



Intelligent Helmet –Assisted Ignition Interlock For Motorcycles

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Abstract: This paper presents the design and implementation of a Smart Bike Safety System that enhances rider protection through automation and real-time monitoring. The system integrates multiple sensors and embedded controllers to verify helmet usage, detect alcohol levels, and control engine ignition based on safety conditions. Two independent modules, placed in the helmet and the bike, communicate wirelessly using the ESP-NOW protocol to ensure reliable and low-latency data exchange. Motion and impact sensors continuously analyze riding conditions to identify potential accidents. Upon detecting a crash, the system initiates an intelligent alert mechanism that seeks rider confirmation and, if necessary, automatically sends emergency notifications through SMS and phone calls using a GSM module. A web-based interface further enables live tracking and system supervision. By combining prevention, detection, and rapid communication features, the proposed system offers an efficient, low-cost, and practical solution to improve two-wheeler safety and emergency response.

Index Terms - ESP-NOW Communication, Wireless Sensor Network, Accident Detection, Motion and Impact Sensors, Engine Ignition Control, Emergency Alert System, GSM Module

I. INTRODUCTION

Two-wheelers play a vital role in modern transportation systems due to their low cost, fuel efficiency, and convenience in congested urban environments. However, two-wheeler riders are highly exposed to road hazards, making them more susceptible to severe injuries and fatalities during accidents. According to global and national road safety studies, two-wheeler accidents contribute to a substantial portion of traffic-related deaths, primarily due to rider negligence and delayed emergency response [1].

Common causes of two-wheeler accidents include non-usage of helmets, riding under the influence of alcohol, over-speeding, and lack of immediate medical assistance after an accident [2]. Although traffic laws mandate helmet usage and prohibit drunk driving, enforcement alone has proven insufficient. In many critical situations, riders are unable to call for help due to unconsciousness or severe injuries, resulting in increased fatality rates [3]. Traditional vehicle safety systems depend largely on human intervention, which limits their effectiveness during emergencies.

With the rapid advancement of embedded systems, sensor technologies, and wireless communication, intelligent safety solutions for transportation have gained increasing attention [4]. Several studies have proposed accident detection and alert systems; however, many existing solutions lack comprehensive safety enforcement, real-time rider condition monitoring, and reliable coordination between helmet and vehicle units. Additionally, delayed or false emergency alerts remain a major concern in automated systems [5].

To overcome these limitations, this paper proposes a Smart Bike Safety System that integrates helmet usage detection, alcohol sensing, accident detection, and automated emergency communication into a single unified framework. The proposed system is divided into two main units: a Helmet Unit and a Bike Control Unit, which communicate wirelessly using the ESP- NOW protocol to ensure fast and reliable data exchange. The bike engine is enabled only when safety conditions are satisfied. In the event of an accident, motion sensors detect abnormal impact or tilt conditions, followed by a rider confirmation phase to minimize false alerts. If no response is received, emergency notifications are automatically sent via SMS and voice call using a GSM module. A web-based interface provides real- time system monitoring and data visualization.

The proposed system aims to enhance rider safety by reducing negligence, improving accident response time, and introducing intelligent automation into two-wheeler safety mechanisms. This work contributes toward the development of reliable and scalable intelligent transportation safety systems.

II. LITERATURE SURVEY

(1) NHTSA Report (2017) – “Examining the Feasibility of Alcohol Ignition Interlocks for Motorcycles” Published by the U.S. National Highway Traffic Safety Administration (NHTSA), this report examines whether alcohol interlock devices—commonly used in cars—can be adapted for motorcycles. The findings indicate that while ignition interlocks are effective in reducing drunk driving incidents in cars, their direct application to motorcycles is challenging due to design, safety, and legal issues. However, the concept of integrating alcohol detection into helmets is suggested as a safer alternative.

(2) Patent (US20090002161A1) – “Security System for Motorcycle Crash Helmet” This patent describes a helmet-integrated system that communicates wirelessly with the motorcycle. The ignition is enabled only when the helmet is detected on the rider’s head through sensors embedded inside the helmet. The patent also includes features such as wireless pairing, ignition lock control, and tamper resistance.

(3) Kumar et al. (2023) – “Smart Helmet with Alcohol Detection and Ignition Control System” This research demonstrates a prototype that integrates an alcohol sensor (MQ-3), IR sensor for helmet detection, and a microcontroller (Arduino UNO). The system communicates wirelessly with the motorcycle using an RF transmitter-receiver pair. The ignition is disabled if alcohol is detected or if the helmet is not worn. The project validates that such systems can be built cost-effectively using basic electronic components. However, issues like RF interference, limited range, and the possibility of signal spoofing remain challenges.

Several research works and commercial solutions focus on improving motorcycle safety. Existing systems include helmet detection mechanisms, alcohol detection circuits, GPS-based accident alert systems, and GSM communication for emergency notifications.

Earlier helmet enforcement systems mainly used simple IR or pressure sensors and lacked wireless communication. Alcohol detection systems using MQ-3 sensors were developed, but these systems were often standalone and did not integrate accident detection or emergency communication.

Accident detection systems based on accelerometers have been widely studied. However, most existing solutions generate false alerts due to road bumps or sudden braking, and they do not provide a rider confirmation window before triggering emergency calls.

Modern IoT-based solutions introduce GPS tracking and mobile applications, but they require constant internet connectivity and complex infrastructure.

Compared to existing systems, the proposed Smart Bike Safety System integrates helmet verification, alcohol detection, accident detection, emergency communication, and a web-based monitoring platform into a single compact and efficient solution, offering higher reliability and practical usability.

III. METHODOLOGY&CIRCUIT DIAGRAM

Bike Control Unit Circuit Diagram

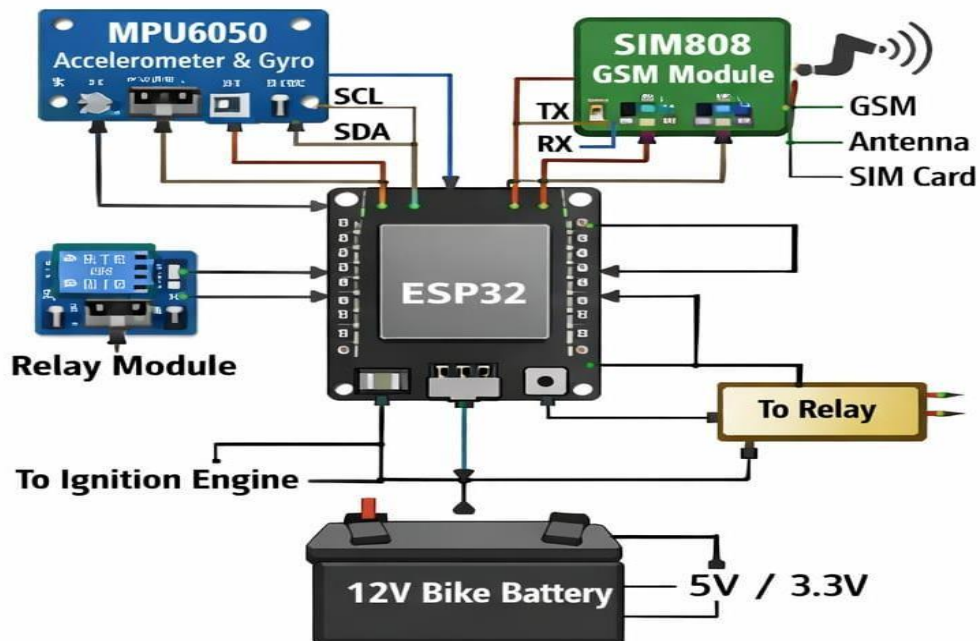


Figure 1 Bike Control Unit Circuit Diagram

Smart Helmet Unit Circuit Diagram

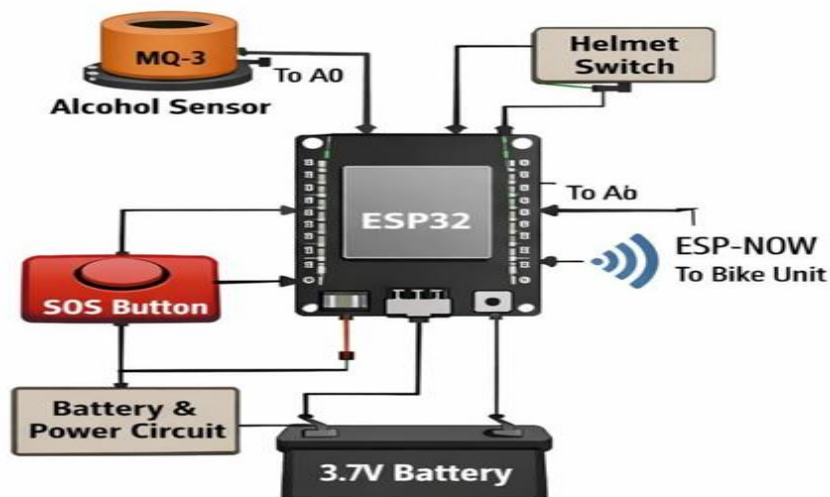


Figure 2 Smart Helmet Unit Circuit Diagram

IV. BLOCK DIAGRAM

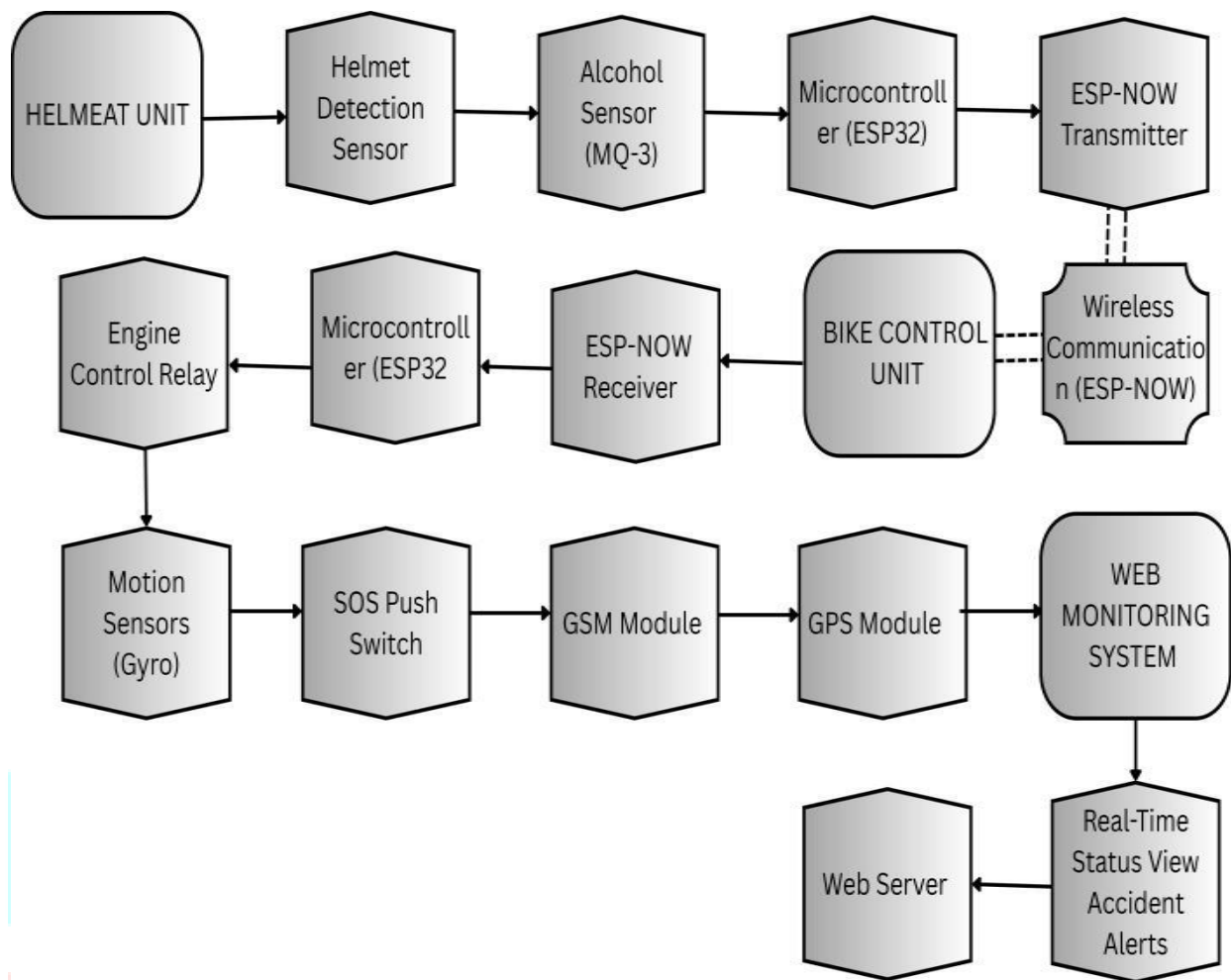


Figure 3 Block Diagram

V. WORKING

The operation of the proposed Smart Bike Safety System is divided into three major stages: safety verification before ignition, continuous monitoring during riding, and automated emergency response during accidents. These stages are achieved through coordinated communication between the Helmet Unit and the Bike Control Unit.

A. Safety Verification and Engine Control

When the rider attempts to start the bike, the Helmet Unit first verifies whether the helmet is properly worn using the helmet detection mechanism. At the same time, the alcohol sensor measures the alcohol concentration in the rider's breath. The sensed data is processed by the helmet-mounted microcontroller and transmitted wirelessly to the Bike Control Unit using the ESP-NOW protocol.

The Bike Control Unit evaluates the received data and allows engine ignition only if all safety conditions are satisfied, namely helmet usage confirmation and alcohol level within permissible limits. If any condition fails, the ignition system remains disabled, thereby preventing unsafe riding and enforcing compliance with safety regulations.

B. Continuous Monitoring and Accident Detection

During normal riding conditions, the Bike Control Unit continuously monitors motion data obtained from inertial sensors such as accelerometers and gyroscopes. These sensors detect abnormal parameters including sudden impact, excessive tilt, or rapid deceleration, which may indicate a possible accident. Upon detecting such abnormal motion patterns, the system initiates an accident detection routine. To reduce false

alerts caused by road bumps or minor disturbances, the system enters a verification phase before declaring an emergency condition.

C. Emergency Alert and Notification Mechanism

After accident detection, the system provides a predefined time interval for rider confirmation through a manual input. If the rider responds within this time, the emergency alert process is canceled. If no response is received, the system assumes a critical accident scenario. The Bike Control Unit then activates the GSM module to automatically send emergency alerts via SMS and voice call to predefined emergency contacts or services. The alert includes essential information such as system status and location details. Simultaneously, system data is updated on a web-based interface, enabling real-time monitoring by authorized users. Through this structured working mechanism, the proposed system effectively enforces rider safety, minimizes false emergency alerts, and ensures timely assistance during accidents.

Algorithm of the Proposed System

The step-by-step operation of the Smart Bike Safety System is described through the following algorithm, which outlines safety verification, accident detection, and emergency response mechanisms.

VI. ALGORITHM: SMART BIKE SAFETY SYSTEM OPERATION

1. Start System
2. Initialize Helmet Unit and Bike Control Unit.
3. Establish wireless communication between both units using ESP-NOW protocol.
4. Helmet Detection
 - Check whether the helmet is worn properly.
 - If helmet is not detected, disable engine ignition and display warning.
5. Alcohol Detection
 - Measure alcohol level using the alcohol sensor.
 - If alcohol level exceeds the permissible limit, disable engine ignition.
6. Engine Control
 - If helmet is worn and alcohol level is within limit, enable engine ignition.
7. Continuous Monitoring
 - Continuously read motion sensor data (accelerometer and gyroscope).
8. Accident Detection
 - If abnormal tilt, sudden impact, or rapid deceleration is detected, trigger accident routine.
9. Rider Confirmation
 - Start a timer and wait for rider confirmation input.
 - If confirmation is received within the time limit, cancel emergency alert.
10. Emergency Alert
 - If no response is received, activate GSM module.
 - Send emergency SMS and voice call to predefined contacts with location details.
11. Update system status on the web-based monitoring interface.
12. End.

VII. FUTURE SCOPE

1. Advanced biometric sensors, such as fingerprint or face recognition, can be incorporated to ensure that only authorized users operate the motorcycle. The alcohol detection mechanism can be enhanced using more accurate and calibrated sensors to reduce false readings. Additionally, AI-based accident detection algorithms can be implemented using accelerometers and gyroscopes to improve accident identification accuracy.
2. The system can also be connected to smart traffic and law enforcement networks, enabling automatic reporting of safety violations and accident data. Integration with cloud platforms would allow data storage,

analytics, and predictive accident prevention. Solar or energy-harvesting techniques can be explored to reduce power consumption and improve sustainability.

3. In the future, this system can be made mandatory by government regulations and implemented on a large scale to reduce road accidents. With further miniaturization of components and improved wireless communication, the intelligent helmet can become lighter, more comfortable, and more affordable, contributing to safer and smarter transportation systems.

VIII. RESULT

The Intelligent Helmet-Assisted Ignition Interlock for Motorcycles was successfully designed, implemented, and tested to evaluate its performance under real-time operating conditions. The system effectively verified helmet usage and alcohol levels before allowing engine ignition, ensuring that the motorcycle could be started only when all safety requirements were satisfied. The alcohol detection mechanism accurately sensed the presence of alcohol in the rider's breath, and the ignition remained disabled whenever the alcohol concentration exceeded the permissible limit.

Wireless communication between the Helmet Unit and the Bike Control Unit using the ESP-NOW protocol proved to be reliable and low-latency, enabling seamless real-time data exchange. During continuous operation, motion and impact sensors accurately detected abnormal tilt, sudden impact, and rapid deceleration events associated with accident scenarios. The inclusion of a rider confirmation mechanism significantly minimized false emergency alerts caused by road bumps or sudden braking.

In cases where no rider response was received after accident detection, the GSM module successfully transmitted emergency SMS alerts and initiated voice calls to predefined contacts along with relevant system and location information. The web-based monitoring interface provided real-time visualization of system parameters such as helmet status, alcohol detection status, ignition condition, and location tracking.

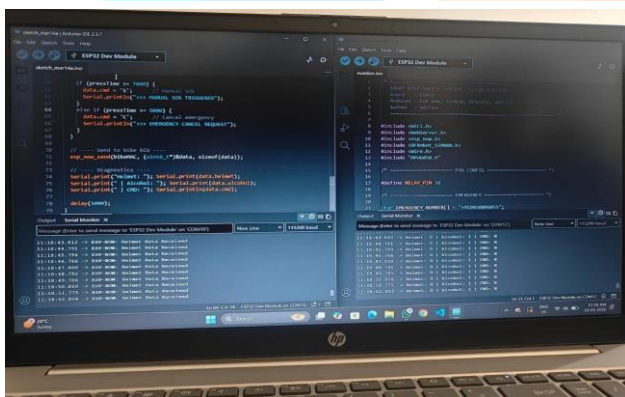


Figure 4 Software Program and output Image



Figure 5 Hardware Image

Overall, the results demonstrate that the proposed system is reliable, cost-effective, and effective in enhancing two-wheeler safety through integrated prevention, monitoring, and emergency response mechanisms.

IX. CONCLUSION

The proposed Smart Bike Safety System provides an intelligent and integrated approach to enhancing two-wheeler safety. By enforcing helmet usage, preventing drunk driving, detecting accidents, and automatically alerting emergency contacts, the system addresses major causes of road accidents. Real-time monitoring through a professional web interface allows riders and authorized personnel to track critical parameters, including helmet status, alcohol detection, ignition condition, and vehicle location, improving

awareness and safety compliance. The use of the ESP32 microcontroller enables seamless wireless communication between the Helmet Unit, Bike Control Unit, and smartphone application, ensuring real-time data exchange. Integration of GPS and GSM modules facilitates location tracking and automatic emergency notifications, enabling timely medical assistance during accidents.

Overall, the system demonstrates a practical application of IoT and embedded technologies for smart transportation. It is cost-effective, scalable, and reliable, with potential to significantly reduce accidents and fatalities. Future enhancements, such as predictive accident prevention and integration with smart city infrastructure, can further strengthen its impact on safer, connected transportation systems.

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