DEVELOPMENT OF A SMART ACCIDENT DETECTION AND ALERT SYSTEM USING SENSOR DATA AND GPS-GSM COMMUNICATION

. Anusha[1], CH. Prajaktha[2], G. Teja[3], B. Sampath[4], CH. Dhanush[5]
[1]Assistant Professor, Department of CSE(DS), TKR College of Engineering, Meerpet, Telangana 500097
[2345]B.Tech (Scholar), TKR College of Engineering, Meerpet, Telangana 500097
*Correspondence: anushathirumani@gmail.com

Abstract--The intelligent accident detection system not only enhances safety but also reduces the time gap between an accident and medical assistance, which is often critical for saving lives. Unlike conventional vehicle safety mechanisms that are expensive and vehicle-specific, this solution is compact, cost-effective, and easily adaptable to helmets, making it highly practical for two-wheeler riders. The use of an accelerometer or vibration sensor ensures accurate crash detection, minimizing false alerts caused by minor shocks or bumps. Furthermore, the system can be extended to support cloud integration for centralized monitoring, IOT-based dashboards for live tracking, and voice call alerts in addition to SMS, making it more versatile. The rechargeable power supply with energy-efficient design allows long-term operation, while the architecture ensures easy upgrades with newer technologies like 4G/5G modules for faster communication. Its integration into daily commuting gear like helmets ensures that the safety mechanism is always with the rider, providing peace of mind for both the user and their families.

Keywords : Smart Safety Helmet, GPS tracking, GSM communication, Real-Time monitoring, Rapid Response System, Power management.

I. INTRODUCTION

Road accidents are one of the major causes of death and serious injuries worldwide. In many cases, the delay in providing immediate medical assistance increases the severity of the situation and may lead to loss of lives [1-2]. Rapid detection of accidents and timely communication with emergency services are therefore very important [3]. To address this issue, an Accident Detection System using GPS and GSM technology can be developed to automatically detect accidents and send alerts to concerned authorities or family members.The proposed system uses sensors and a microcontroller to detect abnormal conditions such as sudden impact or vibration that may indicate a road accident. Once an accident is detected [4], the system collects the exact geographical location using the Global Positioning System (GPS) module.

This location information helps in identifying the precise accident spot, making it easier for emergency responders to reach the location quickly and provide immediate assistance [5]. The Global System for Mobile Communication (GSM) module is used to send alert messages containing the accident location to predefined contacts, hospitals.

By integrating GPS and GSM technologies, the system ensures faster communication and reduces the delay in accident reporting [6]. This intelligent accident detection system can play a significant role in improving road safety and saving human lives by enabling quick rescue operations.

Addition to accident detection and alert transmission, the system can also be designed to continuously monitor vehicle conditions and driving patterns [7-9]. Sensors such as vibration sensors, accelerometers, or tilt sensors can identify sudden changes in motion that usually occur during collisions. The microcontroller processes this sensor data and determines whether the detected event corresponds to an accident. This automated monitoring reduces the need for human intervention and ensures that accidents are detected even if the driver is unconscious or unable to call for help [10]. Furthermore, the integration of GPS and GSM technology makes the system highly reliable and practical for real-world applications. The GPS module provides accurate latitude and longitude coordinates of the accident location, while the GSM module instantly transmits this information through SMS alerts to emergency contacts or rescue teams. This system can be installed in vehicles to enhance safety and improve emergency response time. Therefore, the accident detection system using GPS and GSM technology is an effective solution for

minimizing accident-related fatalities and improving overall road safety.

II. LITERATURE SURVEY

Several researchers have proposed systems to automatically detect road accidents and notify emergency services using modern communication technologies [11]. One of the early approaches involved integrating Global Positioning System (GPS) and Global System for Mobile Communication (GSM) modules with microcontrollers to detect accidents and send alert messages [12]. In such systems, GPS is used to determine the precise geographical location of the accident, while GSM is used to transmit the location information to emergency contacts or rescue teams through SMS notifications [13-14]. These systems aim to reduce the delay in accident reporting and improve emergency response time.

Many studies have implemented sensor-based accident detection mechanisms using accelerometers, vibration sensors, or MEMS sensors [15]. These sensors detect sudden changes in vehicle motion, such as rapid deceleration, impact, or rollover conditions that typically occur during accidents [16]. Once abnormal values exceed a predefined threshold, the system identifies the event as an accident and triggers an alert message [17]. The alert usually includes the latitude and longitude coordinates obtained from the GPS module, enabling rescue teams to quickly locate the accident site [18].

Researchers have also proposed systems that combine microcontrollers such as Arduino with GPS and GSM modules to create cost-effective accident detection solutions. In these systems, the microcontroller processes sensor data and determines whether an accident has occurred [19]. When a crash is detected, the controller retrieves the vehicle's location from the GPS module and sends an emergency notification through the GSM network to predefined mobile numbers such as family members, hospitals, or police control rooms [20]. This approach improves communication efficiency and enables faster rescue operations.

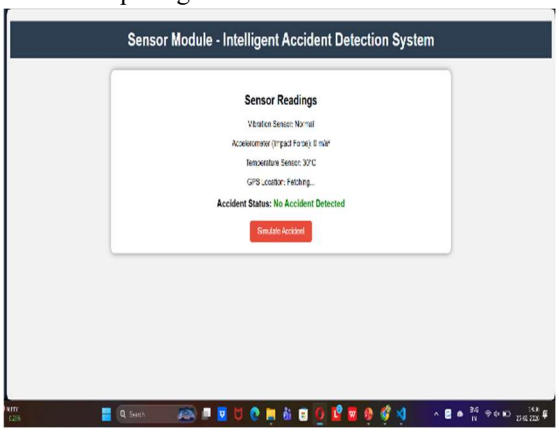
Recent studies have extended accident detection systems by integrating multiple sensors and Internet of Things (IoT) technologies to enhance reliability and accuracy [21]. Sensor fusion techniques combine information from accelerometers, gyroscopes, and GPS receivers to monitor vehicle behavior in real time [22]. These advanced systems can analyze vehicle dynamics more accurately and reduce false accident alerts. Researchers have also explored the use of machine learning algorithms and smart vehicle systems to further improve accident detection performance and road safety [23].

Overall, the literature highlights that GPS and GSM based accident detection systems provide an effective solution for improving emergency response during road accidents. These systems enable automatic accident detection, accurate location tracking, and immediate communication with emergency services. Despite their advantages, researchers continue to explore improvements such as higher detection accuracy, integration with smart transportation systems, and real-time data analysis to further enhance road safety and reduce accident-related fatalities.

III. PROPOSED METHODOLOGY

1. Sensor Based Accident Detection

Sensor-based accident detection is one of the most widely used methodologies in intelligent accident detection systems. In this method, sensors such as vibration sensors, accelerometers, or MEMS sensors are installed in the vehicle to continuously monitor sudden changes in motion or impact forces. When a collision occurs, the sensor detects abnormal vibrations or rapid deceleration that exceed a predefined threshold value. The sensor data is then sent to the microcontroller for analysis, and if the detected values indicate an accident, the system triggers an emergency alert. This method is effective because it allows real-time accident detection without requiring human intervention.

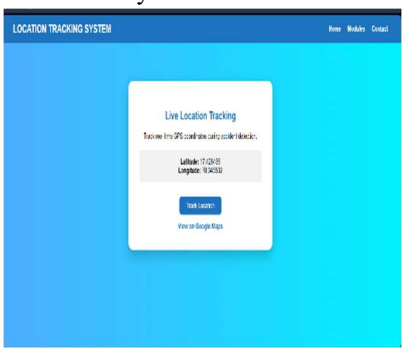


2. Threshold Based Accident Detection

The threshold-based detection algorithm is used to determine whether an accident has occurred by comparing sensor readings with predefined threshold values. Accelerometer or vibration sensor outputs are continuously monitored by the microcontroller. If the measured acceleration or vibration exceeds the set threshold, the system interprets it as a possible accident. This method is simple, computationally efficient, and suitable for embedded systems. It enables quick decision-making and reduces processing complexity, making it ideal for low-cost accident detection systems implemented with microcontrollers.

3. GPS Based Location Tracking

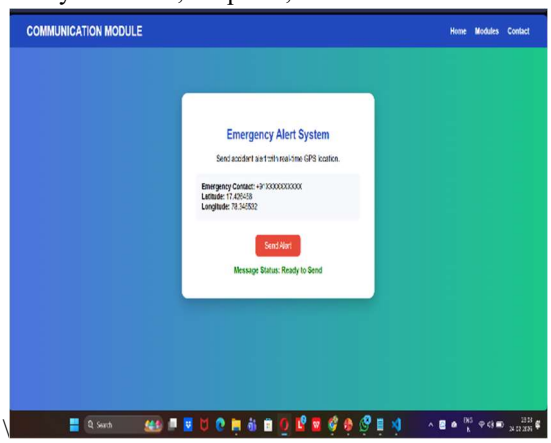
GPS-based location tracking is used to determine the exact geographical position of the vehicle when an accident occurs. The GPS module receives signals from multiple satellites and calculates the vehicle's latitude and longitude coordinates. Once the accident detection system confirms a crash, the GPS module provides the precise location information to the processing unit. This location data is essential for emergency responders because it helps them quickly identify the accident site and reach the location without delay.



4. GSM Based Communication

The GSM communication methodology is used to send emergency notifications after an accident is detected. A GSM module (such as SIM800 or SIM900) is connected to the microcontroller, which sends AT commands to transmit SMS alerts. The message typically includes the vehicle's GPS coordinates and an accident alert message. This SMS is sent to predefined phone numbers such as family members, hospitals, or emergency services. GSM technology ensures fast and reliable communication over mobile networks, making it suitable for real-time emergency alerts.

The GSM module is connected to a microcontroller (such as Arduino) through serial communication (TX and RX pins). When the accident detection sensors detect a sudden impact, the microcontroller processes the data and sends commands called AT commands to the GSM module. After receiving these commands, the GSM module sends an SMS alert containing the accident notification and GPS location coordinates to emergency contacts like family members, hospitals,



5. Micro-controller Processing System

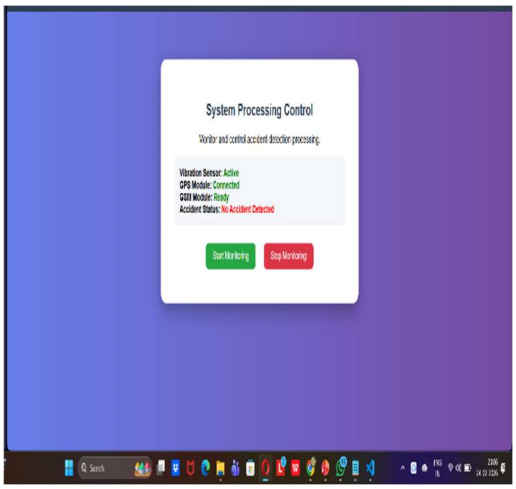
The microcontroller acts as the central processing unit of the accident detection system. It collects data from sensors, processes the information, and controls other modules such as GPS and GSM. Popular microcontrollers used in thesesystems include Arduino, ATmega328, or Raspberry Pi. The controller continuously monitors sensor readings and executes programmed algorithms to determine whether an accident has occurred. Once confirmed, it activates the communication module to send emergency alerts. This methodology ensures efficient system coordination and real-time decision-making.

6. IOT Based Accident Monitoring

IoT-based accident monitoring systems enhance traditional detection methods by enabling real-time data transmission to cloud platforms. Sensors installed in the vehicle collect data related to speed, vibration, and vehicle orientation, which is transmitted through internet-enabled modules to cloud servers. Authorities or emergency services can access this information through mobile apps or web dashboards. IoT integration improves monitoring capabilities and enables centralized control, making accident detection systems smarter and more efficient.

7. Machine Based Accident Detection

Machine learning techniques can also be used to improve accident detection accuracy. In this methodology, sensor data such as acceleration, speed, and orientation are collected and used to train machine learning models. Algorithms like Decision Trees, Support Vector Machines, or Neural Networks analyze patterns in vehicle motion to distinguish between normal driving conditions and accident scenarios.



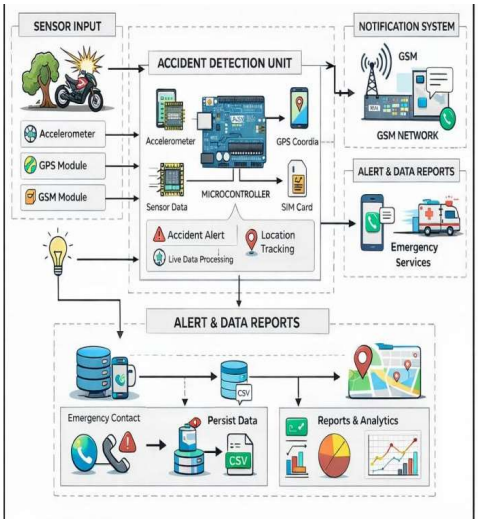
8. Automatic Based Response System

The automatic emergency response system is the final stage of the accident detection process. Once the system detects an accident and retrieves the vehicle's GPS location, it automatically sends alerts to emergency services, hospitals, or predefined contacts. Some systems also activate alarms or display notifications on control panels. This methodology ensures that help is dispatched immediately without relying on manual reporting. By reducing response time and enabling rapid rescue operations, automatic emergency response systems significantly contribute to saving lives during road accidents.

IV. ARCHITECTURE

The architecture of the intelligent accident detection system is designed to automatically detect vehicle accidents and immediately notify emergency contacts. The system integrates multiple hardware components such as sensors, a microcontroller unit, a GPS module, and a GSM communication module. When an accident occurs, the sensors detect abnormal vibrations or sudden changes in motion and send this data to the microcontroller. The controller processes the sensor data and determines whether the event qualifies as an accident.

The model architecture is designed to effectively detect vulnerabilities and plot anomalies. Consists of several layers, including a dashboard, AI analysis and virtual representation, penetration testing, etc.



a) Sensor Layer

The sensor layer is responsible for detecting physical changes that indicate a possible accident. Typically, sensors such as accelerometers, vibration sensors, or gyroscope modules are used. These sensors continuously monitor parameters like sudden impact, abnormal tilt, or rapid deceleration of the vehicle. When the measured values exceed predefined threshold levels, the sensor sends a signal to the microcontroller. This layer acts as the primary input component of the system and ensures real-time monitoring of the vehicle's movement and safety conditions.

b) Processing Layer

The processing layer consists of a microcontroller such as Arduino, Raspberry Pi, or another embedded controller that acts as the brain of the system. It receives input data from the sensors and processes it using programmed algorithms. The controller analyzes the sensor values to determine whether the detected event corresponds to an actual accident. Threshold-based algorithms or simple machine learning models can be implemented to improve detection accuracy. Once an accident is confirmed, the microcontroller triggers the communication module to initiate the emergency alert process.

c) GPS Module

The GPS module is responsible for obtaining the exact geographical location of the vehicle during an

accident. It communicates with satellites to determine the latitude and longitude coordinates. Once the accident is detected, the microcontroller requests location data from the GPS module. The module provides accurate positioning information, which is then included in the emergency notification message

d) GSM Module

The communication layer uses a GSM module to send alert messages to predefined mobile numbers. After receiving the accident confirmation and location data from the microcontroller, the GSM module sends an SMS containing the accident notification and GPS coordinates. This ensures that emergency contacts, hospitals, or authorities are immediately informed about the incident. The GSM network allows the system to function in real-time without requiring internet connectivity.

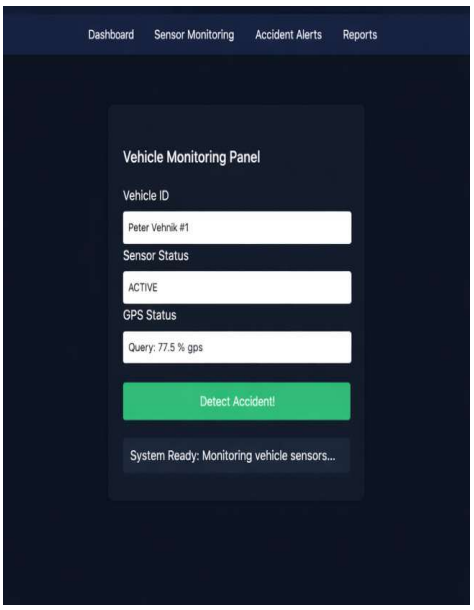
e) Notification-Response System

It architecture focuses on notifying users and enabling a quick emergency response. Once the SMS alert is received, emergency contacts or rescue teams can access the provided GPS location and reach the accident site promptly. Some systems also include additional features such as a manual cancel button that allows the driver to stop the alert if no serious accident has occurred. This layer ensures that the entire system works together to reduce response time and improve the chances of saving lives during road accidents.

V. RESULT

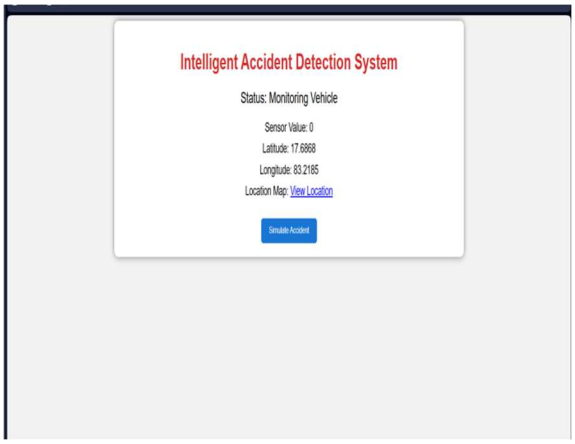
It successfully detects road accidents in real time using sensor data and communication technologies. During testing, the accelerometer sensor accurately identified sudden impacts or abnormal vehicle movements that indicate a possible accident. When the threshold value of acceleration exceeded the predefined limit, the system immediately triggered the accident detection algorithm. This ensured that accidents were detected quickly without requiring manual intervention.

Once an accident was detected, the system successfully obtained the **exact geographic location** of the vehicle using the GPS module. The latitude and longitude coordinates were then processed by the microcontroller and transmitted through the GSM module. The results showed that the system could reliably send emergency SMS alerts containing accident information and location



details to predefined emergency contacts within a few seconds.

The system was also evaluated for response time and reliability. Experimental results demonstrated that the alert message was transmitted within approximately **5–10 seconds after accident detection**, depending on network availability. The system performed consistently under different test scenarios, including sudden braking, collision simulation, and vehicle tilting critical accident conditions.



VI. CONCLUSION

It is developed to enhance road safety by enabling automatic accident detection and immediate alert transmission. The system continuously monitors vehicle conditions using sensors and identifies sudden impacts or abnormal movements that

indicate a possible accident. Once an accident is detected, the system automatically sends an alert message along with the precise GPS location to predefined emergency contacts through the GSM module. This helps reduce the time required for emergency response and ensures that medical assistance can reach the accident location quickly. The integration of sensor technology, GPS tracking, and GSM communication demonstrates an efficient and cost-effective approach for real-time accident reporting without requiring manual intervention.

In the future, this system can be further improved by integrating machine learning algorithms and IoT technologies to enhance the accuracy of accident detection and minimize false alerts. Advanced models can analyze driving patterns, vehicle speed variations, and sensor data to differentiate between minor disturbances and actual accidents. Additionally, integrating a cloud platform and mobile application can enable real-time monitoring, accident data storage, and faster communication with emergency services. The system can also be expanded by incorporating features such as vehicle cameras, driver health monitoring, and smart traffic management integration, which can automatically alert nearby vehicles and authorities, thereby contributing to safer and more intelligent transportation systems.

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