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Real-Time IoT System for Driver Monitoring and Vehicle Safety Automation

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Abstract: The Real-Time IoT System for Driver Monitoring and Vehicle Safety Automation is developed to improve driver and vehicle safety using Internet of Things (IoT) technology. This system constantly checks important factors such as alcohol usage, driver drowsiness, accident detection, and vehicle location. The MQ3 alcohol sensor stops the engine from starting if alcohol is detected, ensuring the driver is not under the influence. The IR eye blink sensor observes the driver's eye movements to detect tiredness and gives sound and visual warnings. The MPU6050 accelerometer and gyroscope sensor identify accidents or vehicle rollovers and automatically send an emergency SOS message through the GSM module, along with the GPS location to saved emergency contacts. All collected sensor data is uploaded to a cloud-based IoT platform (Firebase) for real-time remote monitoring. By combining different sensors and communication modules, this system provides a simple, affordable, and effective solution to reduce road accidents, encourage safe driving behavior, and ensure fast emergency assistance.

Keywords: IoT, driver monitoring, alcohol detection, drowsiness detection, ESP32, vehicle safety, GPS, GSM, Firebase, accident detection

1. INTRODUCTION

In the 21st century, technology has become an important part of everyday life, especially in the automotive industry. Today's vehicles are not just mechanical machines; they are advanced systems made up of sensors, processors, and communication devices. This development is part of the larger Internet of Things (IoT) movement, often called the "connected car" era. According to the World Health Organization (WHO), around 1.3 million people die every year because of road traffic accidents, and driver behavior is responsible for more than 90% of these cases. This situation highlights the need for intelligent systems that can continuously monitor the driver's condition and prevent accidents before they happen. Traditional safety features like seatbelts and airbags are passive systems that only protect passengers after an accident. Active safety features such as Anti-lock Braking Systems (ABS) and Electronic Stability Control (ESC) improve vehicle stability and control, but do not directly address driver impairment. This project aims to address this need by developing a real-time IoT-based driver monitoring and safety system.

A. Problem Statement

The main issue addressed in this project is the large number of road accidents caused by driving under the influence (DUI) of alcohol and drowsy driving. Many existing solutions have certain drawbacks: limited functionality (focusing only on one issue), no automatic control, lack of emergency communication, and underuse of vehicle data. Because of these limitations, there is a need to create an affordable, reliable, and integrated system that can monitor driver behavior continuously, give alerts, take automatic safety actions, and communicate with external users through a cloud platform.

B. Existing Methods and Their Limitations

Current safety solutions are often separate and not well integrated. Alcohol interlock systems prevent vehicle starting if alcohol is detected, but do not monitor driver fatigue. Camera-based drowsiness detection systems can identify tiredness but may not work properly in poor lighting and raise privacy concerns.

Some luxury vehicles provide advanced driver-assistance systems, but these are expensive and not affordable for most people. There remains a gap for a low-cost, integrated system combining multiple sensors, real-time monitoring, cloud connectivity, and automatic vehicle control.

C. Proposed Solution

This project proposes a "Real-Time IoT System for Driver Monitoring and Vehicle Safety Automation" built using an ESP32 microcontroller as the main control unit. It integrates an MQ-3 alcohol sensor, an IR sensor for eye blink monitoring, and an MPU6050 sensor for head movement and accident detection. The system follows a step-by-step response method: when impairment is detected, it first gives warning alerts; if the problem continues, it automatically reduces vehicle speed or prevents engine start. A GPS module provides real-time location, and a GSM module sends alert messages to registered contacts and uploads data to a Firebase cloud server.

D. Scope and Objectives

The main objectives of this project are: (1) to design and develop a prototype of an integrated driver monitoring system; (2) to implement algorithms for detecting alcohol consumption and driver drowsiness; (3) to develop an automatic intervention system for controlling vehicle speed; (4) to establish real-time communication between the vehicle, Firebase, and a mobile application; (5) to use OBD-II data to improve system intelligence; and (6) to test and evaluate the system's accuracy, response time, and reliability.

2. LITERATURE SURVEY

An extensive literature survey was conducted covering recent developments in IoT-based vehicle safety and driver monitoring systems [1]–[20]. Key works include:

Mehta et al. [2021] implemented an MQ3 alcohol sensor integrated with an IoT controller to prevent vehicle ignition when alcohol was detected. Verma and Kulkarni developed an IR eye blink sensor-based system to detect driver fatigue, reducing the risk of accidents caused by drowsy driving. Raghavan et al. proposed an accelerometer-based accident detection system transmitting real-time alerts and GPS coordinates to emergency responders. Lee et al. focused on secure IoT communication for driver monitoring, ensuring data privacy while enabling real-time safety alerts through V2X technology. Herath et al. evaluated deep learning-based eye and facial feature analysis for real-time drowsiness detection, achieving high accuracy suitable for IoT-enabled vehicles. Additional works by Zhao and Wang optimized deep learning models on edge devices for real-time driver monitoring with reduced latency. Choudhary and Malhotra integrated alcohol detection, GPS tracking, and accident alerts to enhance overall vehicle safety using IoT. Nair and Joseph combined alcohol detection, drowsiness monitoring, and accident alerts into a single IoT-based safety platform. The reviewed literature confirms the need for a comprehensive, affordable, and multi-sensor integrated approach as proposed in this work.

3. PROPOSED SYSTEM

A. System Architecture

The proposed system is designed around the ESP32 microcontroller, a powerful and cost-effective system-on-chip with built-in Wi-Fi and Bluetooth capabilities. The system integrates multiple input sensors, output actuators, and communication modules as follows:

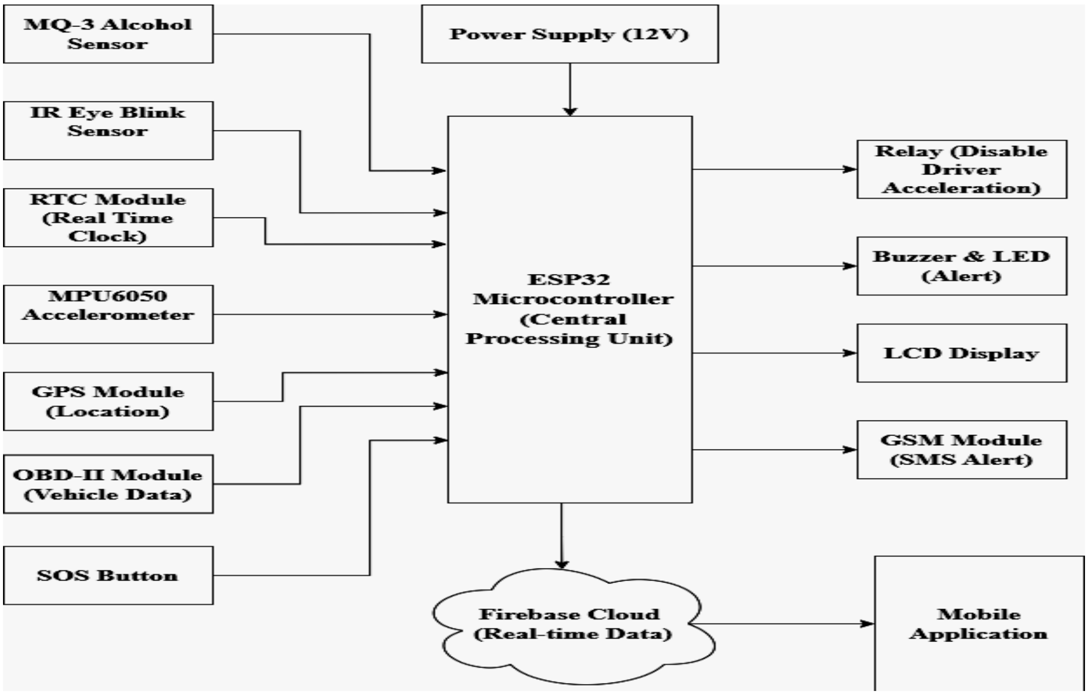


Figure 3.1: System Architecture

Input Sensors: MQ-3 Alcohol Sensor (analog input), IR Eye-Blink Sensor (digital input), MPU6050 IMU (I2C protocol), RTC Module DS3231 (I2C), GPS Module NEO-6M (UART), OBD-II Module ELM327 (UART/Bluetooth), and a manual SOS Button (digital interrupt). Output Actuators: Engine Relay, Buzzer (PWM), LED indicators (Green/Red/Blue), and 16x2 I2C LCD Display. Communication: SIM800L GSM Module (UART) and built-in Wi-Fi for Firebase connectivity.

B. Working Principle and System Modes

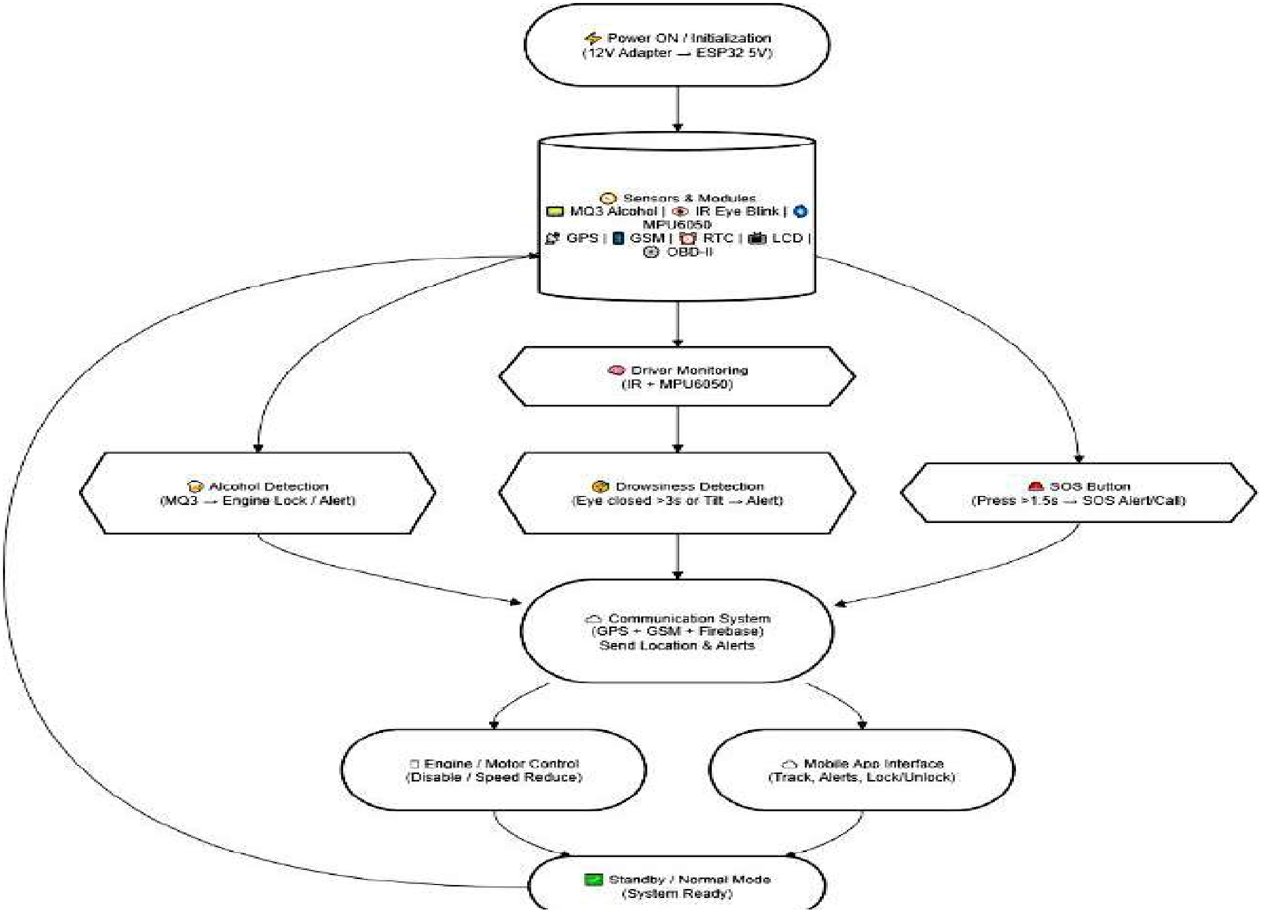


Figure 3.1: System Flow

Mode 1 – Initialization: Upon ignition, the ESP32 boots and initializes all peripherals. Emergency contacts are loaded from non-volatile memory and the LCD displays the RTC time and system status.

Mode 2 – Driver Monitoring: The MQ-3 sensor's analog reading is sampled continuously, the IR sensor checks for eye blinks, the MPU6050 provides accelerometer and gyroscope data for head tilt calculation, the GPS module parses NMEA coordinates, and the OBD-II module is polled for speed and RPM.

Mode 3 – Alcohol Detection: If the alcohol level exceeds the threshold while stationary, the engine relay remains open, preventing the vehicle from starting, and a GSM/Firebase alert is sent. If detected during driving, the system enters Automatic Control mode, gradually reducing speed using OBD-II data.

Mode 4 – Drowsiness Detection: Eyes closed for more than 3 seconds (IR sensor) or a sustained head tilt greater than 30 degrees (MPU6050) triggers the blue LED, buzzer, and Automatic Control mode. The system sends a GPS-tagged alert to the mobile app.

Mode 5 – GPS + GSM + Firebase: Any trigger prompts the ESP32 to format a message with alert type, timestamp from RTC, and GPS coordinates, sent via SMS (GSM) and uploaded to Firebase. The mobile app receives instant push notifications.

Mode 6 – SOS Mode: Pressing the SOS button for more than 1.5 seconds sends an SOS Emergency message with live GPS location via GSM and Firebase.

Mode 7 – Mobile App Control: A companion app communicates with Firebase to display real-time data, receive push notifications, send remote commands (lock/unlock engine), and view historical data logs.

C. Advantages Over Existing Systems

The proposed system overcomes existing limitations through: (1) comprehensive multi-parameter monitoring combining alcohol, eye-blink, and head movement detection simultaneously; (2) proactive automatic control via engine relay and speed reduction rather than warning-only alerts; (3) instant remote communication through GSM, Wi-Fi, and Firebase cloud; (4) intelligent speed-regulated control using OBD-II real-time speed data for smooth deceleration; and (5) lighting-independent and privacy-safe detection using IR and IMU sensors instead of cameras.

4. HARDWARE AND SOFTWARE REQUIREMENTS

A. Hardware Components

ESP32 Microcontroller (Qty: 1): Dual-core 32-bit Tensilica LX6 processor at up to 240 MHz, built-in Wi-Fi (802.11 b/g/n) and Bluetooth (Classic + BLE), multiple GPIO pins (ADC, DAC, PWM, UART, SPI, I2C), and low power modes for energy-efficient operation.

Figure 4.1: ESP32 Microcontroller

MQ-3 Alcohol Sensor (Qty: 1):

Figure 4.2: MQ3 Alcohol Sensor

Detects alcohol concentration from 0.05 mg/L to 10 mg/L with analog and digital output, adjustable sensitivity via potentiometer, and fast response and recovery time.Positioned near the steering area to detect the driver's breath.

IR Eye Blink Sensor (Qty: 1):

Figure 4.3 : IR Eye Blink Sensor

Infrared transmitter-receiver pair with digital HIGH/LOW output. Mounted near the dashboard facing the driver's eyes to monitor blink frequency and detect sustained eye closure beyond 3 seconds.

MPU6050 Accelerometer & Gyroscope (Qty: 1):

Figure 4.4: MPU6050 Accelerometer & Gyroscope

6-axis motion tracking measuring acceleration and angular velocity (X, Y, Z axes) via I2C protocol with Digital Motion Processor (DMP).Detects sudden impacts, vehicle tilt beyond safe limits, and rash driving patterns.

GPS Module NEO-6M (Qty: 1):

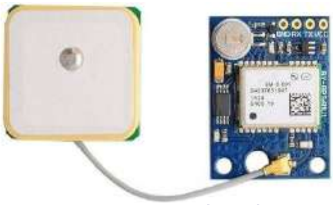


Figure 4.5 : GPS Module (NEO-6M)

50-channel receiver with -161 dBm tracking sensitivity, built-in EEPROM, UART communication, and ceramic antenna.Provides real-time latitude and longitude for live vehicle tracking and emergency alerts.

GSM Module SIM800L (Qty: 1):

Figure 4.6: GSM Module (SIM800L)

Quad-band GSM (850/900/1800/1900 MHz) supporting SMS, voice calls, and GPRS via UART interface. Ensures emergency communication even when Wi-Fi is unavailable.

OBD-II Module (Qty: 1):

Figure 4.7: OBD-II Module

Reads engine parameters (RPM, speed, coolant temperature), detects diagnostic trouble codes, and communicates via CAN protocol. Enables real-time vehicle data extraction for intelligent safety decisions.

Supporting Components:

RTC Module DS3231 (±2ppm accuracy, I2C, battery backup), buzzer (PWM-controlled audio alerts), L298N motor driver (prototype vehicle simulation), 16x2 I2C LCD display, LED indicators (Green/Red/Blue), SOS and accelerator push buttons, 12V DC power adapter with DC-DC buck converters for 5V and 3.3V distribution.

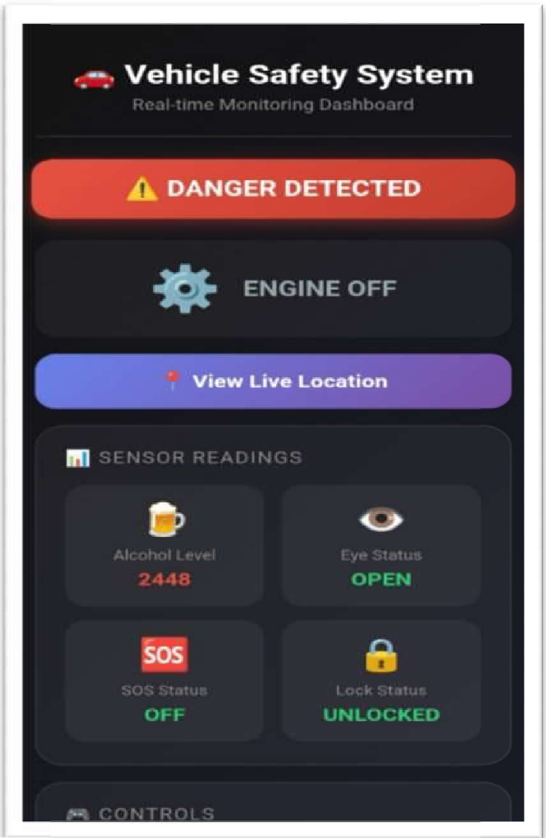
B. Software Requirements

Embedded Firmware (ESP32): Written in C++ using Arduino IDE or PlatformIO. Key libraries include:

Library Name	Functionality
Wire.h	Handles I2C communication for the MPU6050, RTC, and LCD display.
SoftwareSerial.h	Creates software-based UART ports to communicate with GPS and GSM modules.
TinyGPS++.h	Parses NMEA data sentences from the GPS module, extracting latitude, longitude, date, and time.
FirebaseESP32.h	Manages Wi-Fi connection and data streaming to/from Firebase Realtime Database.
MPU6050.h	Simplifies communication with the MPU6050, providing functions to read raw accelerometer and gyroscope data.
EEPROM.h	Reads from and writes to the ESP32's emulated EEPROM for storing non-volatile data.
Preferences.h	Stores key-value pairs in flash memory, used for system settings.

Firebase Realtime Database: Stores live sensor readings (alcohol level, speed, location, tilt data), maintains vehicle status, updates accident notifications instantly, and enables remote monitoring via web interface. React JS Web Dashboard: Component-based architecture with virtual DOM for faster rendering, displaying real-time vehicle data (Speed, RPM, Alcohol level, GPS location), accident alerts, and remote control features with Firebase integration.

Mobile Application:



Vehicle Safety System
Real-time Monitoring Dashboard

⚠ DANGER DETECTED

ENGINE OFF

SENSOR READINGS

Alcohol Level: 2448
Eye Status: OPEN
SOS Status: OFF
Lock Status: UNLOCKED

Figure 4.7: UI Screen

Developed with Flutter (Dart language) for cross-platform compatibility.Uses Firebase Authentication for secure user management, Google Maps API for location display, and Firebase API for real-time data operations. Features include a dashboard with gauges, live data feed, alerts history, and control panel for remote commands.

C. Data Flow and Communication Protocols

The system operates on a layered communication architecture: (1) Peripherals to ESP32 via I2C, UART, and Analog/Digital GPIO; (2) ESP32 to Firebase via HTTPS over Wi-Fi; (3) Firebase to Mobile App via WebSocket managed by Firebase SDK; (4) Mobile App to Firebase via HTTPS REST API; and (5) Firebase to ESP32 via push-based channel at the /commands node, enabling bidirectional remote control.

5. RESULTS AND DISCUSSION

A. Sensor Calibration and Hardware Performance

MQ-3 Alcohol Sensor: The sensor was calibrated under controlled laboratory conditions using real alcohol samples with known concentrations. The sensor was preheated for 24 hours to stabilize its internal heating element. The output showed a logarithmic response curve; average deviation remained within ±5%. The threshold for engine lock was successfully implemented at 0.4 mg/L. The calibration equation derived from experimental data was embedded into firmware to convert ADC values to mg/L.

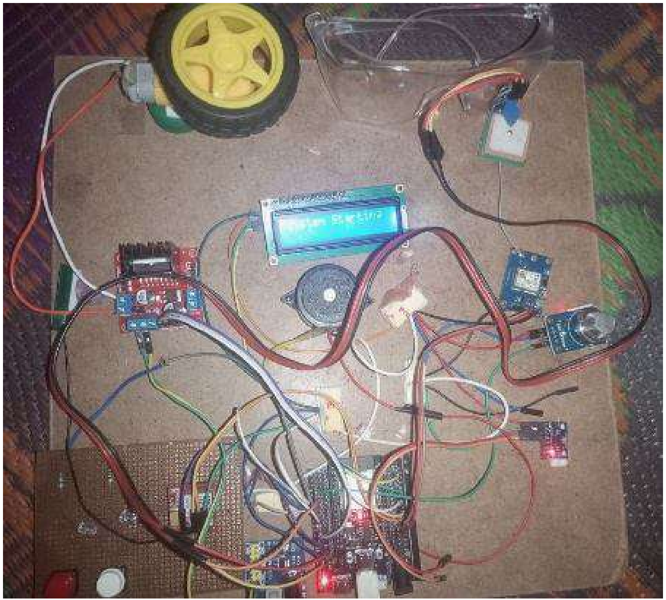


Figure 5.1: Prototype hardware

Drowsiness Detection: The IR eye-blink sensor achieved 98–99% accuracy across 100 trials. Normal blinking was correctly detected, and eye closure beyond 3 seconds reliably triggered drowsiness alerts. False triggers under excessive sunlight were minimized using threshold adjustment. MPU6050 tilt detection matched physical angles within ±2°, accurately detecting sudden jerks and nodding movements. Combining IR eye detection with tilt monitoring improved reliability and reduced false positives.

Figure 5.2 : IR Eye-Blink Sensor Testing

B. System Response Time

The complete hardware chain was tested by triggering actual events and measuring response time using serial timestamps. Results are summarized in Table I.

Table I. System Response Time

Event Triggered	Local Alert (s)	Firebase Update (s)	SMS Sent (s)	Total Time (s)
Drowsiness Detected	0.1	1.4	3.1	3.1
Alcohol Threshold Exceeded	0.1	1.6	3.3	3.3
SOS Button Pressed	0.05	1.3	3.0	3.0

Local alerts (buzzer/LED) were nearly instantaneous. Cloud update delay remained below 2 seconds consistently. SMS delay was mainly due to GSM network latency. Overall response time is acceptable for real-world emergency applications.

C. OBD-II Hardware Integration Results

The OBD-II interface was connected to a real vehicle diagnostic port. Communication was established using UART protocol. Live data recorded is shown in Table II.

Table II. Live OBD-II Data Recorded

PID	Parameter	Measured Value	Unit
0D	Vehicle Speed	54–57	km/h
0C	Engine RPM	2000–2200	RPM
05	Coolant Temperature	90–94	°C

Real-time vehicle parameters were successfully extracted and refreshed every 1 second without interruption. Overspeed detection logic triggered alerts properly. Direct torque control requires CAN-level integration, recommended for future enhancement.

D. Cloud and Mobile Communication

The ESP32 transmitted live data to Firebase Realtime Database via Wi-Fi. The mobile application received updates in less than 2 seconds. Engine Lock commands issued from the mobile app were received by the ESP32 within 2.5 seconds, and the relay module activated successfully. No packet loss was observed during stable network conditions.

6. CONCLUSION

The proposed IoT-Based Driver Safety and Vehicle Monitoring System has been successfully designed, implemented, and validated through real-time hardware testing. The system demonstrated reliable functionality, fast response time, and effective communication between hardware and cloud platforms. The integration of alcohol detection, drowsiness monitoring, accident detection, GPS tracking, GSM communication, and OBD-II vehicle diagnostics into a single embedded framework enhances the overall safety capability of modern vehicles. The calibrated alcohol detection mechanism accurately identified unsafe levels and successfully prevented ignition when the predefined threshold was exceeded. The combination of eye-blink detection and head-tilt monitoring significantly improved drowsiness detection accuracy. Real-time communication between the vehicle unit and cloud platform ensured alerts and location data were updated with minimal latency. Further enhancements such as automotive-grade components, CAN bus integration for advanced control, improved environmental compensation for sensors, and AI-based behavioral analysis can strengthen real-world applicability. The developed system provides a comprehensive, reliable, and scalable solution for enhancing road safety through intelligent sensing, real-time monitoring, and automated response mechanisms.

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