

Smart Helmet 3.0 – A Multi-Functional Safety System for Motorcyclists

Pallavi S¹, Pranathi R M², Nisarga D S³, Velvizhi Ramya R⁴, Mala M Naik⁵

^{1,2,3}Department of Computer Science and Engineering, AMC Engineering College, Bangalore, 560083, India.

^{4,5}Assistant Professor, Department of Computer Science and Engineering, AMC Engineering College, Bangalore, 560083, India.

Emails: pallavishiva2902@gmail.com¹, pranathirudrriha@gmail.com², nisargadsc@gmail.com³, velvizhi.ramya@amceducation.in⁴, mala.naik@amceducation.in⁵

Abstract

The IoT-Based Smart Helmet 3.0 is an innovative safety solution aimed at minimizing motorcycle accidents and saving lives. It combines multiple safety features such as accident detection, alcohol sensing, helmet usage verification, speed and distance monitoring, and drowsiness detection into one smart system. The helmet is equipped with accelerometers and gyroscopes to identify crashes, instantly sending the rider's location to emergency contacts via GPS and GSM modules. It also ensures the bike cannot be started unless the helmet is properly worn and the rider is sober—encouraging responsible behavior. Speed and proximity sensors help the rider stay aware of their surroundings, while a drowsiness detection system, using infrared or eye-blink sensors, keeps track of the rider's alertness and issues timely warnings when fatigue sets in. Powered by Arduino and IoT technology, Smart Helmet 3.0 enables real-time monitoring and communication, significantly enhancing road safety and emergency responsiveness.

Keywords: IoT, smart helmet, accident detection, alcohol sensor, drowsiness detection, safety system.

1. Introduction

Road safety continues to be a serious global concern, especially in developing countries where two-wheelers form a large share of daily transportation. While motorcycles are affordable and convenient, they also expose riders to a higher risk of accidents, injuries, and fatalities due to limited physical protection. In many urban areas today, a significant percentage of road accidents involve two-wheeler riders. Key factors contributing to these accidents include drunk driving, over-speeding, not wearing helmets, rider fatigue, and delayed emergency response. Given these challenges, there is an urgent need for intelligent systems that can not only prevent accidents but also provide rapid assistance when incidents occur. To address this issue, we propose the IoT-Based Smart Helmet 3.0—a next-generation safety device designed to reduce accident risks and improve outcomes in the event of a crash. Unlike conventional helmets, this smart helmet integrates several advanced features within a single unit. It includes an accident detection system that uses accelerometers and gyroscopes to identify a crash and immediately transmit real-time alerts and GPS location to emergency contacts. Additionally, the

helmet is equipped with alcohol detection technology that prevents the motorcycle from starting if the rider is under the influence. Furthermore, the helmet incorporates speed and proximity sensors to continuously monitor the surrounding traffic and warn the rider of potential hazards—helping to proactively avoid collisions. To address the risk of fatigue-related accidents, a drowsiness detection module is included, which uses infrared (IR) or eye-blink sensors to track the rider's alertness and issue timely warnings if signs of drowsiness are detected. All these features are seamlessly integrated and powered by a microcontroller (Arduino), with IoT-based connectivity enabling real-time data processing, remote monitoring, and swift emergency response when needed [1].

1.1. Working Principle

1.1.1. Initialization

Upon powering on, all sensors and communication modules initialize and enter continuous monitoring mode.

1.1.2. Sensor Data Collection

The helmet gathers real-time data from the following sensors: The IoT-Based Smart Helmet 3.0 is

equipped with a variety of sensors that work together to ensure rider safety. The MPU6050 sensor, which combines an accelerometer and gyroscope, monitors the helmet's motion to detect sudden shocks or unusual rotational movements that may signal an accident. An alcohol sensor analyzes the rider's breath to determine if alcohol is present, helping prevent impaired riding. The infrared or proximity sensor ensures that the helmet is being worn correctly by detecting the presence of the rider's head inside the helmet. A speed sensor keeps track of the vehicle's speed and surrounding environment to identify cases of over-speeding or dangerous proximity to other objects. Additionally, drowsiness detection is handled either through the MPU6050 or dedicated blink sensors, which monitor subtle behaviors such as head nodding or slow blinking to recognize signs of fatigue and issue timely warnings [2].

1.1.3. Data Processing

All sensor data is transmitted to the Microcontroller Unit (MCU). The MCU runs programmed algorithms to evaluate sensor inputs and assess the rider's safety status in real-time.

1.1.4. Intelligent Decision-Making

The IoT-Based Smart Helmet 3.0 is designed to make real-time decisions that enhance rider safety in a variety of situations. If the helmet isn't worn correctly, the system immediately issues a reminder alert, encouraging the rider to wear it properly before starting the vehicle. In the case of a suspected accident—detected through sudden or abnormal movement, the Helmet activates an emergency response, captures the rider's GPS location, and automatically sends an SMS with the coordinates to pre-registered emergency contacts. To prevent impaired driving, the built-in alcohol sensor analyzes the rider's breath, and if alcohol levels are above the safe limit, the system warns the rider against operating the motorcycle. For long rides or late-night travel, the helmet monitors signs of drowsiness—such as head nodding or delayed eye responses—and sends alerts to keep the rider awake and attentive. Additionally, the helmet keeps track of speed and nearby obstacles; if it detects that the rider is going too fast or is too close to another object, it issues a

warning to slow down and maintain a safe distance. By combining these intelligent safety measures, the helmet not only responds to emergencies but actively works to prevent them, making every ride significantly safer.

1.1.5. Communication and Alerts

The communication and alert system in the IoT-Based Smart Helmet 3.0 is built to ensure timely responses in both critical and non-critical situations. It integrates GSM, GPS, and Bluetooth modules to relay important information effectively. In the event of an accident, the system instantly detects the incident and sends an SMS with the rider's live GPS location to pre-registered emergency contacts, enabling quick help. For less critical scenarios—such as alcohol detection, signs of drowsiness, failure to wear the helmet properly, or unsafe speed and proximity—the helmet provides immediate feedback to the rider through a built-in buzzer or notifications on a connected mobile app. This two-way communication approach keeps both the rider and their emergency network informed in real time, greatly improving safety and response during the ride [3].

1.1.6. Continuous Monitoring Loop

The system runs in a continuous loop, regularly updating and evaluating sensor data to ensure ongoing safety throughout the ride show Figure 1.

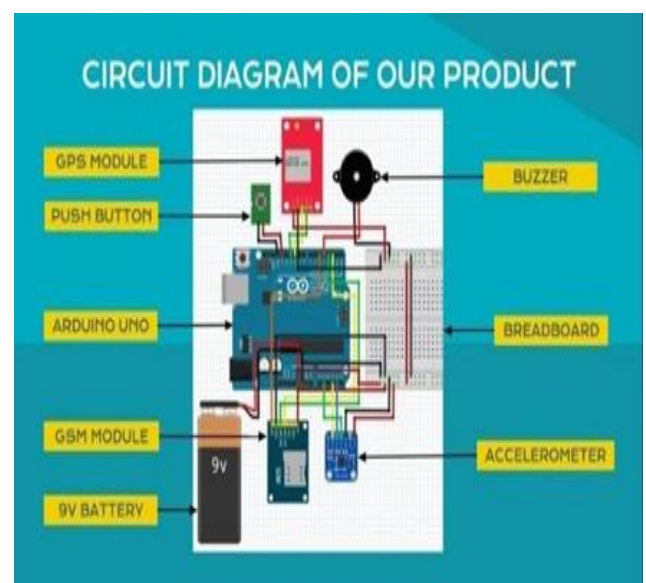


Figure 1 Circuit Diagram

2. System Architecture

The architecture of the Smart Helmet 3.0 is structured as a modular, sensor-integrated system built to interact seamlessly with IoT-based communication protocols. It is organized into five core functional layers: the Sensing Layer, which collects real-time data from the environment and rider; the Processing Layer, which filters and interprets sensor inputs; the Control Layer, responsible for decision-making and command execution; the Communication Layer, which handles data transmission between the helmet, mobile apps, or emergency systems; and finally, the Alert & Response Layer, which activates safety measures such as alarms, messages, or vehicle control in response to detected hazards.

2.1. Functional Layers of the System:

2.1.1. Sensing Layer

The Sensing Layer in the Smart Helmet 3.0 architecture is responsible for collecting real-time data through a range of embedded sensors. These include the MPU6050 sensor, which combines an accelerometer and gyroscope to detect accidents by identifying sudden impacts or falls. The MQ-3 alcohol sensor monitors the rider's breath for alcohol levels, ensuring sobriety before and during travel. An infrared or proximity sensor is used to confirm whether the helmet is being worn, promoting safety compliance. A speed sensor captures the vehicle's movement, typically through wheel rotation. Additionally, a drowsiness detection sensor, which may use infrared technology or a camera, monitors the rider's eye-blinking patterns or nodding behavior to detect signs of fatigue or sleepiness [4].

2.1.2. Processing Layer

All sensor data is transmitted to a Microcontroller Unit (MCU), typically an Arduino Uno or NodeMCU, which acts as the brain of the system. The MCU processes these inputs using pre-defined safety logic, interpreting sensor signals to determine the rider's condition and environmental context. This enables the system to make intelligent decisions, such as activating alerts, preventing vehicle ignition, or initiating emergency protocols based on real-time data analysis [5].

2.1.3. Control Layer

The MCU makes real-time decisions based on the input from various sensors. If the helmet is not worn, the vehicle ignition is disabled to ensure rider safety. In cases where alcohol is detected in the rider's breath, a warning is issued, and the ignition remains blocked. If an accident occurs, the system captures the rider's location and prepares an emergency message for alerting contacts or services. Additionally, if signs of drowsiness are sensed—such as frequent eye blinks or nodding—a real-time alert is generated to prompt the rider to take caution.

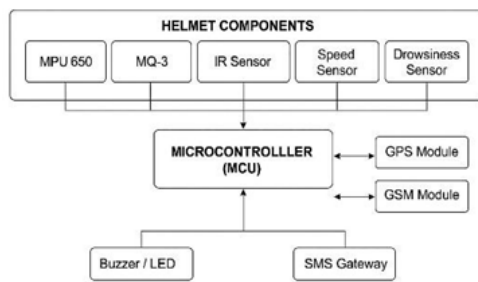
2.1.4. Communication Layer

The system is also equipped to handle external communication through various modules. A GPS module continuously captures the user's real-time location, ensuring accurate tracking during emergencies. This data is then transmitted via a GSM module, which sends SMS alerts

— including the location coordinates — to pre-set emergency contacts. Additionally, an optional Bluetooth module allows the system to connect with a mobile application for real-time updates, alerts, or hardware-level notifications [6].

2.1.5. Alert & Responsive Layer

The helmet's intelligent integration with the vehicle ensures that the engine will not start unless all safety conditions are met, such as the helmet being worn and straps secured. This enforces safe riding habits without compromising convenience. The Bluetooth feature, though optional, allows seamless pairing with a smartphone for easier access to real-time alerts, ride history, or even voice-triggered emergency SOS. The use of GPS and GSM modules makes the system location-aware, enabling it to send precise coordinates during critical moments like an accident or fall detection. To further improve safety, the device can log each ride's data, helping to analyze patterns or identify recurring hazards. This data can be valuable not just for the rider, but also for insurance companies or family members monitoring the rider's well-being. The system serves as a smart bridge between the rider, their vehicle, and emergency support systems—bringing together technology and safety in one compact unit. Show Figure 2.



System Architecture for Smart Helmet 3.0.0

Figure 2 System Architecture for Smart helmet

3. Results And Discussion

3.1. Results

The IoT-Based Smart Helmet 3.0 worked smoothly across all its features during testing. It could correctly sense accidents, check for alcohol, detect if the helmet was worn, monitor for drowsiness, and alert nearby obstacles. Emergency messages were sent in real time to preset contacts without any issues. The overall system turned out to be a dependable and budget- friendly way to improve rider safety and help prevent road mishaps [7].

3.2. Discussion

The project demonstrates that integrating multiple sensors with IoT technology significantly enhances motorcycle safety by proactively preventing accidents and improving emergency response. Smart helmets like alcohol detection and drowsiness monitoring encourage responsible riding habits, while real-time alerts ensure timely assistance, making it a practical and impactful safety solution [8].

Conclusion

In conclusion, the developed smart helmet system integrates crucial safety features such as accident detection, alcohol detection, drowsiness detection, speed and proximity monitoring, and helmet-wearing verification, all aimed at significantly reducing the risks faced by motorcycle riders. By utilizing components like the Arduino Uno, MQ3 alcohol gas sensor, ADXL345 accelerometer, RF module, force sensors, and additional hardware for drowsiness and speed detection, the system effectively monitors both the rider's condition and the riding environment in real time. The inclusion of alcohol sensing prevents impaired driving, while drowsiness detection

addresses a growing cause of accidents linked to rider fatigue. The system's ability to detect accidents and immediately communicate the location via IoT technology allows for faster emergency response, potentially saving lives. Helmet usage enforcement ensures that the ignition does not activate unless the rider is properly geared up, promoting a culture of safe riding practices. Speed and proximity monitoring further enhance rider awareness and vehicle control. Though the project demonstrates promising results in controlled conditions, future enhancements should focus on improving sensor precision, enhancing the stability and coverage of network connectivity, and ensuring the security and privacy of transmitted data. Incorporating advanced technologies such as machine learning for more accurate behavior prediction, or 5G for real-time low-latency communication, can further elevate the system's performance. Overall, this smart helmet system represents a significant step forward in enhancing motorcycle safety and has the potential to contribute meaningfully to road safety initiatives, offering a comprehensive, intelligent solution tailored for the prevention and management of motorcycle related incidents.

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