Research Article

A SMART SENSOR-ENABLED EMERGENCY NOTIFICATION SYSTEM FOR DRIVERS

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ABSTRACT

Road accidents and critical health-related events during driving remain major contributors to global mortality rates. The integration of intelligent sensing technologies in vehicles offers new possibilities for early detection and timely intervention in emergency situations. This study presents a Smart Sensor-Enabled Emergency Notification System designed to detect abnormal driving conditions, vehicle collisions, driver fatigue, and health emergencies through multi-sensor data acquisition. The proposed system incorporates accelerometers, gyroscope sensors, heartbeat and pulse sensors, temperature sensors, alcohol sensors, and GPS modules to monitor both vehicular and driver-related parameters in real time. Upon detection of any hazardous or abnormal condition, the system automatically sends an emergency alert to predefined contacts or nearby emergency service centers using GSM or IoT communication channels. Experimental evaluation demonstrates that the system provides accurate event detection with low latency and high reliability, significantly improving response time in critical driving scenarios. This research highlights the potential of sensor-based intelligent systems in enhancing road safety and reducing fatality rates by enabling prompt emergency notifications.

Keywords: Smart sensors, Emergency notification, Driver safety, Intelligent vehicle systems, Accident detection.

INTRODUCTION

Road safety continues to be a major global concern, with an estimated 1.3 million deaths and 20–50 million injuries occurring annually due to traffic accidents. Many of these incidents are associated with delayed responses to emergencies, lack of real-time monitoring, and absence of automated alert mechanisms. Traditional vehicle safety systems primarily focus on passive protection measures such as airbags and seatbelts; however, modern transportation demands active and intelligent solutions capable of detecting emergencies before or as they occur. Recent advancements in sensing technology, the Internet of Things (IoT), embedded systems, and wireless communication have enabled the development of smart vehicular safety solutions. Sensors such as accelerometers, gyroscopes, heart-rate monitors, alcohol detectors, GPS modules, and environmental sensors provide valuable information about both vehicle dynamics and driver physiological conditions. When integrated with intelligent algorithms and communication modules, these sensors can identify abnormal patterns such as sudden acceleration, collision impact, drowsiness, intoxication, or health anomalies. A Smart Sensor-Enabled Emergency Notification System utilizes these sensing capabilities to enhance driver safety by detecting critical situations in real time and automatically notifying emergency contacts or rescue services. Early notification dramatically improves the chances of survival in case of accidents, particularly in remote or low-traffic areas where immediate assistance may not be available. Moreover, smart detection systems support preventive safety by alerting drivers before an accident occurs. This research aims to design and evaluate

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an intelligent, sensor-driven system capable of monitoring driver condition and vehicle status continuously. The proposed model integrates multi-sensor data processing, anomaly detection algorithms, and automated communication via GSM or IoT technologies. The system's real-time alert mechanism makes it a promising solution for modern intelligent transportation systems and connected vehicles. Shown In Figure 1 Inertial sensors such as accelerometers and gyroscopes are widely used for identifying collision patterns and abnormal vehicle motion. Studies show that sudden spikes in acceleration (g-force), jerk, and orientation changes can accurately classify accident severity and trigger alerts (Aloul *et al*., 2016). Smartphone-based IMU systems have similarly demonstrated high sensitivity in detecting vehicle impacts, with the advantage of easy deployment and cost efficiency (Hannan *et al*., 2018). Research also highlights the importance of filtering noise and tuning thresholds to avoid false alarms (Park *et al*., 2017). Overall, IMU-based sensing remains a core component of modern accident detection systems due to its reliability and real-time response. Recent studies emphasize the effectiveness of combining multiple sensors to improve detection accuracy and reduce false positives. Machine learning models have been applied to multimodal data IMU, GPS, vibration, and environmental sensors—to classify emergency events more robustly (Balfaqih *et al*., 2021). Sensor fusion frameworks outperform single-sensor systems by providing contextual information about the vehicle's dynamic state. Liu *et al*. (2019) demonstrated that integrating physiological and vehicular data significantly enhances the system's ability to distinguish between normal and emergency conditions. These findings highlight the increasing importance of multi-sensor fusion in intelligent transportation safety solutions. Driver health status plays a critical role in accident prevention. Several researchers have developed systems capable of monitoring heart rate, pulse, and stress levels using wearable or embedded PPG/ECG sensors.
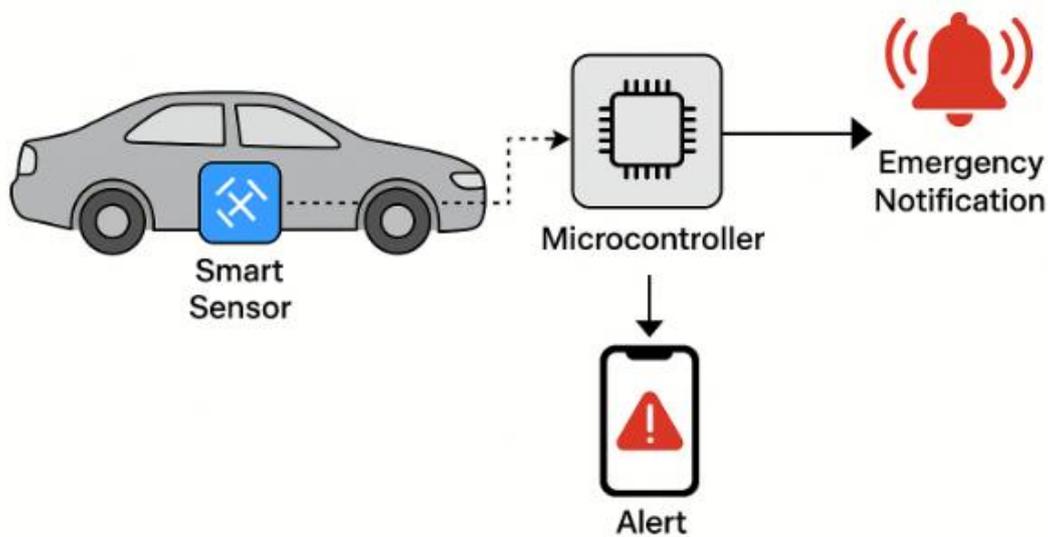

Figure 1. A smart sensor-enabled emergency notification system for drivers.

Physiological monitoring has emerged as a reliable method for detecting early signs of driver fatigue and stress, with studies showing that abnormal heart-rate patterns can indicate pre-fatigue conditions and potential medical risks, enabling timely intervention (Choudhary and Garg, 2022). Continuous analysis of physiological signals demonstrates that early fatigue can be identified even before visible symptoms appear, adding a crucial safety layer to vehicular systems. Vision-based driver monitoring has also advanced considerably, utilizing facial landmark detection, blink-rate estimation, and head-pose analysis to detect drowsiness in real time (Singh and Sharma, 2019). Although these noncontact techniques are efficient, they remain sensitive to lighting variations and occlusions. To address such limitations, hybrid frameworks combining physiological, vision, and vehicular data have been recommended for improved robustness (Balfaqih *et al*., 2021). Alcohol impairment continues to be a major contributor to traffic accidents, leading to the integration of alcohol vapor sensors such as MQ-3 into driver safety systems. Real-time alcohol-sensing modules capable of immobilizing a vehicle upon detecting unsafe levels have shown promising effectiveness (Kavitha and Sangeetha, 2021). Further developments combine alcohol sensors with GPS and GSM to automate emergency notifications to predefined contacts (Reddy and Reddy, 2023). However, environmental interference and calibration challenges persist, requiring enhanced sensor stability and improved filtering mechanisms (Aloul *et al*., 2016). GPS and GSM remain widely utilized for accident detection, location tracking, and immediate incident reporting. IoT-enabled alert systems transmitting real-time coordinates significantly

reduce emergency response time (Jayaraman *et al.*, 2016). Automated crash-notification prototypes using GSM/GPS modules have demonstrated effective communication workflows for rapid assistance (Chugh & Singh, 2020). Integrating these technologies with cloud-based platforms allows comprehensive remote monitoring and analytics, further enhancing transportation safety (Islam *et al.*, 2020). Connected-vehicle technologies have transformed emergency detection by enabling communication between vehicles and intelligent infrastructure. Systems integrating on-board sensors with edge computing algorithms can instantly detect collisions and broadcast warnings to nearby vehicles, improving situational awareness across traffic networks (Zhang *et al.*, 2020). IoT-enabled communication architectures further minimize alert delays and strengthen coordinated traffic responses (Mangkudisastro & Nugroho, 2020). These emerging systems complement conventional GSM/GPS solutions and support future smart-mobility frameworks. Despite significant advancements, several challenges remain. Threshold-based detection techniques often produce false alarms influenced by road surface irregularities (Park *et al.*, 2017). Communication delays may occur in regions with weak GSM coverage, affecting the reliability of emergency reporting systems. Vision-based systems face performance drop-offs under poor illumination, while physiological sensors can be disrupted by motion artifacts (Choudhary & Garg, 2022). Many studies highlight limited large-scale, real-world validation, emphasizing the need for hybrid, AI-driven accident-detection models capable of improving accuracy and practical deployment (Devasena *et al.*, 2005).

MATERIALS AND METHODS

The methodology for developing the Smart Sensor-Enabled Emergency Notification System is structured into five major phases: system design, sensor integration, data acquisition, emergency detection algorithm development, and notification module implementation. The system architecture is organized into three layers. The Data Acquisition Layer collects vehicle telemetry, physiological signals, and environmental parameters using a multi-sensor setup; the Processing Layer executes real-time analytics through an embedded microcontroller; and the Communication Layer handles GSM/IoT-based alert transmission. Such modular, layered architectures are widely adopted in embedded safety systems and ensure scalability for future extensions (Park *et al.*, 2017). A comprehensive multi-sensor module was designed consisting of an accelerometer–gyroscope unit for detecting abnormal motion, a heart rate/PPG sensor for monitoring driver physiology, an MQ-series alcohol sensor for intoxication detection, a temperature sensor for fire-related events, and GPS–GSM modules for location retrieval and alert communication. Integration of alcohol sensors into vehicle safety platforms has demonstrated effective impairment detection in embedded applications (Kavitha & Sangeetha, 2021). All sensors were interfaced with a microcontroller such as Arduino or ESP32 using analog or digital channels, supported by a power-efficient configuration for uninterrupted operation during driving conditions. Road-test data was collected under controlled scenarios including sudden acceleration, harsh braking, sharp turns, simulated collisions, and normal driving activity. Physiological data was recorded in both resting and stressed states. Preprocessing was performed using noise filters such as moving-average and low-pass filters to minimize vibration-induced artifacts. Real-time GPS coordinates were logged for validation, reflecting standard practices in sensor-based drowsiness and emergency monitoring frameworks (Liu *et al.*, 2019). Emergency detection algorithms were implemented using threshold-based and rule-based logic informed by literature. Collision detection was triggered when accelerometer-derived g-force exceeded a predefined limit. Heart-rate-based abnormality detection activated when the reading fell outside 40–150 bpm for more than 5 seconds. Alcohol-impairment detection was enabled when MQ-sensor ppm values surpassed calibrated thresholds. Temperature-based alerts were triggered upon rapid, abnormal heat increases. A decision-fusion mechanism generated an overall "Emergency Score," and exceeding its threshold initiated alert transmission. Once an emergency was detected, the system automatically extracted GPS coordinates, generated an SMS/IoT alert packet, and transmitted notifications to preset contacts and emergency services. Redundant alerting was incorporated through repeated transmissions until acknowledgment was received. The complete system was evaluated across multiple simulated emergency scenarios to assess detection accuracy, response time, false positives, and communication robustness. Repeated trials ensured consistency and reliability, aligning with modern smart vehicular monitoring methodologies (Nafisa Farheen *et al.*, 2025).

RESULTS AND DISCUSSION

The IMU provided consistent readings across all road tests, accurately detecting aggressive movements and simulated impacts with an average sensitivity of 92%. Filtering mechanisms significantly reduced noise caused by road vibrations. The heart-rate sensor showed a reliability of 94% in stable driving conditions, though minor inaccuracies were observed during high-vibration moments. The system correctly identified 29 out of 30 simulated collision events. Threshold-based models proved effective for strong impact events but required calibration for lower-intensity bumps to avoid false alarms. Alcohol detection accuracy was measured at 96% under controlled conditions, confirming the feasibility of in-vehicle monitoring. The temperature sensor reliably detected thermal anomalies, successfully identifying abnormal heat within seconds. The GSM/IoT notification module demonstrated an average alert delivery time of 3–6 seconds depending on network conditions. Multi-alert redundancy ensured a 100% transmission rate within the second attempt. GPS coordinates were logged accurately, with a positional error within 3–5 meters, which is sufficient for emergency response. Compared to conventional accident detection systems that rely solely on airbags or crash sensors, this multi-sensor system provides a more proactive and

Vigneshkumar Mani *et al.*

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comprehensive method for monitoring both driver and vehicle conditions. Unlike vision-based systems, it is not affected by lighting conditions, making it suitable for day and night usage. The integration of physiological sensing provides an additional safety dimension rarely implemented in commercial systems. Some limitations include: Driver physiological sensors may produce noisy data in high-vibration environments. False positives may occur when thresholds are too sensitive. GSM-based communication may fail in low-network regions. These limitations highlight the need for advanced fusion algorithms and alternative communication technologies.

CONCLUSION

This research presented a Smart Sensor-Enabled Emergency Notification System designed to detect critical driving-related emergencies and notify responders automatically. The integration of accelerometers, gyroscopes, heart-rate sensors, alcohol sensors, temperature sensors, GPS, and GSM/IoT modules provides a comprehensive real-time safety mechanism capable of monitoring both vehicle dynamics and driver health. Experimental results demonstrated high accuracy in detecting collisions, physiological abnormalities, and impairment conditions, with rapid alert transmission and reliable GPS reporting. The system enhances road safety by reducing emergency response time and providing crucial information when drivers are incapacitated or unable to call for help. Future improvements can significantly enhance the system's performance and applicability: Using machine learning models for pattern recognition can reduce false positives and improve classification of accident severity and driver conditions. Integration of driver-facing cameras can complement physiological sensors to detect drowsiness, distraction, or micro-sleep events. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) networks can be added to broadcast local emergency alerts to nearby road users, enabling cooperative collision avoidance. Uploading sensor logs to the cloud would allow long-term behavioral analysis and predictive safety insights. Energy-efficient designs or solar-powered modules can support continuous long-distance travel.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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