Drowsy Driver Detection with Crash Alert Mechanism using Arduino and Image Processing

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Abstract

Driver drowsiness is a major cause of automobile accidents, resulting in many fatalities each year. The use of face detection techniques for identifying and warning fatigued drivers can solve this problem and improve transportation safety. This technique detects drowsiness using computer vision technologies based on facial landmarks. Image processing is used by the system to recognize the driver's face, extract pictures of the eyes, and detect tiredness. The camera monitors the driver's eyes in real-time, processing visual data to detect symptoms of tiredness. When sleepiness is detected, an alarm sounds to wake and notify the driver. Furthermore, the system is deployed with an Arduino UNO board with GSM, GPS, and MPU 6050 models to detect and alert emergency services in the case of a car accident, as well as to notify the driver's family. Here the MPU- 6050 sensor detects angular position changes, while the NEO- 6m GPS module identifies the vehicle's location. The SIM800L GSM module delivers an SMS including the location as well as a warning message. This system could be kept in automobiles to improve driver and passenger safety and security.

Keywords: Arduino UNO, Drowsiness, GPS, GSM, Landmark, MPU-6050, SMS

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1. Introduction

A. Background

Drowsy driving is the significant contributor to fatal traffic accidents worldwide, with Nepal experiencing a notable impact. In Nepal, road traffic accidents account for 3.01% of all fatalities, and driver fatigue alone contributes to 18% of road accidents resulting in monetary losses [1]. This alarming situation has prompted the need for effective measures to tackle the issue and improve road safety.

One possible solution is implementing the system that utilizes facial landmarks with OpenCV to detect signs of driver drowsiness. By analyzing facial features like yawning and eye closure, this system can identify when a driver is becoming fatigued and at risk of falling asleep at the wheel. Real-time video processing, facilitated by a camera installed in front of the vehicle, continuously monitors the driver's level of exhaustion. In addition to detecting drowsiness, the system incorporates an alert mechanism to ensure the driver remains attentive. When momentary eye closure is detected, a siren is triggered, alerting the driver and helping to prevent potential accidents. Furthermore, the system includes a vital safety feature that sends alarm SMS messages to the driver's loved ones in the event of an accident. This functionality relies on GPS tracking to determine the driver's precise location. The system promptly relays this information to pre-determined contacts via a GSM module, ensuring that immediate assistance can be provided.

The ultimate objective of this comprehensive system is to enhance road safety and mitigate the adverse consequences of drowsy driving. By promptly detecting signs of fatigue, alerting the driver, and notifying concerned individuals in case of emergencies, this technology- driven solution strives to make roads safer for all.

B. Problem Statement

Driver drowsiness poses a significant problem, contributing to a high number of accidents. Studies show that sleepiness impairs driving performance as much as alcohol. Sleepy driving is responsible for the considerable portion of fatal accidents and hospitalizations. Nepal, in particular, faces challenges with drowsy drivers, despite government initiatives to address the issue. Existing sleepiness detection systems are either expensive and limited to high-end vehicles or affordable but lacking in robustness.

This work aims to bridge this gap by creating an accessible and affordable drowsiness detection system. The complexity of the problem lies in ensuring reliability, accuracy, and speed. This strategy involves developing a mobile, real-time, adaptive system utilizing computer vision capabilities. There is a pressing need for effective sleepiness detection solutions.

C. Objective

The main objective of this practical based research work is to detect drowsiness and provide accident alerts in real time. This can help people to prevent accidents by detecting early signs of drowsiness and sending SMS notifications to the driver's loved ones in the case of an accident.

2. Literature Review

In a study by Hong Su et al., a fusion model based on Partial Least Squares Regression (PLSR) was proposed to predict drowsiness trends. The model utilized multiple eyelid movement variables and addressed the issue of collinearity among these features. The study demonstrated the high prediction accuracy of the developed model [2]. Bin Yang et al. examined the effectiveness of eye-tracking- based fatigue prediction methods for detecting drowsiness in real driving conditions. In the study, it was found that effective sleepiness detection using eye tracking can be facilitated by accurate detection of eye blinks, emphasizing the potential of this approach for detecting sleepiness in specific individuals [3]. A. Cheng and et. al. described driver drowsiness recognition based on computer vision technology. An eye-tracking and image processing-based non-intrusive sleepiness identification approach was demonstrated. To deal with the issues brought on by variations in lighting and driving posture, a reliable eye detection algorithm is introduced [4]. Eyosiyas et al. developed a successful driver drowsiness detection method using Hidden Markov Models (HMM) and facial expression modeling [5]. Siva Reddy and Kumari developed a cost-effective method using Arduino and sensors for accident prevention. This approach effectively enhances road safety by monitoring and regulating critical factors in real-time [6]. Kinage and Patil developed a fatigue detection and accident monitoring system that uses eye-blinking sensors. It sends alert messages to the authorized user via vibration and heart-rate sensors and incorporates GPS and

GSM devices for location tracking and messaging [7]. Ma et al. developed a fatigue detection system using AdaBoost and MB-LBP [8]. In September 2022, Tata Motors introduced India’s first truck equipped with an ADAS, featuring a DMS to detect and warn drivers of drowsiness [9]. The paper highlights the importance of speed as a risk factor in driving. To address this, a GPS receiver is utilized for real-time speed information, enabling effective threat detection. This approach eliminates the need for bulky analog-to-digital converters commonly used with speedometers [10]. The latest iPhone 14 Pro Max incorporates an automatic emergency response feature that activates in the event of a severe car accident. The device immediately sounds an alarm and initiates an emergency phone call after 20 seconds, unless canceled. If the user is unconscious, the iPhone will play an audio message for emergency services, providing them with vital information such as the user’s location coordinates (latitude and longitude) and an estimated search radius [11].

3. Methodology

A. Hardware Implementation

Arduino UNO: The Arduino Uno is 32KB flash memory, 2KB SRAM, and 1KB EEPROM open-source microcontroller board. It is intended for prototyping and learning, and it has digital and analog input/output ports, PWM output, and sensor compatibility. It features a 16 MHz clock speed and can be programmed using the Arduino IDE. The board is powered by 7 to 20 volts of DC and contains a USB port for programming and communication. The Arduino UNO, which has been used in the study, is depicted in the product image on Azurefilm.com (2023) as shown in Fig.1

Figure 1. Arduino Uno. Source: Azurefilm.com (2023).

MPU 6050: The MPU-6050 is a compact module with a 6-axis accelerometer and gyroscope. It measures rotation and acceleration on three axes, enabling motion calculations. It has high accuracy and low power consumption. The module includes a Digital Motion Processor for complex calculations. Connecting it to Arduino is simple. The gyroscope measures rotation rates, the accelerometer measures linear acceleration, and the module uses a 16-bit ADC for easy data reading. The MPU-6050, which has been used in the study, is depicted in the product image on Elementzonline.com (2023) as shown in Fig.2

Figure 2. MPU-6050 Accelerometer. Source: Elementzon- line.com (2023).

Acceleration and Gyroscope*:* The MPU-6050 accelerometer measures linear acceleration along three axes (X, Y, Z) using MEMS technology. It detects motion and orientation by converting acceleration forces into electrical impulses. The MPU-6050 gyroscope measures angular velocity around three axes (X, Y, Z). It detects rotational motion by converting deflection caused by rotation into electrical signals. Both sensors provide digital values for acceleration and angular velocity, allowing for precise motion tracking and orientation determination. The block diagram of Acceleration and Gyroscope used in the study is depicted in the image on Mathworks.cn (2023) as shown in Fig.3

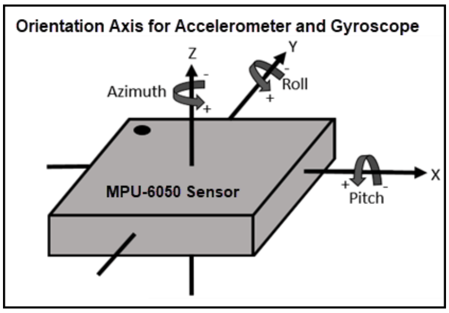

Figure 3. Block Diagram of Acceleration and Gyroscope. Source: Mathworks.cn (2023)

GPS Neo-6M: The GPS Neo-6M module is a compact, low- power receiver with precise position data. It uses a serial interface to interact with a microcontroller and tracks numerous satellites for precise placement. The module is widely seen in GPS tracking systems and requires a 3.5-5V power source. When the GSM module requests it, it calculates the vehicle's position and transmits the information to the Arduino board. The GPS Neo-6M module, used in the study, is depicted in the product image on Amazon.com (2023) as shown in Fig.4

Figure 4. Neo-6M GPS. Source: Amazon.com (2023).

GSM SIM800L: SIM800L is a versatile GSM module that enables mobile network connectivity. It controls operations like call initiation, SMS messaging, and network settings via AT commands over the UART interface. The module handles calls, communicates through voice, and works with a standard-sized SIM card. It runs at frequencies of 850MHz, 900MHz, 1800MHz, and 1900MHz and requires an external GSM antenna. The SIM800L module, used in the study, is depicted in the product image on Faranux.com (2023) as shown in Fig.5

Figure 5. GSM 800L. Source: Faranux.com (2023).

WebCam: Webcams record and transmit audio and video generated in real time. To access and process camera data in Python, OpenCV is utilized. Video frames can be taken using the ’read ()’ method once the camera has been initialized using’cv2.VideoCapture()’. This enables Python to do a variety of computer vision tasks and applications. The Webcam, used in the study, is depicted in the product image on Aliexpress.com (2023) as shown in Fig.6

Figure 6. Webcam. Source: Aliexpress.com (2023).

B. System Architecture

The system architecture as shown in Fig.7 has implemented state-of-the-art techniques to leverage drowsiness detection and crash alert functionalities. Sophisticated facial landmark detection algorithms are employed to meticulously analyze intricate facial features and dynamics, enabling the precise assessment of the driver’s alertness level. Advanced sensor technologies, including the MPU6050 for comprehensive motion tracking, GSM for seamless communication, and GPS for accurate location tracking, are integrated into the system for crash alert mechanisms. This fusion of cutting-edge components ensures real-time collision detection and immediate alert generation, resulting in a significant enhancement of driver safety.

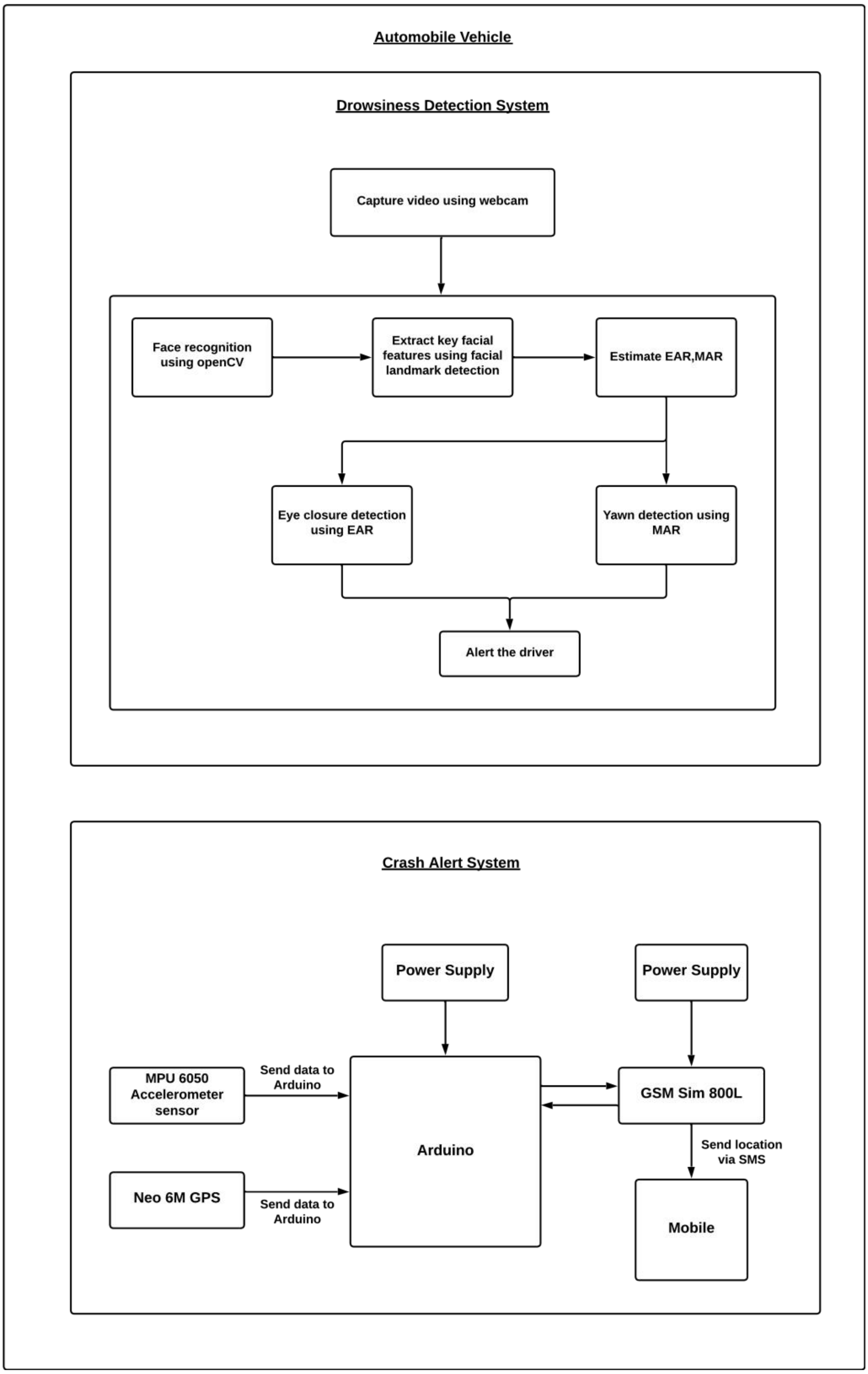

Figure 7. System Architecture of Proposed System

Principle of Drowsiness Detection: Utilizing the dlib face landmark detector in an OpenCV environment, the proposed drowsiness detection system focuses on eye closure and yawn detection.

Facial Landmarks Detection: Facial landmarks are essential for facial identification and analysis. It indicates significant spots on a person's face, allowing activities such as expression analysis and alignment to be performed. Tracking and analyzing face characteristics is possible because for accurate identification utilizing computer vision algorithms and shape prediction. Tracking particular landmarks is used in sleepiness detection, eye closure detection, and yawn detection. For accurate landmark localization, the OpenCV and dlib libraries are widely utilized. Landmarks also help face recognition systems to identify and verify people. Facial landmarks are useful in sophisticated computer vision and facial analysis. Visualizing the 68 facial Landmarks coordinates is shown in fig.8

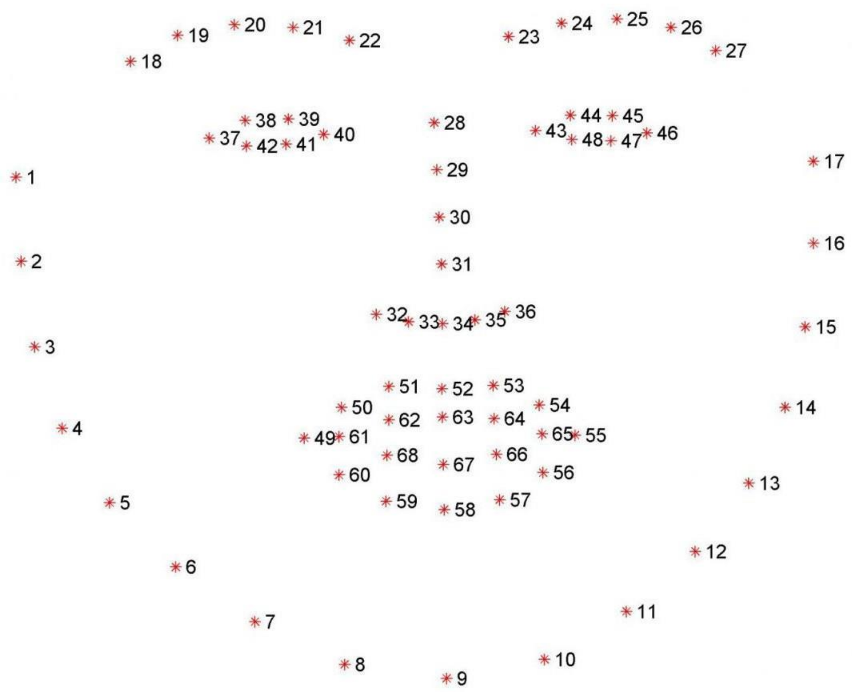

Figure 8. Visualizing the 68 facial Landmarks coordinates. Source: Pyimagesearch.com (2017)

Table 1. Facial Region with their Corresponding Landmarks Coordinates [12].

Part	**Landmark Points**
Left Eye	[37,42]
Right Eye	[43,48]
Mouth	[49,68]

Detecting facial landmarks is, therefore, a two-step process:

Step 1: Localize the face in the image.

Step 2: Detect the key facial structures on the face ROI.

Step 1: Face detection can be achieved in a number of ways. OpenCV offers various face detection methods, including Haar cascades and deep learning-based approaches. The specific algorithm used is not important; the goal is to obtain the coordinates of the detected face bounding box (x, y).

Step 2: Detect the key facial structures in the face region. Facial landmark detectors locate and label key regions on a face, including the mouth, eyebrows, eyes, nose, and jaw.

Eye Closure Detection: The system detects drowsiness by continually capturing video frames with the camera and processing them in OpenCV. It accurately locates the driver’s face and recognizes critical facial points, particularly those associated with the eyes, by employing the dlib facial landmark detector. The approach emphasizes ocular landmark indices, offering a visual depiction of eye motions. The system computes the Eye Aspect Ratio (EAR) based on six eye- related variables to measure drowsiness Based on the EAR value, the given result reflects the amount of sleepiness. When the system detects eye closure below a certain threshold, it gives a warning by sounding an alert to prevent drowsiness-related mishaps. In Eye Closure Detection using the EAR technique, the threshold levels are determined based on empirical analysis and experimentation. The threshold is set by observing the EAR values of a large dataset containing both open and closed eyes. By analyzing the distribution of EAR values, a threshold value is chosen to effectively distinguishes between open and closed eyes. This threshold value determines the point at which the eye is considered closed. The landmarks of the eye position are represented in Fig. 10 and 11

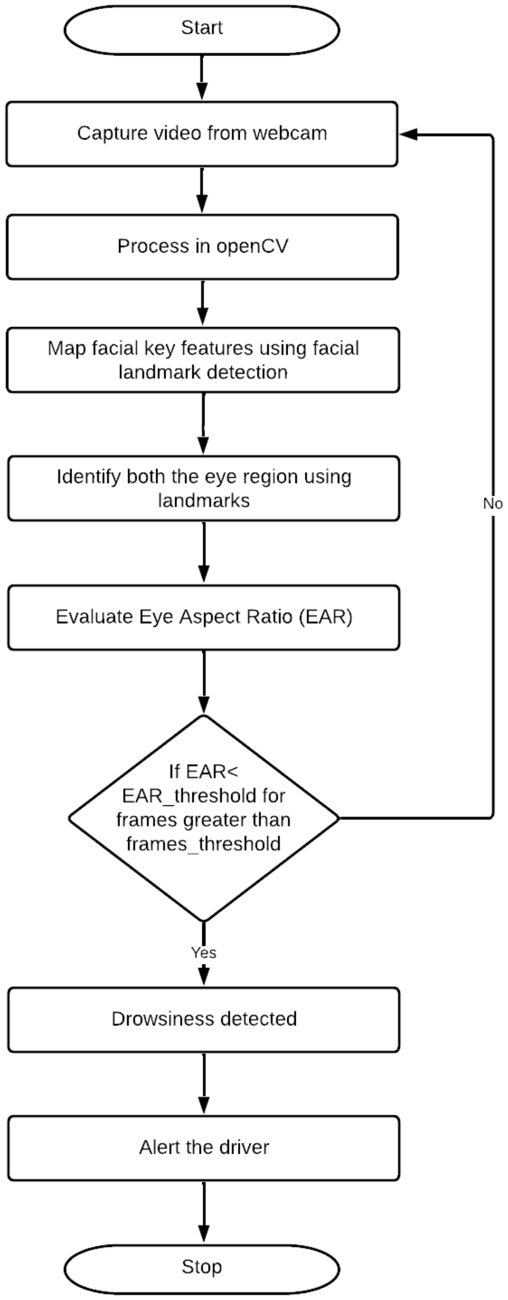

Figure 9. Process Flow of Eye Closure Detection

Eye Aspect Ratio: The EAR (Eye Aspect Ratio) computer vision technique is employed to detect and track eye movements in video recordings. It works by quantifying the distances between multiple facial landmarks, including the corners and top/bottom points of the eyes. It is calculated by dividing the vertical distance between the top and bottom landmarks of the eye by the horizontal distance between the inner and outer corner landmarks. This ratio shows the eye's relative openness or closure. By calculating ratios for each eye individually, it becomes possible to determine whether an eye is open or closed. The specific landmark indices used for the right eye are [36, 37, 38, 39, 40, 41], while the indices for the left eye are [42, 43, 44, 45, 46, 47]. Fig. 9 shows the Process Flow of Eye Closure Detection.

The formula to calculate the Eye Aspect Ratio (EAR) is given as:

$$EAR = \frac{(|P2 - P6| + |P3 - P5|)}{(2 * |P1 - P4|)} \quad (1)$$

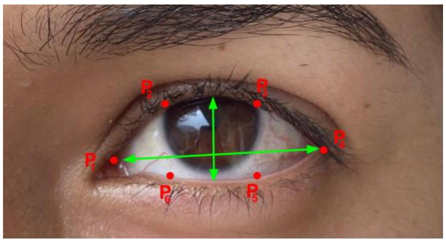

Figure 10. Landmarks When Eyes Opened

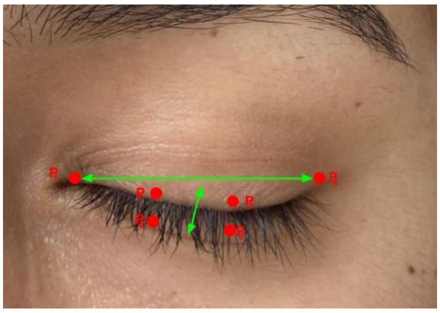

Figure 11. Landmarks When Eyes Closed

Yawn Detection: The drowsiness detection system uses a camera to record and process the driver's face in OpenCV. It employs a facial landmark detection algorithm to locate key points, including the corners of the eyes and mouth. By analyzing the mouth region, the system calculates the Mouth Aspect Ratio (MAR) to detect yawning. By using the MAR technique, the threshold level is determined through experimentation and analysis. The MAR values are observed from a dataset of yawning and non-yawning instances. By analyzing the MAR values in both cases, a threshold value is selected that effectively differentiates between a yawn and a non-yawn. When the MAR exceeds a threshold, indicating a yawn, the system activates an alert. This real-time monitoring and alerting of driver drowsiness enhances road safety by addressing fatigue-related accidents. The process flow in yawn detection is presented in Fig.13

Mouth Aspect Ratio: MAR, or Mouth Aspect Ratio, is calculated by analyzing specific landmarks or features related to the mouth. These landmarks, such as mouth corners, provide information about the shape of the mouth. MAR is determined by comparing the vertical distance of the mouth to its horizontal distance. This ratio is derived from three vertical distances and one horizontal distance. By evaluating MAR, the system can assess the characteristics of the mouth and detect patterns associated with drowsiness. Landmark Indices When Mouth is Open is depicted in fig.12

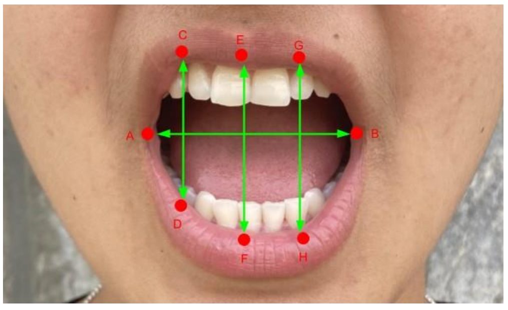

Figure 12. Landmark Indices When Mouth is Open

The formula to calculate Mouth Aspect Ratio (MAR) is given as:

$$MAR = \frac{(|CD| + |EF| + |GH|)}{(3 * |AB|)} \qquad 2$$

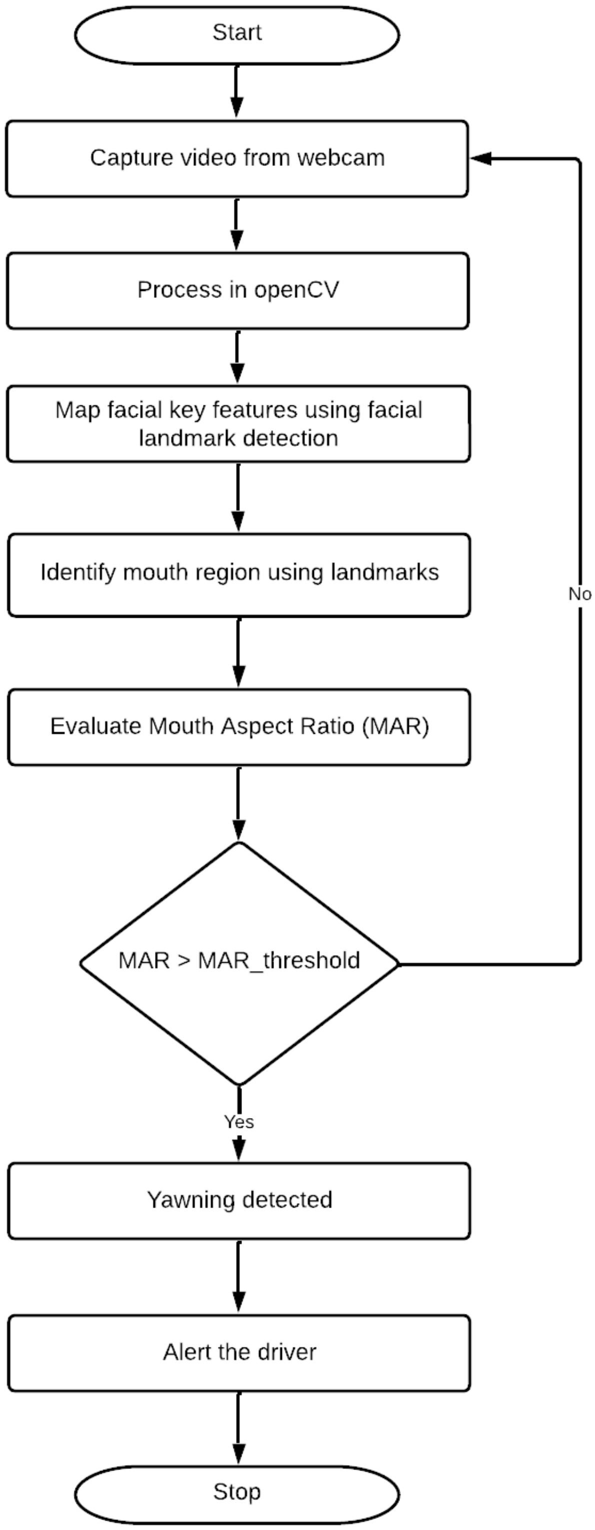

Figure 13. Process Flow of Yawn Detection

Principle of Crash Detection: The accident detection system, built with Arduino Uno, GPS, GSM, and MPU-6050 sensor, quickly identifies vehicle accidents and sends alerts for assistance. GPS tracks the vehicle's position, while GSM enables communication, and MPU-6050 detects motion and orientation. The Overview of the system is depicted in Fig ,14

Figure 14. Overview of the System

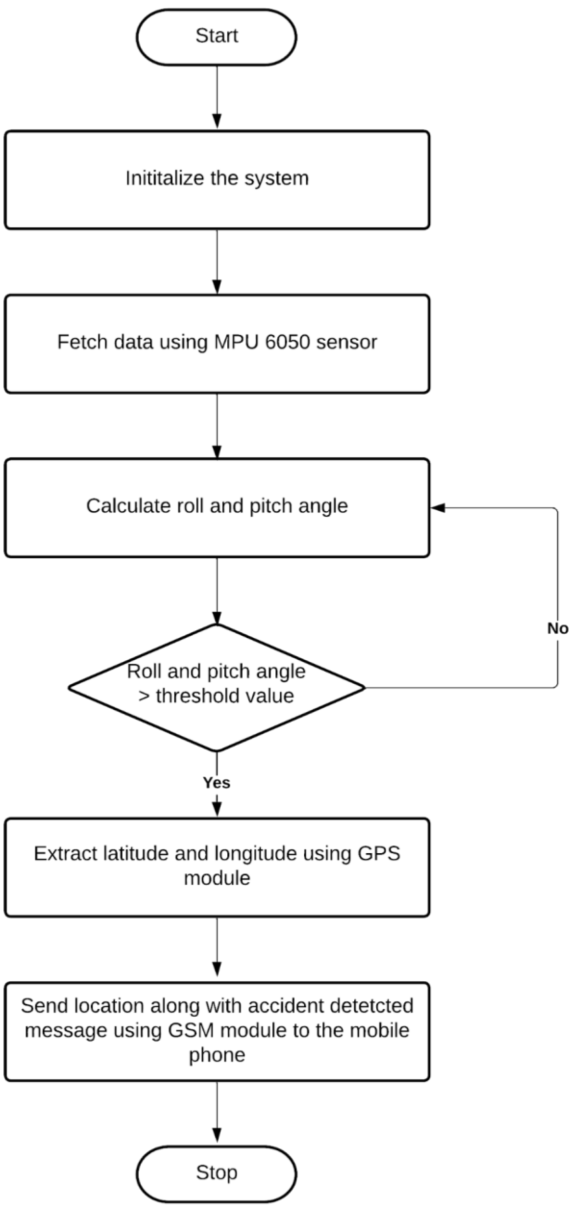

Figure 15. Crash Detection Flowchart

Acceleration and Gyroscope Detection: For the accelerometer data, calculate the acceleration in g-force units by dividing the raw data by 4096. The formula used for general calculation:

$$AccX = \frac{AccelerometerXaxisrawdata}{4096} \quad (3)$$

$$AccY = \frac{AccelerometerYaxisrawdata}{4096} \quad (4)$$

$$AccZ = \frac{AccelerometerZaxisrawdata}{4096} \quad (5)$$

For the gyroscope data, it calculates the angular rate of rotation around each axis by dividing the raw data by 65.5. The formula used for general calculation:

$$RateRoll = \frac{GyroscopeXaxisrawdata}{65.5} \quad (6)$$

$$RatePitch = \frac{GyroscopeYaxisrawdata}{65.5} \quad (7)$$

$$RateYaw = \frac{GyroscopeZaxisrawdata}{65.5} \quad (8)$$

The roll angle (AngleRoll) is calculated using the formula:

$$AngleRoll = arctan\frac{AccY}{sqrt(AccX^2 + AccZ^2)} * \frac{1}{\frac{3.142}{180}} \quad (9)$$

The pitch angle (AnglePitch) is calculated using the formula:

$$AnglePitch = arctan\frac{AccX}{sqrt(AccY^2 + AccZ^2)} * \frac{1}{\frac{3.142}{180}} \quad (10)$$

The crash detection system uses accelerometer data to monitor vehicle orientation. If the roll angle exceeds 50 degrees or falls below -50 degrees, and the pitch angle exceeds 50 degrees or falls below -50 degrees, the system triggers GPS data retrieval. Fig. 15 shows the Flowchart of Crash Detection.

GPS Location Identification: The crash warning system relies on a GPS module, such as the NEO-6M, to track the precise location of the vehicle during a crash. By receiving signals from satellites and converting them into GPS data, the module provides latitude and longitude coordinates. These coordinates are extracted by the microcontroller through NMEA parsing. When a crash is detected, the microcontroller retrieves the current latitude and longitude values from the GPS module for further processing or alerting.

GSM Mechanism: The crash alert system employs a GSM module to send an SMS containing the crash alarm and GPS position. Using AT commands, the module is configured for text mode and instructed to deliver the SMS to designated emergency contacts. The code retrieves GPS coordinates, which are included in the SMS for precise location details. By integrating the GSM module, the system ensures reliable communication and widespread coverage, enabling prompt emergency notifications regardless of the accident location.

Schematic Diagram of Crash Detection and Alert System:

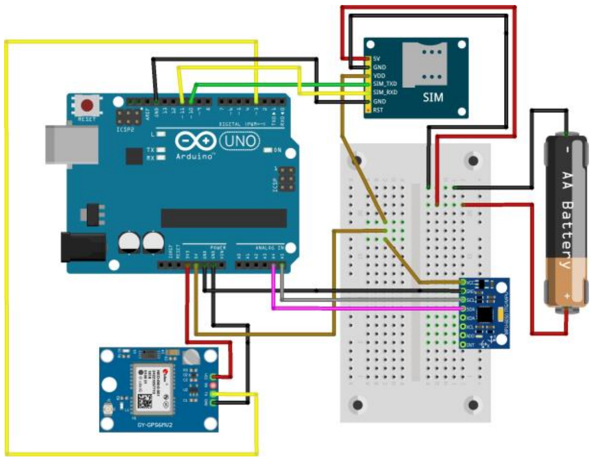

Figure 16. Schematic Diagram

The crash detection system combines the MPU-6050 motion sensor, GPS module, Arduino Uno, and GSM module. The motion sensor tracks acceleration changes, while the GPS module provides accurate location coordinates. The Arduino processes data and evaluates crash conditions. In the event of a crash, the GSM module utilizes the cellular network to promptly inform emergency contacts via SMS, including crash details and coordinates. This advanced system enables rapid response and assistance. The Fig .16 shows the schematic of the proposed crash detection and alert system.

Prototype of System: The prototype's objective is to illustrate the system's fundamental functioning and design idea. It may not perfectly reflect the appearance or characteristics of the final product, but it serves as a visual representation of the system's capabilities.

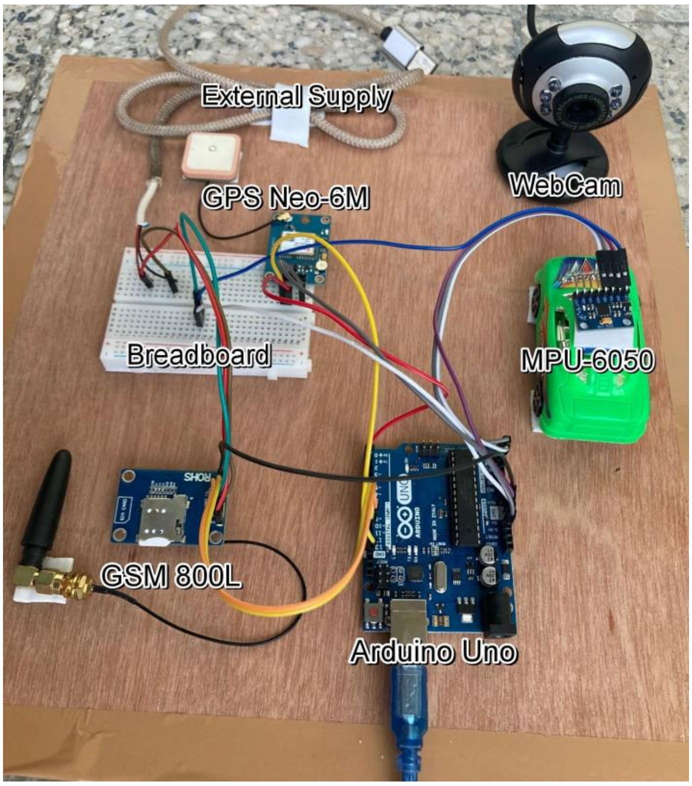

Figure 17. Prototype Design: Drowsiness Detection and Crash Alert Mechanism

The prototype of the Drowsy Driver Detection with Crash Alert Mechanism system as shown in fig.17 incorporates several essential modules. These include a camera for capturing the driver's facial features and eye movements to detect drowsiness and fatigue. The MPU6050 module combines an accelerometer and a gyroscope to analyze the vehicle's acceleration, orientation, and movement, helping to identify potential crash situations. The GPS NEO-6M module provides precise positioning information in real-time, enabling accurate crash alerts and location tracking. The GSM800L module enables communication capabilities, allowing the system to send emergency alerts and crash notifications to predefined contacts or emergency services. Acting as the central processing unit, the Arduino UNO integrates and coordinates the functionalities of these modules. It runs algorithms, processes data, and triggers appropriate alerts or actions based on detected drowsiness or crash risks. Together, these modules form a comprehensive system to enhance road safety and prevent accidents caused by driver fatigue or lapses in attention.

4. Results and Discussion

A. Result

The Drowsiness detection system utilizes facial landmark detection to identify signs of drowsiness and yawning, issuing an alert through a buzzer. The Crash alert mechanism system promptly notifies authorities in case of a vehicle crash. The system's outputs are displayed for reference.

a) Result of Drowsiness Detection System: By leveraging landmarks and threshold values for EAR and MAR, this system effectively identifies and mitigates drowsiness. It accurately detects drowsiness indicators and promptly issues alerts, reducing the dangers posed by driving while drowsy. The results observed are depicted in the figure 18 -21.

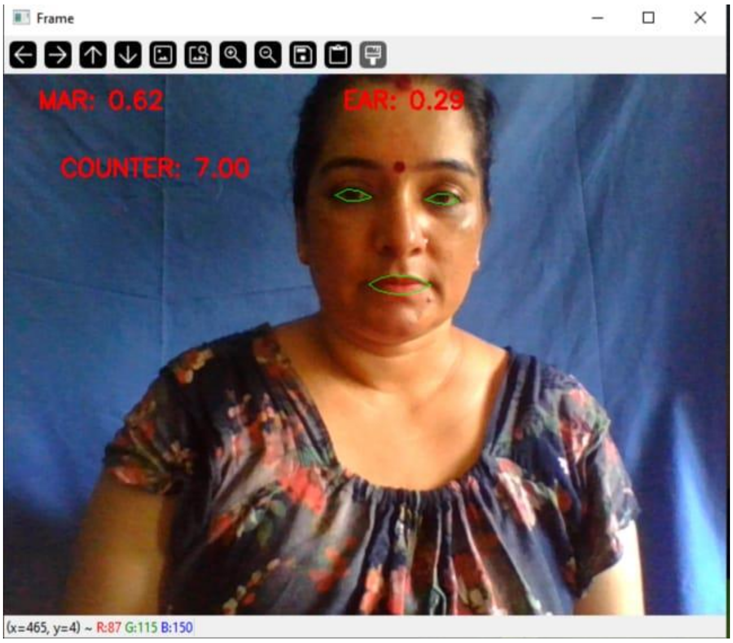

Figure 18. Output When Eyes are Opened

Eye Closure Detection Output: The Facial Landmark Detection algorithm successfully identifies 68 landmark points representing essential facial structures, as depicted in the output.

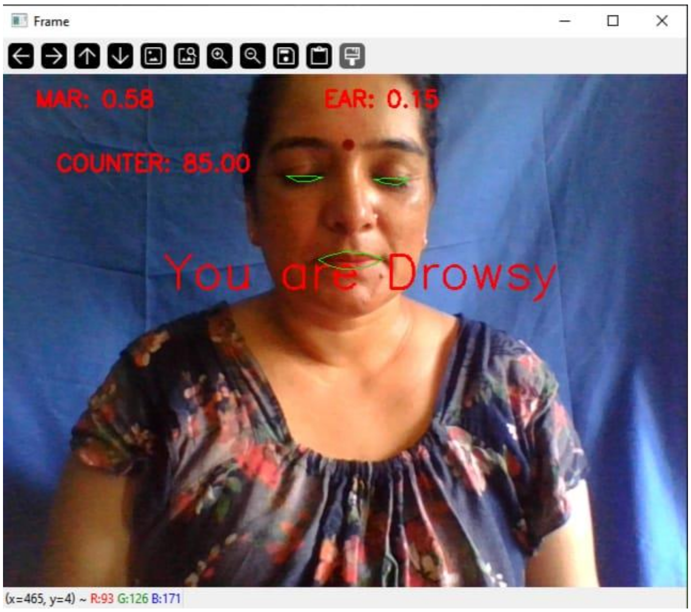

Figure 19. Output When Eyes are Closed

Drowsiness is detected when the Eye Aspect Ratio (EAR) falls below the threshold value of 0.3 and the counter value exceeds 50.

Yawn Detection Output: Yawning is detected when the Mouth Aspect Ratio (MAR) exceeds the threshold value of 0.9.

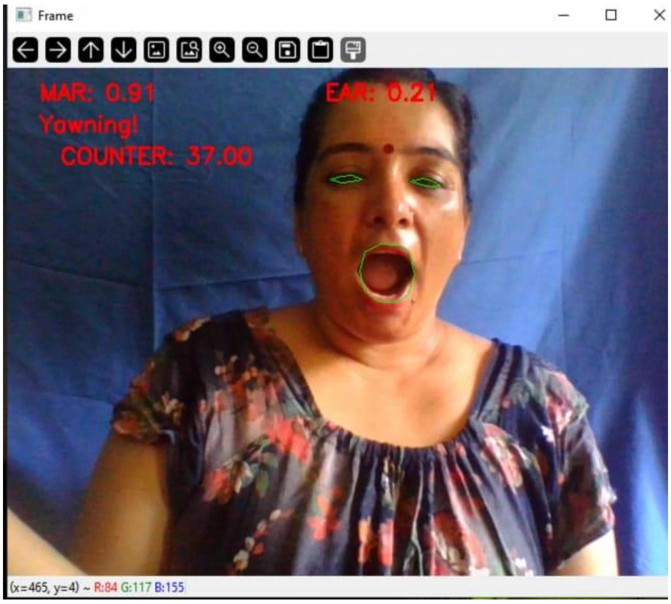

Figure 20. Output When Mouth is Opened

b) Result of Crash Alert Mechanism: The mechanism integrates MPU-6050, GPS, and GSM technologies to detect and notify authorities about vehicular crashes. By combining crash detection, location tracking, and alert generation, it provides precise information to emergency services.

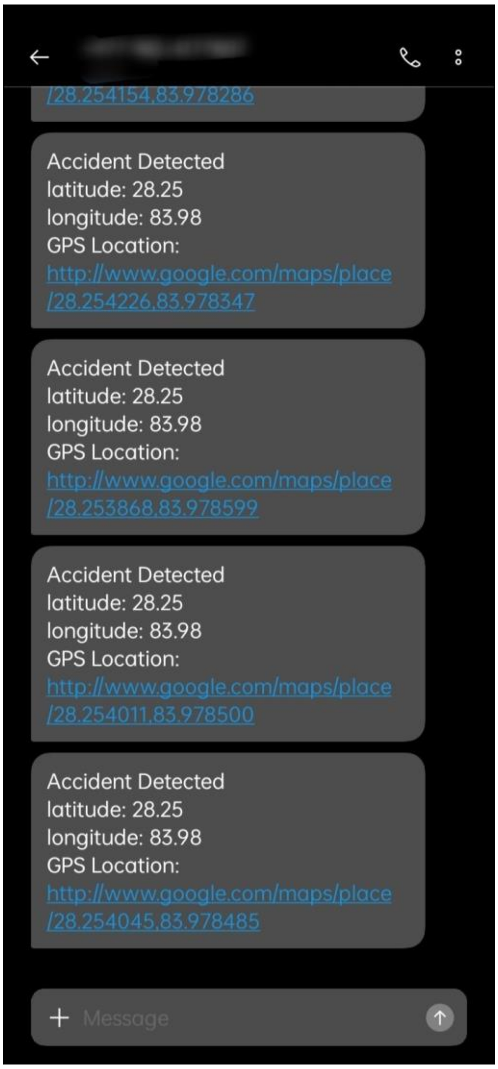

Figure 21. Crash Alert Message Sample

5. Conclusion

This research showcases the successful integration of computer vision and digital electronics to improve road safety. The Drowsiness Detection System effectively identifies signs of driver drowsiness, while the Crash Alert Mechanism swiftly notifies authorities of vehicular crashes. By implementing these systems, accidents caused by drowsy driving and collisions can be significantly reduced. Further research can explore enhancements in system efficiency and the integration of additional safety measures.

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