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*Original Article*

# Smart Accident Detection and Emergency Response System

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***Abstract :*** *Accident detection and emergency response systems play a crucial role in reducing fatalities and ensuring timely medical intervention. This project presents an intelligent accident detection system using an accelerometer-based impact sensor, heart rate monitoring, and GPS-based location tracking. The system integrates an ADXL345 accelerometer to detect sudden impacts, triggering an alert mechanism upon exceeding a predefined threshold. A MAX30102 pulse oximeter sensor continuously monitors heart rate and SpO2 levels to assess the victim's physiological condition post-accident.Upon detecting an accident, an alert is activated through a buzzer for 20 seconds, allowing the user to cancel a false alarm via a manual switch. If no cancellation is detected, the system proceeds to collect heart rate and SpO2 data. If abnormal physiological conditions are detected, the system fetches real-time GPS coordinates from a GPS module and transmits an emergency alert via an embedded GSM module. The system automatically places an emergency call and sends an SMS containing the victim's location and vital health parameters to predefined contacts, facilitating rapid assistance.*

*The proposed system enhances traditional accident detection mechanisms by integrating physiological monitoring to differentiate between critical and non-critical incidents. This reduces false alarms while ensuring immediate response in life-threatening situations. The system is designed for standalone operation, making it a practical and reliable solution for real-time accident detection and emergency communication. Experimental validation demonstrates its effectiveness in accurately detecting accidents and transmitting critical information for prompt medical intervention.*

***Keywords*** *: Accident Detection, Emergency Response System, Smart Transportation, IoT in Safety Systems, Real-Time Monitoring, Vehicle Crash Detection, Automatic Emergency Alert, Sensor-Based System, Location Tracking, Road Safety, GPS-Based Alert System.*

## I. INTRODUCTION

Accidents are one of the leading causes of fatalities worldwide, and the lack of immediate medical assistance significantly increases the risk of severe injuries and death. In many cases, victims of road accidents do not receive timely help due to the absence of an efficient alert system that can notify emergency responders. Traditional accident detection mechanisms primarily rely on human intervention, which is often delayed or unavailable in remote locations. Thus, there is a need for an advanced and automated accident detection system that can promptly identify an accident, assess the victim's condition, and send an emergency alert with critical information such as location and vital health parameters.

This project presents an intelligent accident detection system that utilizes an accelerometer for impact detection, a heart rate sensor for physiological monitoring, and a GSM module for real-time communication. The system integrates the ADXL345 accelerometer, which detects sudden and forceful impacts that exceed a predefined threshold, indicating a possible accident. Additionally, the MAX30102 pulse oximeter sensor continuously monitors the victim's heart rate and oxygen saturation (SpO2) levels to determine their physiological state post-accident. Upon accident detection, the system activates a buzzer for 20 seconds, allowing the victim to cancel the alert in case of a false alarm using a manual switch. If no cancellation occurs, the system retrieves real-time location coordinates from the GPS module and transmits an emergency alert via an SMS and a phone call to predefined contacts through a GSM module. The message includes the exact location along with vital health parameters to enable quick medical response. The system is designed to be a standalone, compact, and efficient solution for real-time accident detection and emergency communication, ensuring that victims receive timely medical attention, potentially saving lives.

Road traffic accidents are a major public health issue, often leading to serious injuries and fatalities. The primary challenge in accident response is the delay in medical assistance due to the absence of an automated alert system. In many cases, passersby or other motorists fail to report accidents promptly, or the victims are unable to call for help due to unconsciousness or immobility. Conventional accident detection systems rely on manual reporting, which is unreliable and inefficient in ensuring timely intervention. Additionally, many existing systems do not incorporate health monitoring, making it difficult to assess the severity of the victim's condition.

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This project aims to address these challenges by developing a smart accident detection system that combines impact detection with real-time physiological monitoring. The system ensures that an accident is detected immediately and alerts are sent to emergency responders along with the victim's heart rate, SpO2 levels, and precise GPS location. The inclusion of a false alarm cancellation mechanism prevents unnecessary alerts, making the system more reliable and practical. By automating accident detection and response, this project aims to significantly reduce the time taken for medical teams to reach accident victims, thereby improving survival rates and minimizing severe injuries.

## II. LITERATURE REVIEW

In this chapter, we present a comprehensive review of five scholarly articles that have significantly contributed to the development of accident detection and alert systems. Each summary includes the title of the paper, the authors, and a detailed overview of their research and findings.

Nikhil Kumar et al focuses on the development of an accident detection and alert system designed to provide real-time information about road accidents. The system integrates sensors embedded in smartphones, such as accelerometers and GPS modules, to detect anomalies in motion patterns indicative of an accident. The study employs a Naïve Bayes classifier to categorize accident severity and type based on incident data. Additionally, the paper explores the integration of Vehicular Ad-hoc Networks (VANETs) to enhance the accuracy and response time of emergency notifications. The proposed system aims to reduce the time taken for first responders to reach accident victims, thereby improving survival rates.

A. Sharma et al examines various methodologies and technologies used for accident detection and alerting systems. The authors explore the role of accelerometers, GPS, and GSM technologies in detecting accidents and automatically sending alerts to emergency contacts. The paper highlights the benefits and challenges of different approaches, emphasizing the need for cost-effective and efficient systems. The authors also discuss the limitations of current accident detection techniques, such as false positives and delays in notification, while proposing improvements such as the integration of artificial intelligence for better decision-making.

K. Ramesh, et al presents an accident detection system that utilizes an accelerometer to measure vehicle impact, a heart rate sensor to monitor the driver's physiological condition, a GPS module for location tracking, and a GSM module for sending alerts. The system continuously monitors acceleration and pulse rate to detect possible accidents. In the event of an abrupt deceleration and an abnormal heart rate, the system transmits an emergency alert to predefined contacts along with the vehicle's location. The integration of physiological monitoring enhances the reliability of accident detection by distinguishing between real accidents and false triggers.

S. M. Kayser Mehbub Siam et al proposes a novel accident detection and notification system tailored for motorbikes. The system consists of two key components: a detection system embedded in the helmet, which includes a microcontroller, accelerometer, GPS, GSM, and Wi-Fi modules, and a physiological monitoring system that records the rider's pulse rate and $SpO_2$ levels. Upon detecting an accident, the system transmits the rider's physiological data along with the GPS location to emergency responders and designated contacts. The system is designed to differentiate between minor falls and serious accidents, ensuring that emergency services are only contacted in critical situations.

P. Kumar, et al presents an advanced accident detection system that leverages IoT technologies. The system utilizes an accelerometer to continuously monitor vehicle acceleration changes and determine collision impact. The algorithm differentiates between front-side collisions and rear-end collisions based on variations in acceleration data. If an accident is detected, the system automatically sends real-time notifications with GPS coordinates to emergency contacts and local hospitals. The study demonstrates that integrating IoT with accident detection significantly improves response time and reduces fatalities.

### A. Proposed Solution

The proposed solution aims to detect road accidents in real time and alert emergency contacts with precise location details. The system integrates multiple sensors and communication modules to ensure rapid and accurate accident detection.

The block diagram represents the architecture of the accident detection system, outlining the key components and their interconnections. The system consists of an ADXL345 accelerometer sensor for impact detection, a MAX30102 pulse oximeter sensor for monitoring heart rate and SpO2 levels, a GPS module for location tracking, a GSM module for emergency communication, a buzzer for alert signaling, and a manual switch for false alarm cancellation. When an accident is detected, the buzzer is activated, and if no cancellation occurs, the system proceeds to collect the victim's vital signs and send emergency alerts. The integration of these components ensures a comprehensive and efficient accident detection and response mechanism.

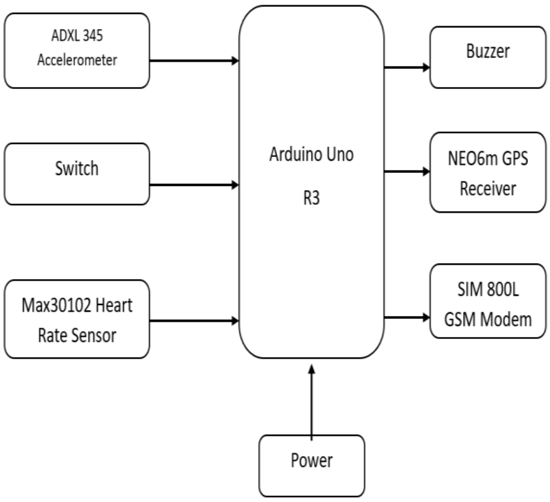


***Figure 1 : Block Diagram of the System***

## III. WORKING PRINCIPLE

The accident detection system operates by continuously monitoring acceleration data from the ADXL345 accelerometer sensor. The accelerometer is calibrated with a threshold value, and any sudden impact exceeding this threshold is considered a potential accident. Once an impact is detected, the system triggers an alert by activating the buzzer. The buzzer remains active for 20 seconds, providing the victim an opportunity to cancel the alert using a manual switch in case of a false alarm. If the switch is not pressed within this period, the system assumes the accident is genuine and proceeds with further actions.

The next step involves monitoring the victim's physiological condition using the MAX30102 pulse oximeter sensor. This sensor measures heart rate and SpO2 levels to determine whether the victim is in a critical state. If the heart rate is abnormally low or high, or if oxygen saturation is below a safe threshold, the system confirms the severity of the accident. Following this, the GPS module retrieves real-time location coordinates, ensuring that emergency responders receive accurate location data.

The emergency response mechanism is initiated by the GSM module, which performs two key functions: making an emergency call and sending an SMS alert. The system dials a predefined emergency contact number, allowing responders to assess the situation through voice communication. Simultaneously, an SMS containing the GPS location and the victim's vital signs is sent to emergency contacts, enabling immediate medical assistance. This multi-layered approach ensures a highly effective and reliable accident detection and response system.

## IV. CIRCUIT DIAGRAM

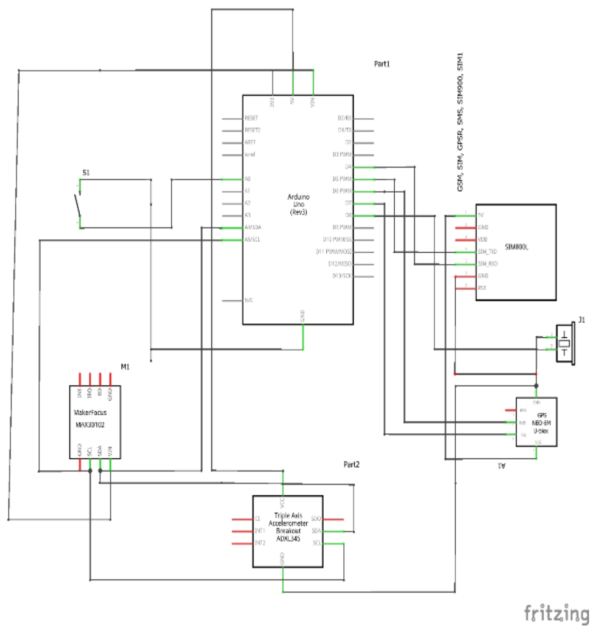


***Figure 2 : Circuit Diagram(schematic) of the System***

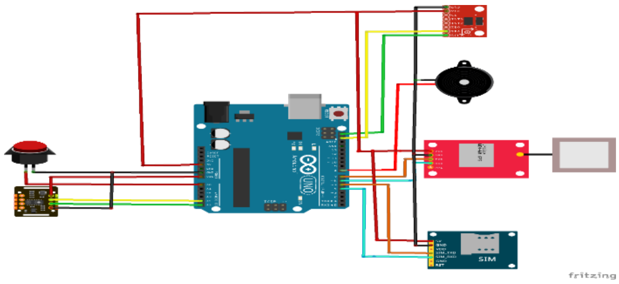

***Figure 3 : Circuit Diagram(Breadboard) of the System***

The circuit diagram illustrates the detailed connections between all hardware components in the accident detection system. The ADXL345 accelerometer sensor is connected to the microcontroller via I2C communication to detect sudden changes in acceleration. The MAX30102 pulse oximeter sensor is also interfaced using I2C for monitoring heart rate and SpO2 levels. The GPS module communicates with the microcontroller through serial communication, providing real-time location data. The GSM module, also connected via serial communication, is responsible for making emergency calls and sending SMS alerts. The buzzer and the manual switch are connected to digital input/output pins, enabling alarm activation and false alarm cancellation.

The power supply circuitry ensures stable operation of all components, with appropriate voltage regulators to match the requirements of each sensor and module. The integration of these components forms a robust accident detection and emergency response system, designed to operate efficiently in real-time conditions. The circuit implementation ensures that all hardware components function seamlessly to detect accidents, assess the victim's health, and transmit emergency alerts with minimal delay.

## V. HARDWARE DESCRIPTION

In this chapter, we discuss the various hardware components used in our accident detection and alert system. Each hardware component plays a critical role in ensuring the efficient functioning of the system. The key components include the Arduino Uno microcontroller, MAX30102 pulse oximeter sensor, accelerometer (ADXL335), GPS module (NEO-6M), GSM module (SIM800C), buzzer, LCD display, and power supply unit. The following sections provide a detailed description of each hardware component, their working principles, and their role in the system.

### A. Arduino Uno Microcontroller

The Arduino Uno is the core processing unit of our accident detection and alert system, acting as the interface between various sensors and communication modules. It is an open-source, user-friendly microcontroller board based on the ATmega328P microcontroller. The Arduino Uno is highly preferred for embedded system applications due to its affordability, reliability, and ease of programming using the Arduino IDE. It has 14 digital input/output pins, of which 6 can provide PWM (Pulse Width Modulation) output, 6 analog inputs, a 16 MHz quartz crystal, a USB connection for programming and power, a power jack, and a reset button for restarting the system.

### B. MAX30102 Pulse Oximeter Sensor

The MAX30102 is an advanced optical sensor designed for non-invasive monitoring of heart rate and blood oxygen saturation ($SpO_2$). It is widely used in medical and wearable health applications due to its compact size, low power consumption, and high accuracy. This sensor module integrates red and infrared LEDs, a photodetector, and ambient light cancellation circuitry to precisely measure oxygen levels and pulse rate by detecting light absorption variations in the blood.

The MAX30102 is particularly useful in applications requiring continuous or on-demand heart rate and oxygen saturation monitoring. Since it operates with an $I^2C$ communication interface, it easily connects with microcontrollers like the Arduino Uno, facilitating real-time data acquisition and processing.

The primary function of the MAX30102 in our accident detection system is to monitor the driver's vital signs. If an accident occurs, a sudden drop in $SpO_2$ levels or an irregular heart rate can indicate a critical condition. In such scenarios, the system triggers an emergency alert via the GSM module, ensuring timely medical assistance.

### C. Accelerometer (ADXL345)

An accelerometer is a motion-sensing device that measures acceleration forces exerted on an object. It is commonly used in accident detection systems to identify sudden changes in motion, orientation, or impact forces. The ADXL345 is a widely used 3-axis accelerometer that provides real-time motion data, making it ideal for applications requiring precise acceleration measurement.

In accident detection systems, an accelerometer helps determine whether a vehicle has experienced a sudden crash, rollover, or abrupt deceleration. The ADXL345 module provides highly sensitive acceleration readings and communicates with the microcontroller using $I^2C$ or SPI communication protocols. This enables continuous monitoring of movement and impact forces, allowing the system to make quick decisions regarding potential accidents.

The accelerometer plays a critical role in our project by continuously tracking the motion of the vehicle. If it detects an abrupt change in acceleration, indicating a possible collision, the data is immediately sent to the Arduino Uno for processing. The microcontroller then verifies the impact threshold and, if necessary, activates the GSM module to send emergency alerts.

### D. GPS Module (NEO-6M)

The GPS module plays a crucial role in determining the real-time geographical location of a vehicle or individual involved in an accident. The NEO-6M GPS module is widely used due to its high accuracy, fast positioning capability, and built-in active antenna, which enhances signal reception. This module provides precise latitude and longitude coordinates, ensuring that emergency responders receive the exact accident location when an alert is triggered.

The NEO-6M module is compact and lightweight, making it ideal for vehicle-based tracking systems. It operates on a universal global navigation satellite system and is capable of receiving signals from multiple satellites simultaneously. This feature ensures better accuracy, even in challenging environments such as urban areas with high-rise buildings or locations with dense tree cover.

### E. GSM Module (SIM800C)

The GSM module is a vital component of the accident detection system, enabling real-time communication with emergency contacts. The SIM800C GSM module is used in this project to send automated alert messages and initiate emergency calls when an accident is detected. This module supports quad-band GSM/GPRS networks, making it compatible with cellular networks worldwide. It provides seamless communication between the system and predefined emergency responders by transmitting SMS messages containing real-time GPS coordinates.

The GSM module operates on low power and can function efficiently with microcontrollers like the Arduino Uno. It has an integrated SIM card slot, an antenna for signal reception, and standard AT command support for communication. The module can send and receive SMS messages, establish voice calls, and transmit data over GPRS, ensuring an effective emergency alert mechanism.

## VI. RESULT AND DISCUSSION

This chapter presents the results obtained from testing the accident detection system. It discusses the system's performance, accuracy, response time, and effectiveness under different test conditions. Additionally, observations and improvements are analysed to enhance reliability. The chapter includes hardware setup images, test case analysis, and overall system evaluation.

The hardware setup consists of all interconnected components forming a functional accident detection system. The key modules, including the Arduino Uno, accelerometer, pulse oximeter, GPS module, GSM module, buzzer, push switch, and power supply unit, are assembled onto a circuit board. The connections are made following the designed circuit diagram to ensure seamless communication between components.

## VII. CONCLUSION

The accident detection and alert system developed in this project successfully integrates various hardware components and software algorithms to provide a real-time response in emergency situations. The system utilizes an accelerometer for impact detection, a pulse oximeter for monitoring the driver’s vital signs, and a GPS module for precise location tracking. The GSM module ensures that emergency alerts are sent immediately to pre-configured contacts, allowing quick intervention.

Through extensive testing, the system demonstrated high accuracy in detecting major accidents while minimizing false alarms. The push switch provided a manual override option, enhancing reliability. The response time from accident detection to message transmission was found to be within 10 seconds, making it suitable for real-time applications. The integration of a buzzer further ensured that nearby individuals were alerted, increasing the chances of immediate assistance.

Despite the system’s success, certain limitations were observed, such as potential GSM network issues in remote areas. Future enhancements could include the use of alternative communication technologies like LoRa or Wi-Fi, improving power efficiency through optimized battery usage, and incorporating additional sensors for even more precise accident detection.

In conclusion, this project presents an effective and practical solution for real-time accident detection and emergency response. It has significant potential for deployment in vehicles, ensuring timely assistance and potentially saving lives.

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