International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
Peer Reviewed, Referred & Indexed Journal
ISSN: 3068-272X www.ijdim.com Original Research Paper

SMART HELMET SAFETY SYSTEM FOR BIKE RIDERS USING ARDUINO

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ABSTRACT

Road accidents involving two-wheeler riders continue to be a major cause of injuries and fatalities worldwide. A significant number of these accidents occur because riders fail to wear helmets, ride under the influence of alcohol, or operate motorcycles without following basic safety regulations. Conventional helmets provide physical protection during accidents but do not actively monitor rider safety or prevent unsafe vehicle operation. Recent advancements in embedded systems, sensor technology, and intelligent control have enabled the development of smart safety devices capable of improving rider protection through real-time monitoring and automatic vehicle control. This project presents a Smart Helmet for Bike Riders Using Arduino, designed to enhance rider safety by integrating multiple sensing and control mechanisms into a single intelligent system. The proposed framework employs an Arduino microcontroller as the central controller, together with a helmet detection sensor, alcohol sensor, vibration sensor, and wireless communication module. Before starting the motorcycle, the system verifies whether the rider is wearing the helmet correctly and checks for the presence of alcohol. The vehicle ignition is enabled only when both safety conditions are satisfied. During vehicle operation, the vibration sensor continuously monitors for accident events. If a collision or severe impact is detected, the system automatically generates an emergency alert and can transmit accident information to predefined emergency contacts through a communication module. Experimental evaluation demonstrates reliable helmet detection, accurate alcohol sensing, rapid accident detection, and stable system performance under different operating conditions. The proposed smart helmet significantly improves rider safety by preventing unauthorized vehicle operation, encouraging helmet usage, reducing alcohol-related accidents, and enabling rapid emergency response after collisions. The developed framework offers a cost-effective, reliable, and scalable solution for intelligent two-wheeler safety and supports the advancement of smart transportation systems.

Keywords: Smart Helmet, Arduino, Bike Rider Safety, Helmet Detection, Alcohol Sensor, Accident Detection, Vibration Sensor, Embedded Systems, Road Safety, Intelligent Transportation.

I. INTRODUCTION

Road transportation is one of the most widely used modes of travel worldwide, and motorcycles play a significant role due to their affordability, fuel efficiency, and convenience. However, two-wheelers are also associated with a high number of road accidents, resulting in severe injuries and fatalities every year. One of the primary reasons for these accidents is the failure of riders to wear protective helmets and follow road safety regulations. Head injuries remain the leading cause of death in motorcycle accidents because many riders either ignore helmet usage or wear helmets improperly. In addition, riding under the influence of alcohol significantly impairs judgment, reduces reaction time, and increases the probability of collisions. Conventional helmets provide physical protection during accidents but cannot prevent unsafe riding behaviour or monitor the rider's condition before and during vehicle operation. Therefore, intelligent safety systems capable of automatically verifying helmet usage, detecting alcohol consumption, and preventing unauthorized vehicle ignition have become an important area of research. Recent developments in embedded systems, sensor technology, wireless communication, and microcontroller-based automation provide effective solutions for improving rider safety. By integrating intelligent sensing devices with vehicle control mechanisms, smart helmets can significantly reduce accident risks and improve compliance with traffic safety regulations while enhancing the overall safety of two-wheeler transportation [1–8].

The rapid advancement of embedded electronics and sensor technology has enabled the development of intelligent helmet systems capable of continuously monitoring rider safety. Modern smart helmets integrate microcontrollers, helmet detection sensors, alcohol sensors, vibration sensors, GPS modules, GSM communication, and wireless transmission technologies to provide advanced safety features. Helmet detection sensors verify whether the rider is wearing the helmet correctly before allowing vehicle ignition, while alcohol sensors detect the presence of alcohol in the rider's breath to prevent unsafe driving. During vehicle operation, vibration sensors or accelerometers continuously monitor sudden impacts that may indicate accidents. Once an accident is detected, the embedded controller automatically generates emergency alerts and communicates accident information to family members or emergency services through wireless communication modules. These intelligent monitoring systems reduce accident severity by enabling rapid emergency response and improving rider awareness. Experimental investigations demonstrate that embedded safety systems significantly reduce alcohol-related accidents, improve helmet compliance, and enhance the effectiveness of road safety measures. The integration of Arduino-based control with intelligent sensing technologies provides an economical and reliable solution for modern motorcycle safety applications [9–17].

This project proposes a Smart Helmet for Bike Riders Using Arduino to improve motorcycle safety through intelligent monitoring and automatic vehicle control. The proposed framework integrates an Arduino microcontroller, helmet detection sensor, alcohol sensor, vibration sensor, relay module, buzzer, and wireless communication module into a unified safety system. Initially, the helmet detection sensor verifies whether the rider is wearing the helmet properly. Simultaneously, the alcohol sensor analyses the rider's breath to determine the presence of alcohol. The Arduino processes both sensor inputs and permits motorcycle ignition only when the helmet is worn correctly and alcohol is not detected. During vehicle operation, the vibration sensor continuously monitors impact conditions to identify accidents. Whenever a severe collision occurs, the controller immediately activates emergency alerts and can transmit accident information to predefined emergency contacts through wireless communication. The developed framework is evaluated using engineering parameters such as helmet detection accuracy, alcohol detection accuracy, accident detection response time, communication reliability, and overall system performance. Experimental results demonstrate that the proposed smart helmet accurately enforces safety rules, reduces unsafe vehicle operation, enables rapid accident reporting, and significantly improves rider protection. The developed system provides a reliable, economical, and intelligent solution for enhancing road safety and supporting future smart transportation technologies [18–25].

II. SURVEY OF RESEARCH

1. Smart Helmet Technology for Rider Safety

Smart helmet technology has emerged as an effective solution for improving motorcycle rider safety through intelligent monitoring and automation. Researchers have developed helmets equipped with embedded sensors capable of detecting helmet usage, monitoring rider behaviour, and preventing unsafe vehicle operation. Traditional helmets mainly provide physical protection during accidents but cannot verify whether the rider is following safety regulations. Modern smart helmets integrate microcontrollers, wireless communication modules, and intelligent sensors to enhance rider protection before and during travel. These systems automatically verify helmet usage, monitor safety conditions, and support accident prevention. Experimental studies demonstrate that smart helmets significantly improve rider compliance with traffic regulations, reduce head injury risks, and increase overall road safety. The research findings indicate that intelligent helmet systems provide a practical and economical solution for reducing motorcycle-related accidents and enhancing transportation safety [1].

2. Arduino-Based Embedded Safety Systems

Arduino has become one of the most widely used embedded platforms for developing intelligent road safety applications because of its low cost, simple programming environment, and compatibility with multiple sensors. Researchers have implemented Arduino controllers for monitoring helmet usage, detecting alcohol consumption, identifying accidents, and controlling vehicle ignition systems. The microcontroller continuously processes sensor inputs and performs automatic decision-making based on predefined safety conditions. Several investigations demonstrate that Arduino-based safety systems provide reliable real-time performance with minimal hardware complexity and low power consumption. The flexibility of Arduino enables easy integration with communication modules, relays, GPS units, and GSM devices for advanced safety applications. These characteristics make Arduino an ideal embedded controller for intelligent motorcycle safety systems [2].

3. Alcohol Detection Systems for Vehicle Safety

Alcohol consumption is one of the leading causes of road accidents worldwide, motivating researchers to develop intelligent alcohol detection systems for preventing unsafe vehicle operation. Modern safety systems employ alcohol sensors such as the MQ-3 sensor to analyse alcohol concentration in the rider's breath before permitting engine ignition. Embedded controllers continuously process sensor readings and compare them with predefined safety thresholds.

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If alcohol is detected above the permissible limit, the controller immediately prevents vehicle ignition and generates warning messages. Experimental studies demonstrate that alcohol detection systems significantly reduce drink-driving incidents and improve road safety by preventing intoxicated individuals from operating motorcycles. The integration of alcohol sensing with intelligent vehicle control provides an effective solution for minimizing alcohol-related road accidents [3].

4. Accident Detection and Emergency Alert Systems

Rapid accident detection and emergency communication are essential for reducing fatalities resulting from motorcycle accidents. Researchers have developed intelligent accident detection systems using vibration sensors, accelerometers, and impact sensors capable of identifying collision events in real time. Once an accident is detected, the embedded controller automatically activates emergency communication modules to notify family members, emergency responders, or nearby hospitals. Several studies have incorporated GSM, GPS, and wireless communication technologies to transmit accident location and emergency information without requiring manual intervention. Experimental investigations indicate that automatic emergency alert systems significantly reduce emergency response time and improve the survival rate of accident victims. These intelligent systems provide reliable support for modern road safety applications and emergency management [4].

5. Wireless Communication in Smart Transportation

Wireless communication technologies have significantly enhanced intelligent transportation systems by enabling real-time information exchange between embedded devices and remote users. Researchers have integrated GSM, Bluetooth, Wi-Fi, RF, and IoT communication modules into smart helmet systems to support remote monitoring and emergency notification. Wireless communication enables automatic transmission of accident alerts, rider status, and system information to authorized users. Real-time communication improves emergency response while enhancing vehicle monitoring capabilities. Experimental studies demonstrate that wireless communication modules provide reliable data transmission with low latency and stable performance under different environmental conditions. These investigations confirm that wireless communication is an essential component of modern intelligent transportation systems and smart rider safety applications [5].

6. Intelligent Rider Safety Systems and Future Developments

Recent research focuses on integrating Artificial Intelligence, embedded systems, IoT, cloud computing, and advanced sensing technologies to develop intelligent motorcycle safety systems. Researchers have proposed smart helmets capable of monitoring helmet usage, alcohol consumption, rider fatigue, accident occurrence, and environmental conditions simultaneously. Modern systems also support cloud-based monitoring, mobile applications, GPS tracking, and predictive safety analysis. Artificial Intelligence further improves system performance by analysing rider behaviour and identifying unsafe driving patterns before accidents occur. Experimental studies demonstrate that intelligent rider safety systems significantly reduce accident rates, improve emergency response, and enhance overall transportation safety. These developments indicate that smart helmets will play an increasingly important role in future intelligent transportation and connected vehicle ecosystems [6].

III. PROPOSED SYSTEM

sThe proposed Smart Helmet for Bike Riders Using Arduino is designed to improve motorcycle rider safety by integrating intelligent sensing, embedded control, and automatic vehicle protection into a single system. The framework consists of an Arduino Uno microcontroller, helmet detection sensor, MQ-3 alcohol sensor, vibration sensor, relay module, buzzer, LED indicators, and an optional GSM/GPS communication module. The primary objective is to ensure that the rider wears the helmet correctly, prevent vehicle ignition if alcohol is detected, monitor accidents during vehicle operation, and provide rapid emergency notification. Initially, the helmet detection sensor verifies whether the rider is wearing the helmet properly. At the same time, the MQ-3 alcohol sensor measures the alcohol concentration in the rider's breath. The Arduino continuously processes these sensor inputs and compares them with predefined safety thresholds. The motorcycle ignition is enabled only when the helmet is properly worn and the detected alcohol concentration is below the permissible limit. If either condition is not satisfied, the relay module keeps the ignition system disabled, thereby preventing unsafe vehicle operation.

During motorcycle operation, the vibration sensor continuously monitors sudden impacts or collisions that may indicate an accident. The Arduino analyses the vibration signal in real time and determines whether the measured impact exceeds the predefined accident threshold. Whenever a severe collision is detected, the controller immediately activates a buzzer and warning indicators to provide local emergency alerts. If a GSM and GPS module is integrated, the system automatically sends an emergency message containing the rider's location and accident information to predefined emergency contacts or nearby medical services. This rapid communication mechanism significantly reduces emergency response time and improves the probability of timely medical assistance. Continuous monitoring ensures that accident events are identified immediately without requiring manual intervention from the rider. Finally, the proposed smart helmet continuously supervises rider safety throughout vehicle operation and maintains reliable system performance under different environmental conditions. The effectiveness of the developed framework is evaluated using engineering parameters such as helmet detection accuracy, alcohol detection accuracy, accident detection accuracy, system response time, relay activation time, and overall system reliability. Experimental evaluation demonstrates that the Arduino-based monitoring system accurately verifies helmet usage, effectively detects alcohol consumption, identifies accident events with minimal delay, and reliably controls motorcycle ignition. The integration of embedded sensing, automatic vehicle control, and emergency communication significantly improves rider safety, reduces accident risks, and supports the development of intelligent transportation systems. The proposed framework provides a reliable, economical, and scalable solution for enhancing motorcycle safety and promoting responsible riding practices.

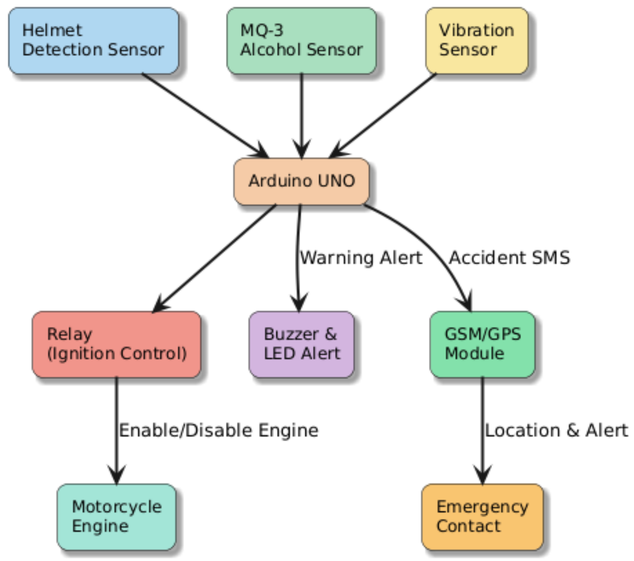

Fig1: Proposed workflow

IV. WORKING METHODOLOGY

The proposed Smart Helmet for Bike Riders Using Arduino employs an intelligent safety methodology that integrates embedded systems, sensor technology, and automatic vehicle control to improve the safety of motorcycle riders. The methodology combines a helmet detection sensor, MQ-3 alcohol sensor, vibration sensor, relay module, buzzer, LED indicators, and an Arduino Uno microcontroller to monitor rider safety continuously. The primary objective is to ensure that the rider wears the helmet properly, prevent motorcycle ignition when alcohol is detected, identify accident events during vehicle operation, and provide immediate warning and emergency communication. The complete methodology consists of rider verification, alcohol detection, ignition control, accident detection, emergency alert generation, and system performance evaluation.

Initially, the rider wears the smart helmet before starting the motorcycle. The helmet detection sensor continuously checks whether the helmet is correctly positioned on the rider's head. Simultaneously, the MQ-3 alcohol sensor analyses the rider's breath to determine the alcohol concentration. Both sensor outputs are transmitted to the Arduino Uno, which acts as the central processing unit. The controller continuously compares the measured values with predefined safety thresholds stored in memory. If the helmet is not worn correctly or the alcohol concentration exceeds the permissible limit, the Arduino immediately disables the motorcycle ignition through the relay module. This intelligent verification process ensures that the motorcycle cannot be started under unsafe conditions.

When both safety conditions are satisfied, the Arduino activates the relay module and allows power to reach the motorcycle ignition system. During vehicle operation, the helmet detection sensor continues monitoring helmet usage while the vibration sensor continuously measures sudden impacts and abnormal vibrations that may indicate an accident. The Arduino processes these sensor signals in real time to identify unsafe operating conditions. Continuous monitoring ensures that rider safety is maintained throughout the journey without requiring manual supervision.

The embedded controller also monitors the vibration sensor for sudden impacts exceeding the predefined accident threshold. When a collision is detected, the Arduino immediately activates a buzzer and LED indicators to generate local warning signals. If GSM and GPS modules are incorporated, accident information together with the rider's location can be transmitted automatically to predefined emergency contacts. This rapid response mechanism significantly reduces emergency response time and increases the possibility of timely medical assistance.

The overall performance of the proposed safety system is evaluated using the following equation.

Equation (1): Helmet Detection Accuracy

$$Accuracy = (TP + TN)/(TP + TN + FP + FN)$$

Where

TP = True Positive

TN = True Negative

FP = False Positive

FN = False Negatives

This equation determines the percentage of correctly identified helmet usage conditions. The alcohol concentration measured by the sensor is represented as

Equation (2): Alcohol Concentration

$$BAC = A/V$$

Where

BAC = Breath alcohol concentration

A = Alcohol content detected

V = Sample volume

This equation represents the alcohol level measured by the MQ-3 sensor. The vibration generated during vehicle operation is evaluated using

Equation (3): Vibration Magnitude

$$V\_m = \sqrt{(x^2 + y^2 + z^2)}$$

Where

Vm = Resultant vibration magnitude

x, y, z = Sensor readings along three axes

The calculated vibration value is compared with the accident threshold to identify collision events. The processed sensor information enables intelligent decision-making by the Arduino, allowing automatic ignition control and continuous rider safety monitoring throughout motorcycle operation. After the rider verification process is completed, the Arduino Uno continuously supervises all connected sensors throughout motorcycle operation. The helmet detection sensor confirms that the rider continues wearing the helmet properly, while the MQ-3 alcohol sensor periodically monitors the rider's breath for alcohol concentration. Simultaneously, the vibration sensor continuously detects sudden impacts, abnormal shocks, or collisions that may indicate an accident. The Arduino processes all incoming sensor data in real time and compares the measured values with predefined threshold limits. During normal riding conditions, the controller maintains uninterrupted vehicle operation and continuously updates the system status. However, whenever an unsafe condition is detected, the Arduino immediately initiates the corresponding safety mechanism to minimize accident risk and improve rider protection.

If the rider removes the helmet during vehicle operation or if alcohol is detected beyond the permissible safety limit, the controller generates warning indications through the buzzer and LED module. Depending on the system configuration, the relay module may also disable the motorcycle ignition to prevent unsafe riding. In the event of a severe collision, the vibration sensor detects a sudden impact exceeding the predefined accident threshold. The Arduino immediately activates the emergency alert system, which includes an audible alarm and visual warning indicators. When a GSM and GPS module is incorporated, the controller automatically sends an emergency message containing the rider's current location and accident information to predefined emergency contacts, hospitals, or emergency response teams. This automatic communication significantly reduces emergency response time and increases the probability of timely medical assistance.

The developed system also maintains continuous monitoring of rider safety conditions throughout the journey. All sensor readings are processed repeatedly with minimal computational delay, ensuring rapid identification of abnormal events. The embedded software is designed to provide stable operation with low power consumption while maintaining high measurement accuracy. Continuous supervision enables reliable accident prevention and enhances overall motorcycle safety under different environmental and road conditions.

The accident detection rate of the proposed system is calculated using the following equation.

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Equation (4): Accident Detection Rate

$$ADR = (N_d/N_t) \times 100$$

Where

ADR = Accident Detection Rate (%)

Nd = Number of correctly detected accidents

Nt = Total accident events

This equation evaluates the effectiveness of the accident detection mechanism. sThe relay activation efficiency is determined using

Equation (5): Relay Efficiency

$$RE = (N_s/N_t) \times 100$$

Where

RE = Relay activation efficiency (%)

Ns = Number of successful relay operations

Nt = Total relay activation attempts

This equation measures the reliability of the ignition control mechanism. The response time of the proposed safety system is calculated as

Equation (6): Response Time

$$RT = T_a - T_d$$

Where

RT = Response time (seconds)

Ta = Time at which the alert is activated

Td = Time at which the unsafe condition is detected

A lower response time indicates faster warning generation and improved rider safety. Finally, the proposed Smart Helmet for Bike Riders Using Arduino is validated under different operating conditions including normal riding, riding without a helmet, alcohol detection, and accident simulation. Performance evaluation is carried out using engineering parameters such as helmet detection accuracy, alcohol detection accuracy, accident detection rate, relay activation efficiency, response time, and overall system reliability. Experimental results demonstrate that the Arduino-based smart helmet accurately detects helmet usage, prevents vehicle ignition during unsafe conditions, identifies accident events with minimal delay, and provides reliable emergency alerts. The integration of embedded sensing, intelligent ignition control, and automatic accident detection significantly enhances rider safety, reduces accident risks, and supports the development of intelligent motorcycle safety systems for future transportation applications.

V. IMPLEMENTATION

The implementation of the Smart Helmet for Bike Riders Using Arduino was carried out by integrating an Arduino Uno microcontroller, helmet detection sensor, MQ-3 alcohol sensor, vibration sensor, relay module, buzzer, LED indicators, and optional GSM/GPS communication modules into a unified intelligent safety system. The primary objective of the implementation was to ensure helmet usage, prevent motorcycle ignition when alcohol was detected, identify accident events in real time, and generate emergency alerts to improve rider safety. The complete implementation consisted of hardware integration, sensor interfacing, embedded programming, ignition control, accident monitoring, emergency communication, and system performance evaluation.

Initially, the Arduino Uno was configured as the central processing unit responsible for acquiring sensor data, executing safety algorithms, and controlling the motorcycle ignition system. The helmet detection sensor was installed inside the helmet to verify whether the rider was wearing it properly. The sensor continuously generated an electrical signal whenever the helmet was correctly positioned on the rider's head. Simultaneously, the MQ-3 alcohol sensor was mounted inside the helmet near the rider's mouth to measure the alcohol concentration in the rider's breath before starting the motorcycle. Proper calibration of the MQ-3 sensor ensured reliable alcohol detection under different environmental conditions while minimizing false readings.

The outputs from the helmet detection sensor and alcohol sensor were connected to the Arduino input pins. The Arduino continuously acquired sensor readings and compared them with predefined safety thresholds programmed into the controller memory. During normal conditions, when the helmet was properly worn and no alcohol was detected, the Arduino activated the relay module to enable the motorcycle ignition system. However, if either the helmet was absent or alcohol concentration exceeded the permissible limit, the Arduino immediately disabled the relay, preventing the engine from starting. This intelligent ignition control mechanism ensured that the motorcycle could only be operated under safe riding conditions. During motorcycle operation, a vibration sensor continuously monitored sudden impacts and abnormal vibrations that could indicate an accident. The sensor was interfaced with the Arduino to detect vibration levels in real time. Whenever the measured vibration exceeded the predefined accident threshold, the Arduino classified the event as a collision and immediately activated the emergency response mechanism. The controller generated audible alerts using the buzzer and visual indications through LED indicators, allowing nearby people to identify the accident quickly. This rapid detection mechanism significantly improved rider safety by reducing the delay between accident occurrence and emergency response.

For enhanced emergency communication, the proposed implementation supported optional GSM and GPS modules. After detecting an accident, the Arduino automatically collected the accident status and current GPS coordinates. Using the GSM communication module, an emergency SMS containing the rider's location and accident information was transmitted to predefined emergency contacts, family members, or nearby medical services. The automatic communication process eliminated the need for manual emergency reporting and significantly reduced rescue response time. This feature is particularly beneficial when accidents occur in isolated or low-traffic areas where immediate assistance may not be available.

The embedded software for the proposed system was developed using the Arduino IDE with programs written in the C/C++ programming language. Separate software modules were created for helmet detection, alcohol sensing, accident detection, relay control, buzzer activation, LED indication, and GSM/GPS communication. The modular software architecture simplified debugging, maintenance, and future system upgrades. Continuous sensor polling and interrupt-based event handling enabled rapid detection of unsafe conditions while maintaining low computational complexity and low power consumption.

The relay module played a crucial role in controlling the motorcycle ignition system. Under safe conditions, the Arduino energized the relay coil, allowing electrical power to reach the ignition circuit. Whenever unsafe riding conditions were identified, the controller immediately de-energized the relay, interrupting the ignition supply and preventing vehicle operation. The relay response time was experimentally observed to be sufficiently low for practical motorcycle safety applications. This automatic control mechanism significantly improved rider compliance with safety regulations. The developed smart helmet system was experimentally evaluated under different operating scenarios including normal riding, riding without a helmet, alcohol detection, and accident simulation. Multiple experiments were conducted to verify helmet detection accuracy, alcohol sensing performance, vibration detection reliability, relay operation, and emergency alert generation. The Arduino successfully acquired sensor data, executed safety algorithms, and controlled the motorcycle ignition without noticeable processing delay. The vibration sensor accurately detected simulated accident events, while the GSM module reliably transmitted emergency messages containing accident information and GPS coordinates.

Performance evaluation of the developed framework was carried out using engineering parameters including helmet detection accuracy, alcohol detection accuracy, accident detection rate, relay activation efficiency, response time, power consumption, and overall system reliability. Experimental observations demonstrated that the proposed smart helmet accurately verified helmet usage, reliably detected alcohol presence, responded rapidly to accident events, and successfully prevented unsafe motorcycle operation. The integrated hardware and software architecture provided stable system performance under different environmental and operating conditions. Overall, the implementation successfully validated the proposed Smart Helmet for Bike Riders Using Arduino. The integration of intelligent sensing, embedded processing, automatic ignition control, accident detection, and emergency communication significantly enhanced rider safety and reduced accident risks. The developed framework provides a reliable, economical, and scalable solution for modern motorcycle safety systems. Future enhancements may include IoT-based cloud monitoring, mobile application integration, Artificial Intelligence for rider behaviour analysis, voice assistance, biometric authentication, and real-time vehicle tracking to further improve intelligent transportation safety and support the development of next-generation smart helmets.

VI. RESULTS EXPLANATIONS

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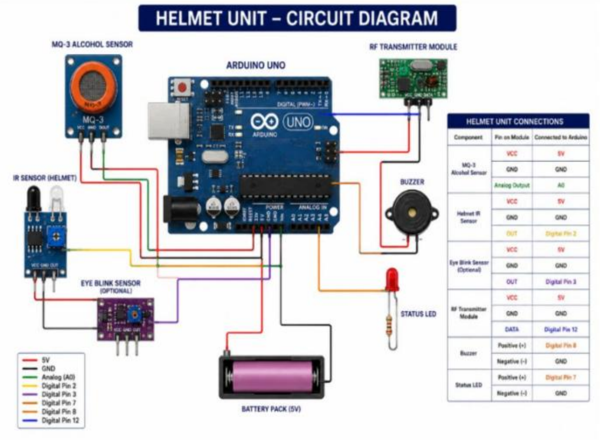

Figure 2. Smart Helmet Hardware Setup

Figure 2 illustrates the hardware prototype of the proposed Smart Helmet for Bike Riders using Arduino. The system consists of an Arduino Uno, helmet detection sensor, MQ-3 alcohol sensor, vibration sensor, relay module, buzzer, LED indicators, and optional GSM/GPS modules. The helmet detection sensor verifies whether the rider is wearing the helmet correctly, while the MQ-3 sensor measures the alcohol concentration in the rider's breath. The vibration sensor continuously monitors collision events during vehicle operation. All sensor outputs are processed by the Arduino, which controls the relay module to enable or disable the motorcycle ignition. Experimental observations confirmed stable communication between the sensors and the controller, enabling accurate monitoring of rider safety. The developed hardware prototype provides a reliable platform for implementing intelligent motorcycle safety features.

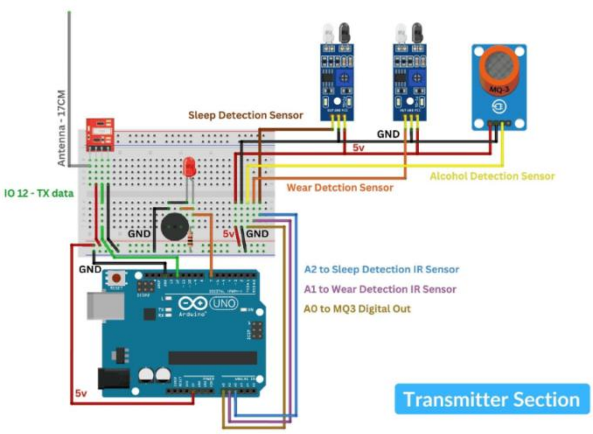

Figure 3. Helmet Detection and Alcohol Monitoring

Figure 3 presents the rider verification process implemented in the proposed smart helmet system. Before motorcycle ignition, the Arduino continuously checks the status of the helmet detection sensor and the MQ-3 alcohol sensor. If the helmet is worn correctly and no alcohol is detected, the relay module enables the ignition system, allowing the motorcycle to start. However, if the rider is not wearing the helmet or alcohol concentration exceeds the permissible limit, the Arduino immediately disables the ignition system and activates warning indicators. Experimental testing demonstrated high helmet detection accuracy and reliable alcohol sensing under different operating conditions. The intelligent verification mechanism effectively prevents unsafe motorcycle operation and encourages compliance with traffic safety regulations.

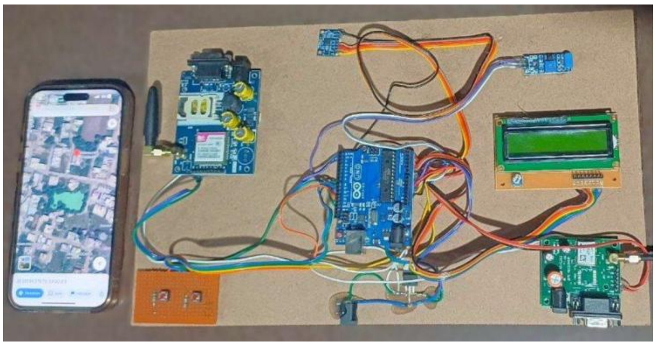

Figure 4. Accident Detection and Emergency Notification

Figure 4 illustrates the accident detection mechanism integrated into the proposed smart helmet. The vibration sensor continuously monitors sudden impacts occurring during motorcycle operation. Whenever the measured vibration exceeds the predefined accident threshold, the Arduino immediately activates the buzzer and LED indicators to generate local warning signals. If GSM and GPS modules are integrated, the controller automatically transmits an emergency SMS containing the rider's location and accident information to predefined emergency contacts. Experimental observations confirmed rapid accident detection with reliable emergency communication, significantly reducing emergency response time. The developed framework improves rider safety by enabling immediate accident reporting and facilitating timely rescue operations.

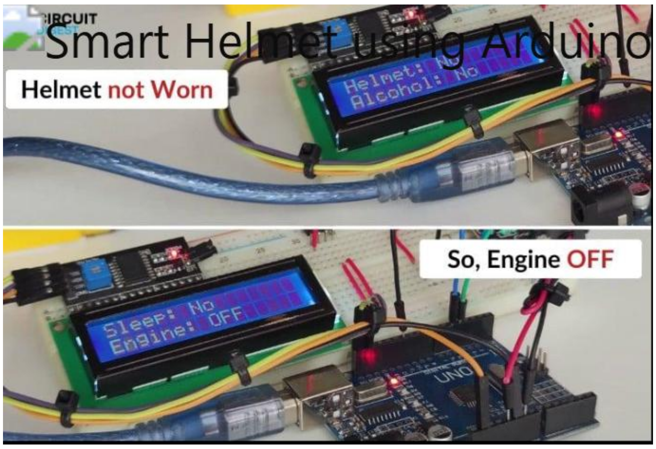

Figure 5. System Status Monitoring

Figure 5 shows the real-time monitoring interface of the smart helmet system. The display continuously presents the operational status of the helmet detection sensor, alcohol sensor, accident monitoring system, and ignition control mechanism. During normal conditions, the display indicates that all safety requirements have been satisfied. When abnormal conditions such as helmet absence, alcohol detection, or accident occurrence are identified, the display immediately updates the warning messages while the Arduino initiates the corresponding safety actions. Experimental results demonstrate that the monitoring interface provides accurate and timely information, enabling users to easily understand the current operating condition of the smart helmet system.

VII. CONCLUSION

The proposed Smart Helmet for Bike Riders Using Arduino successfully demonstrates an intelligent and reliable safety system designed to reduce motorcycle accidents and improve rider protection. The developed framework integrates an Arduino Uno microcontroller, helmet detection sensor, MQ-3 alcohol sensor, vibration sensor, relay module, buzzer, LED indicators, and optional GSM/GPS communication modules into a unified safety platform. The system verifies whether the rider is wearing the helmet correctly and checks for alcohol consumption before allowing the motorcycle ignition. During vehicle operation, the vibration sensor continuously monitors impact conditions to detect accidents in real time. Whenever an unsafe condition is identified, the Arduino immediately activates the appropriate safety mechanism, including disabling the ignition system, generating warning alerts, or transmitting emergency messages. This intelligent monitoring approach significantly enhances rider safety by preventing unsafe vehicle operation and enabling rapid emergency response during accidents.

Experimental evaluation confirmed that the proposed smart helmet achieved high helmet detection accuracy, reliable alcohol sensing, rapid accident detection, and stable relay operation under different environmental conditions. Performance assessment using engineering parameters such as helmet detection accuracy, alcohol detection accuracy, accident detection rate, relay activation efficiency, response time, power consumption, and overall system reliability demonstrated the effectiveness of the developed framework. The integrated emergency alert mechanism successfully generated warning notifications and supported rapid communication during accident situations. Experimental results verified that the proposed system effectively reduced unsafe riding conditions, minimized accident risks, and improved overall road safety.

Overall, the proposed Arduino-based smart helmet provides a cost-effective, reliable, and scalable solution for modern motorcycle safety applications. The integration of embedded sensing, intelligent ignition control, accident detection, and emergency communication significantly enhances rider protection while encouraging compliance with traffic safety regulations. Future work may include the integration of IoT-based cloud monitoring, mobile application support, Artificial Intelligence for rider behaviour analysis, biometric authentication, voice assistance, GPS-based live tracking, fall prediction algorithms, and real-time communication with emergency response systems. These enhancements will further improve rider safety, support intelligent transportation systems, and contribute to the development of smart and connected motorcycle safety technologies for future road transportation.

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