

# Smart Helmet and Accident Alert System

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## ABSTRACT

Road accidents have become one of the major causes of fatalities across India and many other parts of the world. A significant number of deaths occur due to the delay in providing immediate medical assistance after an accident. In several urban as well as rural regions, emergency rescue services often fail to reach the accident location on time because of communication gaps and lack of instant accident reporting systems. As a result, the chances of saving the victim's life are greatly reduced. Therefore, the development of an intelligent safety system capable of detecting accidents and transmitting emergency alerts in real time has become an important requirement in modern transportation systems. The Smart Helmet with Crash Alert System is an advanced safety solution developed to improve the protection of motorcycle riders and minimize accident-related casualties. The proposed system integrates multiple sensors, including an accelerometer, gyroscope, and vibration sensor, to accurately identify sudden impacts or crash conditions. Once an accident is detected, the system automatically activates an emergency alert mechanism that transmits the rider's real-time location through GPS technology to pre-registered emergency contacts using GSM communication. In addition to accident detection, the helmet also incorporates an ignition control mechanism that ensures the motorcycle can only be started when the rider is properly wearing the helmet, thereby promoting adherence to road safety regulations. The entire system is controlled using a microcontroller-based architecture combined with sensor and wireless communication technologies to provide a reliable, efficient, and real-time accident monitoring framework. The proposed model is expected to reduce emergency response time significantly and contribute toward enhancing the overall safety of motorcyclists on the road.

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## 1. INTRODUCTION

The rapid increase in the number of vehicles has led to a significant rise in road accidents across the world, resulting in a large number of injuries and fatalities every year. Among all categories of vehicles, two-wheelers are highly vulnerable due to their limited structural protection and direct exposure to road hazards. A major cause of death in such accidents is the delay in receiving immediate medical assistance, especially on highways, rural roads, and less populated urban areas where accidents may remain unnoticed for a long period. Therefore, the implementation of an intelligent accident detection and alert mechanism has become essential to improve

emergency response and reduce mortality rates. The Smart Helmet with Crash Alert System is proposed as an advanced safety solution aimed at enhancing rider protection and ensuring rapid communication during emergency situations. The system combines modern sensor technology with wireless communication to create an efficient and reliable accident monitoring framework. The helmet is equipped with sensors such as an accelerometer and vibration sensor that continuously monitor sudden impacts, abnormal movements, and crash conditions. When an accident is detected, the system automatically activates an alert mechanism that transmits the rider's real-time GPS

location to predefined emergency contacts using GSM communication technology. This immediate notification enables quicker medical response and increases the possibility of saving the victim's life.

In addition to accident detection, the proposed smart helmet also encourages responsible riding behavior through an ignition control mechanism integrated with the vehicle. The engine is allowed to start only when the rider properly wears the helmet, thereby enforcing helmet usage and improving compliance with road safety regulations. The integration of accident detection, location tracking, wireless communication, and ignition control makes the system a valuable contribution toward intelligent transportation and modern road safety initiatives. The proposed model aims to minimize accident-related fatalities by reducing emergency response time and promoting safer riding practices among motorcyclists.

## 2. LITERATURE SURVEY

Most of the existing accident detection systems mainly focus on IoT-based hardware modules connected with smartphones for monitoring and emergency communication. Although these systems provide basic accident detection capabilities, they still suffer from several limitations that reduce their reliability during real-time emergency situations. In many cases, the external hardware device may become damaged, disconnected, or malfunction during a severe accident, which can prevent the transmission of emergency alerts. Furthermore, several existing models are highly dependent on sensor thresholds, resulting in false accident detection and inaccurate notifications. Many of the currently available systems are capable only of detecting accidents and sharing location details, but they do not provide immediate assistance regarding nearby medical facilities or rescue coordination. Consequently, the delivery of critical information to emergency responders may be delayed. In situations where local people attempt to help the victim, they may face difficulties in identifying the nearest hospitals or emergency centers, especially if they are unfamiliar with the surrounding area. The proposed Smart Helmet with Crash Alert System is designed to overcome these limitations by integrating reliable accident detection, real-time location tracking, and rapid emergency communication to improve the effectiveness of rescue operations and increase the probability of saving human lives.

Several researchers have contributed toward the development of intelligent accident detection and road safety systems. In 2017, Patil Ashish N and Yadav Abhilash proposed an accident detection system using an Android application published in

IEEE Access. Their work focused on GPS-based location tracking to provide accident information even in isolated and less populated regions. In 2018, Mohd Nazri Bin Ismail developed a framework for accident detection and emergency alert messaging using Android applications. The proposed system concentrated on crash detection, location identification, and emergency notification transmission using smartphone technology. Later, in 2019, Jesudoss, R. Vybhavi, and B. Anusha introduced a smart helmet design presented at the International Conference on Communication and Signal Processing 2019. Their prototype integrated multiple sensors, including accelerometers, to identify accidents and improve decision-making speed during emergencies. In 2020, Chirag Yadav published research in SAGE Journals analyzing road traffic accidents and proposing a low-cost communication solution for two-wheeler riders to minimize delays during accident reporting.

Further advancements were observed in 2021 when the World Health Organization emphasized that proper helmet usage can reduce fatal head injuries by nearly seventy percent, while also highlighting the ongoing issue of non-compliance with helmet safety regulations. In 2022, Ying Lu, Yufa Liu, and Yu Shu proposed an adaptive crash recognition algorithm that utilized discrimination threshold analysis and road-vehicle simulation models to improve accident identification accuracy. During the same year, Peng-Wei Lin and Chih-Ming Hsu introduced an innovative distracted-driving alert framework through IEEE Access, where driver perception and behavior recognition techniques were combined to reduce false alert generation. These studies collectively demonstrate the growing importance of integrating smart technologies, sensor systems, and wireless communication in modern transportation safety solutions.

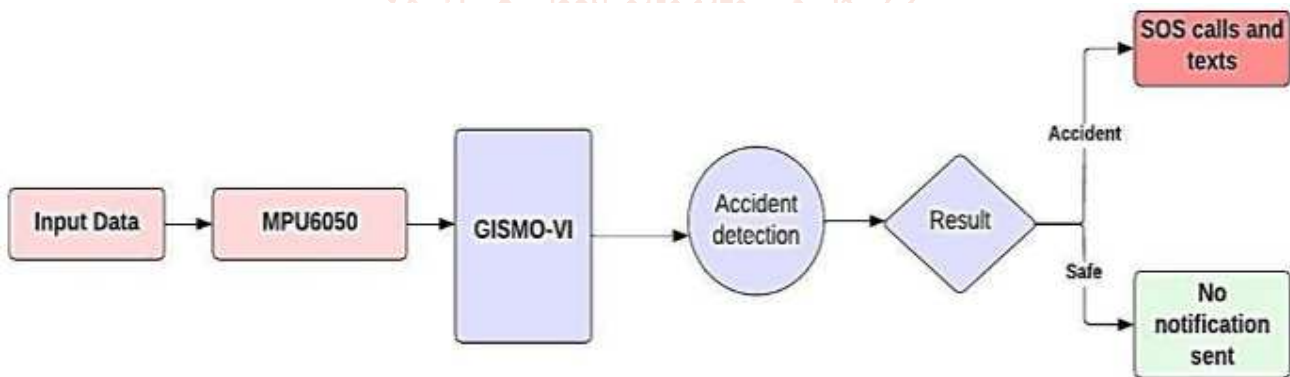
## 3. PROPOSED SYSTEM

The proposed Smart Helmet with Crash Alert System is developed to enhance the safety of two-wheeler riders through the integration of intelligent sensing, automated control mechanisms, and real-time communication technologies within a single compact platform. Conventional helmets primarily provide passive protection during accidents; however, they are incapable of monitoring rider behavior, identifying hazardous conditions, or initiating emergency communication. To overcome these limitations, the proposed system introduces an advanced smart safety framework capable of continuously monitoring the rider's status, detecting accidents or unsafe conditions, and automatically initiating emergency response actions. The system

combines multiple hardware and software technologies to provide a reliable, efficient, and intelligent road safety solution that contributes toward reducing accident-related fatalities. The overall architecture of the proposed system is centered around the Espressif Systems based ESP32 microcontroller, which acts as the primary processing and decision-making unit. The ESP32 is selected due to its high processing capability, integrated Wi-Fi and Bluetooth support, low power consumption, and compatibility with IoT-based applications. Various sensors and communication modules are interfaced with the microcontroller to continuously monitor riding conditions and execute intelligent control operations. The system integrates an accelerometer and gyroscope sensor module, specifically the MPU6050, which measures acceleration, tilt, and angular velocity to identify abnormal movement patterns, collisions, or sudden impacts associated with road accidents. In addition, a vibration sensor is incorporated to strengthen accident detection accuracy by identifying severe shocks or crash conditions. These sensors collectively help reduce false accident detection and improve system reliability under practical road conditions.

To improve rider safety and prevent drunk driving, the system incorporates the MQ-3 Alcohol Sensor, which detects alcohol concentration from the rider's breath. The analog output generated by the sensor is continuously processed by the ESP32

microcontroller. If the detected alcohol concentration exceeds the predefined safety threshold, the system automatically disables the vehicle ignition mechanism and prevents the rider from operating the motorcycle. Simultaneously, warning notifications can be transmitted to predefined contacts to indicate unsafe driving conditions. Furthermore, an IR-based or pressure-based helmet detection sensor is integrated into the helmet structure to ensure that the rider is properly wearing the helmet before the vehicle can be started. If the helmet is not worn correctly, the ignition system remains disabled, thereby enforcing compliance with helmet safety regulations and encouraging responsible riding behavior. The proposed system also integrates advanced communication technologies to provide real-time accident alerts and location tracking. A NEO-6M GPS Module is used to acquire accurate geographic coordinates of the rider during emergency situations. In the event of an accident, the GPS module retrieves the real-time location data and forwards it to the ESP32 controller for further processing. The system then activates the SIM800L GSM Module, which automatically sends emergency SMS notifications containing the accident location coordinates to pre-registered emergency contacts or nearby rescue authorities. This rapid communication mechanism significantly reduces the delay in emergency response and increases the possibility of providing timely medical assistance to accident victims.



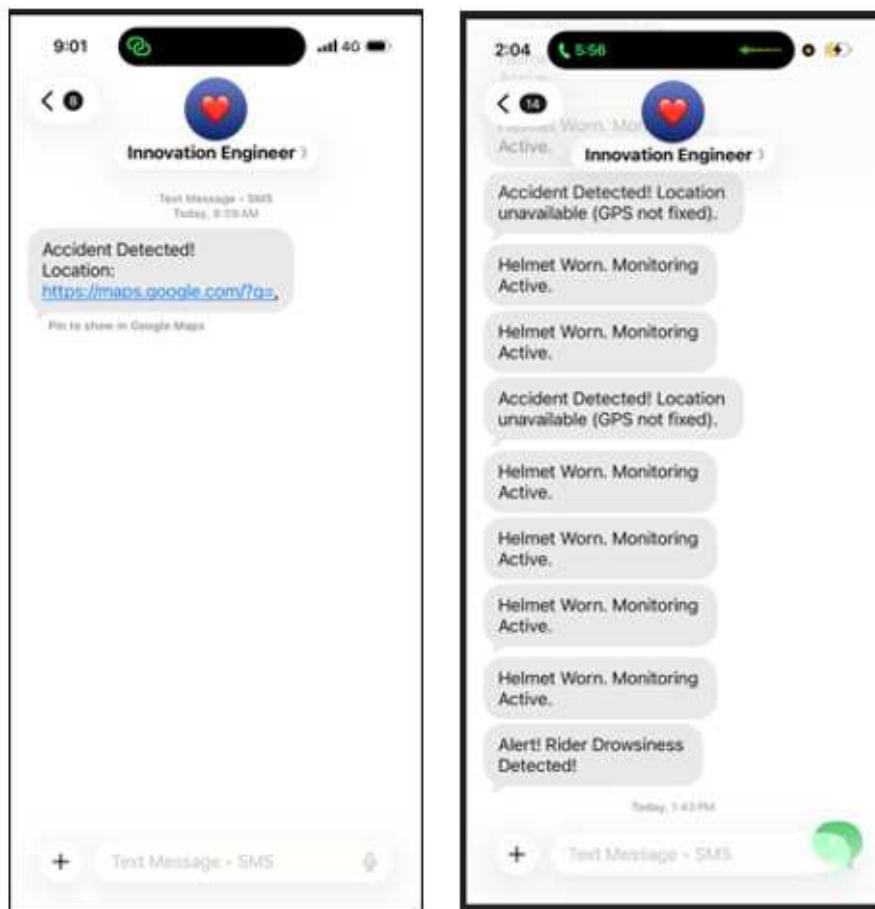
The software architecture of the system is implemented using the Arduino IDE platform with Embedded C/C++ programming for system control and sensor integration. Different software libraries are utilized to establish communication between hardware modules and simplify data processing operations. Libraries such as TinyGPS++ are employed for parsing GPS data, Wire.h is used for I2C communication with the MPU6050 sensor, and SoftwareSerial facilitates serial communication with the GSM module. The software continuously monitors sensor readings, analyzes riding conditions, processes motion data, and executes decision-making algorithms for accident detection, alcohol monitoring, helmet verification, and emergency communication. The integrated logic ensures accurate system response under both normal and emergency situations. In addition to the core safety features, the proposed system also supports IoT-based monitoring capabilities through the built-in Wi-Fi functionality of the ESP32 controller. The smart helmet can communicate with IoT platforms such as Blynk to provide real-time monitoring of helmet status, alcohol detection results, accident alerts, and GPS location information. This enables remote monitoring and improves accessibility for emergency management applications. The system workflow involves continuous acquisition of sensor data, real-time processing by the

microcontroller, condition evaluation, and automatic activation of emergency protocols whenever unsafe conditions or accidents are detected. All sensor data can also be logged for future analysis and performance evaluation. The proposed Smart Helmet with Crash Alert System functions as both a preventive and protective safety device. Preventively, it restricts vehicle ignition when unsafe conditions such as alcohol consumption or absence of helmet usage are detected. Protectively, it identifies accidents in real time and immediately initiates emergency communication to reduce rescue delays. The integration of intelligent sensors, IoT connectivity, wireless communication modules, and real-time processing technologies makes the system highly suitable for modern intelligent transportation systems and smart mobility applications. Owing to its compact design, low power consumption, cost-effectiveness, and scalability, the proposed system offers a practical and efficient solution for enhancing road safety and minimizing fatality rates among two-wheeler riders.

#### 4. RESULTS

The primary objective of the sensor module is to continuously monitor the rotational movement and orientation of the helmet in real time to improve accident detection accuracy. The system periodically updates the motion parameters at regular intervals and analyzes the collected data to identify abnormal movement patterns associated with crashes or sudden impacts. Simultaneously, the acquired sensor readings are uploaded to Google Firebase for real-time data storage, remote monitoring, and future analysis. This cloud-based integration enables continuous tracking of helmet movement data and supports rapid access to accident-related information whenever required. The proposed system utilizes the MPU6050 Inertial Measurement Unit (IMU), which combines a three-axis accelerometer and a three-axis gyroscope within a single compact module. The accelerometer measures linear acceleration along the X, Y, and Z axes, while the gyroscope measures angular velocity and rotational movement across the same axes. The gyroscope continuously detects variations in angular position over time, making it highly effective for identifying sudden tilts, abnormal head movements, or crash-related impacts experienced by the rider. The sensor operates using MEMS (Micro-Electro-Mechanical Systems) technology along with the Coriolis Effect to generate accurate motion measurements. The gyroscope output is represented in degrees per second ( $^{\circ}/s$ ), and the real-time sensor values can be visualized through the serial monitor available in the Arduino IDE platform.

The performance of the proposed sensor system is evaluated using several important metrics to ensure reliability and efficiency under practical operating conditions. One of the key evaluation parameters is the accuracy of rotational measurement, where the gyroscope readings are compared with controlled rotational movements to verify the precision and consistency of angular velocity measurements. Another critical factor is the response time of the system, which determines the ability of the sensor module to update and process motion data within the required time interval for real-time accident monitoring. Accident detection efficiency is also analyzed by testing the system under simulated crash and abnormal motion conditions to evaluate its capability to accurately identify potential accidents while minimizing false detections. In addition, the reliability of data upload and cloud storage is assessed by monitoring the successful transmission of sensor readings to the Firebase platform without interruption. Continuous synchronization of motion data with the cloud database ensures effective remote monitoring and supports emergency response applications. The system can also incorporate user feedback and emergency alert mechanisms, where alerts generated due to abnormal helmet movement or accident detection are evaluated based on their speed, reliability, and communication accuracy. Through the integration of real-time sensing, cloud-based monitoring, and intelligent motion analysis, the proposed sensor framework significantly enhances the effectiveness of the smart helmet system for modern road safety applications.



## 5. CONCLUSION

The proposed Smart Helmet with Crash Alert System presents an effective and intelligent solution for improving the safety of two-wheeler riders through the integration of advanced sensing, communication, and real-time monitoring technologies. The system successfully combines accident detection, helmet verification, alcohol monitoring, GPS tracking, and GSM-based emergency communication into a single compact and automated safety framework. By utilizing the ESP32 microcontroller along with sensors such as the MPU6050 and MQ-3 Alcohol Sensor, the proposed model is capable of continuously monitoring rider conditions and identifying unsafe situations with improved accuracy and reliability. The system ensures that the motorcycle can only be operated when the rider is properly wearing the helmet and is free from alcohol influence, thereby promoting responsible driving behavior and adherence to traffic safety regulations. In the event of an accident, the smart helmet automatically detects abnormal motion patterns or severe impacts and instantly transmits emergency alerts along with the rider's real-time GPS location using the SIM800L GSM Module and NEO-6M GPS Module. This rapid communication mechanism significantly reduces the delay in providing medical assistance, which plays a crucial role in minimizing

fatalities and severe injuries during road accidents. Furthermore, the integration of IoT-based cloud monitoring through Firebase enhances the system by enabling real-time data storage, remote monitoring, and continuous tracking of helmet and accident-related information. The proposed framework is designed using cost-effective components with low power consumption, making it suitable for practical implementation and large-scale deployment in modern transportation systems. The evaluation of rotational measurement accuracy, accident detection efficiency, response time, and data transmission reliability demonstrates that the system performs effectively under real-world operating conditions.

Overall, the Smart Helmet with Crash Alert System represents a significant advancement in intelligent transportation and rider safety technology. The combination of preventive safety measures and automated emergency response mechanisms makes the system highly beneficial for reducing accident-related deaths and improving road safety standards. Future enhancements such as machine learning-based accident prediction, voice assistance, advanced IoT analytics, and mobile application integration can further improve the efficiency and functionality of the proposed system, contributing toward the development of smarter and safer transportation infrastructures.

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