘Blynk IoT’, which is an IoT platform for iOS or Android smartphones that is used to control NodeMCU via the Internet. The following components have been used in our system:

1. **NodeMCU:** NodeMCU is an open-source development board based on the ESP8266 microcontroller. It features built-in Wi-Fi. It is widely used for IoT projects and prototyping due to its low cost, ease of use, and versatility. Here are the specifications of the NodeMCU board:
    - Operating Voltage: 3.3V
    - Digital I/O Pins: 16
    - Analog Input Pins: 1
    - Clock Speed: 80 MHz
    - Flash Memory: 4 MB
    - SRAM: 64 KB
    - Wi-Fi: 802.11 b/g/n (2.4 GHz)
    - Encryption: WPA/WPA2
    - Antenna: On-board PCB antenna
    - Programming Language: Lua, Arduino IDE, MicroPython
2. **GPS6MV2 Module:** The GPS6MV2 module is a small, low-cost GPS module that provides accurate positioning information using the Global Positioning System (GPS). It is commonly used in a variety of applications, including navigation, tracking, and geolocation. The GPS6MV2 module includes a GPS receiver, antenna, and a small microcontroller that communicates with other devices over a serial interface. It can communicate with a host device such as a microcontroller or a computer using standard communication protocols such as UART or USB. The module is capable of receiving GPS signals from multiple satellites, and uses this information to calculate the device's location, altitude, speed, and time.
3. **L293D Motor Driver:** The L293D is a commonly used motor driver IC (integrated circuit) that is designed to control the direction and speed of small DC motors. It can drive up to two small DC motors simultaneously, providing bi-directional control for each motor. It can handle a maximum current of 600 mA per channel and can operate at voltages up to 36V DC. The IC also includes built-in protection features such as thermal shutdown and over-current protection. It is commonly used with microcontrollers or other control systems to provide precise control over motor speed and direction. It can be easily interfaced with a microcontroller using standard digital or PWM output pins and requires minimal external components for operation.
4. **Power Supply V1.2:** A power supply is designed to be connected to a battery. It is a DC/DC converter that converts the battery voltage to the voltage required by the IoT device. The power supply may also include overvoltage, undervoltage and overcurrent protection to prevent damage to the IoT device and battery.
5. **Lead-acid Battery:** A 12V/1.3Ah lead-acid battery is a small, rechargeable battery commonly used in a variety of applications, including backup power systems, emergency lighting, and security systems. The battery is composed of lead plates immersed in an electrolyte solution of sulfuric acid, which reacts with the lead plates to produce electrical energy. The 12V designation refers to the nominal voltage of the battery, which is typically around 12 volts when fully charged. The 1.3Ah designation refers to the battery's amp-hour (Ah) rating, which indicates the amount of charge the battery can deliver over a period of one hour. In practical terms, a 1.3Ah battery can deliver 1.3 amps of current for one hour before being fully discharged. However, the actual runtime of the battery will depend on factors such as the current draw of the device it is powering and the battery's state of charge.
6. **Crash Collision Sensor:** A crash collision sensor is a type of sensor that is specifically designed to detect and respond to high-impact collisions or crashes, typically in automotive safety systems.

All the components mentioned above have been integrated into a robocar prototype which shows a practical scenario of collision detection.

3.3.2.1 Connections

1. Connect the NodeMCU to the computer using a USB cable for programming and power.

2. Connect the GPS6MV2 module to the NodeMCU using jumper wires. Ensure you connect the appropriate pins (TX, RX) to the NodeMCU's serial communication pins.

3. Connect the L293D Motor Driver to the NodeMCU. Connect the control pins (IN1, IN2, IN3, IN4) to any available GPIO pins on the NodeMCU.

4. Connect the motor outputs (OUT1, OUT2, OUT3, OUT4) of the motor driver to the motors powering the wheels of your robocar.

5. Connect the Power Supply V1.2 to the NodeMCU and the motor driver for providing power.

6. Connect the Crash Collision Sensor to the NodeMCU. Connect the appropriate pins to any available GPIO pin.

3.4 Advantages of Proposed System

The various advantages of our proposed system are:

- No active participation of the driver is required.
- No sensors are required to be placed on the head and the body of the driver.
- No vehicle-based measures are used in our system.
- Two systems – drowsiness detection and collision detection, can be integrated into a single system.

3. Results

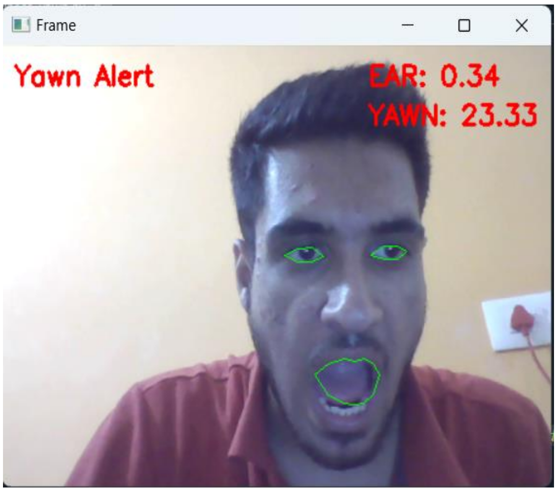

Figure 6 Yawn Alert

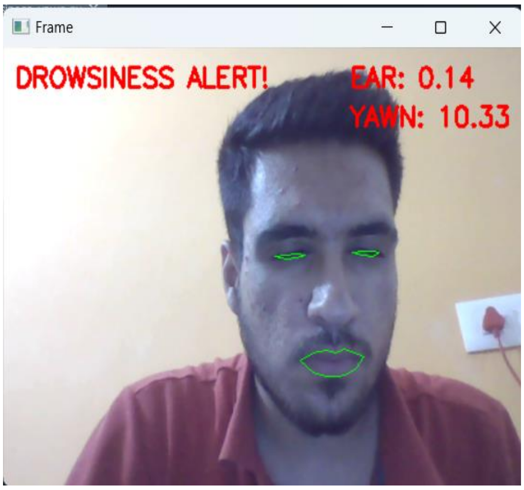

Figure 7 Drowsiness Alert

Figure 8 Alert Message

Figure 9 Location Information

4. Conclusion and Future Scope

The proposed driver abnormality monitoring system is able to quickly identify drowsy, intoxicated, and hazardous driving behaviours in drivers. The Drowsiness Detection System, which was created based on the driver's eye closure, is able to distinguish between regular eye blinking and tiredness and can identify drowsiness while driving. The proposed system here can halt the mishaps caused by drivers who are feeling sleepy. If the webcam produces better results, the system still functions well even when the driver is wearing eyeglasses and in low light. Many in-house image processing methods are used to gather information about the position of the head and eyes. The monitoring system has the ability to determine whether the eyes of the driver are open or closed. A warning signal is given when the eyes are closed for an extended period of time. Continuous eye closures are used by processing to determine the driver's level of awareness. Additionally, the impact of a collision is measured by the use of sensors and a GPS module to accurately trace the position of the accident and notify a nearby medical facility to provide emergency diagnosis.

The future scope of drowsiness alert systems is that they have the potential to significantly reduce the number of accidents caused by driver fatigue. In the future, these systems are likely to become more advanced and widespread, with the integration of additional sensors and machine learning algorithms to improve their accuracy and reliability. Additionally, there is potential for these systems to be integrated into other modes of transportation, such as trains and airplanes, to improve safety and prevent accidents caused by drowsy operators.

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