Enhancing Driver Safety: Deep Learning Approach for Drowsiness Detection and Accident Prevention

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Abstract

Road safety concerns have spurred the development of innovative technologies aimed at reducing accidents, particularly those caused by driver fatigue. The main scope of the driver drowsiness detection system is to minimize road accidents caused by fatigue or sleepiness of drivers. This system leverages deep learning and computer vision, employing a Raspberry Pi camera to monitor facial expressions, including yawning, to assess the driver's alertness. Upon detecting signs of drowsiness, such as prolonged eye closure or altered facial expressions, the system triggers a buzzer alert by analyzing the Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) ratios. Integrated within an embedded system, it utilizes frontal face detection algorithms and Haar cascade classifiers to localize key facial features in real-time, facilitating efficient monitoring for signs of fatigue or distraction. Additionally, it issues vibration alerts if the seat belt is not fastened. The seat belt remainder will be helpful to ensure the safety of the driver, reduces accidents and monitors the driver's heart rate, triggering a PANIC message if irregularities are detected. At traffic signals, the system automatically reduces vehicle speed using a vibration motor. In the unfortunate event of an accident, the system initiates speed reduction and promptly notifies registered contacts through the Blynk application, thereby significantly reducing accidents caused by drowsy driving.

DOI: https://doi.org/10.36548/jismac.2024.2.001
Received: 15.03.2024, received in revised form: 14.04.2024, accepted: 01.05.2024, published: 10.05.2024

Keywords: Deep learning methodology, computer vision techniques, Raspberry pi camera, yawning, facial expressions, EAR, MAR, embedded system, buzzer, frontal face detection algorithm, Haar cascade classifier, real-time monitoring, vibration alert, heartbeat sensor, panic message, vibration motor, Blynk application.

1. Introduction

Detecting driver drowsiness is a major road safety issue. Symptoms include fatigue, drowsiness, and loss of attention. Drowsiness can be caused by a variety of factors, including lack of sleep, long periods of driving, or monotonous conditions. To reduce the number of accidents, it is necessary to create a reliable driver drowsiness detection system that can warn drivers before accidents occur. Driver drowsiness detection is a technology that uses various sensors and algorithms to monitor driver behavior and detect signs of drowsiness or fatigue. Some of the most popular and effective approaches to detect driver drowsiness are computer vision and deep learning methods. Computer vision involves using cameras and image processing algorithms to capture and analyze drivers' facial features, including eye movements and facial expressions, to detect signs of drowsiness. The rapid development of artificial intelligence, especially deep learning, is causing a paradigm shift in approaches to solving complex problems in various fields. Deep learning, a subset of machine learning, has demonstrated a remarkable ability to automatically learn complex patterns and features from raw data, making it particularly suitable for tasks such as image analysis and pattern recognition. Through empirical evaluation and real-world implementation, the research aims to demonstrate the effectiveness and feasibility of the proposed system in reducing risks associated with driver drowsiness [9].

We propose an algorithm that detects, tracks, and analyzes the driver's face and eyes. Drowsiness is detected using vision-based methods, such as eye detection and yawning. If the driver falls asleep, an audible signal alerts the driver. If the driver does not wake up, the system sends a warning message about the situation to the family through the Internet of Things (IoT). Vehicle speed is automatically reduced depending on signals (school zone, stop sign). The research combines machine learning and Internet of Things (IoT) technologies to promote safe driving and reduce the number of traffic accidents caused by drowsy driving. Monitoring driver fatigue is important to prevent traffic accidents and improve road safety. When a driver is tired, they display special symptoms that are easily recognizable (yawning, closing their eyes for a relatively long period of time, shaking their head, etc.). The driver fatigue detection system is a system that automatically analyzes the driver's behavior and generates an alarm to wake the driver when the driver is tired. The driver drowsiness detection system can locate, track, and analyze the driver's face and eyes. If the driver is not wearing a seat belt, the seat will vibrate when the driver starts the engine. If an accident occurs while driving, the driver stops the car in time and sends a message to his family. Driver drowsiness monitoring systems work using image processing, pattern recognition, computer vision, and deep learning. Driver face detection method using a Raspberry Pi camera to analyze driver drowsiness while driving. Once the image is captured, the system detects yawning and eye contact and sounds an alarm. The degree of eye closure was adopted as a standard for measuring the driver's drowsiness[10].

2. Background

A. Computer Vision

Computer vision plays an important role in driver drowsiness detection systems, assessing attentiveness by analyzing the driver's facial features and behavior. The system monitors the driver's gaze to detect signs of drowsiness such as increase the blink duration or decrease the blink frequency. The system can analyze the driver's entire face for additional indicators of drowsiness. The advantage of computer vision is real-time analysis. The system continuously monitors the driver and provides warnings (sound, vibration) if drowsiness is detected.

B. Convoluted Neural Networks (CNNs)

CNNs are well-suited to image data processing, making them ideal for analyzing video streams from car cameras that track the driver's face and eye movements. CNN automatically learns hierarchical features from input images. In the context of detecting drowsiness, these signs may include eye closure, head posture, facial expressions, and blinking patterns, which are important indicators of driver fatigue. After feature extraction, the CNN can classify whether the driver is alert or sleepy based on the learned features. This classification can trigger warnings or interventions, such as alarms or seat vibrations, to alert the driver or even allow the autonomous driving system to take control.

C. Recurrent Neural Networks (RNNs)

RNNs are well-suited to sequential data processing, making them ideal for analyzing time-series data such as EEG signals, which can provide insight into the driver's cognitive state and attention level. RNNs capture temporal dependencies in data, allowing us to understand temporal changes in sleepiness-related characteristics, such as changes in eye blink patterns or head movements over time. RNNs can be combined with other modalities, such as CNNs for video data analysis or traditional machine learning algorithms for physiological signal processing, to enable multimodal fusion and improve the accuracy of drowsiness detection. It can handle input sequences of different lengths, allowing them to adapt to different driving scenarios and different durations of drowsy episodes.

D. Internet of Things (IoT)

IoT devices can integrate various sensors such as cameras, accelerometers, gyroscopes, and biometric sensors (e.g. heart rate monitors, EEG sensors) to continuously monitor driver behavior, physiological signals, and environmental conditions. IoT devices can collect sensor data in real time and wirelessly transmit it to a central processing unit or cloud server for analysis. IoT devices can trigger different types of alerts to notify drivers and relevant stakeholders when drowsiness is detected. Alerts can be delivered through auditory signals (e.g., alarms), visual signals (e.g., LED lights), haptic feedback (e.g., vibrating seats), or connected wearables (e.g., smart watches).

3. Related Works

Driver drowsiness and alcohol detection [1] The research on driver drowsiness detection contributed to the development of a system that can effectively monitor driver attentiveness in real time. These systems can reduce the number of accidents caused by drowsy driving by alerting drivers or implementing interventions when signs of fatigue are detected. Here, a sensor system is developed that can accurately measure blood alcohol concentration (BAC) or detect alcohol-induced impairment using various physiological indicators. This system can help prevent accidents caused by drunk driving by warning or disabling the vehicle when alcohol is detected. Despite advances, challenges remain in achieving consistently high accuracy in detecting drowsiness and alcohol, especially under real-world driving conditions.

Factors such as individual differences, environmental factors, and sensor noise can affect the reliability of a detection system.

Driver drowsiness detection system and techniques [2] Provide real-time monitoring, which can sound the alarm in time to prevent accidents caused by drowsy drivers. In fact, it adapts to individual differences and environmental factors. Many systems are designed to be unobtrusive, using sensors that do not obstruct the driver's view or require intrusive installation, increasing user acceptance and action tracking. Some technologies require specialized hardware (e.g. EEG sensors, infrared cameras), which can be expensive and difficult to integrate for commercial or everyday use. Sometimes the system may not detect sleep correctly, causing false alarms, or conversely, it may not detect the true state of sleep, causing security risks. Issues such as privacy, perceived access, and security vulnerabilities can impact the use of these systems in real-world environments.

Detection driver drowsiness using wireless wearable [3] Wireless wearable products provide mobility and comfort, allowing drivers to move freely without being tied to a specific place in the vehicle. This increases user acceptance and compliance with search fatigue. Electronic devices that can be integrated into smart vehicle applications or data communications to enable communication and data connectivity. Calibration and verification of sensor data is important to ensure correct performance. Securing data transfer and storage while complying with privacy laws is important for public use. Improved battery technology is needed to address this limitation. Powerful signal processing techniques are needed to reduce these effects.

An efficient approach for detecting driver drowsiness based on deep learning [4] Deep learning models improve drowsy driver detection accuracy by learning complex patterns and expressions directly from raw data, such as images or physical signals. It can learn complex patterns and representations of objects of interest. Features are learned on the device, eliminating the need for time-consuming and specialized manual feature engineering. Deep learning utilizes facial expressions, eye movements, and body movements. Improve the dynamics and realism of fatigue studies. Various modes can be integrated into a single system. Transparency, fairness, and compliance with regulations such as GDPR and HIPAA are essential for responsible service delivery.

Drowsiness detection of a driver using conventional computer vision application [5] Computer vision models can monitor a driver's behavior, such as covering their eyes, head, and face, to identify aspects related to fatigue over time. Infrared sensors become cost-effective and can be integrated into existing vehicles or driver assistance systems. Computer-based fatigue detection can be integrated with other driver services or in-car monitoring, improving safety, and performance. Traditional computer vision algorithms can have limited accuracy in detecting signs of mild fatigue, resulting in negative or poor results, especially in difficult situations such as low light or occlusion.

Driver fatigue detection using viola jones and principal component analysis [6] Viola-Jones algorithm detects eyes, mouth, nose, etc. Good at detecting facial features, provides a reliable basis for subsequent analysis in a robust and effective manner. The system can adapt to different lighting conditions, face orientation and driving characteristics to stabilize energy and achieve various fatigue detection. Viola-Jones and PCA performance can be affected by image quality, including resolution, noise and light. Poor image quality can reduce the accuracy of fatigue detection. It can also be caused by other behaviors such as driving, yawning, head nodding, or changes in attitude. Integrating additional sensor types can increase the sensitivity of fatigue detection.

Driver drowsiness detection system – an approach by machine learning application [7] Machine learning algorithms demonstrate accuracy in detecting drowsy drivers by learning patterns from different data sources, such as facial images, physiological signals, and traffic dynamics. States including facial recognition, eye movements, EEG signals, heart rate changes, and vehicle characteristics are used to capture the representation of drowsy drivers. The operation is generally non-invasive, requiring minimal installation and no contact with the driver, ensuring user comfort and assurance. Collecting data to train learning models can be difficult and time-consuming, especially for rare events such as sleep-related events. Using machine learning-based drowsiness detection systems raises ethical questions about personal data, consensus, and bias in decision-making. Transparency, honesty and compliance are essential to fulfilling the mission.

Real-time driver drowsiness detection using computer vision [8] The system can prevent accidents by detecting signs of fatigue such as eye contact, yawning, and giving timely warnings. Many machines focus on defining the geometric shapes of the eyes and mouth. The

EAR ratio calculates the distance between eye marks horizontally and vertically. It helps detect fatigue based on eye behavior. The number of accidents caused by drowsy drivers is often underestimated. Slight changes from fatigue to fatigue may not be noticed by drivers, making the impact difficult to measure. For example, a drowsy driver may show signs of sleepiness or forgetfulness even without yawning or closing their eyes. While too many alarms can cause anxiety, too many alarms can compromise security.

4. Preliminaries

A. Problem Definition

This includes specifying the target behavior to be detected (e.g., eye closure, yawning), the input data sources (e.g. Live image capturing), and the desired output (e.g., alert into driver through the buzzer and giving the message).

B. Data State Acquiring

Relevant datasets for training and evaluation purposes. This may involve recording video footage of drivers in various driving conditions, collecting physiological signals and traffic signals annotating the data with labels indicating periods of drowsiness or alertness.

C. Feature Extraction

Extracting informative features from the raw input data to represent relevant characteristics associated with drowsiness. In the case of image data, this may involve preprocessing techniques such as facial landmark detection, image cropping, and normalization to extract facial expressions and head movements.

D. Model Selection

Choosing appropriate deep learning architectures and models for the task of drowsiness detection. This may include convolutional neural networks (CNNs) for image-based tasks, recurrent neural networks (RNNs) for sequential data processing, or Machine learning for the processing different components in an application through hardware and software.

5. System Components

Raspberry pi 3 - Raspberry pi 3 is used in this system to detect the open state of eyes only. Then the algorithm counts the number of open eyes in each frame and calculates the criteria for detection of drowsiness. If the criteria are satisfied, then the driver is said to be drowsy.

Quantum QHM495 Camera – It is used in this system to detect drowsiness by capturing the facial expressions such as eyes and mouth. Another camera is mounted on the dashboard to detect the traffic signal, thereby reducing the speed of the vehicle.

Heartbeat Sensor - The working of the sensor can be divided into two parts one is heart rate measurement and another is blood oxygen level measurement. The oxygen in the hemoglobin has a specific characteristic, that it can absorb IR light. As the blood is pumped through the veins in the finger the amount of reflected light changes creating an oscillating waveform. And by measuring this wave we can get the heartbeat reading.

Buzzer – The buzzer can detect the driver's face for any signs of drowsiness and can alert them before anything harmful could happen. It will be activated if the drowsiness of the driver is found abnormal.

IR Sensor – IR sensor detects whether the seat belt buckle is inserted and if obstacle has been detected the vibration will be stopped.

Vibration Motor - After the engine starts and once the driver has fastened their seat belt, if the seat belt, then becomes unfastened, the system alerts the driver by generating a seat belt vibration.

Buck Convertor – A buck converter is used to step down voltage of the given input in order to achieve required output.

DC Motor – Speed controlling is done with the help of DC motor. If the vehicle reaches the school zone or stop signal the DC motor helps to reduce the speed of the vehicle.

Node MCU – It is an extensively employed development board in IoT applications, providing a versatile and cost-effective approach to connect devices to the internet. It features Wi-Fi and programming capabilities, facilitating speedy prototyping and deployment of IoT solutions.

Mechanical End Switch - The sensor is used to analyze the accident quickly when a collision happens to alert the emergency services to the registered contacts through Blynk application.

6. System Architecture

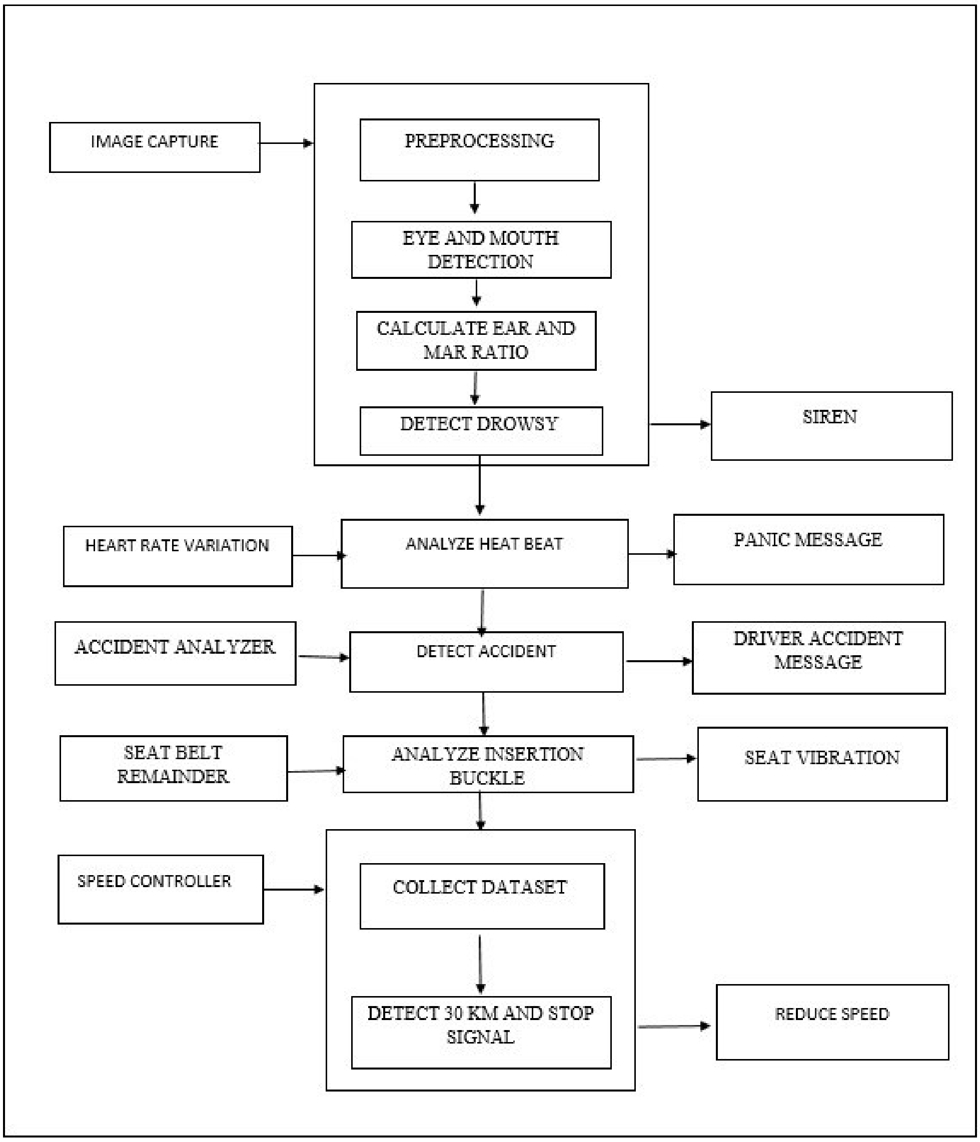

Figure 1. Architecture

1. **Face Detection and Heartbeat Sensing Module:** The features for facial landmark detection is implemented to identify the state of drowsiness and fatigue. 68- predefined facial landmarks help in shape prediction to clearly identify the various regions of the face like eyes and mouth region. By using 68-predefined landmarks on the basis of EAR and MAR, it set the values for measuring the sign of drowsy and alert the driver through buzzer. In addition, it can measure the heartbeat variation and identify if the

driver is drowsy. These are done with the help of Haar Cascade frontal face detection algorithm.

2. **Accident Analyzer:** An accident analyzing module can be used in a driver drowsiness detection system to help prevent accidents caused by drowsy driving. The module can analyze the driver's state of activeness and alert the driver before an accident occurs. Mechanical end switch is a component that used for the purpose of providing brake automatically. While accident occurred, the pressure will analyze on the basis of force accident is detected and accident message is sent to corresponding contacts through Bylnk application. Piezo sensor analyzes if the accident is occurred, message along with location is send to the registered contacts.
3. **Seat Belt Remainder:** An IR sensor positioned near the seatbelt latch detects whether the driver is buckled in. If not instead of blaring alarms, the microcontroller controlling the system sends a signal to a vibration motor that is embedded in the driver's seat. It's subtle yet effective, avoiding the annoyance of traditional reminders. An IR sensor and vibrating seat combination presents a more effective approach to seatbelt reminders.
4. **Speed Controller:** Based on the dataset (school zone and stop signals), the images are trained and annotated. When the vehicle reaches the school zone or stop signal the system analyzes and it compares with the dataset. If matches with the dataset, the speed of the vehicle is reduced. In this module, two functions are performed one is YOLO that capture the image from the dataset that analyze from different distance and angle of signals, second is MobileNet that classify the image signal from the dataset and allocate the signals to detect through camera. By this process speed controller is performed. The Figure 1 shows the proposed architecture.

7. Evaluation

Driver drowsiness detection system is crucial for road safety, aiming to prevent accidents caused by drivers falling asleep at the wheel. The system can be evaluated based on various criteria, such as accuracy, hardware requirements, and the ability to operate in real-time. They typically involve techniques like physiological signals analysis, facial features analysis, and driving patterns analysis.

The effectiveness of the system is often verified through performance metrics like accuracy, sensitivity, and precision. Recent advancements have led to the development of non-invasive systems that monitor signs of drowsiness using sensors and artificial intelligence algorithms. This system can be accessible to all four-wheel vehicles as depending on the structure of vehicle the components can be accurate on the capacity of functions.

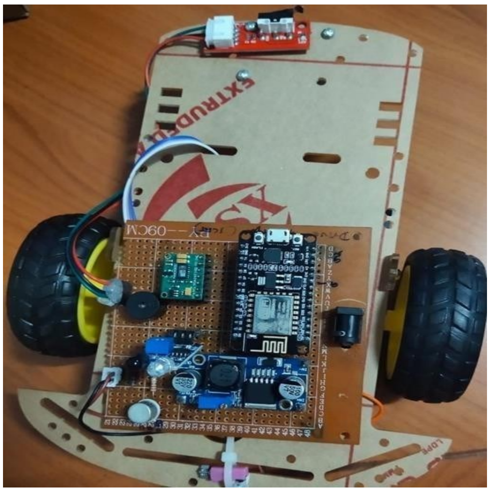

Figure 2. Robot Car Structure Model Front Portion

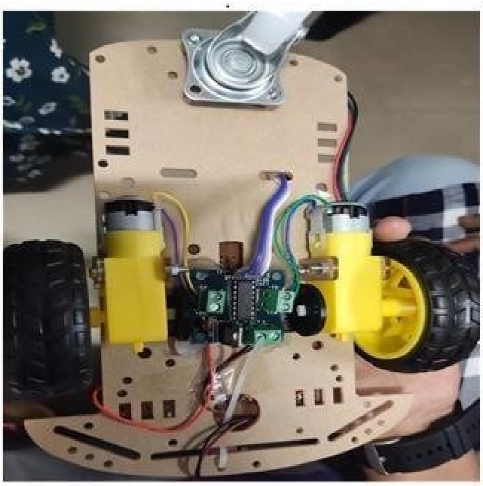

Figure 3. Robot Car Structure Model Back Portion

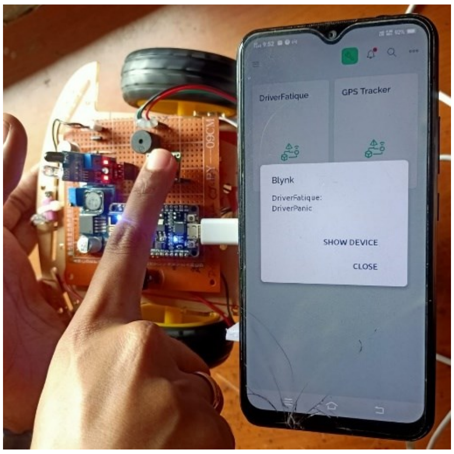

Figure 4. Driver Panic Alert

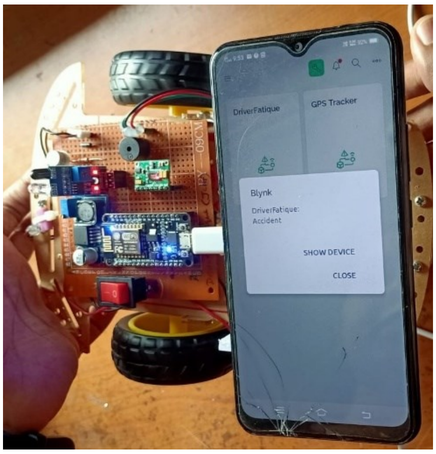

Figure 5. Driver Accident Alert

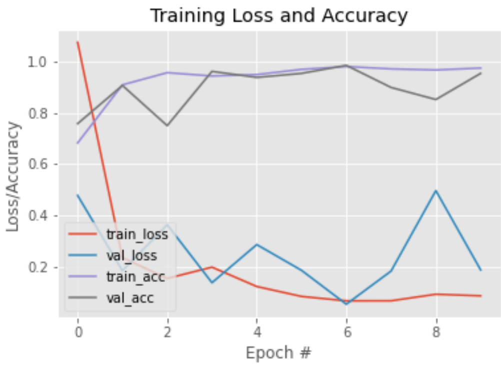

Figure 6. Data Set Analysis

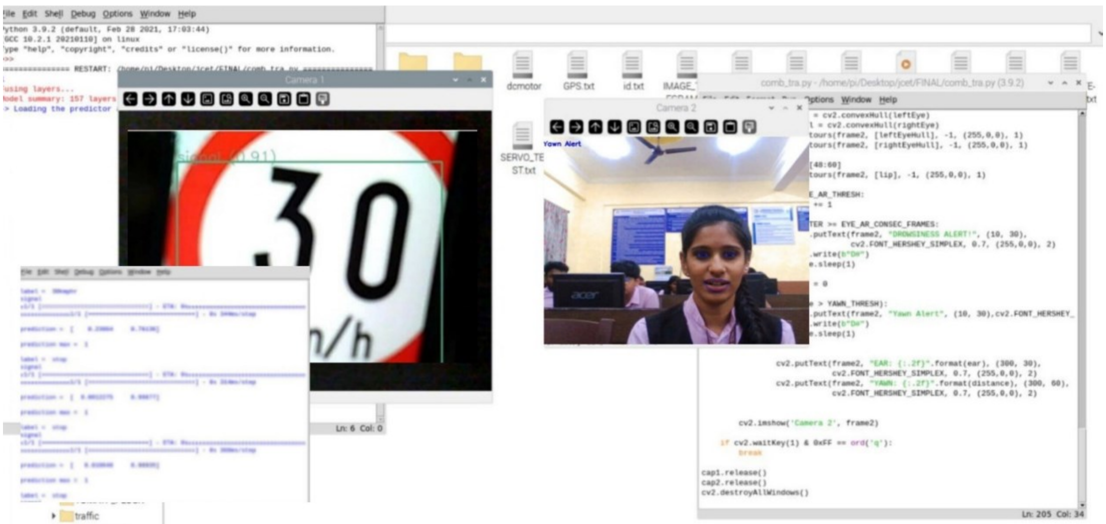

Figure 7. Yawn Alert

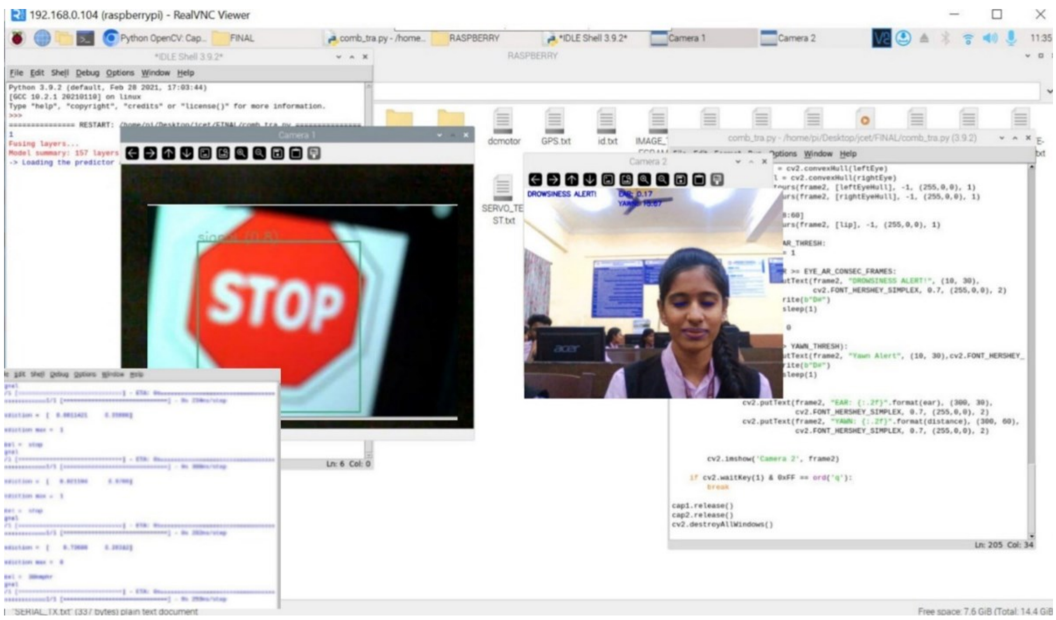

Figure 8. Drowsy Alert

The results are illustrated in Figure 2 to 8

8. Future Works

Future systems may leverage smartphones and the Internet of Things (IoT) for more accessible and widespread drowsiness detection. As autonomous driving technology advances, drowsiness detection might shift focus from preventing accidents to ensuring the comfort and well-being of the passengers. Emotion Recognition and Stress Levels extend the system to recognize emotions (e.g., stress, anxiety) through facial expressions or voice analysis. Provide real-time feedback to drivers about their emotional state and suggest relaxation techniques. This system will be provoked to 2 wheels too as per the conditions and capacity of the components.

9. Conclusion

In conclusion, developing a driver drowsiness detection system is a critical application of deep learning technology. This system aims to enhance road safety by monitoring a driver's state and issuing alerts when signs of drowsiness are detected. Different techniques have been proposed and implemented for driver drowsiness detection, each with its own advantages and limitations. Physiological signals, such as physiological signals traffic single and speed controlling can provide accurate and reliable measurements of the driver's state, but they require invasive sensors and complex signal processing. Driver drowsiness detection systems are still facing some challenges, such as the lack of standard datasets, the variability of individual drivers, the ethical and legal issues, and the user acceptance and feedback.

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