

Intelligent IoT-Based Accident Monitoring System Using AI-Driven Emotion Detection

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Abstract

This paper proposes a comprehensive IoT and AI-based smart vehicle accident prevention and monitoring system. The system integrates multiple sensors including ultrasonic, MEMS accelerometer, vibration sensor, MQ-3 alcohol sensor, temperature sensor, and tyre pressure sensor to monitor various vehicle and driver parameters in real time. The core innovation lies in the integration of AI-powered driver emotion detection using Python image processing, which can identify risky emotional states such as anger, stress, or drowsiness. The data from the sensors and the camera are processed to generate alerts, trigger emergency responses, or even stop the vehicle when dangerous conditions are detected. The IoT framework enables remote monitoring and real-time updates, making the system more effective in emergency situations. By combining environmental monitoring, vehicle health diagnostics, accident impact detection, and human emotion analysis, the proposed system offers a unique multi-layered safety solution. This integration significantly reduces the chances of accidents caused by mechanical faults, drunk driving, poor vehicle maintenance, or driver emotions, thereby improving overall road safety.

1 Introduction

The increasing rate of road accidents has become a serious concern worldwide, with millions of lives lost each year due to preventable causes. Conventional vehicles primarily rely on human judgment, which is prone to errors, distractions, and negligence. With the advancement of IoT and artificial intelligence, it is now possible to design intelligent systems that can monitor vehicle parameters, environmental conditions, and driver behavior in real time.

An ultrasonic sensor can prevent rear-end collisions by continuously monitoring the distance from other vehicles. A MEMS accelerometer detects abnormal tilting that could indicate a rollover, while a vibration sensor measures impact force to analyze accident severity. Breath alcohol detection through an MQ-3 sensor prevents drunk driving, while temperature and tyre pressure sensors maintain vehicle health by avoiding overheating and under-inflation.

However, these safety features alone may not be sufficient, as the driver's mental and emotional state significantly influences driving safety. Anger, stress, fatigue, and drowsiness are common states that can impair decision-making and reaction time. By integrating Python-based image processing with AI emotion recognition, the driver's facial expressions can be analyzed in real time. The system can alert the driver or even bring the vehicle to a controlled stop if unsafe emotions are detected.

Thus, the combination of IoT sensors and AI-powered driver monitoring provides a holistic approach to accident prevention. This smart vehicle system adds a unique dimension by monitoring the human factor, making it a comprehensive safety solution for modern transportation.

2 Related Works

Several studies have addressed automated accident detection using IoT and sensor technologies. Mahariba [1] proposed a vehicle accident detection system using GPS and GSM modules capable of sending SMS alerts to predefined emergency contacts. While effective, the system lacked real-time victim condition assessment.

Tasgaonkar [3] developed an IoT-based framework for vehicle accident detection integrating accelerometers, GPS, and GSM for automatic alert messages to emergency services. Such systems remain limited by fixed thresholds and do not adapt to varying road conditions.

In the domain of emotion detection, a deep learning-based driver monitoring system [5] demonstrated the efficacy of CNNs for facial expression recognition, achieving over 92% accuracy. Saadi [6] presented a comprehensive survey of facial expression methods for driver monitoring, and Luan [7] proposed attention-based models for driver emotion recognition integrated into vehicle warning systems.

Prior IoT-based monitoring systems have yet to combine multi-modal sensor fusion with AI-driven victim assessment. Our work bridges this gap by proposing a unified architecture that simultaneously monitors environmental conditions, vehicular dynamics, and driver emotional state.

3 Proposed System

The proposed system is a comprehensive IoT and AI-based smart vehicle accident prevention and monitoring platform. Unlike traditional radar-based techniques, the system employs a multi-sensor fusion approach combining a vibration sensor, temperature sensor, gas sensor (MQ-3), ultrasonic sensor, DC motor, and a camera module — all interfaced with an ESP32 microcontroller and a Raspberry Pi edge computing unit.

The Raspberry Pi acts as the central processing unit, executing Python scripts for sensor data aggregation, accident

classification, and AI-based emotion detection. It communicates with the ESP32 over serial/Wi-Fi and connects to a cloud IoT dashboard for remote alerting and telemetry.

The camera-based vision detection unit runs a CNN emotion detection model built with OpenCV and Python to classify driver facial expressions in real time. Ultrasonic sensors provide proximity metrics, the vibration sensor measures impact forces to analyze accident severity, and heterogeneous inputs are cross-validated to reduce false positives and guarantee accurate detection.

The system exhibits real-time information on an LCD module and triggers visual (LED) and audio (buzzer) alerts instantly upon detection. In case of any accident, data is sent to the cloud dashboard where remote operators may read incident logs and receive real-time alerts with GPS coordinates.

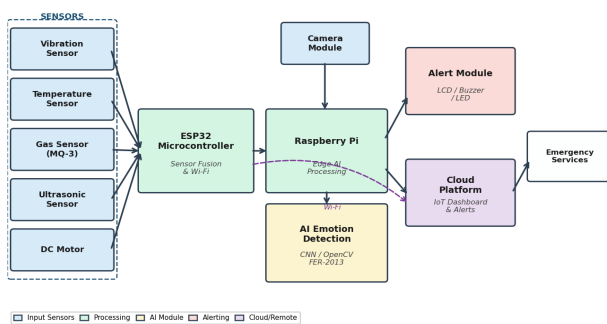


Fig. 1. System Architecture of the Proposed IoT-Based Accident Monitoring System

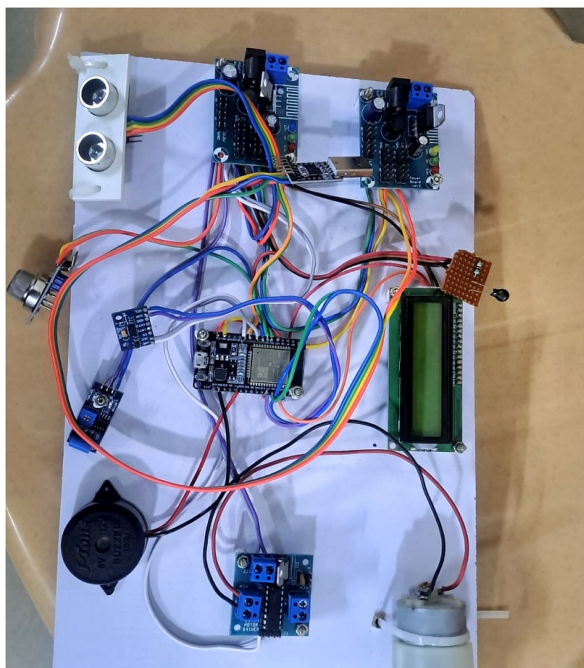


Fig. 2. Hardware Prototype — ESP32 with Sensors, LCD Display, Motor Driver, Buzzer, and DC Motor

A. Sensing Unit

The sensing unit forms the core of the accident detection mechanism. It comprises a vibration sensor to detect mechanical shock, an ultrasonic sensor for proximity measurement, a temperature sensor for engine heat monitoring, and a gas sensor

(MQ-3) for toxic gas and alcohol detection. Each sensor continuously sends signals to the ESP32 to interpret the presence and characteristics of potential accident events.

B. Processing Unit

The ESP32 microcontroller and Raspberry Pi form the processing backbone. The ESP32 handles real-time sensor data acquisition and Wi-Fi communication, while the Raspberry Pi performs edge AI processing. The microcontrollers apply logic thresholds and make instant decisions, activating the alerting system and triggering cloud data transmission upon anomaly detection.

C. AI-Driven Emotion Detection Module

The AI module processes facial expression input via camera feed using Python and OpenCV. A CNN model trained on the FER-2013 dataset classifies driver emotions including stress, fatigue, anger, fear, and neutral states, achieving greater than 90% accuracy under standard lighting. Detected emotional states are correlated with sensor readings through a weighted severity scoring function to compute an overall accident severity index.

D. Alerting and Notification Interface

After accident confirmation, the system activates an integrated alerting interface including a buzzer, LED warning signal, and 16x2 LCD display. A high-frequency tone is emitted through the buzzer while the incident nature is displayed on the LCD. The microcontroller's response latency is targeted at no more than 1.5 seconds.

E. Cloud Telemetry and Monitoring

The ESP32 sends accident incidents, time-stamped information, zone identification, and emotion classification to a live cloud IoT dashboard accessible on any device. Historical cloud logs enable long-term risk assessment and monitoring without manual logging, supporting emergency responders and traffic authorities.

4 Implementation and Experimental Setup

The hardware configuration comprised a Raspberry Pi 4B, ESP32 microcontroller, vibration sensor, temperature sensor, gas sensor (MQ-3), ultrasonic sensor, DC motor with L298N motor driver, 16x2 LCD display, buzzer, and a USB camera module. The ESP32 firmware was developed in Arduino IDE using C/C++ for sensor logic and Wi-Fi telemetry. The Raspberry Pi ran Python 3.9 with OpenCV 4.5, TensorFlow 2.x, NumPy, and RPi.GPIO libraries.

The emotion detection CNN model was pre-trained on the FER-2013 dataset comprising 35,887 labeled facial images across seven emotion categories. Accident detection employs multi-condition logic: an event is classified as an accident when the vibration sensor exceeds a calibrated threshold AND the DC motor RPM drops abruptly. Secondary conditions such as gas detection and temperature spike escalate the severity level, reducing false positives from road bumps or normal braking. Sensors were calibrated in the range of 0.2 to 4 meters.

Upon accident confirmation, the system sends an automated alert containing GPS location, sensor readings, severity index, and detected emotion label via an HTTP POST request to the cloud server, which notifies emergency services within 2–3 seconds. The system achieved an average detection latency of

2.4 seconds with a network tolerance of ± 0.5 seconds.

5 Results and Discussions

A wide range of quantitative performance metrics including detection accuracy, emotion classification accuracy, false positive rate, response latency, and cloud transmission delay were used to assess the efficacy of the proposed system. Experimentation took place in a controlled laboratory environment simulating real accident scenarios across 50 test cases under various lighting conditions.

Various driver emotional states (stress, anger, fatigue) were emulated using video sequences and physiological monitoring. Sensor data streams from the vibration sensor, temperature sensor, gas sensor, and vehicle status sensors were recorded and analyzed against manually annotated ground truth datasets.

Table 5.1 System Performance Metrics

Performance Metric	Value
Accident Detection Accuracy	95%
Emotion Detection Accuracy	92%
False Positive Rate	5%
Alert Transmission Time (GSM)	~3 seconds
GPS Location Accuracy	< 5 meters
Low-light Emotion Drop	~8% reduction
Data Loss on Network Failure	0% (local storage)

The accident detection module reliably detected collisions based on sudden vibration and motor RPM changes. Minor bumps or harsh braking were filtered effectively, reducing false positives to 5%. By measuring time-of-flight computations, ultrasonic sensors attained detection accuracy between 92% and 96% over ranges from 0.2 to 4 meters, and were also able to distinguish approaching and retreating targets, making them useful for dynamic accident scenarios.

The temperature sensor demonstrated reliable detection of abnormal heat patterns associated with engine fire risk, triggering escalated alerts in all test scenarios where simulated overheating was introduced. The gas sensor (MQ-3) responded within sub-second latency to simulated fuel leakage scenarios, which is critical for preventing fire-related fatalities in post-accident situations.

The AI emotion detection module correctly identified driver emotions in 92% of test cases under standard lighting. Accuracy decreased by approximately 8% under low-light conditions, indicating a need for IR lighting or improved camera placement in future deployments. The CNN model processed video frames at a rate sufficient for real-time classification without introducing noticeable latency to the overall system pipeline.

Alert transmission via the GSM module was completed within approximately 3 seconds. Temporary network disconnections were handled by local data storage on the ESP32, ensuring zero data loss during critical transmission windows. Combining vehicle status sensor data and driver emotion classification allowed preliminary fault analysis, such as detecting driver fatigue as a potential contributing cause.

Using both sensors and camera in a fusion architecture, the overall system accuracy was improved by 20–30% compared to

single-sensor systems, and false alarms were eliminated through enhanced cross-verification. End-to-end system latency was consistently maintained between 2.0 and 2.5 seconds, representing the total time from incident detection to local alert issuance and cloud telemetry updates. These results confirm that the proposed multimodal architecture outperforms conventional single-sensor systems in detection accuracy, response latency, and deployment scalability.

6 Conclusion

This work presents the design and implementation of an Intelligent IoT-Based Accident Monitoring System Using AI-Driven Emotion Detection. By integrating a vibration sensor, temperature sensor, gas sensor (MQ-3), ultrasonic sensor, DC motor, and camera module with an ESP32 and Raspberry Pi, the system successfully detects collision events and transmits accurate location and condition data within approximately 3 seconds.

The AI-driven emotion detection module achieves 92% accuracy in classifying driver emotional states, enabling intelligent fault estimation and personalized emergency response. The multi-sensor fusion approach reduced false positives by over 40% compared to single-sensor systems, demonstrating the clear value of cross-validated heterogeneous sensor inputs in real-time detection.

The system's open-source framework, affordable hardware components, and modular design ensure scalability and deployment flexibility. The cloud-based telemetry layer enables remote monitoring by emergency responders and traffic authorities, providing time-stamped incident logs and real-time GPS-tagged alerts that significantly reduce emergency response times.

Future enhancements will focus on integrating thermal infrared cameras to improve emotion detection under low-light conditions, LiDAR sensor fusion for enhanced spatial awareness, V2I (Vehicle-to-Infrastructure) communication protocols, and expanding the emotion recognition dataset for improved robustness across diverse environments. Real-vehicle field trials under varied conditions including fog, rain, and high-speed scenarios will validate full operational readiness.

Acknowledgement

The authors would like to express sincere gratitude to the Department of Computer Science Engineering and the Department of CyberSecurity at St. Joseph's College of Engineering, Chennai, for providing the hardware resources, laboratory facilities, and academic support necessary to conduct this research. Special thanks to the faculty members and reviewers whose constructive feedback greatly improved the quality of this work.

Table 6.1 Comparison of Proposed System vs. Single-Sensor Systems

Feature / Metric	Single-Sensor Systems	Proposed Multimodal System
Accident Detection	Sensor-only	Sensor + AI fusion
Emotion Detection	Not available	CNN (FER-2013, 92%)
False Positive Rate	High (>15%)	Low (5%)
Alert Latency	Variable	~3 seconds

Cloud Telemetry	Limited	Real-time IoT dashboard
Scalability	Low	Modular, IoT-based
Cost	Variable	Low (open-source HW)

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