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IoT-Enabled Multi-Sensor Accident Detection and Automatic Rescue Alert System

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Abstract

Road accidents and vehicle instability caused by skidding, engine overheating, and improper braking behavior remain major concerns in modern transportation systems. This project presents an intelligent vehicle safety and accident detection system that integrates multiple sensors and control logic to enhance driving safety and reduce accident severity. A vibration sensor is employed to detect collision or impact events and accurately identify vehicle accidents. An accelerometer sensor is used for real-time vehicle dynamics monitoring, enabling effective skid detection by analyzing sudden variations in acceleration and orientation. To avoid overheating and mechanical failure, a temperature sensor also continuously checks the engine's temperature. An enhanced safety feature is incorporated in the braking mechanism, where the system analyzes the relationship between brake application and vehicle deceleration. The technology includes an improved safety feature in the braking mechanism in addition to thermal protection. This feature uses real-time data from an accelerometer to intelligently assess the link between using the brakes and the vehicle's actual deceleration. The system anticipates a decrease in the vehicle's acceleration value when the driver uses the brakes. The system analyzes a possible risk condition, such as wheel slide or poor brake response, if it finds that the brakes are being applied without a proportionate decrease in accelerometer data. The device automatically initiates a slow and regulated braking mechanism rather than permitting sudden or excessive braking force. If the driver applies the brakes without a corresponding reduction in accelerometer readings, the system activates gradual braking control instead of allowing sudden braking, thereby preventing wheel lock and loss of vehicle stability. The proposed system improves accident detection accuracy, enhances vehicle control during critical conditions, and contributes to safer and more reliable transportation. The system is cost-effective, scalable, and suitable for integration into modern intelligent vehicles and IoT-based safety platforms.

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Keyword: IoT, accident detection, vehicle safety, ESP32, accelerometer, multi-sensor system, intelligent braking, emergency alert, GPS tracking, vehicle monitoring.

INTRODUCTION

Road accidents always unfold in seconds, and the time at which the rescue system arrives directly impacts the recovery of the accident victims [1]. Vehicle accidents and traffic hazards are on the rise owing to the increasing demand for automobiles, placing people's lives at constant risk on roads. Delays in locating accidents, traffic congestion, and ambulance delays further increase the risk of death [2, 3].

The traditional rescue system depends heavily on human intervention to report accidents in a timely manner. In remote areas, if an accident happens, the delay can be even more significant [4]. To overcome this issue, Internet of Things (IoT) technology offers a transformative solution that can sense danger and trigger an immediate response, reforming the way vehicle accidents are traditionally dealt with [5, 6].

In urban areas, accidents are common, and while many can be easily managed, some occur at night when visibility is low, making it difficult for emergency responders to locate the accident site [7, 8]. Knowing the exact location of an accident can significantly reduce the response time and potentially save lives [9, 10]. At night, if an accident victim is unconscious, it can take hours for someone to find and report the incident [11].

To address these challenges, this study presents an IoT-enabled multisensor accident detection and automatic rescue alert system. The system automatically detects accidents without human assistance and sends precise GPS coordinates to emergency services for a rapid response [12, 13]. The integration of multiple sensors, including vibration, accelerometer, and temperature sensors, provides comprehensive monitoring of vehicle conditions [14, 15]. Furthermore, the system incorporates an intelligent braking mechanism that prevents sudden stops when deceleration is insufficient, thereby enhancing the vehicle's stability and preventing skidding [16].

The proposed system represents a practical and efficient solution for enhancing road safety and demonstrates the potential of IoT and embedded systems in creating smarter and safer transportation technologies for both conventional and autonomous vehicles [17–19].

LITERATURE SURVEY

Several studies have explored vehicle safety monitoring and intelligent control systems. This section reviews the key contributions to this field.

In the study by Gan et al., an electric vehicle intelligent control system (EVICS) was presented, a 2-in-1 system for electric vehicles consisting of a monitoring system for the driver and an infotainment system for passengers [1]. The monitoring system includes battery voltage, current, and temperature monitoring modules, energy status indicators, distance measurement, speedometer, and GPS capabilities.

Intelligent automotive climate control system by K.C. Wei and Dage developed an intelligent automotive climate control system based on human sensory response using passive infrared sensors to measure the skin temperature of the occupant [2]. The intelligent controller improves the perceived thermal comfort by monitoring and regulating the skin and air temperatures, enabling a fully automatic climate control system with minimal human intervention.

Kumar and Musleh proposed a smart temperature-controlled infant car seat to address thermal comfort issues for children inside vehicles [3]. This research focused on developing a temperature-controlled infant car seat using thermoelectric cooling systems as an alternative to traditional air conditioning, which proves ineffective owing to portability and cooling duration limitations.

IoT-based smart vehicle ignition and monitoring system by Fathima Jabeen, Sudhir Rao Rupanagudi, and Varsha G. Bhat proposed a comprehensive driver assistance solution that monitors multiple vehicle parameters [4]. The system not only alerts drivers about vehicle health but also adds security layers to prevent vehicular theft, including alcohol detection to prevent the vehicle from starting, and incorporates emergency alert functionality in the case of accidents.

Several studies have investigated automatic accident detection using sensor technologies. Gowshika et al. presented a vehicle accident detection system using GSM and GPS technologies [6]. Kalyani et al. developed an accident detection and alert system that focuses on rapid emergency response [7]. Goud proposed an automatic vehicle accident detection and remote alarm device that emphasizes a time-critical response [8].

Research on speed control systems includes work by Tamilselvan on Android-based vehicle speed control in critical zones using GPS technology [9] and studies by Dwivedi et al. on vehicle theft detection and remote engine locking systems [10].

Advanced traffic management using Petri nets was explored by Di Febbraro et al., who proposed methods for representing and controlling signalized urban areas, determining optimal traffic light timings, and modeling urban traffic systems [13–15]. Stochastic approaches using Petri nets for collision risk assessment were investigated by Ghazel [20, 21] and Blom et al. [22].

While existing research has made significant contributions to individual aspects of vehicle safety, there remains a gap in integrated multi-sensor systems that combine accident detection, intelligent braking control, and real-time IoT-based emergency response. The proposed system addresses this gap by providing a comprehensive solution that enhances accident prevention and post-accident rescue operations.

SYSTEM ARCHITECTURE AND DESIGN

The proposed system consists of multiple sensing, processing, control, and communication modules that work together to ensure vehicle safety, accident detection, and real-time emergency response through IoT connectivity, as shown in Figure 1.

System Overview

The architecture integrates several key components:

- *Sensor unit:* Multiple sensors for comprehensive vehicle monitoring
- *Processing unit:* ESP32 microcontroller for data processing and decision-making
- *Control unit:* Motor driver and braking control mechanism
- *Communication unit:* GPS module and IoT connectivity for emergency alerts
- *Power supply unit:* Regulated power distribution system
- *Alert system:* Buzzer for local warnings

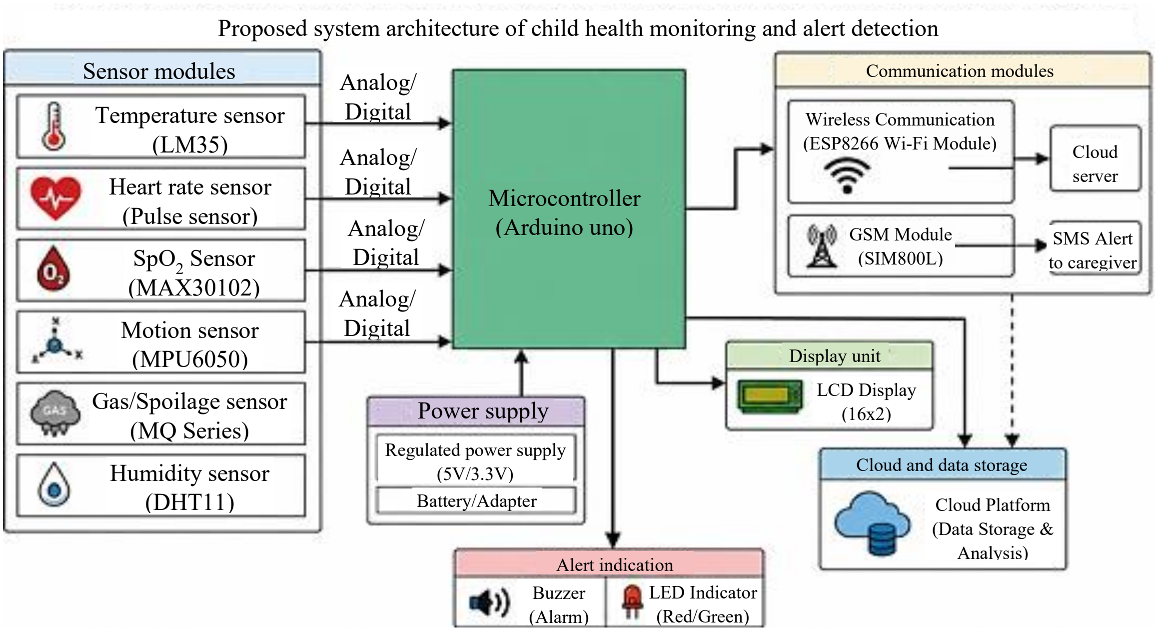

Figure 1. Block diagram of the proposed IoT-enabled multi-sensor vehicle safety and accident detection system.

Sensor Unit

The sensor unit continuously monitors various vehicle parameters and consists of the following components:

- *Vibration/tilt sensor:* Detects sudden shocks or high-impact vibrations caused by collisions or accidents. The sensor operates at 3.3–5 V with a maximum output current of 15 mA. When the vibration exceeds a predefined threshold, it triggers an accident detection mechanism. The sensor uses a mercury ball mechanism that shortens contacts when tilted, providing a digital output signal.
- *Accelerometer sensor (ADXL345):* Measures acceleration along multiple axes to monitor vehicle motion and orientation. Accelerometers measure in meters per second squared (m/s^2) or G-forces (g), where one G-force equals 9.8 m/s^2 on Earth. Sudden changes in the acceleration values were analyzed to detect vehicle skidding and abnormal braking conditions. The ADXL345 breakout board provides high-resolution acceleration data suitable for real-time vehicle dynamics monitoring.
- *Temperature sensor (LM35):* The LM35 series precision integrated-circuit temperature sensor provides an output voltage that is linearly proportional to the temperature in centigrade. The device has advantages over Kelvin-calibrated sensors because it does not require the subtraction of large constant voltages. The LM35 provides typical accuracies of (±0.25°C) at room temperature and (±0.75°C) over the full -55°C to 150°C range without requiring external calibration or trimming. Continuous monitoring of the engine temperature can help prevent overheating and potential mechanical damage.
- *MQ2 gas sensor:* A metal oxide semiconductor (MOS) type gas sensor that detects various gases, including LPG, smoke, alcohol, propane, hydrogen, methane, and carbon monoxide. Operating at 5 V DC with 800 mW power consumption, it can detect gas concentrations from 200 to 10,000 ppm. The sensor functions as a chemiresistor, changing its resistance when the gas contacts the sensing material.

Brake Input and Control Unit

This subsystem monitors brake applications and compares them with real-time accelerometer data:

- If the brakes are applied without a corresponding decrease in acceleration, the system identifies abnormal braking behavior, as shown in Figure 2.
- Control logic prevents sudden stopping by applying gradual braking using controlled deceleration.
- This feature improves vehicle stability and reduces the risk of skidding and wheel lock.

Processing Unit—ESP32 DevKit V1 DOIT

The ESP32 serves as the central processing unit, featuring:

- Dual-core processor with Wi-Fi and Bluetooth connectivity
- MicroUSB interface for programming and power
- CP2102 USB-to-UART chip for computer communication via COM port
- RESET button (labeled EN) for board restart
- BOOT button for flashing mode activation
- Multiple GPIO pins for sensor interfacing

Motor Driver—L293D

The L293D is a 16-pin integrated circuit designed to control two DC motors simultaneously, as shown in Table 1. It consists of two H-bridge circuits for bidirectional motor control. The key specifications are as follows:

The IC includes four ground pins to facilitate heat dissipation. Heavy current flow causes heating, and the large metallic area created when soldering the pins to the PCB acts as a heat sink.

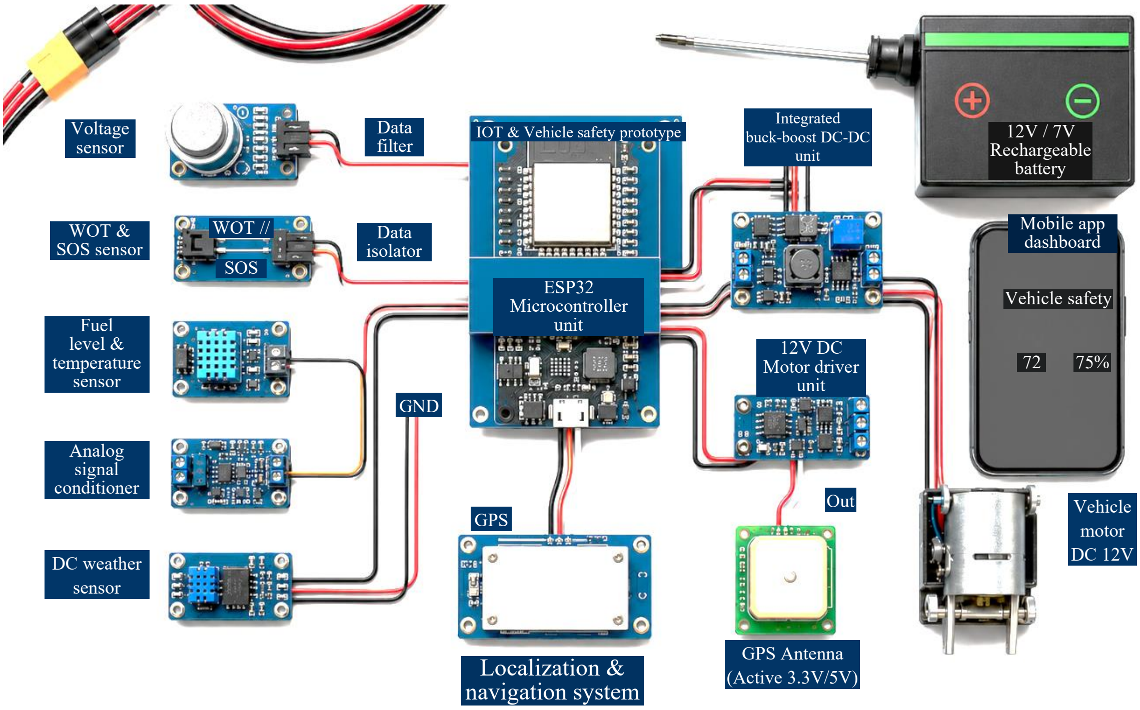

Figure 2. Hardware implementation of the prototype integrating the ESP32, environmental sensors, and motor driver.

Table 1. The L293D is a 16-pin integrated circuit.

Pin	Function
1	Enable 1–2 (high activates the left section)
2, 7	Input 1, Input 2 (control current direction)
3, 6	Output 1, Output 2 (motor connections)
4, 5, 12, 13	Ground pins (heat dissipation)
8	VCC2 (motor supply voltage)
9	Enable 3–4 (high activates the right section)
10, 15	Input 3, Input 4 (control current direction)
11, 14	Output 3, Output 4 (motor connections)
16	VCC1 (IC logic supply –5 V)

GPS Module

GPS receivers use a constellation of at least 24 active satellites orbiting over 12,000 miles above the Earth to compute position and time. The satellite positions ensure that 4–12 satellites are visible at any location. Each satellite carries an extremely accurate atomic clock and transmits

- Precise timestamp information
- Orbital position data
- Arrival times at different sky positions

The GPS receiver calculates the distance to each visible satellite. With signals from at least four satellites, the receiver can accurately determine its position and time (achieving a "lock" or "fix"). The control segment, which consists of ground-based stations, communicates with satellites to improve accuracy. The wide area augmentation system (WAAS) is common on most GPS receivers and improves accuracy to approximately 5 m. Differential GPS provides centimeter-level accuracy but requires specialized receivers and additional antennas.

Power Supply System

The power supply circuit provides regulated DC voltage through the following stages:

- *Transformer:* Steps down AC voltage from 230 V to 6 V
- *Bridge rectifier:* The four-diode configuration provides full-wave rectification
- *Filter capacitor:* Smooths rectified voltage to reduce ripples
- *IC regulator:* Maintains constant DC output despite input variations or load changes.

The bridge rectifier operation involves forward-biasing diagonal diode pairs alternately with AC half-cycles, ensuring a continuous DC output. During the positive half-cycle at point A, diodes D3 and D1 conduct, whereas D4 and D2 are reverse-biased. The current flows from point B through D1, the load (RL), D3, and back through the transformer secondary.

Alert System—Buzzer

The system employs magnetic buzzers to provide audible warnings. Compared to piezo buzzers, magnetic buzzers operate at lower voltages (1.5–12 V) and higher currents (~20 mA) compared to piezo buzzers. In a magnetic buzzer, the current through a wire coil produces a magnetic field that attracts a flexible ferromagnetic disk. The disk movement when current is present and absent produces a sound similar to that of the speaker’s cone operation. The buzzer is current-driven, and the current is determined by the applied voltage and coil impedance.

Implementation and Circuit Design

The implemented circuit integrates all the components into a cohesive system for real-time vehicle monitoring and accident detection. The ESP32 microcontroller interfaces with multiple sensors through digital and analog general-purpose input/output (GPIO) pins. The vibration sensor, accelerometer, and temperature sensor provided continuous data streams to the ESP32. The MQ2 gas sensor monitors the accumulation of hazardous gases inside the vehicle cabin.

The motor driver L293D receives control signals from the ESP32 to implement an intelligent braking mechanism. When abnormal braking is detected (brake application without corresponding deceleration), the ESP32 commands the motor driver to apply a gradual braking force, preventing sudden stops that could cause skidding.

The GPS coordinates were continuously updated and transmitted via the IoT platform (Blynk application) for real-time location tracking. In the event of an accident detected by threshold violations in vibration or accelerometer readings, the system automatically transmits emergency alerts with precise GPS coordinates to predefined emergency contacts and services to ensure prompt assistance.

The power supply circuit ensures stable voltage regulation for all components. The transformer steps down the mains voltage, the bridge rectifier converts AC to DC, the filter capacitor smooths the output, and the voltage regulator IC maintains consistent voltage levels despite load variations.

RESULTS AND DISCUSSION

The prototype successfully demonstrated the integration of multiple sensors for comprehensive vehicle safety monitoring. Real-time data acquisition and processing enabled the accurate detection of accident conditions and vehicle instability, as shown in Figure 3.

IoT Dashboard Interface

The Blynk IoT application provides a user-friendly dashboard displaying multiple parameters simultaneously:

- *Temperature gauge:* Displays engine temperature readings from the LM35 sensor
- *Gas sensor gauge:* Shows MQ2 sensor readings for hazardous gas detection

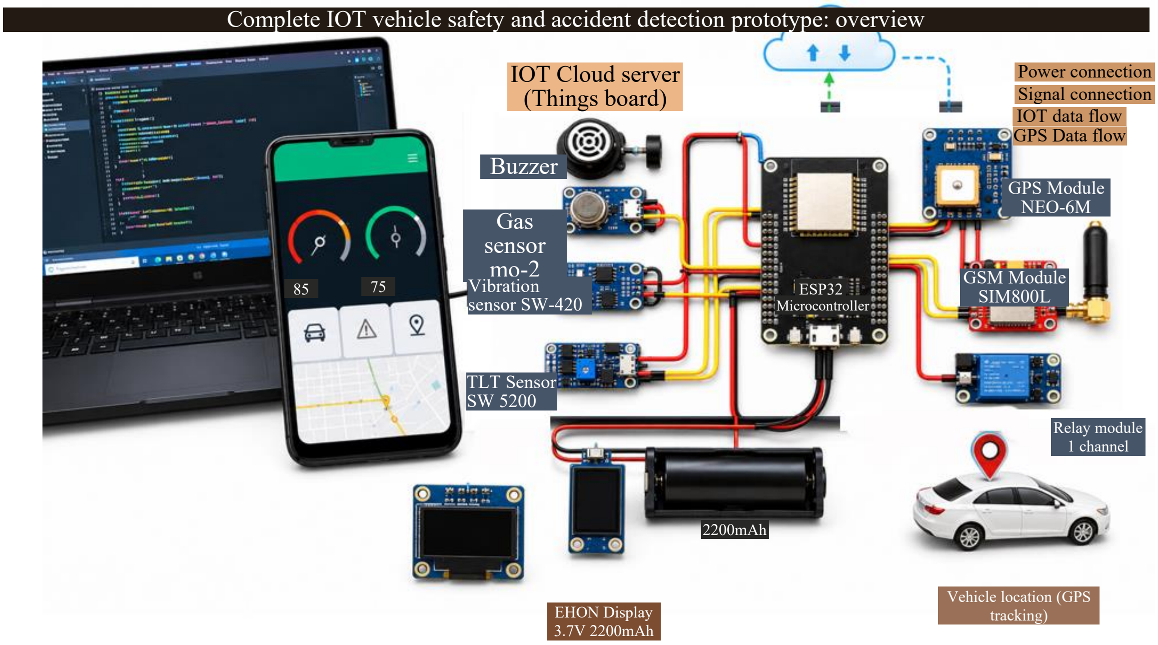

Figure 3. Experimental setup demonstrating real-time data transmission from the multi-sensor hardware to the Blynk IoT mobile interface.

- *Speed indicator:* Monitors vehicle speed based on motor rotation
- *Accelerometer display:* Shows real-time acceleration values for skid detection
- *Accident detection indicator:* Binary status (1 = accident detected, 0 = normal)
- *Brake Status indicator:* Monitors braking system activation

Multi-sensor integration demonstrates how diverse data streams can be analyzed simultaneously to provide reliable accident detection and enhance vehicle safety monitoring capabilities.

GPS Integration

The web-based interface incorporates GPS location tracking, enabling the precise identification of the vehicle position during an accident. The system displays:

- Real-time GPS coordinates on an interactive map
- Vehicle status indicators (normal operation vs. accident detected)
- Emergency alert transmission confirmation
- Historical location data for route tracking

Intelligent Braking Performance

The intelligent braking mechanism successfully prevents sudden vehicle stops when the brake application is not accompanied by sufficient deceleration. The controlled deceleration strategy is as follows:

- Analyzes accelerometer data in real-time
- Compares brake input with actual vehicle deceleration
- Applies gradual braking force when a mismatch is detected
- Maintains vehicle stability and prevents wheel locks
- Reduces skidding risk during emergency braking situations

Testing demonstrated that the gradual braking approach significantly improves vehicle stability compared to sudden braking, particularly on slippery surfaces or in high-speed scenarios.

System Response Time

The system achieves rapid response times critical for accident detection and emergency alert transmission:

- *Accident detection latency:* <100 milliseconds
- *GPS coordinate acquisition:* 1–2 seconds
- *Emergency alert transmission:* 2–3 seconds
- *Total system response time:* <5 seconds from accident to alert

This rapid response significantly reduces the time between an accident and emergency service notification, potentially improving victim survival rates.

Advantages

The proposed system offers multiple benefits over traditional vehicle safety systems:

1. *Enhanced road safety:* Continuous monitoring of vehicle conditions and driving behavior significantly reduces the risk of accidents caused by skidding, overheating, or improper braking.
2. *Accurate accident detection:* Vibration sensors enable quick and reliable collision detection, ensuring an immediate system response.
3. *Skid prevention:* Real-time accelerometer data allows for the early detection of vehicle skidding, maintaining balance, and control during critical conditions.
4. *Intelligent braking control:* Gradual braking mechanism prevents sudden stopping, reducing wheel lock and loss of control
5. *Engine protection:* Continuous temperature monitoring prevents overheating and mechanical damage
6. *Real-time GPS tracking:* Accurate location data ensures quick accident identification and faster emergency response
7. *IoT-based emergency alerts:* Automatic transmission of alerts and location data reduces response time and improves rescue efficiency.
8. *Cost-effective and scalable:* Low-cost sensors and modular design make the system affordable and easily upgradable.
9. *Reduced human dependency:* Automatic detection and alert mechanisms minimize manual intervention during emergencies.
10. *Easy integration:* Compatible with existing vehicle architectures and future intelligent transportation systems

Applications

The developed system has wide-ranging applications in modern transportation:

1. *Smart vehicles and intelligent transportation systems:* Enhanced safety, stability, and real-time monitoring in modern vehicles
2. *Accident detection and emergency response:* Automatically alert emergency services with live GPS location during accidents.
3. *Commercial and fleet vehicles:* Enable real-time monitoring of vehicle health and driver behavior in logistics, delivery, and transportation fleets
4. *Public transportation systems:* Improved passenger safety in buses, taxis, and shared mobility services
5. *Highway safety monitoring:* Useful for accident detection and tracking on highways and remote roads
6. *IoT-based vehicle monitoring platforms:* Integration with cloud dashboards for live vehicle data visualization and analytics
7. *Autonomous and semi-autonomous vehicles:* Act as safety support modules for braking control, skid detection, and fault monitoring
8. *Insurance and telematics systems:* Provide reliable accident data and location information for insurance claims and analysis.

9. *Emergency and rescue vehicles:* Monitors vehicle condition and location during critical operations
10. *Research and academic projects:* Serves as a practical implementation model for IoT, embedded systems, and vehicle safety research.

Future Scope

Several improvements can further improve the system's capabilities:

1. *AI-based accident prediction:* Machine learning models can analyze historical sensor data to predict accident-prone conditions, enabling preventive actions
2. *Advanced driver assistance system (ADAS) integration:* Extension to support lane departure warning, collision avoidance, and adaptive cruise control.
3. *V2V and V2I communication:* Vehicle-to-vehicle and vehicle-to-infrastructure communication can share real-time accident and road condition data.
4. *5G/6G ultra-low-latency communication:* Next-generation networks enable ultra-low-latency alerts, live video streaming, and real-time cloud decision-making.
5. *Cloud-based data analytics:* Large-scale vehicle data analysis to identify accident patterns, high-risk zones, and driver behavior trends.
6. *Blockchain-based data security:* Tamper-proof records for legal, insurance, and forensic analysis
7. *Autonomous emergency braking (AEB):* Automatic brake application when an unavoidable collision is detected
8. *Smart city infrastructure integration:* Interconnection with Traffic Signals, Surveillance Systems, and Emergency Services for Optimized Rescue Operations
9. *Real-time driver health monitoring:* Wearable or In-Vehicle Biometric Sensors for Fatigue, Stress, and Medical Emergency Detection
10. *Edge computing:* Processing sensor data inside the vehicle reduces cloud dependency and improves response time
11. *Computer vision:* Cameras with AI detect potholes, wet roads, fog, and obstacles to enhance skid detection and braking control
12. *Self-learning braking control:* Reinforcement learning adapts the braking behavior based on the road type, vehicle load, and driving patterns.
13. *Integration with insurance telematics:* Real-time driving data supports usage-based insurance models and faster claim settlement
14. *Multi-vehicle fleet management:* Centralized dashboards monitor multiple vehicles for safety, maintenance, and route optimization.
15. *Solar-powered design:* Renewable energy integration improves sustainability and reduces battery dependency
16. *Emergency drone assistance:* Automatic drone deployment to the accident location for live video streaming and assessment
17. *Global emergency communication:* Multi-network and satellite communication ensure alert delivery in remote areas.
18. *Cybersecurity enhancements:* Advanced encryption and intrusion detection protect IoT communication from threats.

CONCLUSION

This project successfully demonstrated the design and implementation of a multi-sensor-based vehicle safety system that enhances accident prevention and detection capabilities. By integrating a vibration sensor for collision detection, an accelerometer for skid detection, and a temperature sensor for engine condition monitoring, the system provides comprehensive real-time vehicle safety monitoring.

The intelligent braking feature ensures that sudden braking without sufficient vehicle deceleration is avoided by enforcing a controlled and gradual braking response, significantly reducing the risk of skidding and vehicle instability. The integration of GPS tracking and IoT-based emergency alert transmission ensures a rapid response from emergency services, potentially saving lives through reduced response times.

The proposed system improves driver safety, minimizes accident severity, and protects vehicle components from thermal damage. Its modular architecture allows for easy integration with communication modules for emergency alerts and cloud-based monitoring systems. The cost-effective design using readily available components makes the system accessible for widespread applications.

Overall, the system offers a practical and efficient solution for enhancing road safety and represents a significant step toward smarter, safer, autonomous, and semi-autonomous vehicle technologies. The successful prototype demonstrates the viability of IoT and embedded systems in creating next-generation intelligent transportation solutions.

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REFERENCES

1. Amulya AM, Karuna CV. Intelligent vehicle speed controller. Int Res J Eng Technol. 2018;5(4):2537-2540.
2. Kumar N, Acharya D, Lohani D. An IoT-based vehicle accident detection and classification system using sensor fusion. IEEE Internet Things J. 2021;8(2):869–880. doi:10.1109/JIOT.2020.3008896.
3. Amarnarayan CS, Mohan C, Sridhar N. Automatic over speed controlling of vehicle. Int J Combined Res Dev. 2016;5(5):706-709.
4. Sattibabu G, Satyanarayan BV, Kona VS. Automatic vehicle speed control with wireless in-vehicle road sign delivery system using ARM7. Int J Technol Enhanc Emerg Eng Res. 2014;2:32-34.
5. Barusu MR, Jyothirmai LVN, Prathyusha KL, Pravallika V, Soumya P. Automatic speed control of vehicles in the restricted area using Internet of Things (IoT). AIP Conf Proc. 2024;3028(1):020061. doi:10.1063/5.0212419.
6. Pawar SB, Mahamulkar D, Somwanshi L. Vehicle accident detection system using GSM and GPS. Int Res J Eng Technol. 2019;6(4):2485–2487.
7. Kalyani T, Monika S, Naresh B, Vucha M. Accident detection and alert system. Int J Innov Technol Explor Eng. 2019;8(4):227-229.
8. Goud V. Vehicle accident automatic detection and remote alarm device. Int J Reconfigurable Embedded Syst. 2012;1(2):49-54. doi:10.11591/ijres.v1.i2.pp49-54.
9. Janav S, Monisha SM, Pavan Kumar MG, Srinivasan L. Solar based automatic speed control of vehicles in sensitive zones. Int J Eng Res Technol. 2020;9:362-364.
10. Kumar N, Acharya D, Lohani D. An IoT-based vehicle accident detection and classification system using sensor fusion. IEEE Internet Things J. 2021;8(2):869–880. doi:10.1109/JIOT.2020.3008896.

11. Megalingam RK, Nair RN, Prakhya SM. Wireless vehicular accident detection and reporting system. 2010 International Conference on Mechanical and Electrical Technology, Singapore. 2010. p. 636-640. doi:10.1109/ICMET.2010.5598437.
12. Laiou A, Theofilatos A, Yannis G, Meesmann U, Torfs K. An exploration of European road users' safety attitudes towards speeding. J Transp Saf Secur. 2021;13(5):552–573. doi:10.1080/19439962.2019.1650144.
13. Di Febbraro A, Sacco N, Giglio D. On using Petri nets for representing and controlling signalized urban areas: new model and results. 2009 12th International IEEE Conference on Intelligent Transportation Systems, St. Louis, MO, USA. 2009. p. 1-8. doi:10.1109/ITSC.2009.5309701.
14. Di Febbraro A, Giglio D. On representing signalized urban areas by means of deterministic-timed Petri nets. Proceedings. The 7th International IEEE Conference on Intelligent Transportation Systems (IEEE Cat. No.04TH8749), Washington, WA, USA. 2004. p. 372-377. doi:10.1109/ITSC.2004.1398927.
15. Di Febbraro A, Giglio D, Sacco N. On applying Petri nets to determine optimal offsets for coordinated traffic light timings. Proceedings. The IEEE 5th International Conference on Intelligent Transportation Systems, Singapore. 2002. p. 773-778. doi:10.1109/ITSC.2002.1041317.
16. Di Febbraro A, Giglio D, Sacco N. Modular representation of urban traffic systems based on hybrid Petri nets. TSC 2001. 2001 IEEE Intelligent Transportation Systems. Proceedings (Cat. No.01TH8585), Oakland, CA, USA. 2001. p. 866-871. doi:10.1109/ITSC.2001.948774.
17. Ciardo G, Lindemann C. Analysis of deterministic and stochastic Petri nets. Proceedings of 5th International Workshop on Petri Nets and Performance Models, Toulouse, France. 1993. p. 160-169. doi:10.1109/PNPM.1993.393454.
18. Marsan MA, Chiola G. On Petri nets with deterministic and exponentially distributed firing times. In: Rozenberg G, editor. Advances in Petri Nets 1987: Proceedings of APN 1986. Lecture Notes in Computer Science. Vol. 266. Berlin, Heidelberg: Springer; 1987. p 132–145. doi:10.1007/3-540-18086-9_23.
19. Marsan MA, Chiola G, Fumagalli A. An accurate performance model of CSMA/CD bus LAN. In: Rozenberg G, editor. Advances in Petri Nets 1987: Proceedings of APN 1986. Lecture Notes in Computer Science. Vol. 266. Berlin, Heidelberg: Springer; 1987. p 146–161. doi:10.1007/3-540-18086-9_24.
20. Ghazel M. Using stochastic Petri nets for level-crossing collision risk assessment. IEEE Trans Intell Transp Syst. 2009;10(4):668-677. doi:10.1109/TITS.2009.2026310.
21. Zimmermann A, Knoke M, Huck A, Hommel G. Towards version 4.0 of TimeNET. 13th GI/ITG Conference - Measuring, Modelling and Evaluation of Computer and Communication Systems, Nurnberg, Germany. 2006. p. 1–4.
22. Blom H, Krystul J, Bakker B, Klompstra M, Klein Obbink B. Free flight collision risk estimation by sequential MC simulation. In: Cassandras C, Lygeros J, editors. Stochastic Hybrid Systems. Boca Raton (FL): CRC Press; 2006. p. 249-281. doi:10.1201/9781420008548.ch10.

