ANALYSIS OF SMART HELMETS

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***Abstract**: Smart Helmet is an IoT-enabled safety device designed to address the high risk of road accidents and fatalities among motorcyclists. It integrates advanced safety features such as crash detection, alcohol sensing, helmet compliance, and emergency alerts systems that can significantly enhance rider safety and emergency response. With motorcyclists making up a large portion of global traffic deaths, the need for smart, reliable, and cost-effective safety solutions is critical. Traditional safety measures are often passive and dependent on user behavior, leading to non-compliance and delayed response during accidents. This project leverages IoT and sensor technologies to create a proactive helmet system that automatically enforces helmet usage, prevents drunk driving, and provides real-time alerts during emergencies. The solution is non-intrusive, sustainable (through solar charging), and scalable, making it a practical option for both urban and rural environments. It improves road safety standards and offers timely assistance, ultimately reducing fatalities and enhancing the well-being of riders and their families.*

Keywords: Smart Helmet, IoT (Internet of Things), Crash Detection, Alcohol Detection , Emergency Alert, Road Safety, Motorcyclist Protection, Solar Charging, Real-time Monitoring

1.INTRODUCTION

Motorcycle riders are indeed an extremely vulnerable group on global road networks, accounting for sizeable shares of injuries and deaths. Despite the existence of helmet laws and numerous safety campaigns, non-compliance remains a major challenge, resulting in preventable accidents and severe consequences. These helmets serve little more than basic physical protection while they do not actively encourage high-risk behaviour such as drunk-driving or fast emergency response. Moreover, depending on traditional battery-based safety devices limits sustainability and accessibility, especially in developing contexts.

A comprehensive approach for rider safety is proposed by increasing helmet functionality through embedded technologies. Smart helmets with crash detection systems, alcohol sensing modules, and helmet compliance mechanisms will facilitate real-time monitoring

and automated intervention. GPS-enabled emergency alerting systems facilitate prompt assistance once an accident occurs. Solar-power charging modules represent an environmentally sound energy solution for such smart helmets. Thus, the field of safety is experiencing innovation, moving toward proactive measures aiming to reduce fatality incidence, ensure compliance, and incorporate design for a green environment.

Problem Statement

Motorcyclists remain highly vulnerable to road accidents due to minimal physical protection and frequent non-compliance with helmet regulations. Traditional helmets do not offer any active safety features to enforce usage or respond to emergencies. Drunk driving continues to be a critical cause of road fatalities, with no preventive mechanism integrated into conventional headgear. Delays in emergency medical response further reduce survival rates, especially in remote or low-connectivity areas. Battery-dependent safety devices also pose sustainability and maintenance challenges. Existing solutions are often expensive, intrusive, or limited in scope. To address these multifaceted issues, a smart helmet system is proposed that integrates crash detection, alcohol sensing, helmet compliance, and real-time alerts. The design aims to enhance rider safety through intelligent automation and sustainable power solutions.

2.LITERATURE SURVEY

Many research works have helped create intelligent helmet designs, focusing on different safety aspects for riders and the effectiveness of the systems. Divyasudha and colleagues created an affordable IoT-enabled safety helmet that includes alcohol monitoring, helmet usage confirmation, accident detection, and emergency notification systems using GSM and GPS. Although the layout was finished, it did not take into account actual user trials and energy control research. The alternative initiative, Konnect, focused on identifying mishaps through accelerometers and a Wi-Fi chip, highlighted the importance of instant crisis alerts, yet lacked features for alcohol or helmet adherence.

Additional studies on how riders recognize patterns while riding used GPS and motion sensors to evaluate rider actions, with an emphasis on forecasting safety, but did not include measures like starting the engine. Another research on motorcycle security systems presented a theft warning system by combining sensors, but it did not concentrate on the safety of the rider while using it. At the same time, self-sufficient mishap alert systems used phone-triggered GSM alerts, but faced problems with the dependability of instant communication and the precision of sensors. A unique feature involved a smart helmet with a force sensor to check helmet use and a fan-powered speed warning for when going too fast. Still, it lacked alcohol monitoring or adjusting to surroundings. A study focused solely on alcohol sensing using MQ3 detectors made sure the ignition system would activate if alcohol was detected and used radio modules for messaging, but it didn't include GPS tracking or crash

Other than that, an intelligent helmet with rear-view functionality integrated visual perception with crash notification and emergency alert systems, but with features such as helmet compliance or alcohol detection left out. Vehicle tracking setups using Arduino were also created, enabling GPS-triggered alerts for mishaps, but lacking in compliance verification. Lastly, a smart helmet design combined different safety elements like alcohol and helmet detection, crash sensors, radio communication, and location tracking. This

study closely matched the current project's range but did not investigate the integration of renewable energy with solar power.
Together, these initiatives form a solid foundation for the creation of intelligent headgear. However, most of them addressed safety elements separately. None offered a complete, self-reliant setup that combines helmet rules, alcohol checks, crash warnings, and eco-friendliness—areas the ongoing project aims to address with its practical and all-encomp.

3.SYSTEM ARCHITECTURE

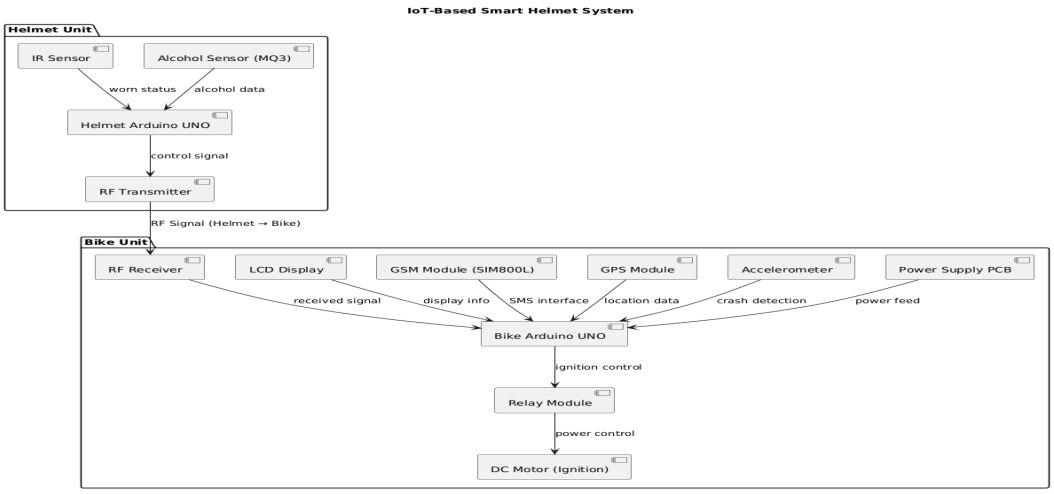

Figure 1. SYSTEM ARCHITECTURE OF SMART HELMET

3.1 HELMET MODULE

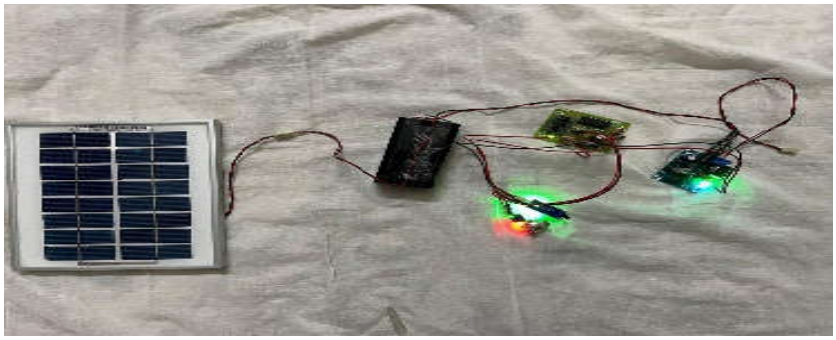

FIGURE 2. HELMET UNIT

The Smart Helmet helmet module is an important part and serves as the first series of safety checks for riders. It is integrated with different sensors and microcontroller for measuring the rider readiness to control the motorcycle. The main items of this module are infrared (IR) sensor, alcohol sensor (MQ3), Arduino Uno and RF transmitter. The IR sensor is strategically located inside the helmet to see if the helmet is worn. Works by capturing the proximity of the rider's head; If the sensor does not find any obstacle, the helmet concludes that the helmet is not worn, thus deactivating further operation of the motorcycle. This sensor enforces the mandatory use of the helmet prevents ignition if the rider is not in line. In addition to the helmet detection, the MQ3 alcohol sensor has a breath alcohol level. It can detect the concentration of ethanol steam and is set to recognize intoxication thresholds. When the rider drinks and the level achieved, it is out

of the stated threshold, the system considers the rider unfit to ride and prevents ignition. These inputs from IR and alcohol sensors are then processed using the Arduino UNO helmet, a local control unit. It processes input signals and decides whether the rider meets the safety conditions. Depending on the output of Arduino, it sends the control signal to the RF transmitter and sends this decision wirelessly to the wheels using the radio frequency communication (RF). This wireless configuration removes the physical connection between the helmet and the motorcycle and increases the comfort and reliability of the user. To ensure a long -term run without the need to replace the battery or access to an external charging device, the helmet module would generally run on the on -board battery and the integral system of solar panels. In addition to being environmentally friendly, it also makes the system more accessible to long -distance users or in areas with poor access to electric charging devices.

3.2 BIKE MODULE

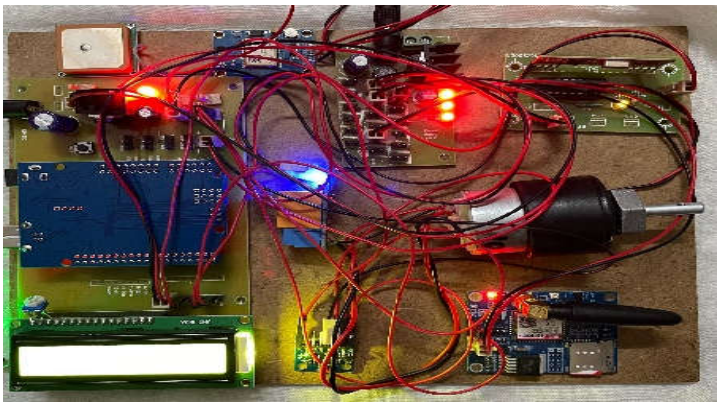

FIGURE 3. BIKE MODULE

The bike module is the control center that communicates with the helmet unit and makes decisions based on the safety messages received. It is also in charge of observing safety conditions, managing the ignition system of the bike, and handling emergency response procedures. The bike module is developed around an Arduino UNO microcontroller and incorporates several elements like an RF Receiver, Relay Module, DC Motor (Ignition Simulation), LCD Display, GSM Module (SIM800L), GPS Module, Accelerometer, and Power Supply PCB.The system starts with the RF Receiver detecting the control signal transmitted from the helmet unit. The signal contains data regarding helmet use and alcohol status. The signal received is fed into the Bike Arduino UNO, which is the decision-making unit. If the signal shows that the helmet is not in use or alcohol is present, the Arduino halts the ignition process. If the two conditions are met, then Arduino sends a control signal to the Relay Module, which triggers the electrical circuit to supply power to the DC Motor—thus simulating or facilitating real ignition of the motorcycle.Alongside the ignition system, the bike module features a GSM Module (SIM800L) and a GPS Module, which constitute the heart of the emergency alert subsystem. The GPS Module regularly retrieves the real-time location of the rider, while the GSM Module sends SMS warnings in cases of emergencies. These modules are triggered when an accident is sensed.Accident detection is handled by an Accelerometer, which continuously monitors motion and orientation. If an impact or abnormal collision is sensed (using sudden deceleration or abnormal tilt), the system automatically activates the

GSM module to send an SOS emergency message with GPS location to pre-programmed emergency contacts, such as family members or local authorities.A small LCD Display is also added to offer real-time system feedback to the rider, for example, ignition on/off status, helmet detection verification, or warnings. The whole bike module is driven by a specialized Power Supply PCB, which manages voltage and current to provide a stable operation of all parts.The bike module, together with the helmet unit, constitutes a complete safety enforcement and emergency response system. It guarantees the motorcycle to be started only in safe conditions and gives real-time communication in case of an accident—thus augmenting rider protection, minimizing response time, and encouraging responsible riding conduct.

4.RESULTS

The Smart Helmet system was successfully implemented and tested across multiple safety scenarios. The helmet compliance feature effectively detected whether the helmet was worn and prevented engine ignition when it was not. The alcohol detection module accurately identified the presence of alcohol and blocked ignition while sending an emergency alert via SMS. The crash detection system reliably triggered alerts based on sudden motion, displaying real-time sensor values on an LCD and transmitting location data through GSM and GPS modules. Each module functioned as intended, validating the system's ability to enhance rider safety through automated monitoring and rapid response.

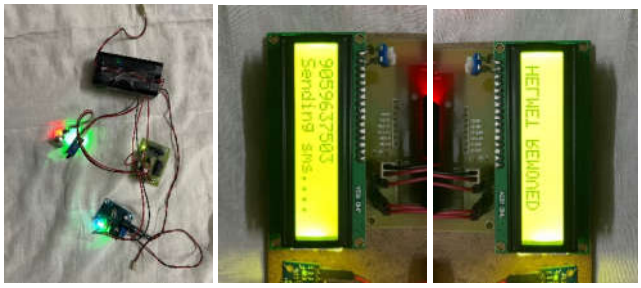

FIGURE 4. RESULT OF HELMET REMOVAL

The image shows the hardware setup for helmet detection, where an IR sensor is used to verify if the helmet is being worn. When the sensor fails to detect the rider's presence, the system interprets it as a helmet not worn condition. As a result, as shown in the image, the LCD displays a message indicating that an SMS is being sent to a predefined contact number. This confirms that the system successfully identifies non-compliance and triggers an emergency alert via the GSM module, while also preventing engine ignition. This feature ensures the rider cannot start the vehicle without wearing the helmet, reinforcing safety.

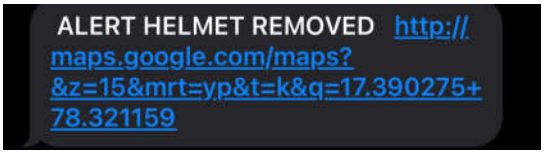

FIGURE 5. ALERT MESSAGE OF HELMET REMOVAL SENT TO CONTACT NUMBER WHEN HELMET IS NOT WORN.

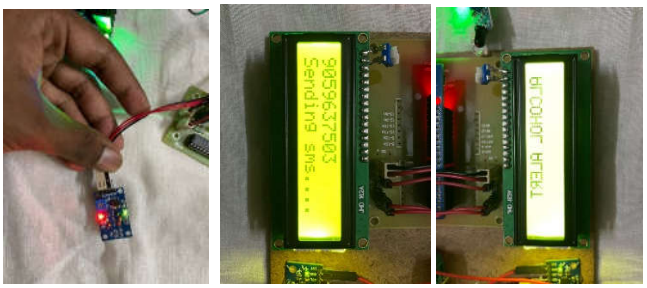

FIGURE 6. RESULT OF ALCOHOL DETECTION

The image demonstrates the scenario where alcohol is detected by the Smart Helmet system. The illuminated red LED on the MQ3 alcohol sensor indicates that the rider's breath contains alcohol levels above the safe threshold. Once detected, the sensor sends this data to the Arduino microcontroller, which immediately takes action by disabling the ignition system—ensuring that the motorcycle cannot be started. At the same time, the system triggers the GSM module to send an SMS alert to a predefined emergency contact. This alert notifies the contact that the rider has attempted to operate the vehicle under the influence of alcohol. This real-time detection and alert mechanism not only prevents drunk driving but also ensures that someone is informed to take necessary action, thereby significantly enhancing rider and public safety.

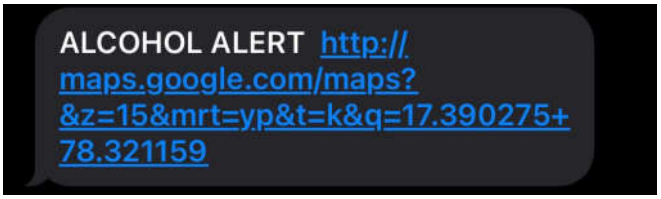

FIGURE 7. ALERT MESSAGE SENT TO CONTACT NUMBER WHEN ALCOHOL IS DETECTED.

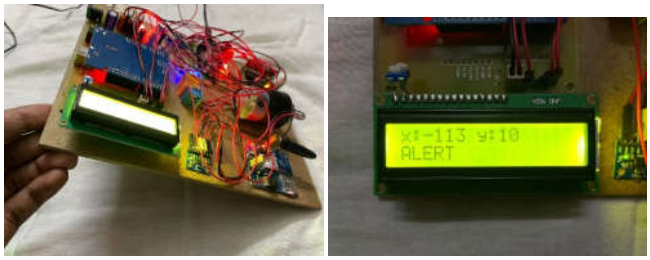

FIGURE 8. RESULT OF CRASH DETECTION

The images depict the successful implementation of the crash detection feature in the IoT-based Smart Helmet system. The first image shows the complete hardware setup, including an Arduino UNO, MPU6050 accelerometer, GSM module, LCD display, and power supply components. This setup continuously monitors the rider’s movement using the accelerometer. When a sudden impact is detected, the Arduino processes the data and initiates an emergency alert.

The second image captures the LCD output, displaying abnormal accelerometer readings (X = -113, Y = 10) and an “ALERT” message, confirming a crash event. This triggers the GSM module to send an SOS message with the rider’s GPS location to emergency contacts. The test validates the system's ability to detect accidents in real time and respond automatically, enhancing rider safety and reducing emergency response time.

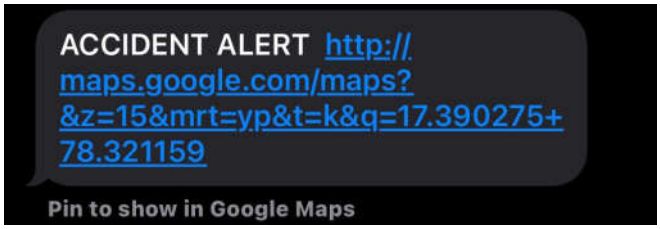

FIGURE 9. ALERT MESSAGE SENT TO CONTACT NUMBER WHEN ACCIDENT IS DETECTED.

5.CONCLUSION

This review presents a comprehensive solution to address the increasing concerns regarding road safety, particularly for motorcyclists, who are among the most vulnerable road users. By integrating technologies such as IoT, alcohol detection, crash detection, GPS tracking, and solar charging, the helmet enhances rider protection while promoting responsible behavior. The IoT integration enables real-time communication, allowing the helmet to send alerts to emergency services in the event of an accident. The alcohol detection feature ensures that riders are not impaired, thereby reducing the risk of alcohol-related accidents. Furthermore, the crash detection system identifies collisions instantly and notifies emergency responders with precise GPS coordinates, enabling timely intervention. GPS tracking offers real-time location updates, enhancing both navigation and safety. The inclusion of solar charging ensures the sustainability of the helmet by reducing dependency on conventional power sources. In comparison to standard Bluetooth helmets, the smart helmet provides significant advancements in safety, usability, and environmental sustainability. However, its higher cost and reliance on power remain challenges. Despite these limitations, the smart helmet represents a transformative approach, converting traditional safety gear into a proactive, intelligent system that not only enhances rider safety but also fosters responsible road discipline and supports eco-friendly innovation.

6. FUTURE SCOPE

Whereas the existing Smart Helmet system integrates helmet compliance, alcohol detection, crash response, and emergency alert features relatively successfully, there is enormous potential for further development. Integrating cloud-based storage and analytics to provide real-time logging of rider actions, crash history, and GPS movement for insurance or law enforcement purposes offers one exciting direction. The inclusion of biometric sensors like body temperature and heart rate monitors would give information about the health status of the rider, and detect fatigue or medical issues. For enhanced communication strength, upcoming designs can include 4G/5G or LoRa-based communication for enhanced connectivity in distant locations. Crash patterns can be analyzed using machine learning algorithms to predict reckless behavior, allowing predictive safety features. Voice feedback or alerting systems are crucial enhancements that can assist the rider during violations or emergency situations. At the hardware level, substitution of traditional components with low-power, miniaturized sensors and flexible PCB layouts can minimize size and enhance wearability. Coupling solar energy harvesting with battery optimization algorithms can increase power efficiency further, as

well as increase the system's sustainability for long-term use. Broadening compatibility to a range of motorcycle models and providing waterproof and rugged enclosures will also make it applicable in real-world usage. With these developments, the Smart Helmet can transform into an all-round, smart safety partner for motorcyclists globally.

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