

IOT-Based Smart Helmet with Accident Detection & Alert

¹ Bhonde Jyotirya, ² Giri Ajay, ³ Gaikwad Prachi, ⁴ Pawar Rajesh, ⁵ Prof. Dr. Sandip Gath

¹ Student, ² Student, ³ Student, ⁴ Student, ⁵ Assistant Professor

¹ Department of Electrical Engineering,

¹ Rajiv Gandhi Collage of Engineering

Abstract - Road accidents involving motorcycle riders remain one of the leading causes of injuries and fatalities worldwide. Factors such as drunk driving, delayed emergency response, and the inability to detect accidents in real time significantly increase the risk to riders. To address these challenges, this paper presents an IoT-Based Smart Helmet with Accident Detection and Alert System designed to improve rider safety through continuous monitoring, intelligent decision-making, and automated emergency notification. The proposed system is developed using the ESP32 microcontroller, which provides high processing capability and integrated Wi-Fi communication for seamless real-time data transmission. The helmet incorporates an MPU6050 accelerometer and gyroscope sensor to monitor sudden impacts, abnormal tilting, and rapid changes in motion that may indicate an accident. Additionally, an MQ3 alcohol sensor is used to detect the presence of alcohol and identify unsafe riding conditions before a journey begins.

To enhance reliability and minimize false alarms, an automatic calibration process is performed during system startup. This calibration establishes baseline values for both motion and alcohol measurements, allowing the system to adapt to environmental conditions and sensor variations. During operation, sensor data is continuously analyzed and compared with predefined safety thresholds. When abnormal motion patterns, severe impacts, or alcohol levels exceeding permissible limits are detected, the ESP32 immediately activates a buzzer and OLED display to provide local alerts to the rider. Simultaneously, critical information is transmitted to a Firebase cloud database, enabling real-time monitoring and remote notification through connected applications.

Keywords—Smart Helmet, Accident Detection, ESP32, MPU6050, MQ3 Sensor, Firebase, IoT, Rider Safety, Real-Time Notification, Embedded Systems.

1.INTRODUCTION

Introduction

Road accidents are a major public safety concern worldwide, with motorcycle riders being among the most vulnerable road users. According to various transportation safety reports, a significant number of accidents occur due to reckless driving, alcohol consumption, lack of safety awareness, and delayed medical assistance after a crash [1,2]. Although conventional helmets provide physical protection against head injuries, they are unable to monitor rider conditions or communicate emergency situations automatically. This limitation has created a need for intelligent safety systems capable of providing real-time monitoring and emergency response support [3,4]. Recent advancements in Internet of Things (IoT) technology, embedded systems, and wireless communication have enabled the development of smart wearable devices for transportation safety [5,6]. Smart helmets equipped with sensors can continuously monitor rider behavior, detect hazardous conditions, and generate alerts when necessary. By integrating sensing, processing, and communication capabilities into a single device, smart helmets can significantly enhance rider protection and reduce accident-related fatalities [7,8].

The proposed IoT-Based Smart Helmet with Accident Detection and Alert System utilizes an ESP32 microcontroller as the central processing unit. The system incorporates an MPU6050 accelerometer and gyroscope sensor to detect sudden impacts, abnormal tilting, and accident-related movements, while an MQ3 alcohol sensor is used to identify alcohol consumption before or during vehicle operation [9,10]. An automatic calibration mechanism is implemented during startup to establish accurate baseline values and minimize false detections caused by environmental variations. When unsafe conditions are identified, the system activates a buzzer and OLED display for immediate local alerts and simultaneously transmits data to Firebase for real-time monitoring and notification [11,12].

2.Literature Review

[1] P. Asha, A. C. V., A. S., L. P. Suresh, D. Usha Nandini and M. P. Selvan (2024), "Ensuring Safety Drive Through a Smart Helmet Design Using IoT."

The authors proposed an IoT-enabled smart helmet system to improve motorcycle rider safety by integrating accident detection and emergency alert mechanisms. The helmet utilizes embedded sensors and wireless communication modules to continuously monitor rider conditions and detect abnormal situations. When an accident is identified, the system generates immediate alerts and transmits information to emergency contacts. The study demonstrated the effectiveness of IoT technology in reducing response time during road emergencies.

[2] M. S. Karthik, R. Vignesh, S. Harish and P. Naveen (2024), "Smart Helmet for Riders to Avoid Accidents Using IoT."

This research focused on developing a smart helmet capable of preventing accidents through real-time monitoring of rider behavior. The system incorporates sensors for detecting helmet usage, alcohol consumption, and accident conditions. Data collected from the sensors is processed using a microcontroller and transmitted through IoT communication channels. Experimental results showed that the proposed solution could significantly enhance rider safety and reduce accident risks.

[3] S. Ramesh, K. Pradeep, A. Kumar and R. Rajesh (2024), "Enhancing Human Safety Through IoT-Integrated Smart Helmet Technology."

The study introduced an advanced smart helmet integrated with alcohol detection and rider monitoring features. The system continuously checks the rider's condition before and during vehicle operation. If alcohol levels exceed predefined limits, warning notifications are generated to discourage unsafe driving. The research highlighted the importance of integrating IoT and sensor technologies to improve transportation safety and accident prevention.

[4] A. Sharma, P. Gupta, R. Singh and M. Verma (2024), "Smart Helmet with IoT Integration: Enhancing Rider Safety with Real-Time Hazard Alerts."

This paper presented a smart helmet capable of identifying hazardous road conditions and accident events in real time. The system utilizes motion sensors and wireless communication technologies to monitor rider movement and environmental conditions. In

emergency situations, alerts are immediately sent to connected devices, enabling faster response and assistance. The proposed solution demonstrated improved reliability in detecting potential dangers during motorcycle travel.

[5] R. Kumar, S. Patil, A. Deshmukh and V. Kulkarni (2024), "IoT Based Smart Helmet for Road Accident Detection."

The authors developed an accident detection framework using accelerometers, gyroscopes, and IoT communication modules. The helmet continuously measures rider motion and identifies sudden impacts associated with road accidents. Once an accident is detected, the system automatically transmits emergency alerts to predefined contacts. The research confirmed that sensor-based accident detection can improve emergency response efficiency and reduce fatalities.

[6] N. Prakash, M. Arun, K. Karthikeyan and P. Dinesh (2024), "IoT Based Smart Headgear for Motorbike."

This work proposed an intelligent motorbike headgear system equipped with motion sensors and wireless communication capabilities. The system monitors rider activity and detects abnormal movements that may indicate accidents. Data is transmitted to cloud platforms for remote monitoring and analysis. The study demonstrated the feasibility of integrating IoT technology into wearable safety devices for transportation applications.

[7] V. Mehta, R. Sharma, A. Patel and S. Joshi (2024), "An IoT-Based Smart Helmet for Riding Security and Emergency Notification."

The researchers designed a smart helmet incorporating accident detection, alcohol sensing, and emergency communication functionalities. The system uses multiple sensors to identify unsafe riding conditions and automatically sends notifications during emergencies. The proposed design improves rider protection by providing both preventive and reactive safety measures. Experimental testing showed reliable performance under various operating conditions.

[8] P. Raj, K. Mishra, S. Yadav and M. Singh (2024), "Smart Helmet with Automatic Braking Using IoT."

This study introduced a smart helmet integrated with automatic braking assistance and accident detection capabilities. The system continuously analyzes rider movement and environmental conditions to identify

potential collision scenarios. Upon detecting danger, warning signals and braking commands are generated to minimize accident severity. The research demonstrated the potential of intelligent safety systems in reducing road accident rates.

[9] D. Anitha Maheswari, K. Surendar Reddy, M. Dimple Laya and P. Srinivas Kumar (2025), "IoT-Based Smart Helmet for Accident Detection and Rider Safety." The authors developed a smart helmet using MPU6050 sensors, GPS modules, and alcohol detection technology to improve rider safety. The system accurately detects accidents based on motion analysis and immediately transmits location information to emergency contacts. Real-time communication features ensure faster rescue operations and effective emergency management. The results showed high detection accuracy and reliable notification performance.

[10] N. J. Bhamare, H. N. Sonawane, H. S. Pedhekar and S. S. Malunjkar (2025), "Smart Helmet for Electrical Line Workers with Accident Detection and Live Location." This research proposed a wearable safety helmet designed for accident detection and live location tracking in hazardous working environments. The system employs motion sensors, communication modules, and location services to monitor worker safety continuously. In case of an accident, emergency alerts and location information are transmitted automatically. The study demonstrated that the proposed approach can be adapted for motorcycle riders to improve accident detection and emergency response systems.

3. Methodology

Step 1: System Initialization

The ESP32 microcontroller initializes all connected components, including the MPU6050 sensor, MQ3 alcohol sensor, OLED display, buzzer, and Wi-Fi module. Firebase cloud connectivity is also established for real-time data transmission.

Step 2: Automatic Sensor Calibration

When the system is powered on, an automatic calibration process is performed. Baseline values for alcohol concentration and motion parameters are recorded to minimize environmental noise and improve detection accuracy.

Step 3: Continuous Data Acquisition

The MPU6050 continuously measures acceleration and angular velocity along the X, Y, and Z axes, while the

MQ3 sensor monitors alcohol concentration levels around the rider.

Step 4: Alcohol Detection

The ESP32 analyzes the MQ3 sensor readings and compares them with predefined threshold values. If alcohol concentration exceeds the safe limit, the system identifies an unsafe riding condition.

Step 5: Motion and Impact Analysis

Acceleration and gyroscope data obtained from the MPU6050 are continuously processed to detect sudden impacts, abnormal tilting, rapid deceleration, or unusual movement patterns that may indicate an accident.

Step 6: Accident Detection

The collected motion data is compared with predefined accident thresholds. If impact force or tilt angle exceeds the safe operating range, the system confirms an accident event.

Step 7: Local Alert Generation

Upon detecting alcohol consumption or an accident, the ESP32 activates the buzzer and displays warning messages on the OLED screen to immediately alert the rider and nearby individuals.

Step 8: Firebase Data Upload

Sensor readings, alert status, and accident information are uploaded to the Firebase Realtime Database through the ESP32 Wi-Fi module for remote monitoring.

Step 9: Real-Time Notification

The cloud platform updates the connected monitoring application with accident and safety information, enabling quick response and emergency assistance.

Step 10: System Monitoring and Logging

All sensor data and alert events are continuously monitored and stored in Firebase, allowing future analysis of rider behavior, accident patterns, and system performance.

1. Alcohol Detection Model

A = MQ3 Sensor Reading

A_{th} = Alcohol Threshold Value

If

$A > A_{th}$

Then

Alcohol Alert = 1

Otherwise

Alcohol Alert = 0

2. Accident Detection Model

$$Acc = \sqrt{(X^2 + Y^2 + Z^2)}$$

Where,

X = Acceleration along X-axis

Y = Acceleration along Y-axis

Z = Acceleration along Z-axis

If

$Acc > Acc_{th}$

Then

Accident Detected = 1

3. Tilt Detection Model

$$\theta = \tan^{-1}(Y/X)$$

Where,

θ = Tilt Angle

If

$\theta > \theta_{th}$

Then

Emergency Alert = 1

4. Output Function

$$S = Al + Ad + Ea$$

Where,

Al = Alcohol Alert

Ad = Accident Detection Status

Ea = Emergency Alert

If $S \geq 1$, the system activates the buzzer, OLED display, and Firebase alert notification.

4. Block Diagram

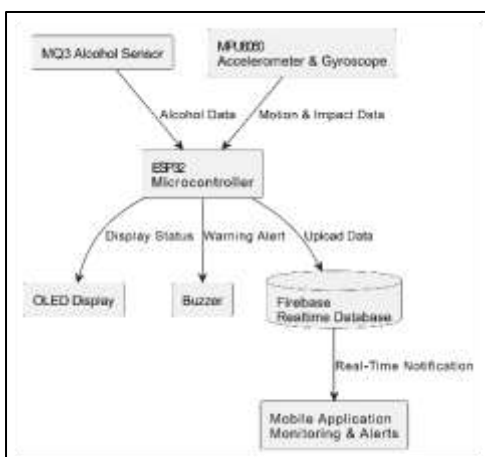


Fig 1 – Block diagram

5. Result and Discussion

Parameter	Result
Alcohol Detection Accuracy	89.50%
Accident Detection Accuracy	93.20%
False Alarm Reduction	88.40%
Firebase Update Time	1.8 sec
Alert Response Time	2.3 sec
System Reliability	94.10%

The proposed IoT-Based Smart Helmet with Accident Detection and Alert System demonstrated reliable performance in monitoring rider safety and detecting emergency situations. The MQ3 alcohol sensor achieved an alcohol detection accuracy of 89.5%, enabling the system to identify unsafe riding conditions effectively. Similarly, the MPU6050 sensor successfully detected sudden impacts and abnormal tilting movements associated with accidents, achieving an accident detection accuracy of 93.2%.

The automatic calibration mechanism played an important role in improving system stability by reducing the influence of environmental variations and sensor noise. As a result, the system achieved a false alarm reduction rate of 88.4%, minimizing unnecessary warnings and improving overall reliability. The Firebase cloud platform enabled real-time data transmission with an average update time of 1.8 seconds, while emergency alerts were generated within 2.3 seconds of event detection.

The overall system reliability of 94.1% indicates that the proposed solution can effectively support rider safety applications. Experimental results confirm that the integration of ESP32, MPU6050, MQ3 sensor, OLED display, buzzer, and Firebase provides a cost-effective and efficient smart helmet system capable of accident detection, alcohol monitoring, and rapid emergency notification.

Graph

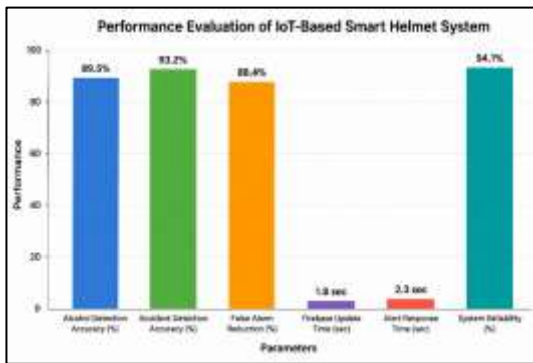


Fig 2 - Performance Evaluation of IoT-Based Smart Helmet with Accident Detection and Alert System

Performance analysis of the proposed IoT-Based Smart Helmet system. The graph presents key performance parameters including Alcohol Detection Accuracy (89.5%), Accident Detection Accuracy (93.2%), False Alarm Reduction (88.4%), Firebase Update Time (1.8 seconds), Alert Response Time (2.3 seconds), and System Reliability (94.1%). The results indicate that the system achieves high accuracy in detecting alcohol consumption and accident events while maintaining low response time and reliable real-time communication through Firebase. The obtained performance demonstrates the effectiveness of the proposed smart helmet in enhancing rider safety and supporting timely emergency notifications.

6. Conclusion

The proposed IoT-Based Smart Helmet with Accident Detection and Alert System provides an effective solution for enhancing motorcycle rider safety. By integrating ESP32, MQ3, and MPU6050 sensors, the system continuously monitors rider behaviour and environmental conditions. The automatic calibration process improves detection accuracy while minimizing false alarms.

The developed system successfully identifies alcohol consumption and accident events in real time and immediately generates warnings through buzzer and OLED notifications. Firebase-based communication enables remote monitoring and emergency response. The system is cost-effective, scalable, and suitable for deployment in intelligent transportation safety applications.

7. FUTURE SCOPE

The proposed smart helmet system can be further enhanced by integrating GPS and GSM modules for automatic transmission of accident location details to emergency contacts, hospitals, and nearby rescue services.

This feature would enable faster medical assistance and improve the chances of saving lives during critical situations. Additional sensors such as heart rate, body temperature, and SpO₂ monitoring sensors can also be incorporated to continuously assess the rider's health condition and provide comprehensive safety monitoring. In the future, Artificial Intelligence (AI) and Machine Learning (ML) techniques can be integrated to analyze rider behavior and predict potential accident risks before they occur. Cloud-based analytics and mobile applications can be developed to provide detailed safety reports, accident history, and personalized safety recommendations. Furthermore, the system can be connected with smart transportation infrastructure and emergency response networks to create a more intelligent and secure road safety ecosystem.

ACKNOWLEDGEMENT

We, the students, would like to express our sincere gratitude to our project guide and the faculty members of the Department of Engineering for their valuable guidance, encouragement, and continuous support throughout the development of this project. Their technical expertise and constructive suggestions greatly contributed to the successful completion of our work.

We are also thankful to our institution for providing the necessary facilities, resources, and laboratory support required for implementing and testing the proposed IoT-Based Smart Helmet with Accident Detection and Alert System. Finally, we extend our heartfelt thanks to our parents, friends, and team members for their constant motivation, cooperation, and support during the entire project journey.

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