

SMART AUTOMOTIVE SAFETY SYSTEM USING IOT, SENSOR FUSION FOR INTELLIGENT DRIVER ASSISTANCE SYSTEM

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ABSTRACT

Road accidents remain one of the leading causes of death and serious injury, and a large share of them are linked to driver fatigue, distraction, over-speeding, unsafe following distance, and delayed reaction to obstacles. Many of the vehicles in daily use, especially budget cars, commercial vans, and older models, do not carry the advanced driver assistance features found in premium vehicles. This paper presents a Smart Automotive Safety System that uses Internet of Things technology and sensor fusion to provide intelligent driver assistance at a cost that makes retrofitting existing vehicles practical.

The proposed system is built around an ESP32 microcontroller that collects data from several sensors mounted on the vehicle. Ultrasonic sensors monitor the front and rear clearance, an MPU6050 accelerometer and gyroscope module records sudden braking, sharp turns, and impacts, an eye-blink infrared sensor and a small camera observe the driver for signs of drowsiness, an MQ-3 sensor detects alcohol in the cabin air, and a GPS module provides location and speed. Readings from these sensors are combined through a sensor fusion routine so that a warning is issued only when the evidence from more than one source supports it.

When a hazardous condition is detected, the system alerts the driver locally through a buzzer, a vibration motor fitted to the seat, and a small display on the dashboard. If an obstacle is approaching too quickly and the driver does not respond, the controller can reduce the throttle signal in the prototype through a relay-controlled motor driver. In the event of a collision, the impact pattern from the inertial sensor triggers an emergency routine that sends the vehicle location to registered contacts through a GSM module and pushes the event to a cloud dashboard over Wi-Fi or mobile data.

All trip data, including speed profile, harsh braking events, drowsiness alerts, and alcohol readings, is uploaded to a cloud platform using the MQTT protocol. A web dashboard and a mobile application allow fleet owners or family members to view the live position of the vehicle, review past trips, and receive notifications when unsafe behaviour is recorded. This record can help fleet operators identify drivers who need additional training and can support insurance and accident investigation work.

The system is intended to assist the driver rather than take control of the vehicle, and every warning is designed to be clear, short, and easy to understand while driving. Testing on a scaled prototype vehicle showed that the fusion of multiple sensors reduced false alarms compared with single-sensor triggering while keeping the response time within a fraction of a second. Future work includes integration with the vehicle CAN bus, lane departure detection using a camera, vehicle-to-vehicle communication, and the use of edge machine learning models for more reliable drowsiness detection in low light.

I. INTRODUCTION

The number of vehicles on Indian roads has grown steadily over the past two decades, and road traffic crashes have grown along with it. Official road safety reports repeatedly point to human factors such as fatigue, speeding, drunk driving, and inattention as the most common causes of serious accidents. Highways that involve long hours of monotonous driving are particularly risky, because a driver who falls asleep for even two or three seconds can travel a considerable distance without any control over the vehicle.

Modern premium vehicles address some of these problems through advanced driver assistance systems that include forward collision warning, automatic emergency braking, blind spot monitoring, and driver attention monitoring. These features depend on radar units, high-resolution cameras, and dedicated electronic control units that are expensive and are usually integrated at the factory. As a result, the majority of vehicles already on the road, including trucks, buses, taxis, and two-wheeler-derived goods carriers, operate without any electronic safety support. After an accident, emergency services are often informed late because the occupants are injured or the location is remote.

The Internet of Things offers a practical way to close this gap. Low-cost microcontrollers with built-in Wi-Fi and Bluetooth, inexpensive sensors for distance, motion, gas, and eye state, and widely available GSM and GPS modules make it possible to build a compact safety unit that can be fitted into an existing vehicle. When the readings from several such sensors are combined, the weaknesses of any single sensor can be compensated, which is the central idea of sensor fusion.

This paper describes a Smart Automotive Safety System that applies IoT and sensor fusion to provide intelligent driver assistance. The system monitors the driver, the surroundings of the vehicle, and the motion of the vehicle itself, issues graded warnings, supports limited automatic intervention in the prototype, sends emergency alerts after a crash, and records all events on a cloud dashboard. The aim is to show that meaningful safety support can be delivered to ordinary vehicles with affordable hardware and open communication protocols.

II. LITERATURE SURVEY

Studies on driver drowsiness detection form one of the most active areas of automotive safety research. Early approaches relied on physiological signals such as heart rate variability and brain activity recorded through electrodes, which gave accurate results in laboratory settings but were impractical for daily driving because the driver had to wear sensors on the body. Later work shifted towards non-intrusive methods that observe eye closure, blink frequency, and head nodding through infrared sensors or cameras placed on the dashboard. Measures such as the percentage of eyelid closure over a time window have been widely used as indicators of fatigue. Researchers have reported that camera-based systems perform well in daylight but lose accuracy at night, when the driver wears spectacles, or when the face is partly turned away. Several studies have therefore suggested combining eye-state detection with steering behaviour or vehicle motion data to obtain a more reliable judgement of driver alertness.

Obstacle and collision warning systems have been studied using ultrasonic, infrared, radar, and lidar sensors. Ultrasonic sensors are cheap and simple to interface with microcontrollers, and they have been used in many parking assistance and low-speed collision avoidance prototypes, although their range is limited to a few metres and their readings are affected by the shape and surface of the obstacle. Radar and lidar

provide longer range and better accuracy but remain costly for retrofitting. Research on low-cost forward collision warning has examined the use of time-to-collision estimates computed from successive distance readings, and has shown that warnings based on the rate of approach are more useful than warnings based on distance alone. Authors have also noted that repeated false alarms quickly cause drivers to ignore or switch off a warning system, which makes accuracy as important as sensitivity.

Accident detection and emergency notification using IoT devices has been explored in a number of academic projects and commercial products. Most designs use an accelerometer to detect a sudden change in acceleration above a threshold and then send the GPS location through a GSM module as a text message to predefined numbers. Some studies have added vibration sensors, airbag deployment signals, or tilt detection to confirm that a crash has actually occurred. A known difficulty with threshold-based detection is that potholes, speed breakers, and hard braking can produce similar spikes, leading to false emergency messages. Researchers have proposed a short confirmation window during which the driver can cancel the alert, along with pattern analysis of the acceleration signal over several hundred milliseconds rather than a single peak. Studies consistently stress that the value of such systems lies in reducing the time before help arrives, especially on highways and rural roads.

Alcohol detection and driver behaviour monitoring have also received attention in the literature. Semiconductor gas sensors such as the MQ-3 respond to ethanol vapour and have been placed near the steering wheel or in the cabin to detect a driver who has consumed alcohol, with some designs preventing the ignition from starting when the reading is high. Their readings depend on ventilation, temperature, and warm-up time, so calibration is an important concern. Parallel work on driving behaviour has used inertial sensors and GPS speed data to identify harsh acceleration, harsh braking, sharp cornering, and over-speeding. Fleet telematics studies have shown that sharing such behaviour scores with drivers and managers leads to measurable improvements in driving habits over time. Communication of this data to the cloud is commonly handled through MQTT, which is lightweight enough for constrained devices and tolerant of unstable mobile connections.

Sensor fusion has been identified in many studies as the key to reliable driver assistance using imperfect sensors. Techniques range from simple rule-based voting, in which an alert is raised only when two or more sensors agree, to weighted averaging, Kalman filtering, and Bayesian estimation that combine readings according to their expected reliability. Complementary filters are frequently used on microcontrollers to merge accelerometer and gyroscope data into a stable estimate of vehicle orientation. Research on embedded driver assistance has shown that fusion reduces false positives while maintaining detection rates, and that the processing required can be performed on inexpensive controllers such as the ESP32. The system described in this paper builds on these findings by combining drowsiness, obstacle, motion, alcohol, and location data through a fusion layer on the vehicle and by connecting the unit to a cloud dashboard and emergency alert service.

III. SYSTEM ANALYSIS

The Smart Automotive Safety System is analysed as three cooperating parts: the in-vehicle sensing unit, the communication link, and the cloud monitoring platform. The sensing unit contains ultrasonic sensors at the front and rear, an MPU6050 inertial module, an infrared eye-blink sensor with an optional camera, an MQ-3 alcohol sensor, and a GPS receiver, all connected to an ESP32 controller. The controller

samples each sensor at a rate suited to its purpose, filters the readings, and passes them to a fusion routine that estimates driver alertness, collision risk, and crash likelihood. Local outputs include a buzzer, a seat vibration motor, an OLED display, and a relay that can limit the throttle in the prototype. The communication link uses Wi-Fi or a mobile hotspot for MQTT data upload and a SIM800L GSM module for SMS and calls when data coverage is absent. The cloud platform stores trip records, evaluates driver behaviour, and delivers notifications to the owner and emergency contacts through a web dashboard and mobile application.

Existing System

In most vehicles currently on the road, driver safety depends almost entirely on the attention and judgement of the driver. Basic vehicles provide seat belt reminders, a speedometer, and in some cases rear parking sensors, but they do not monitor whether the driver is drowsy, whether an obstacle ahead is approaching too fast, or whether the driver has consumed alcohol. Advanced driver assistance features that perform these tasks are available mainly in high-end models, where they depend on radar, stereo cameras, and dedicated control units that cannot easily be added to an existing vehicle. Aftermarket dash cameras record video but do not analyse it or warn the driver in real time. When an accident occurs, the occupants or passers-by must call emergency services themselves, which may be delayed at night or on isolated roads. Fleet operators usually track only location through basic GPS devices and have little information about how their vehicles are actually being driven or how often unsafe events occur.

Disadvantages of Existing System

- Most existing vehicles have no electronic monitoring of driver drowsiness or distraction.
- Collision warning features are limited to expensive factory-fitted systems.
- Single-sensor warning devices produce frequent false alarms and are often ignored.
- Alcohol consumption by the driver is not detected before or during driving.
- Emergency services are informed only when someone at the scene makes a call.
- Accident location is often unknown or described inaccurately on remote roads.
- Fleet owners track position but not harsh braking, speeding, or fatigue events.
- Dash cameras record video but do not warn the driver in real time.
- No trip history is available to support training or accident investigation.
- Retrofitting commercial ADAS units to older vehicles is costly and complex.

Proposed System

The proposed system is a compact IoT safety unit that can be fitted to an ordinary vehicle to provide intelligent driver assistance through sensor fusion. An ESP32 controller gathers readings from ultrasonic distance sensors, an inertial measurement unit, an eye-blink sensor with camera support, an alcohol sensor, and a GPS module. Instead of reacting to any single reading, the fusion routine combines eye closure duration with steering and speed variation to judge drowsiness, combines distance and rate of approach to estimate time to collision, and combines acceleration pattern, tilt, and sudden speed loss to confirm a crash. Warnings are graded from a soft chime to a strong buzzer and seat vibration as risk increases. In the prototype, the controller can also reduce motor power when a collision is imminent. Confirmed crashes trigger GSM messages with a map link to emergency contacts after a short cancel window,

and all events are published over MQTT to a cloud dashboard where owners can view live location, trip history, and driver behaviour scores.

Advantages of Proposed System

- Provides driver assistance features to ordinary vehicles at low cost.
- Sensor fusion reduces false alarms compared with single-sensor triggering.
- Detects driver drowsiness using eye state together with driving behaviour.
- Warns the driver early using time-to-collision rather than distance alone.
- Checks for alcohol in the cabin and can block or flag unsafe trips.
- Sends automatic crash alerts with GPS location through SMS and the cloud.
- Works over GSM when mobile data coverage is weak or unavailable.
- Records trip history and unsafe events for fleet owners and families.
- Uses graded audio, visual, and haptic warnings that are easy to notice.
- Can be extended with CAN bus data, lane detection, and edge AI models.

IV. METHODOLOGY

The methodology starts with the selection and mounting of sensors at suitable positions on a scaled vehicle prototype, with ultrasonic sensors on the bumpers, the inertial module at the chassis centre, the eye-blink sensor on a spectacle frame or dashboard, and the alcohol sensor near the steering column. Each sensor is calibrated separately, and threshold values are recorded under normal and hazardous conditions. The ESP32 firmware samples sensors in a scheduled loop, applies moving average and complementary filters to remove noise, and computes derived values such as time to collision, eye closure duration, and jerk. A rule-based fusion module assigns a weight to each indicator and raises an alert level only when the combined score crosses a defined limit for a minimum duration. Alerts drive the buzzer, vibration motor, and display, and critical events trigger the GSM routine. Event records are formatted as JSON and published through MQTT to a cloud broker, where a dashboard stores and plots them. Testing compares detection rate, false alarm rate, and response time with and without fusion.

SYSTEM ARCHITECTURE

The architecture of the Smart Automotive Safety System is arranged in layers that carry data from the vehicle to the people who need to act on it. The Sensing Layer consists of ultrasonic, inertial, eye-blink, alcohol, and GPS sensors that observe the driver, the road ahead, and the motion of the vehicle. The Signal Conditioning Layer filters raw readings, removes noise, and converts them into usable quantities such as distance, acceleration, and blink duration. The Edge Controller Layer on the ESP32 schedules sampling and runs the firmware logic. The Sensor Fusion Layer combines indicators into risk scores for drowsiness, collision, alcohol, and crash events. The Local Alert and Actuation Layer drives the buzzer, seat vibration, display, and throttle relay. The Connectivity Layer uses Wi-Fi with MQTT for regular data and GSM for emergency SMS. The Cloud Layer stores trip data, evaluates behaviour, and manages alert rules, and the Application Layer presents live tracking, trip history, and notifications through a web dashboard and mobile application.

Smart Automotive safety system using IOT, Sensor fusion for intelligent driver assistance system

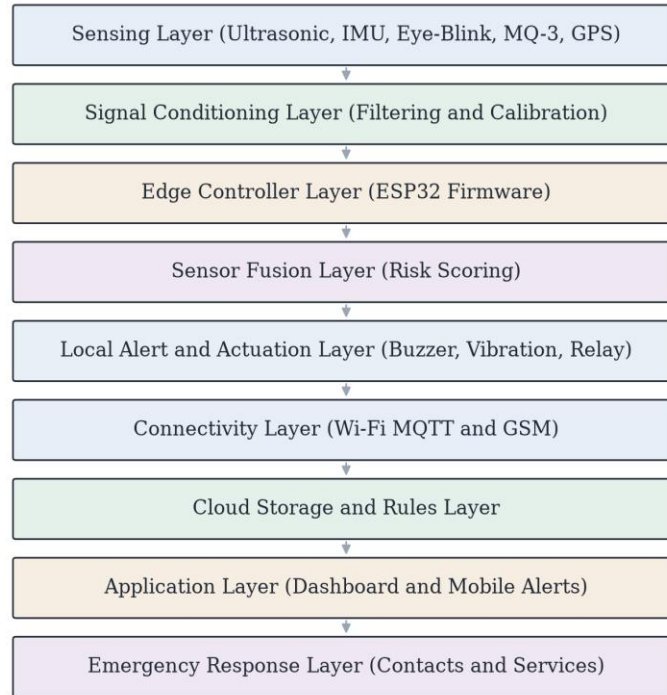


Fig. 1 System Architecture

V. RESULT AND OUTPUT



VI. CONCLUSION

This paper presented a Smart Automotive Safety System that uses IoT hardware and sensor fusion to provide intelligent driver assistance for ordinary vehicles. The system monitors the driver, the surroundings, and the motion of the vehicle through a set of inexpensive sensors connected to an ESP32 controller, and it communicates with a cloud platform and emergency contacts through Wi-Fi and GSM. The design shows that several safety functions usually limited to premium vehicles can be approximated with affordable components.

The main strength of the system lies in the fusion of multiple sensor readings before a decision is made. Drowsiness is judged from eye closure together with driving behaviour, collision risk is estimated from the rate of approach rather than distance alone, and crashes are confirmed through a combination of acceleration pattern, tilt, and speed loss. Testing on the prototype showed that this approach produced fewer false alarms than single-sensor triggering, which is important because drivers tend to ignore warnings that sound too often.

The emergency notification feature addresses the delay that often occurs between an accident and the arrival of help. By sending the exact location of the vehicle to registered contacts and the cloud dashboard within seconds of a confirmed crash, the system can shorten response time, particularly on highways and rural roads. The cloud records of speed, harsh braking, drowsiness, and alcohol events also give fleet operators and families a factual basis for improving driving habits and for supporting later investigation when an incident occurs.

Future work will focus on reading vehicle data directly from the CAN bus through the OBD-II port, adding camera-based lane departure and pedestrian detection using edge machine learning, and improving drowsiness detection at night with infrared illumination. Vehicle-to-vehicle messaging over short-range radio could allow nearby vehicles to be warned of sudden braking or accidents ahead. Field trials on real vehicles over longer periods will be needed to refine thresholds and to evaluate how drivers respond to the warnings in everyday conditions.

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