Smart Helmet for Accident Detection and Safety

[1]Prof. Anuja Chavan, [2]Nikita Avhad, [3]Kaveri Bedse, [4]Aryan Shelar, [5]Vivek Parab, [6]Tushar Chincholkar

[1]Assistant Professor, [2,3,4,5,6]Department of Information Technology,

Savitribai Phule Pune University, International Institute of Information Technology, Pune, India.

Abstract
Though most developing countries have enacted stringent traffic laws, non-compliance with helmet-wearing, alcohol-influenced riding, and poor emergency response increase the fatality rate in road accidents involving two-wheelers. This paper proposes an IoT-enabled intelligent Smart Helmet that provides safety to motorcycle riders by using sensing, actuating, and communication mechanisms. The proposed system integrates different modules such as helmet wear detection, alcohol detection, accident impact analysis, real-time location reporting, and anti-theft. Using an IR sensor, MQ-3 breath sensor, MPU-6050 accelerometer, GSM/GPS modules, and RF wireless communication, the developed prototype will ensure that a motorcycle can be started only when the rider wears the helmet and the alcohol level is below the safe limit. Automatic transmission of the SOS message containing GPS coordinates sends it to the emergency contact in the event of crash detection.

Keywords: IoT, Smart Helmet, Accident Detection, GPS-GSM Alerting, Alcohol Detection, Vehicle Theft Prevention.

I. INTRODUCTION

Two-wheeler transportation dominates the roads because of its affordability and easy movement, but it also results in a high percentage of fatalities from road accidents. Global transportation authorities report that a high proportion of fatalities in motorcycle incidents are caused by helmet negligence and driving under intoxication. Classic enforcement depends mainly on the discipline of riders and does not help much in emergency situations.

Recent advancements in embedded computing and IoT have enabled smart mobility solutions that are capable of real-time sensing, communication, and automation. This work targets the creation of an affordable smart helmet ecosystem that enforces safety compliance, supporting emergency response by automated sensor decisions.

The proposed solution enforces the use of a helmet before starting, monitoring alcohol concentration and detecting a crash incident, thereby preventing unauthorized vehicle movement. Further, it integrates a GSM-GPS-based emergency call framework for quick rescue post-accident, ensuring safety beyond conventional helmet protection.

II. LITERATURE REVIEW

Somantri et al. [1] proposed a scheme for an IoT-enabled smart helmet system to ensure road-safety protocols between the rider's helmet and motorcycle. The authors' framework supported RF communication, GPS, and GSM for the authentication of helmet usage and exigency notifications during accidents. This work pioneered real-time interlocking of the rider and vehicle, ensuring better protection of riders. However, the system faced limitations in the realms of wireless range and power optimisation, attributes which influence reliability in dynamic environments.

S. M. S. et al. [2] presented a functional prototype that combines alcohol detection and accident monitoring using an Arduino-based smart helmet framework. The system used an MQ-3 sensor for breath analysis and a GSM module for emergency alerts. Work demonstrated the application viability of low-cost embedded systems to detect crash events in real time. While effective for controlled testing, network dependency and false-trigger sensitivity in high-vibration scenarios pose operational challenges in real-world deployment.

T. D. Ngoc and L. L. T. Huyen [3] designed a wireless control system with the use of RF and Wi-Fi modules for the management of devices at distant ends, including smart home applications. This study, while based on household automation, establishes the baseline for low-cost wireless communication systems that can be applied in smart vehicle systems. The investigation showcases efficient bidirectional signaling and device control; however, its indoor-centric design limits applicability in mobile outdoor safety systems such as smart helmets.

YOLOv8n-ASF-DH [4] proposed a deep-learning-based method for automatically detecting a helmet using live video streams. Indeed, their model greatly improved the detection speed and precision across a wide range of lighting and motion conditions, showing relevance to traffic monitoring and automation of law enforcement. While it offers very high precision, the approach entails heavy computational resources that make it unsuitable for direct integration into compact embedded helmet systems with limited processing capability.

The SIMCom AT Command Manual [5] goes to great detail on the technical specifications and programming instructions for GSM-based SIM800L modules. These guidelines provide structured SMS communication, network registration, and emergency messaging capabilities in IoT systems. The documented AT command set ensures robust integration of the telecommunications feature, whereas its dependency on GSM results in delayed message delivery at places where the network coverage is weak.

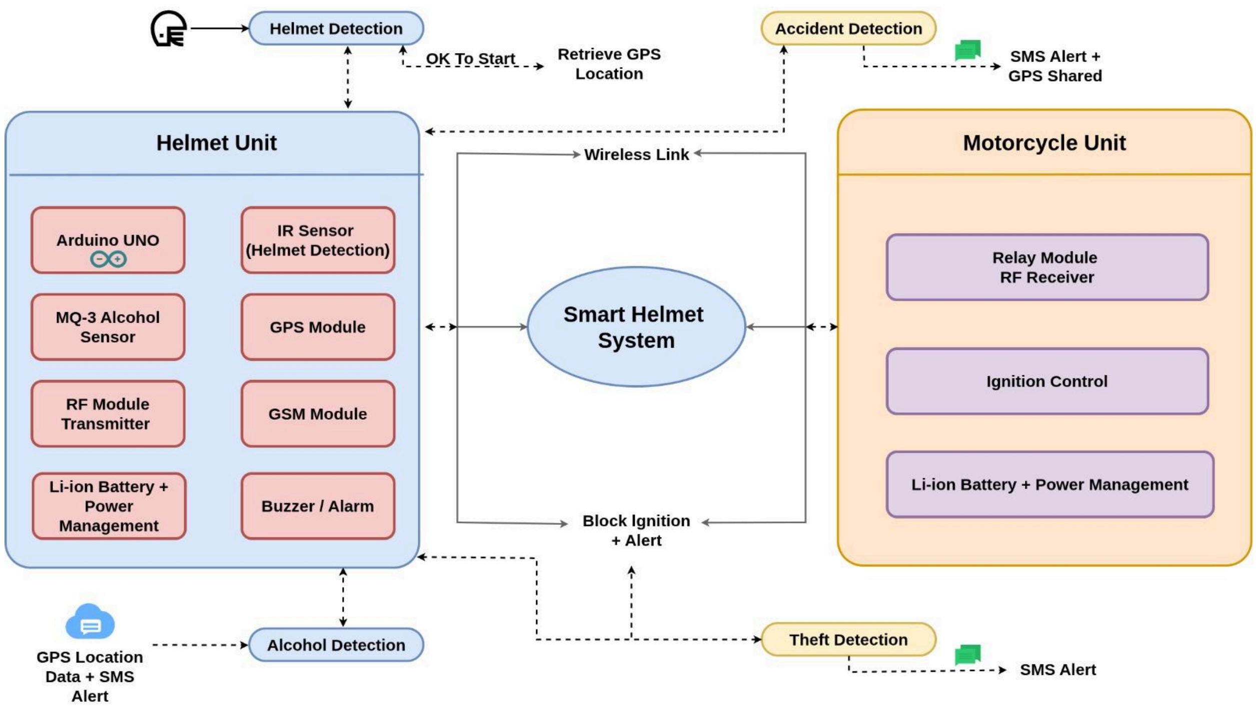
InvenSense's [6] MPU-6050 Register Map provides detailed configurations and functional registers of accelerometers and gyroscopes for motion sensing. This reference will be helpful in accurately measuring acceleration and tracking orientation, which is highly essential for crash detection mechanisms. Precise calibration is necessary to reduce interference from noise and increase accuracy in sudden movements or impacts.

The NEO-6M GPS datasheet, presented by u-blox [7], describes positioning accuracy and satellite acquisition for real-time location tracking, And it provides reliable navigation data essential to send accident location coordinates in emergency situations. Fast and widely supported, the initial satellite lock time and environmental obstruction are the most influential factors on the speed of acquiring data.

The product specification of nRF24L01+, from Nordic Semiconductor [8], presents the basic outlines of a low-power wireless transceiver for short-range communication, thereby enabling helmet-to-motorcycle data and ignition control efficiently. With this module, configurable frequency channels and SPI interfacing robustness are made possible at the price of careful noise management and antenna placement in motion-intensive and interference-rich environments to sustain good quality communication.

III. SYSTEM ARCHITECTURE

System Architecture for project is



[Figure 1 – System Architecture]

The system architecture of the Smart Helmet for Accident Detection and Rider Safety has been designed to ensure smooth coordination among several embedded components and communication modules. The entire system operates on two integrated units, mainly Helmet Unit and Motorcycle Unit, which are connected via a wireless RF link. Both units work side by side to enforce safety protocols, monitor rider conditions, and initiate emergency responses.

Helmet Unit:

The Helmet Unit serves as the main safety node, comprising sensors and communication modules for the detection of helmet usage, alcohol concentration. The helmet is equipped with an IR sensor, MQ-3 alcohol sensor, and MPU-6050 accelerometer, which are all interfaced with an Arduino microcontroller. If the helmet detects that riding conditions are safe, it sends an enable signal to the motorcycle unit via the RF transceiver. In cases of an accident, the system will automatically send an alert message displaying real-time GPS coordinates via the GSM and GPS modules. The helmet also includes a buzzer and LEDs for local indication and system alerts.

Motorcycle Unit:

The motorcycle unit is the execution and control module. It receives the RF from the helmet for the detection of helmet usage and the sobriety of the rider before enabling ignition. It contains an RF receiver, relay module, buzzer, and microcontroller, all performing in coordination with each other for the ignition and alarm systems. In default mode, if the helmet is not detected or the rider is found under the influence, the ignition remains in a locked state. Secondly, the motorcycle unit continuously monitors the RF link in real time. The bike is running and the link breaks, then the system considers its unauthorized access to the bike, triggers an alarm, and shuts off the ignition. This ensures that there is complete coordination between the rider and the vehicle for safety and security.

IV. IMPLEMENTATION DETAILS

1) System Architecture:

The architecture of the Smart Helmet system is modular, scalable, and integrated with various IoT components to assure the safety of riders, detection of accidents, and security in vehicles. Wireless communication between the helmet and motorcycle units is enabled via an RF module, while the GSM and GPS modules provide for emergency messaging and location tracking. This can establish smooth coordination among the different modules within its layered architecture for stable performance with real-time response during every critical scenario. Each module communicates with the microcontroller, processing sensor data and executing safety decisions; hence, it provides a reliable and efficient accident-response ecosystem.

2) Helmet Detection & Ignition Authorization Module:

The Helmet Detection module limits the motorcycle from start to until the helmet is put on and properly attached. It also contains an IR sensor inside that detects the presence of a rider. If it detects one, it sends an authorization signal to the motorcycle unit via RF communication. If the helmet is not worn, then ignition will not be turned on, and buzzer sounds to alert the rider. This mechanism applies safe riding habits and prevents ignoring helmet safety protocols, acting as a primary gateway to the system's secure functioning.

3) Alcohol Monitoring Module:

The Alcohol Monitoring module checks breath alcohol concentration using the MQ-3 gas sensor that is attached near the mouth region of the helmet. The system switches off the ignition and triggers a buzzer there and then if the level of concentration exceeds a certain threshold limit. The system passes on a signal to the motorcycle unit not to get on the vehicle in case of intoxication. Thus, such an automatic prevention strategy motivates responsible driving and reduces the risk of road accidents due to alcohol consumption.

4) Accident Detection & Emergency Response Module:

The Accident Detection module constantly monitors the motion of the helmet through the MPU-6050 accelerometer and gyroscope sensor. Abnormal patterns in the movement, such as sudden impact, trigger the emergency mode. Immediately upon detecting a crash, the microcontroller fetches the GPS coordinates of the rider and sends off an automated SMS alert to pre-registered emergency contacts via the GSM module. This life-saving feature ensures that the rider, even if he is unconscious or unable to call for help, gets prompt medical response, thus minimizing the chances of fatality.

5) Anti-Theft & Vehicle Security Module:

This Anti-Theft module helps enhance vehicle safety against non-allowed usage of the vehicle. RF communication is used to connect between helmet and bike; in case the motorcycle is moved beyond RF range without a helmet, it will automatically kill the ignition and trigger an alarm. This mechanism prevents the vehicle from going into unauthorized movement without merely depending on the conventional mechanical locks. The system ensures that only the authenticated helmet can operate the bike for trusted access control.

6) Interactions and Integration:

These modules cooperate through a central microcontroller-based logic system. All Sensors continuously feed data into the processor, which makes real-time decisions about ignition control, alert messaging, and accident handling. Units communicate over RF signals, while GSM and GPS modules respectively handle external messaging and tracking. It is an integrated ecosystem wherein all the safety features operate in cohesion: helmet detection, alcohol verification, accident monitoring, and theft prevention-these will go on to make a seamless and robust user experience. The modular nature of the system ensures upgradability in the future for mobile app support, cloud integration, and enhancement of AI-based monitoring of the system.

V. KEY ATTRIBUTES OF PROJECT

Following are the basic technological and functional components of the Smart Helmet project that focuses on enhancing the safety of riders and ensuring road security. These attributes represent the main principles for assuring reliability, usability, and effectiveness of the system.

Aspect 1: Intelligent Safety Enforcement

A helmet wear detection mechanism would be designed in such a way that the motorcycle ignition is on only when the helmet is accurately worn. This would automatically enforce disciplined riding behavior, filling in gaps in compliance.

Aspect 2: Real-Time Alcohol Monitoring
An integrated alcohol-sensing module with the ability to detect the presence of alcohol in the rider's exhaled breath and immediately block vehicle ignition should this exceed the threshold limit, thus discouraging drunk driving and improving safety on public roads.

Aspect 3: Automated Accident Detection & Alerting
A smart accident-detection system using an accelerometer/gyroscope that detects crash events, with follow-through transmission of an emergency alert message along with GPS location to pre-programmed contacts. This, together with an increase in the possibility of much-reduced medical response times, increases the probabilities of survival after severe incidents.

Aspect 4: Vehicle Security & Anti-Theft Controls
A helmet wear detection mechanism would be designed in such a way that the motorcycle ignition is on only when the helmet is accurately worn. This would automatically enforce disciplined riding behavior, filling in gaps in compliance.

Aspect 5: Seamless IoT-Based Integration
It integrates sensors, a microcontroller, GSM/GPS modules, and wireless communication within one embedded system, enabling all the safety functions to work in a synchronized manner. The cohesive architecture provides great responsiveness and reliability.

Aspect 6: User-Centric Alerts & Support
Automation of safety alerts and emergency notifications will help in seeking timely assistance during life-or-critical situations. In addition, it helps in rider awareness and public alerting through real-time location sharing and audible warning systems, thus creating a safer riding ecosystem.

VI. CONCLUSION

In a nutshell, the proposed Smart Helmet system gives paramount importance to integrating safety enforcement features, real-time monitoring mechanisms, and automatic emergency response functions seamlessly to ensure enhanced road safety and protection of the rider. By integrating sensor-based alcohol detection, mandatory helmet wear verification, accident recognition, and wireless communication, this system is sure to go a long way in reducing the severity of accidents and preventing irresponsible riding behavior.

The Smart Helmet addressed modern road-safety challenges confronting the users of two-wheelers through its ignition-locking mechanism, crash alert, and anti-theft capabilities. The riders get an intuitive and automated safety system devoid of explicit handling, thereby driving more discipline and confidence among them. Finally, the cost-effective IoT modules combined with intelligent control logic make the solution more affordable and pragmatic to adopt. This system becomes a promising step toward safer and secure transportation environments.

REFERENCES

[1] Somantri et al., “Smart Helmet Integrated with Motorcycles to Support Rider Awareness and Safety Based on Internet of Things,” IEEE Access, 2022.

[2] S. M. S. et al., “Real-Time Accident Detection and Alcohol Monitoring Using a Smart Helmet,” International Journal of Engineering Research and Technology (IJERT), 2023.

[3] T. D. Ngoc and L. L. T. Huyen, “Improvement of Remote Control Panel for Smart Homes Using RF and Wi-Fi,” IJOBE, 2019.

[4] “YOLOv8n-ASF-DH: An Enhanced Safety Helmet Detection Method,” 2024.

[5] SIMCom AT Commands Manual, SIM800L Series, SIMCom Wireless Solutions.

[6] “MPU-6050 Accelerometer and Gyroscope Register Map and Descriptions,” InvenSense Inc., 2020.

[7] “NEO-6M GPS Module Datasheet,” u-blox AG, 2021.

[8] “nRF24L01+ 2.4 GHz Transceiver Product Specification,” Nordic Semiconductor, 2022.a