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Smart helmet for accident detection and prevention using IoT

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Abstract

Motorcycle accidents are a significant contributor to road fatalities worldwide. Many of these accidents are due to the non-wearing of helmets or delayed emergency response times. This paper proposes a Smart Helmet system integrated with Internet of Things (IoT) technology to enhance rider safety by ensuring helmet usage, detecting accidents in real-time, and sending alerts to emergency services. The system consists of sensors such as accelerometers, alcohol detectors, GPS, and GSM modules embedded in the helmet. When an accident occurs, the system automatically detects the event and transmits the location to predefined emergency contacts. The proposed solution also prevents the bike from starting unless the helmet is worn and the rider is sober. The implementation shows promising results in real-world simulations and offers a low-cost, scalable approach to improving motorcycle safety.

Keywords: Smart Helmet; IoT; Accident Detection; Safety System; GPS; GSM; Sensor Integration; Motorcycle Safety

1. Introduction

Road traffic accidents are a leading cause of death and injury worldwide, with motorcyclists being disproportionately affected due to their vulnerability on the road. According to the World Health Organization (WHO), more than 1.35 million people die each year as a result of road traffic crashes, and a significant portion of these fatalities involve two-wheeler riders. In many developing countries, motorcycles are a primary mode of transportation due to their affordability and convenience. However, the lack of safety measures and enforcement of traffic laws contributes to a high rate of motorcycle-related injuries and deaths.

One of the most effective protective measures for motorcyclists is wearing a helmet, which significantly reduces the risk of severe head injuries. Despite this, many riders neglect to wear helmets either out of habit, negligence, or discomfort. Additionally, incidents involving alcohol-impaired driving further exacerbate the problem, as intoxicated riders have slower reaction times and impaired judgment, increasing the likelihood of accidents.

Another critical issue is the delay in emergency response time after an accident occurs. In many cases, especially in rural or low-traffic areas, victims may remain unattended for extended periods due to the absence of timely accident reporting. This delay in receiving medical attention can make the difference between life and death.

With the emergence of the Internet of Things (IoT) and smart devices, there is a growing opportunity to integrate technology into personal safety equipment to address these challenges. The proposed Smart Helmet is an intelligent safety system designed not just to enforce helmet usage but also to monitor the rider's condition, detect accidents in real-time, and notify emergency contacts with precise location data.

The system utilizes a combination of sensors and communication modules, including:

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- An Infrared (IR) sensor to detect whether the helmet is worn,
- An alcohol sensor (MQ-3) to determine if the rider is under the influence,
- An accelerometer (ADXL335 or MPU6050) to detect sudden impacts or falls indicating a possible accident,
- A GPS module to capture the exact location of the incident,
- A GSM module (SIM800L) to send real-time alerts to predefined emergency contacts.

The bike's ignition system is also integrated with the helmet system, ensuring that the vehicle cannot be started unless the helmet is worn and the rider is not intoxicated. In the event of an accident, the system automatically sends an SMS containing the GPS coordinates to family members or emergency services, enabling rapid response.

This project aims to increase motorcycle rider safety, encourage responsible behavior, and reduce fatalities due to late medical assistance. The proposed Smart Helmet system is cost-effective, scalable, and suitable for real-world deployment, especially in regions with high accident rates and limited emergency infrastructure.

The following sections of this paper will present a review of existing related works, a detailed explanation of the proposed system architecture, implementation details, results from testing, and future enhancements.

2. Background

Road traffic accidents are a leading cause of injury and death worldwide, with motorcyclists being among the most vulnerable road users. According to the World Health Organization (WHO), more than 1.3 million people die each year due to road traffic crashes, and a significant portion of these fatalities involve two-wheeler riders. Despite widespread awareness campaigns and legislation mandating helmet use, non-compliance and improper usage continue to pose serious risks.

Helmets have long been a fundamental protective gear for motorcyclists, yet traditional helmets offer only passive protection—providing safety during impact but lacking mechanisms for real-time monitoring, emergency response, or preventive actions. With the advent of the Internet of Things (IoT), it is now possible to enhance helmet functionality by integrating smart technologies for both accident detection and prevention.

Smart helmets, powered by sensors, microcontrollers, and wireless communication modules, have the potential to revolutionize motorcyclist safety. These helmets can detect collisions through accelerometers and gyroscopic sensors, monitor the rider's state (such as drowsiness or alcohol intoxication), and automatically alert emergency services with real-time GPS data in the event of an accident. Moreover, such systems can incorporate features like speed monitoring, helmet-wear detection, and vehicle ignition control, thus preventing unsafe riding conditions from the outset.

This research focuses on the design and implementation of a smart helmet system that leverages IoT technologies to detect accidents, monitor rider conditions, and communicate essential data to emergency responders and caretakers. By bridging the gap between passive safety gear and active safety systems, smart helmets aim to significantly reduce response times and improve survival rates following accidents, while also encouraging safer riding behavior.

3. Related works

In recent years, researchers and developers have explored various technological approaches to enhance the safety of two-wheeler riders. These efforts have led to the development of intelligent helmet systems, accident detection frameworks, and integrated IoT-based safety solutions. This section reviews several significant works in this area, highlighting their contributions and limitations in relation to the proposed Smart Helmet system.

3.1. Helmet Usage Detection

Sharma et al. (2020) proposed a smart helmet that enforced helmet usage by integrating Infrared (IR) sensors to detect whether the rider is wearing the helmet. If the helmet was not worn, the system disabled the ignition of the bike. While this method effectively enforced helmet compliance, it lacked any accident detection or emergency alert features, limiting its usefulness during actual incidents.

3.2. Alcohol Detection

Patel and Mehta (2019) designed a helmet-based alcohol detection system using the MQ-3 gas sensor. The system was capable of sensing alcohol vapor near the rider's mouth and preventing the vehicle from starting if the detected level

exceeded a safe threshold. However, their design did not integrate other essential features such as accident detection or GPS/GSM-based alerting, making it a standalone alcohol prevention tool.

3.3. Accident Detection Using Accelerometers

Kumar et al. (2018) developed a low-cost accident detection system using accelerometers and Arduino. The system continuously monitored the accelerometer's readings and detected abrupt changes in motion, signaling a possible crash. Upon detection, a GSM module was used to send an SMS to a predefined contact. While this system improved response times, it did not verify helmet usage or rider sobriety and could be prone to false positives due to rough road conditions.

3.4. IoT-Based Vehicle Safety Systems

Saini et al. (2021) introduced an IoT-based vehicle monitoring system that included GPS and GSM modules for real-time tracking and accident alerts. Their project was primarily focused on four-wheelers and lacked the wearable aspect, which is crucial for two-wheeler safety. Nevertheless, their use of IoT technologies demonstrated the viability of remote monitoring in improving emergency response efficiency.

3.5. Comprehensive Safety Helmets

Rao and Shinde (2022) proposed a more integrated helmet safety system, combining alcohol detection, IR-based helmet usage verification, and accelerometer-based accident detection. Their system also utilized GSM and GPS modules for alerting and location tracking. While similar in approach to our proposed system, their implementation did not focus on optimizing power usage, minimizing hardware size, or ensuring system scalability, which are key areas addressed in our work.

4. Methodology

The proposed Smart Helmet system is designed to enhance motorcycle safety by enforcing helmet usage, preventing drunk driving, detecting accidents, and automatically sending emergency alerts with real-time location. The system is developed using a modular approach involving both hardware components (sensors, microcontroller, communication modules) and software logic (embedded C/C++ or Arduino code).

The methodology can be divided into the following phases:

4.1. System Design and Architecture

The system consists of the following modules:

4.1.1. Helmet Module:

- IR Sensor to detect helmet wear
- MQ-3 Alcohol sensor to detect alcohol in the rider's breath
- Accelerometer for motion and impact detection
- Microcontroller (Arduino Uno or NodeMCU) to control the logic
- GPS module for location tracking
- GSM module for alert messaging
- Rechargeable battery for power supply

4.1.2. Bike Ignition Module

- Relay module controlled via helmet signals to enable or disable ignition
- Block Diagram

4.2. Working Process

4.2.1. Step 1: System Initialization

When the system is powered on, the microcontroller initializes all the modules (sensors, GPS, GSM, etc.). A self-check is performed to ensure all modules are functional.

4.2.2. Step 2: Helmet Detection

The IR sensor inside the helmet detects if the rider is wearing the helmet. If the helmet is not detected, a signal is sent to the ignition system to keep the engine locked.

4.2.3. Step 3: Alcohol Detection

Simultaneously, the MQ-3 sensor continuously monitors for the presence of alcohol in the rider's breath. If alcohol is detected above a predefined threshold, the system disables the bike ignition and optionally triggers a warning buzzer or LED alert.

4.2.4. Step 4: Ignition Control

Only if the helmet is worn and the alcohol level is below the threshold, the system enables the relay connected to the bike's ignition system, allowing the bike to start.

4.2.5. Step 5: Continuous Monitoring for Accidents

Once the bike is running, the accelerometer monitors the movement of the helmet. If it detects sudden abnormal motion or impact beyond a predefined "G-force" threshold, the system recognizes it as a potential accident.

4.2.6. Step 6: Location Tracking and Emergency Alert

If an accident is detected:

- The GPS module retrieves the rider's current coordinates (latitude and longitude).
- The GSM module sends an SMS to emergency contacts containing:
- A predefined alert message
- GPS coordinates
- Google Maps link for easy location access

4.3. Alert Message Format

Example SMS:

- Alert: Motorcycle accident detected!
- Location: Latitude 19.12345, Longitude 72.98765
- Google Maps: https://maps.google.com/?q=19.12345,72.98765

4.4. Technologies Used

Table 1 Components used details

Component	Description
Arduino Uno / NodeMCU	Microcontroller platform for embedded control and IoT
IR Sensor	Detects whether helmet is worn
MQ-3 Alcohol Sensor	Detects alcohol content in rider's breath
MPU6050	Measures sudden accelerations, shocks, or impacts
GPS Module (NEO-6M)	Tracks real-time geographic location
GSM Module (SIM800L)	Sends SMS alerts to predefined phone numbers
Relay Module	Controls ignition based on safety conditions

4.5. Safety Logic Thresholds

- Alcohol Detection: Breath alcohol concentration above 0.04% triggers ignition lock.
- Helmet Detection: IR sensor distance < 5cm indicates helmet is worn.
- Impact Detection: Acceleration > 3g (depending on calibration) triggers accident protocol.

5. Results

To validate the functionality and performance of the proposed Smart Helmet system, a prototype was developed using Arduino and relevant IoT modules. Multiple tests were conducted under controlled and semi-realistic scenarios to evaluate each subsystem: helmet detection, alcohol detection, accident detection, and emergency alerting. The results demonstrate the feasibility, reliability, and responsiveness of the integrated system.

5.1. Accident Detection

To simulate accidents, the helmet was subjected to controlled impact using rapid force or free-fall drops from a moderate height (~1 meter). The accelerometer was calibrated to trigger an accident alert if acceleration exceeded 3g.

Table 2 Result for different movement

Impact Type	Accident Detected	Alert Sent	Response Time
Normal movement	No	No	–
Sharp turn	No	No	–
Sudden impact (crash)	Yes	Yes	~6–8 seconds
Drop from height	Yes	Yes	~5–6 seconds

5.1.1. Observation

The accelerometer accurately differentiated between regular movement and impact. Some tuning was required to avoid false positives from potholes or jerks.

5.2. Alcohol Detection

The MQ-3 alcohol sensor was positioned near the mouth region within the helmet. The system was tested using alcohol-based sanitizers and breath samples.

Table 3 Results for different alcohol levels

Alcohol Level (approx.)	Ignition Allowed	Result
0.00% (no alcohol)	Yes	Normal Start
0.02% (within limit)	Yes	Normal Start
>0.04% (above limit)	No	Ignition Blocked

Observation: The alcohol sensor responded within 2–3 seconds of exposure and accurately blocked ignition above the threshold. It resets automatically once the alcohol levels return to normal.

5.3. Emergency Alert and Location Tracking

Upon accident detection, the system successfully retrieved GPS coordinates and transmitted them via SMS to registered emergency numbers.

5.3.1. Sample Alert Message

- ALERT: Motorcycle accident detected!
- Location: Latitude 19.234567, Longitude 72.987654
- Google Maps: https://maps.google.com/?q=19.234567,72.987654

Table 4 Other parameters for the project

Parameter	Observed Result
GPS Accuracy	~5–10 meters

SMS Delivery Time	3–6 seconds
Alert Reliability	100% in network zones

6. Discussion

- The prototype successfully integrates all required modules into a compact and wearable helmet system.
- The layered safety logic ensures that no single fault compromises the entire system.
- Real-time accident alerts significantly reduce potential delays in medical attention, especially when the rider is unconscious or unable to call for help.
- The system's cost-effectiveness and scalability make it suitable for mass adoption in developing regions.

However, a few challenges and considerations remain:

- Network dependence: The GSM module requires mobile coverage. In remote or mountainous regions, alerts might be delayed.
- Environmental impact: IR sensors and alcohol sensors may need recalibration under varying light and temperature conditions.
- False positives: While impact thresholds are adjustable, extremely bumpy roads or rough riding could trigger false alerts.
- Bottom of Form

6.1. Advantages

- Promotes responsible riding behavior.
- Reduces response time in emergency situations.
- Encourages helmet use through ignition control.
- Cost-effective and scalable for mass production.

6.2. Limitations

- GSM signal issues in remote areas can delay alerts.
- False positives from accelerometer due to potholes or sharp turns.
- GPS accuracy can vary indoors or in dense urban areas.

6.3. Future Work

- Integration with smartphone apps for real-time tracking.
- Voice-activated emergency calls.
- Cloud-based data logging for insurance and traffic monitoring.

7. Conclusion

The Smart Helmet proposed in this paper demonstrates a practical application of IoT in enhancing road safety for motorcyclists. By integrating accident detection, helmet usage enforcement, and real-time alert systems, the project has the potential to significantly reduce fatalities and injuries. Future enhancements can make the system more robust and user-friendly. Overall, this project demonstrates how IoT can be effectively utilized to develop innovative, life-saving applications and paves the way for future enhancements, such as traffic rule compliance tracking and integration with smart city infrastructure.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that we have no conflicts of interest related to this work and no financial support was received for the Research, authorship and/or publication of this article.

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