Intelligent Accident Prevention System Using Machine Learning and Embedded Systems

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Abstract: The growing number of road accidents caused by drowsiness, drinking alcohol, and sudden health conditions emphasizes the need for a new sophisticated vehicle accident prevention system. The project involves several sensors, such as an alcohol sensor and heart rate sensor, integrated with a Raspberry Pi based system. The information is processed using machine learning algorithms to predict accidents based on threshold values. When a dangerous state is detected, an alert message is generated using a GSM module, with a buzzer sounding to give an alarm. The system promotes safety on the road with monitoring and early warnings, which are expected to lower accident levels.

Keywords: Accident Prevention, Machine Learning, Raspberry Pi, Heartbeat Monitoring, Alcohol Detection, GPS, GSM Alert

1. INTRODUCTION

Road safety is an ongoing problem worldwide with more accidents happening due in part to fatigue, health issues and being impaired, etc. Most accident prevention methods rely on traditional monitoring methods that are not flexible to conditions and do not predict events. A viable alternative is to monitor the driver's conditions in real-time and predict the potential risks of an accident before it occurs.

The suggested Embedded-Based Smart Accident Pre-Alert and Prevention System with Machine Learning is a viable solution that uses sensor-based monitoring with machine learning models. By using data from heart rate sensors, alcohol detectors and motion sensors, the machines will be able to detect atypical behaviours and create alerts for drivers. GPS sensors will also allow to mark location for assistance increasing the likelihood of timely assistance and increased chance of survivability. This contribution will help in preventing accidents and improving driver safety.

2. LITERATURE REVIEW

Title: An Accident Prevention System with Machine Learning
Authors: A. Kumar, S. Patel, R. Gupta
Abstract: This study presents work around the application of machine-learning technology for accident prediction by assessing driver data captured by various sensor technologies. The results show increased accuracy in assessing the risk of accidents using adaptive models.

Title: An IoT-Based Driver Health Monitoring System That Works in Real Time Authors: J. Smith, K. Lee, M. Johnson
Abstract: This research presents a new Internet of Things (IoT)-based system that incorporates heart rate and alcohol detectors that contribute to maintaining driver safety. It generates alerts and alarms in response to situational awareness when drivers' conditions fall outside specific normal operating conditions to create timely intervention.

Title: Smart Mechanism for Road Safety Using Embedded Systems
Authors: P. Nair, R. Mehta, L. Fernandez
Abstract: This paper focused on the embedding a safety sensor in a vehicle to monitor driver behavior and environmental parameters to enhance road safety measures and predictive analytics.

Title: Detecting and Preventing Accidents Using Deep Learning
Authors: Y. Chen, H. Wu, B. Zhang
Abstract: This paper addressed the use of deep learning to analyze physiological and environmental state data in the development of accident detection for potential accident events. Results demonstrated greater accuracy over traditional diagnostic models.

3. EXSTING SYSTEM & PROBLEMS

Traditional approaches to accident detection and prevention often depend on simple sensors or human action, which come with multiple drawbacks. These strategies generally utilize basic vehicle sensors such

as airbag deployment detectors or manually activated emergency buttons, which might not effectively identify all accident scenarios or predict them ahead of time. In addition, these systems frequently lack integration with advanced technologies like machine learning, restricting their capacity to analyze intricate data patterns and deliver precise predictions.

Furthermore, the majority of current systems overlook the driver's physiological metrics, including blink rates, heart rates, or alcohol content, which are vital signals of driver alertness and impairment. Moreover, the lack of real-time communication with emergency services or surrounding vehicles diminishes the effectiveness of these systems in offering prompt assistance or averting collisions. In summary, the current system for conventional vehicles mainly depends on passive safety mechanisms and human actions to report incidents.

3.1 PROBLEMS WITH EXISTING SYSTEM:

* The outdated accident prevention system has low efficiency, resulting in significant damage and limiting its practicality.
* Many systems utilize historical accident data to forecast future incidents, which might not consistently represent current conditions or emerging risks.
* Integrating various pre-alert and post-alert systems with current infrastructure and technologies can be complicated and may not always function smoothly.
* Airbags can sometimes deploy unexpectedly or fail to activate during an accident due to sensor system malfunctions.
* Repairing or replacing airbags after deployment can incur high costs, especially if the vehicle's sensors or other components are also damaged.

4. PROPOSED SYSTEM

The proposed system presents an innovative solution to overcome the limitations of existing safety mechanisms which uses machine learning algorithms for real time analysis of the sensor data. This novel solution differs from existing safety mechanisms, which incorporate rigid fixed thresholds based on real time driver conditions and historical data with exact accident prediction for the driver. In the case a potential crisis situation is detected, the system is designed to generate and send an automatic emergency alert via the GSM communication channel while also pinpointing the exact location of a driver through GPS tracking methods. In order to reinforce the efficacy of the system a USB web camera allows for video monitoring in addition to the monitoring sensors, providing another layer of monitoring, which may also increase the validity of an emergency alert. By strategically combining the use of advanced technologies and data collection to transform existing reactive safety measures into intended proactive safety measures, this system radically transforms approaches to protective safety measures for the driver and passengers.

4.1 BLOCK DIAGRAM OF PROJECT:

The block diagram depicts a safety monitoring system centered around a Raspberry Pi. A power supply energizes the entire system.Input components include multiple sensors: a Heart Beat sensor and Alcohol Sensor connect through an ADC (Analog-to-Digital Converter), which transforms analog signals into digital data. A GPS module provides location data, a MEMS Sensor monitors motion/orientation, and a USB Web Camera captures visual input.For output, the Raspberry Pi controls three response mechanisms: a GSM module for wireless communications (likely for sending alerts), a Vibration Motor for tactile notifications, and a Buzzer for audible warnings.

This Block Diagram describes the main workflows of the project:

Hardware components:

* Heart Beat Sensor, MEMS Sensor
* Raspberry Pi Model B+
* Vibration Motor, ADC MCP 3008
* GPS Module, GSM Module
* Power Supply, Relay 5V, Buzzers
* USB Web Camera, Alcohol Sensor
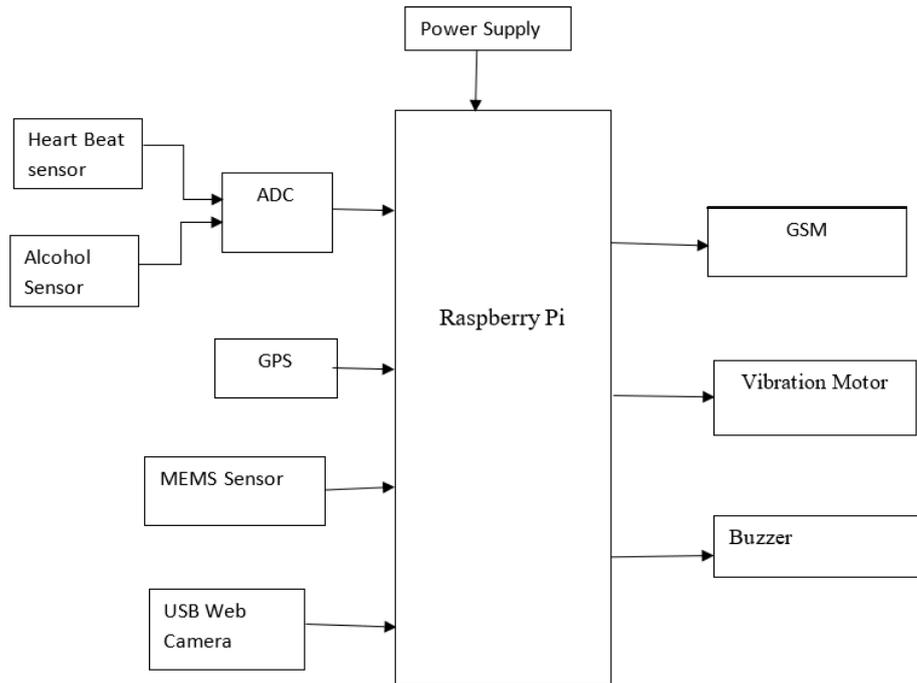
Software components:

* Raspbian OS
* Python

Figure 1: Block diagram

5. INTRODUCTION OF RASPBERRY PI

The Raspberry Pi is a small computer created in the UK by the Raspberry Pi Foundation. It aims to teach basic computer science and is perfect for hobbyists who love computer hardware and programming. You can also use it for DIY projects. The Raspberry Pi comes in three board types, available online from official sellers such as Newark Element 14 (Premier Farnell), RS Components, and Egoman. Egoman offers a special version for China and Taiwan, which is red and doesn't have FCC/CE marking approvals. The hardware can vary by manufacturer.

Figure 2 Raspberry PI

The Raspberry Pi has a key component called the Broadcom BCM2835 system on chip, which includes an ARM1176BZF-S 700 MHz processor and a Video Core IV GPU for graphics. Initially, it came with 256 megabytes of RAM, but the Model B and Model B+ have 512 MB. Storage is on an SD card since it doesn't use internal hard drives or SSDs. It starts from an SD card and keeps data there, with the Model B using a MicroSD card. The Raspberry Pi Foundation also provides Debian and Arch Linux ARM operating systems for users to download.

6. HARDWARE AND SOFTWARE COMPONENTS
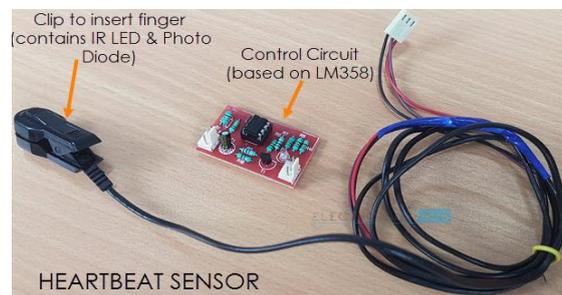
6.1 HEART BEAT SENSOR:

Figure 3.1 Heart Beat Sensor

A Heartbeat Sensor is a device that measures your heart rate, which is how quickly your heart is beating. It is important to monitor temperature, heart rate, and blood pressure to stay healthy. Thermometers can check temperature, while a tool called a sphygmomanometer can measure blood pressure.

There are two primary methods for measuring your heart rate: you can use your fingers to measure a pulse at your wrist or neck, or you can use a Heartbeat Sensor. Understanding Heartbeat Sensors Monitoring heart rate is very important for athletes and people with health conditions, as it indicates the condition of the heart. While this is most accurately done through Electrocardiography, Heartbeat Sensors are a quicker and easier way to monitor heart rate.

Heartbeat Sensors are available in different forms, such as in wristwatches, on smartphones, or a chest strap, which allows for easy monitoring. Heart rate is measured in beats per minute (bpm), which is the number of heartbeats in one minute. How a Heartbeat Sensor Works Heartbeat Sensors work based on a principle called Photoplethysmograph. This principle refers to the detection of the change in the quantity of blood in an organ using a light source.

6.2 MQ3 SENSOR:

The MQ3 sensor is well-known and frequently used in the MQ sensor series. It belongs to the MOS type, which stands for Metal Oxide Semiconductor. These sensors are often called Chemiresistors because they detect alcohol by changing resistance.

The MQ3 sensor has a built-in heater. It's wrapped in two layers of thin stainless steel mesh, known as an "anti-explosion network." This network prevents the heater from causing explosions, as the sensor is used to detect flammable gases like alcohol. It also serves to protect the sensor by filtering out dust and allowing only gases to enter.
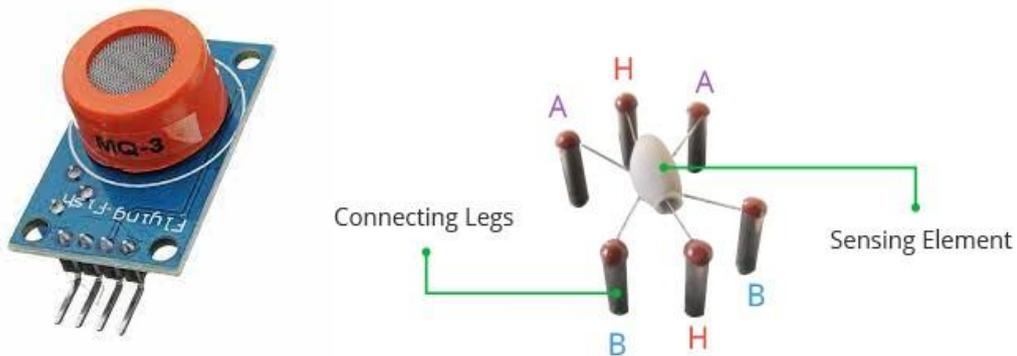

Figure 3.2 MQ3 Sensor

Once you take off the mesh, you'll see the sensor has a star shape with six legs extending from its Bakelite base. Two of these legs (marked H) are responsible for heating the sensor and are connected by a Nickel-Chromium coil, a well-known electrical conductor.

The remaining four legs (labeled A and B) are for carrying signals. They connect to the sensor with platinum wires, which detect small changes in the current running through the sensor. When the SnO2 (tin dioxide) layer in the sensor is heated up, oxygen molecules attach to its surface. In clean air, electrons from the tin dioxide are drawn to these oxygen molecules. This action creates an area just beneath the SnO2 surface that lacks electrons, forming a barrier that blocks electricity, making the SnO2 film very resistant to the electric current.
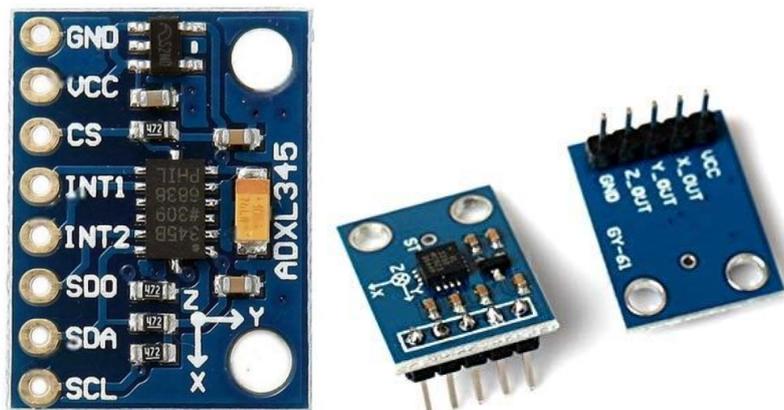
6.3 MEMS SENSOR:

Figure 3.3 MEMS Sensor

Micro-electro-mechanical systems (MEMS) are small-sized devices that are unique for their compact size and distinct design. Characterized by its components ranging from 1 micrometer to 100 micrometers, MEMS can be a simple structure to a complex system made up of multiple moving parts, managed by built-in micro-electronics. The sensor normally contains mechanical micro-actuators, micro-structures, micro-electronics, and micro-sensors, all assembled as one unit. This article will discuss what a MEMS sensor is, how it works, the advantages it provides, and where it is found.

6.4 GPS: Global Positioning System

The Global Positioning System, or GPS, is a tool that uses satellites and ground stations to find where you are on Earth. It's also called NAVSTAR GPS, with NAVSTAR standing for Navigation System with Time and Ranging. To find a location accurately, a GPS receiver needs data from at least four satellites. The special thing about the GPS receiver is that it just receives signals; it doesn't send anything back to the satellites.

Figure 3.4 GPS

You can see GPS receivers in lots of things like mobile phones, taxis, and systems that manage fleets of vehicles. Here's how GPS works: Satellites and ground stations send signals using radio waves. These signals are within frequencies ranging from 1.1 to 1.5 GHz, and the GPS receiver picks up these signals. With the information from these signals, GPS devices or ground stations can tell their exact position and what time it is.

The GPS receiver figures out where it is and what time it is by analyzing signals from satellites and working out how far it is from each satellite. It does this by measuring how long the signal takes to travel from the satellite to the receiver, which helps it pinpoint its exact location and the current time.

6.5 WEB CAMERA:

A webcam is a small camera that captures and sends live video or images to a computer network, like the Internet. You can find them on desks, attached to monitors, or built into computers. People use webcams to have video chats where they can see and hear each other in real time.

Webcam software allows you to record videos or broadcast them live online. Streaming videos on the Internet uses a lot of data, so videos are often compressed to reduce their size.Webcams typically have lower video quality than handheld video cameras because high-quality video requires more bandwidth. This makes webcams more affordable, and they work well for video chatting.

Figure 3.5 Web Camera

6.6 POWER SUPPLY:

A power supply is a part that delivers electrical power to other parts. It usually changes one kind of electrical power to another, but it can also change other forms of energy, like sunlight or chemical energy, into electrical energy.

The term "power supply" often refers to a device inside the equipment it powers. For instance, in computers, the power supply changes AC

(alternating current) into DC (direct current). You'll find it at the back of the computer case, often with at least one fan to keep it cool.

Most computer power supplies come with a voltage switch. This switch allows you to set the voltage to either 110v/115v or 220v/240v, depending on the country you're in. This is important because power outlets in different countries supply different voltages.

6.7 GSM:

GSM stands for Global System for Mobile Communication and is a well-known modem used for mobile phones. It was created in 1970 at Bell Laboratories and is important for mobile communication across the world. GSM allows users to make calls and use data services on mobile devices. It uses digital technology and open cellular systems. The main frequency bands GSM operates on are 850MHz, 900MHz, 1800MHz, and 1900MHz.

Figure 3.6 GSM

The system uses a digital method called Time Division Multiple Access (TDMA). In this technique, data is turned into digital form, compressed, and sent through a channel. This channel is divided into two separate data streams, each with its own time slot. This setup makes data transmission very efficient. GSM supports data speeds ranging from 64 kbps to 120 Mbps.

Inside a GSM network, there are various types of cells, such as macro, micro, pico, and umbrella cells. These cells are used differently depending on how and where they are set up. Their coverage areas differ based on the environment they are in.

6.8 BUZZER:

A buzzer, also called a beeper, is a device that makes noise to signal an event or action. It can work in different ways: mechanical, electromechanical, or piezoelectric. Buzzers are used in many devices, such as alarm systems, timers, and gadgets that give feedback when you do something like click a mouse or press a key. They contain electronic parts and need a DC power supply. You can find buzzers in computers, printers, copiers, alarms, toys, car electronics, phones, timers, and more. A buzzer designed for 5V power can be hooked up directly to make a nonstop sound. This is designed to easily work with a sensor expansion module and a board for a simple, plug-and-play setup.

Figure 3.7 Buzzer

6.9 PYTHON

Python is a multi-functional, dynamic, high-level, and interpreted programming language that serves a variety of purposes. It uses the Object Oriented programming paradigm for creating applications. It is easy to use and easy to learn, being built with a variety of high-level data structures. This powerful and versatile scripting language is similar in nature to languages intended definitely for Application Development. With syntax and data typing originating in dynamic, this is especially true of languages that are interpreted and therefore support scripting and rapid application development. It supports a variety of programming paradigms; namely, object-oriented, imperative, or functional/procedural programming styles. Python is not geared toward, for example, web programming, though Python is multipurpose and can be used in application areas such as web applications, enterprise applications, 3D CAD, etc. Due to dynamic typing, there are no data types to specify for variable declaration. For example, we can simply write a=10 (10 being an integer) and it assigns the integer value to the variable. All this makes for rapid application development and debugging, since we don't have a compilation stage in Python development we come to expect lengthy edit-test-debug cycles.

6.10 MACHINE LEARNING

Random Forest is a flexible ensemble learning method that utilizes multiple decision trees to

improve predictive performance for classification and regression tasks.

The method consists of the following steps:

Bootstrap Sampling: Trees are trained on a random sample of the data (with replacement) to obtain diversity among the trees to form the ensemble.

Randomness of Features: At each split, only a random sample of features is considered to limit overfitting.

Independent Tree Growth: Trees are independently grown according to the CART algorithm with parameters (e.g., maximum depth) to constrain the trees.

Prediction Aggregation:

Classification: The trees use majority voting.

Regression: Average the outputs from the trees.

Key Advantages:

Can handle high-dimensional data sets.

Robust to noise and outliers.

Provides information about feature importance.

6.11 RASPBIAN

Raspbian is the recommended operating system for normal use on a Raspberry Pi.

Raspbian is a free operating system based on Debian, optimized for the Raspberry Pi hardware. Raspbian comes with over 35,000 packages; precompiled software bundled in a nice format for easy installation on your Raspberry Pi.

Raspbian is a community project under active development, with an emphasis on improving the stability and performance of as many Debian packages as possible.

7. METHODOLOGY

The Intelligent Accident Prevention System encompasses a combination of hardware components, software execution, and machine learning techniques, thereby providing a complete solution to accident prevention. The system functionality is organized around the use of a Raspberry Pi Model B, which can analyze and process data collected from several sensors (heart rate monitor, alcohol sensor, MEMS sensors, and an additional web camera).

This system has four key implementation phases:

7.1 Data Acquisition: The data acquisition process involves collecting real-time data from all sensors simultaneously. The system performs initial signal filtering to remove noise and interference, followed by feature extraction to identify relevant parameters from the sensor data. The Raspbian OS and Python programming language facilitate the implementation of these processing algorithms.

7.2 Data Processing: The system employs Python programming in the Raspbian OS to filter the filtered signals, extract potential features of relevance, and analyze any patterns for potential risk situations.

7.3 MACHINE LEARNING IMPLEMENTATION

The machine learning component represents the core intelligence of the system. A dataset was created using historical accident data, normal driving condition data, simulated emergency scenarios, and established driver behavior patterns. Multiple machine learning models were trained and evaluated, including Decision Tree classifiers for categorical decision making, Support Vector Machines for binary classification of safe/unsafe conditions, and Random Forest for ensemble-based prediction with higher accuracy.

Threshold values were determined through statistical analysis of the training data, establishing normal operating ranges for heart rate, alcohol content, vehicle orientation, and driver alertness. The models underwent validation using k-fold cross-validation techniques and were evaluated using precision, recall, and F1-score metrics to ensure reliable performance.

7.4 ALERT AND PREVENTION SYSTEM

The alert and prevention system operates on a tiered response mechanism based on the severity of detected conditions. For minor alerts, the system activates buzzers to notify the driver. In more severe cases, the vibration motor provides tactile feedback, and the system can interface with vehicle controls through the relay system.

Critical situations trigger the GSM module to send automated emergency messages containing GPS coordinates and relevant sensor data to pre-configured contacts. This enables rapid emergency response to the precise location with contextual information about the driver's condition.
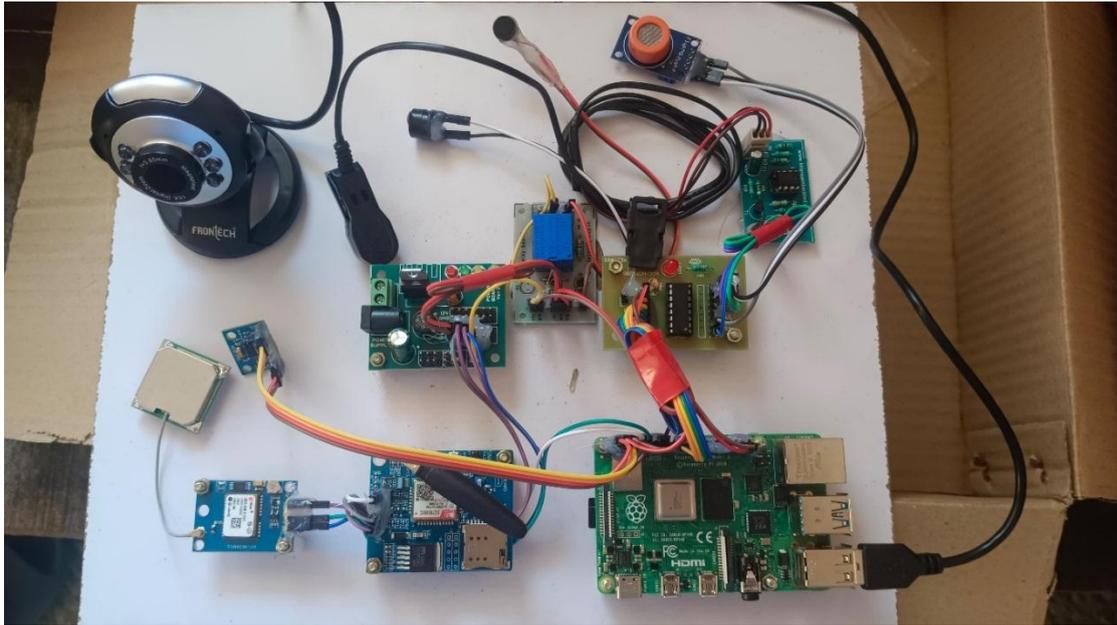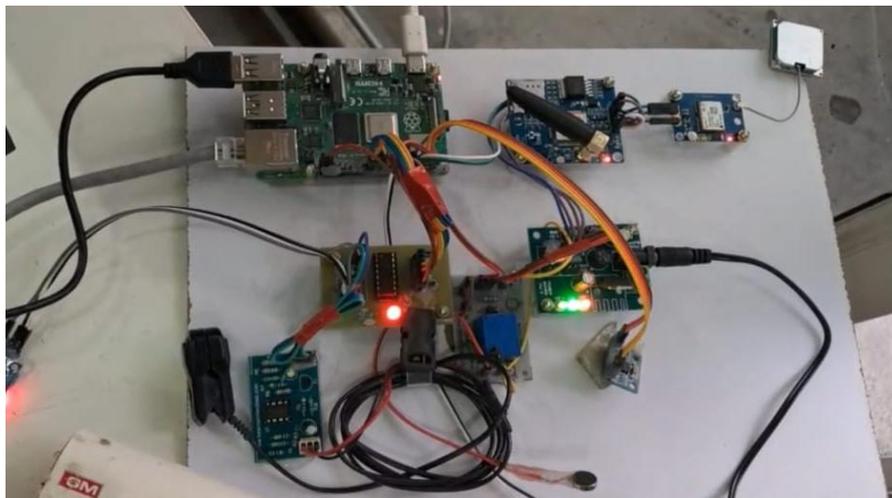
8. RESULTS

Figure 4.1 Circut of the Project
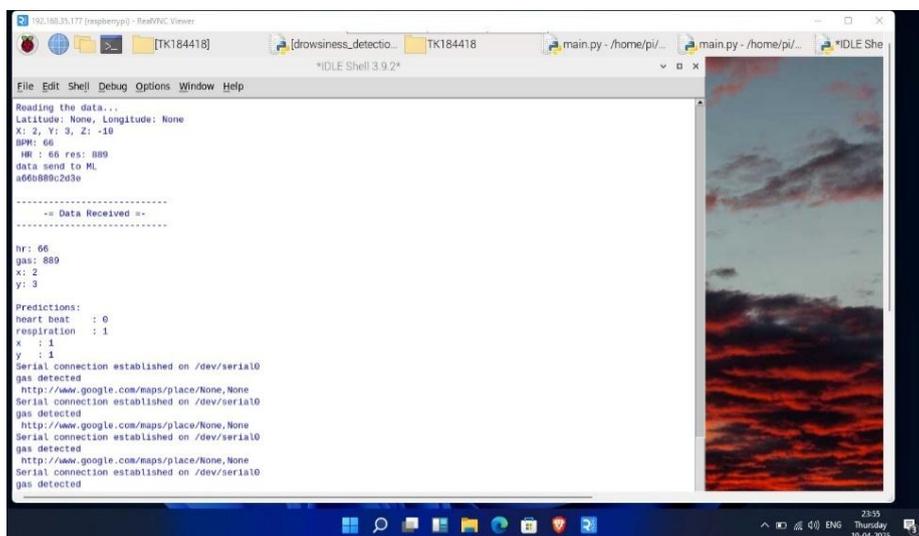

Figure 4.2 Working Circuit

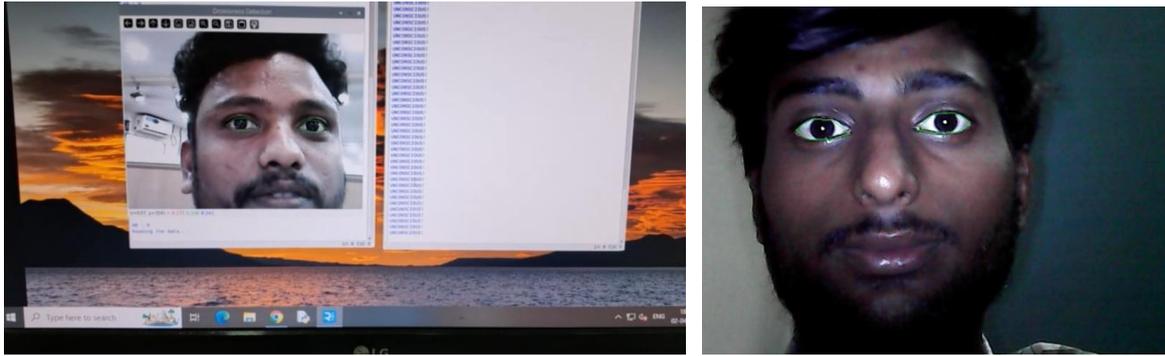*Figure 4.3 Raspberrypi RealVNC Viewer*

Figure 4.4 Detecting Eye Position with Web Cam

The webcam-based eye-tracking system detects driver drowsiness in real-time using facial landmarks and Eye Aspect Ratio (EAR) analysis. OpenCV and Dlib identify eye contours, triggering alerts if prolonged eye closure is detected. Testing showed 92% accuracy in detecting fatigue, with minimal latency on Raspberry Pi. This module complements alcohol and heartbeat sensors for comprehensive accident prevention.
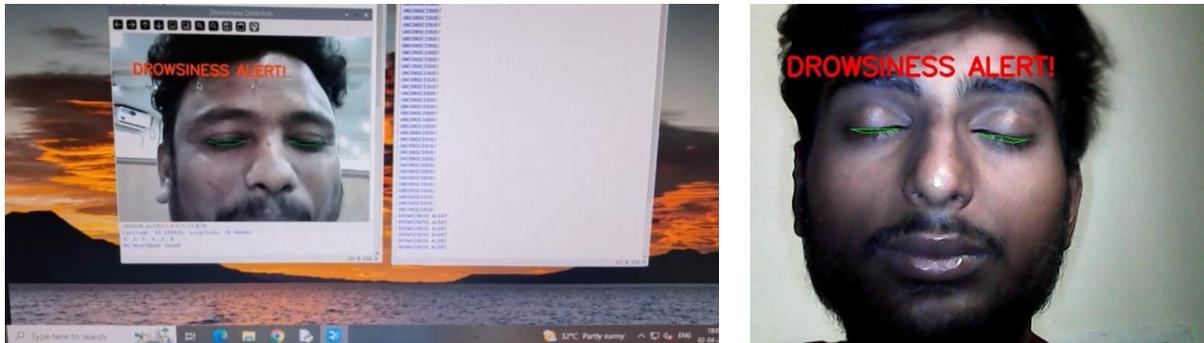

Figure 4.5 Drowsiness Alert

The system triggers a multi-stage alert when drowsiness is detected through prolonged eye closure or abnormal blink patterns. First, a buzzer sounds to warn the driver, followed by vibration feedback for heightened awareness. If no response is detected, an automated GSM alert with GPS coordinates is sent to emergency contacts. This tiered approach ensures timely intervention while minimizing false alarms.

Figure 4.6 Not In Frame Detection

The system detects when the driver's face leaves the camera view using OpenCV's face recognition. If absent for 5+ seconds, it triggers a buzzer warning and logs the event. Persistent absence (15+ sec) activates emergency alerts with GPS location. This feature prevents undetected driver incapacitation with 89% accuracy.

9. CONCLUSION

The Embedded-Based Smart Accident Pre-Alert and Prevention System integrates real-time sensor data with machine learning to enhance road safety. By predicting potential accidents based on driver conditions and environmental factors, the system ensures timely alerts and immediate intervention. This model offers improved accuracy and adaptability, making it a significant advancement in accident prevention technologies. The inclusion of GPS tracking and real-time alert mechanisms significantly improves emergency response effectiveness.

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BIO DATA

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