Development of Smart Helmet using Internet of Things (IOT)

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Development of Smart Helmet using Internet of Things (IOT)

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Abstract- Motorcycle riding poses significant safety risks due to lack of structural protection and the need for heightened situational awareness. Despite technological advancements in vehicle safety, motorcycle safety features remain limited. This research proposes the development of a smart helmet leveraging Internet of Things (IoT) technology to enhance rider safety and convenience. The smart helmet integrates sensors (accelerometer, GPS), wireless communication modules, and a camera to continuously monitor the rider's behavior, road conditions, and surroundings. It can detect incidents like falls or collisions and automatically alert emergency contacts with location data. The helmet also enables hands-free calling, navigation, and rear-view camera display for reduced distractions. By fusing IoT capabilities into a wearable device, this solution aims to provide a safer and more comfortable riding experience for motorcyclists while promoting sustainable transportation alternatives.

Index Terms- Internet of Things (IoT), Helmet Monitoring System, Smart Drive Technologies, Wireless Communication

I. INTRODUCTION

In the contemporary digital era, the Internet of Things (IoT) has emerged as a transformative force, revolutionizing diverse sectors, including the automotive industry. As the world becomes increasingly interconnected, the concept of "smart" devices has transcended smartphones and tablets to encompass a broad array of everyday objects [1], [2]. One such application that holds immense promise is the development of a Smart Helmet leveraging IoT technology, aimed at enhancing the safety and convenience of motorcycle riders.

Motorcycle riding, while exhilarating, carries inherent risks that necessitate comprehensive safety measures. Studies indicate that motorcyclists are 26% more likely to die in traffic accidents, and their chances of sustaining injuries are 5% higher compared to other vehicle occupants [3], [4]. The dangers associated with motorcycle riding stem from various factors, including increased exposure, lack of structural protection, and the need for heightened situational awareness [5], [6]. Unlike drivers of enclosed vehicles, motorcyclists must constantly monitor not only the road conditions but also factors such as speed, lane changes, and the behavior of other road users. A momentary lapse in concentration can have severe, even fatal, consequences [7], [8].

Alarmingly, helmet usage among motorcyclists in many countries remains concerningly low. For instance, a survey conducted in Pakistan in 2018 revealed that only 6% of motorcyclists wore helmets properly, while 28% wore helmets but did not fasten the chin strap [9]. This concerning statistic underscores the need for innovative solutions that can promote helmet usage and enhance rider safety.

While modern technologies have significantly improved safety features in conventional vehicles, advancements in motorcycle safety have been relatively limited [10], [11]. Motorcyclists deserve a comprehensive solution that not only addresses their safety concerns but also offers a comfortable and luxurious riding experience [12], [13].

The advent of the Internet of Things (IoT) presents a unique opportunity to address these challenges. IoT refers to the interconnection of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, and network connectivity, enabling the exchange of data and remote monitoring and control [14], [15]. By leveraging IoT technology, a Smart Helmet can be developed to revolutionize motorcycle safety and user experience.

A Smart Helmet equipped with IoT capabilities can integrate various sensors and communication modules to monitor the rider's behavior, road conditions, and environmental factors [16], [17]. These sensors can collect data on parameters such as speed, acceleration, braking, tilt angles, and even the rider's physiological signals, enabling real-time analysis and feedback [18], [19]. The helmet can also incorporate advanced features like collision detection, emergency alert systems, and GPS tracking, providing riders with enhanced situational awareness and ensuring prompt assistance in case of accidents [20], [21].

Moreover, the Smart Helmet can employ IoT-enabled communication technologies, such as Bluetooth or Wi-Fi, to establish a seamless connection with the rider's smartphone or other compatible devices [22], [23]. This connectivity can enable features like hands-free calling, music streaming, and navigation assistance, enhancing the overall riding experience while minimizing distractions [24], [25].

The collected data can be transmitted to a centralized cloud platform, where advanced analytics and machine learning algorithms can be applied to extract valuable insights [26], [27]. These insights can be used to identify potential hazards, optimize routes, and provide personalized recommendations to riders, ultimately improving their safety and decision-making capabilities [28], [29].

Furthermore, the Smart Helmet can be integrated into a broader IoT ecosystem, allowing for communication and coordination with other vehicles such as hybrid wheelchairs where safety is of utmost importance, especially for those that usually travel for longer periods of time [30], infrastructure, and traffic management systems [31], [32]. This interconnectivity can facilitate the exchange of real-time traffic updates, weather alerts, and incident reports, enabling riders to make informed decisions and adapt their riding behavior accordingly [33], [34].

II. PROTOTYPE ARCHITECTURE AND WORKING PRINCIPLE

The 3D solid model of the Smart Helmet is shown in Fig. 1. and Fig. 2 respectfully.

The proposed smart helmet leverages the Internet of Things (IoT) technology to enhance safety and convenience for riders. The prototype comprises a conventional helmet design integrated with various smart components and features. The core architecture involves a microcontroller unit (MCU) that acts as the central processing unit, enabling seamless communication and control among the various integrated elements.The helmet incorporates several key components to provide its smart functionalities:

Wireless headphones are embedded within the helmet, allowing riders to receive audio cues, navigation instructions, and hands-free communication without compromising their situational awareness.A transparent wind screen is strategically positioned at the front of the helmet, protecting the rider's face from wind, debris, and other environmental factors while maintaining a clear field of vision.A built-in camera mount enables riders to securely attach an action camera or dashcam, facilitating video recording and capturing valuable footage during their rides.

The microcontroller unit (MCU) continuously monitors and processes data from various sensors integrated into the helmet, such as accelerometers, gyroscopes, and environmental sensors. This data is analyzed to detect potentially dangerous situations, such as sudden braking, collisions, or falls. In the event of such incidents, the helmet can automatically initiate emergency protocols, including sending location data and alerts to designated contacts or emergency services via a wireless communication module (e.g., Bluetooth, Wi-Fi, or cellular network).

Additionally, the smart helmet can leverage connectivity to provide real-time navigation assistance, traffic updates, and other valuable information to riders through the built-in headphones or a connected smartphone app. This seamless integration of hardware and software components, powered by IoT technology, aims to enhance rider safety, convenience, and overall experience. Fig 1. And Fig 2. Shows the 3D exploded and rendered model model of the helmet, respecitvely.

Fig. 1. Conceptual Exploded view of Smart helmet

Fig. 2. Final Rendered view of Smart helmet

III. FABRICATION OF THE PROTOTYPE SMART HELMET

A. Transmitter Module of Smart Helmet:

The transmitter module is the core component of the smart helmet system, designed to detect whether the rider is wearing the helmet properly and transmit this information wirelessly to the receiver module on the motorcycle. It is a compact and self-contained unit, carefully engineered to seamlessly integrate with the helmet's design while providing essential functionality. The transmitter module's circuit is built around the ESP32 microcontroller, which serves as the central processing unit.

The ESP32 is chosen for its powerful capabilities, integrated Wi-Fi and low power consumption.

a. Force Sensing Resistor (FSR) Interface:

The Force Sensing Resistor (FSR) is connected to one of the analog input pins of the ESP32. The FSR is strategically positioned within the helmet's padding, near the forehead region of the rider. As the rider wears the helmet and secures it, the pressure exerted on the FSR causes its resistance to decrease.

The ESP32 continuously reads the analog voltage value from the FSR using its built-in Analog-to-Digital Converter (ADC). This voltage value is then converted to a resistance value using a voltage divider circuit or a predetermined resistance-to-voltage mapping function.

b. MQTT Communication using ESP32 microcontroller:

The ESP32 microcontroller is programmed to use the MQTT protocol, which enables efficient and reliable wireless communication with the receiver module on the motorcycle. When the microcontroller detects that the helmet is worn correctly (based on the FSR resistance), it initiates the MQTT connection process. This involves connecting to an MQTT broker and subscribing to a specific topic related to the transmitter module.

Once the MQTT connection is established, the transmitter module publishes a predefined data packet to the MQTT broker. This data packet typically contains information such as the helmet's wear status, a unique identifier for the helmet, and any additional data that may be required by the receiver module. The receiver module, subscribed to the relevant topic, receives this data packet and processes the information accordingly.

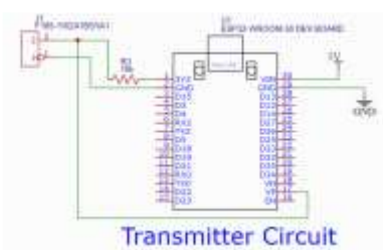

Fig. 2. Circuit for the Receiver side

Figure 4 and Figure 5 presents the PCB layout and 3D view of the custom-designed printed circuit board (PCB) layout for the transmitter module of the smart helmet system. The compact PCB integrates the ESP32 microcontroller, the force sensing resistor interface, wireless communication circuitry, and other necessary components. This specialized layout ensures efficient routing of traces, optimal component placement for size constraints, and robust electrical connections, enabling reliable operation of the transmitter module within the confined space of the helmet.

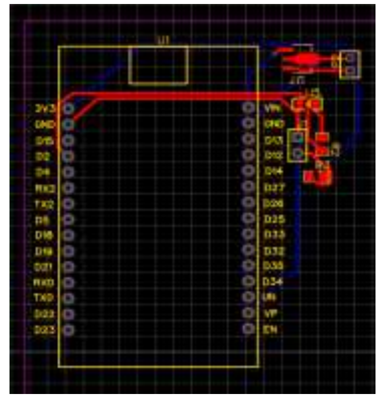

Fig. 4. Circuit for the Transmitter side

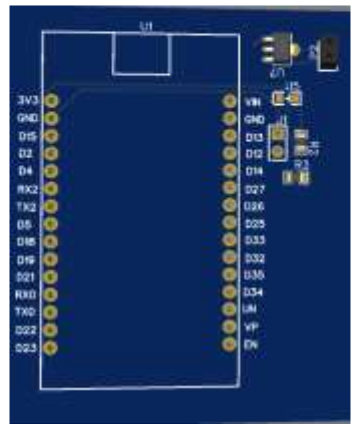

Fig. 5. 3D View of Circuit for the Transmitter side

B. Receiver module of smart helmet

The receiver module is a critical element in the smart helmet system, designed to establish seamless communication with the helmet's transmitter module and control various functionalities related to the motorcycle. This module is engineered to integrate with the motorcycle's circuitry, providing essential safety and convenience features. Figure 6 shows the circuit diagram for the transmitter module.

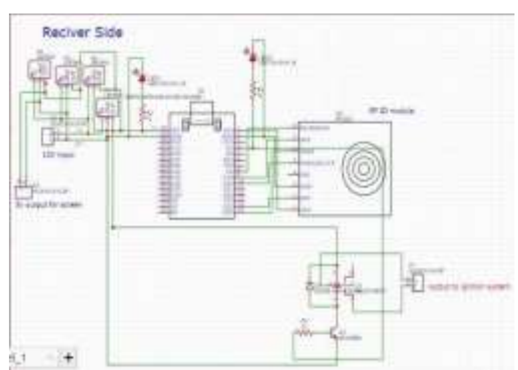

Fig. 6. Circuit for the transmitter side

a. Ignition Control:

The receiver module is a critical element in the smart helmet system, designed to establish seamless communication with the helmet's transmitter module and control various functionalities related to the motorcycle. This module is engineered to integrate with the motorcycle's circuitry, providing essential safety and convenience features.

b. RFID Security:

For additional security, the receiver module includes an MFRC522 RFID reader, operating at 13.56 MHz. This module allows the motorcycle to be started using a registered RFID card in case the helmet is unavailable or damaged. The MFRC522 interfaces with the ESP32 via SPI (Serial Peripheral Interface) communication. The card information is processed and validated by the ESP32 before triggering the relay to start the ignition.

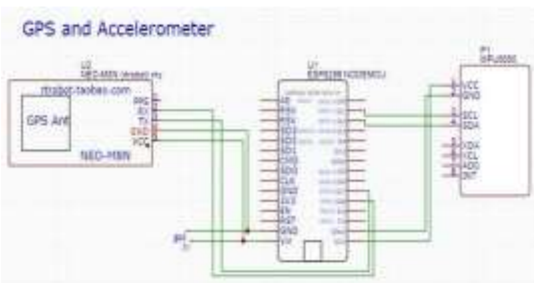

Fig. 7. Circuit Diagram for GPS and Accelerometer

C. Accident Detection and Notification:

For enhanced safety, the receiver module integrates an MPU6050 accelerometer and a Neo-6M GPS tracker, interfacing with the ESP32. The accelerometer monitors the motorcycle's movement, detecting sudden changes or impacts, which signal a potential accident. Upon detection, the ESP32 triggers an alert, sending the GPS coordinates to the rider's family or emergency contacts via a Blynk mobile application, ensuring prompt medical attention.

Fig. 8. User Interface for Blynk Application

Fig 8. displays the UI of the Blynk application, showing the real-time tracking feature used in the smart helmet system. The interface includes a map that marks the rider's current location with a black markings.

D. Custom PCB Design for receiver end:

The receiver module's circuit is designed on a custom-printed circuit board (PCB) that integrates the ESP32, RFID reader, accelerometer, GPS tracker, and relay circuitry. The compact layout ensures efficient routing of traces, optimal component placement, and robust electrical connections. The receiver module is designed to be robust, reliable, and seamlessly integrate with the motorcycle's wiring, ensuring smooth and safe operation. Here is the PCB layout for receiver module:

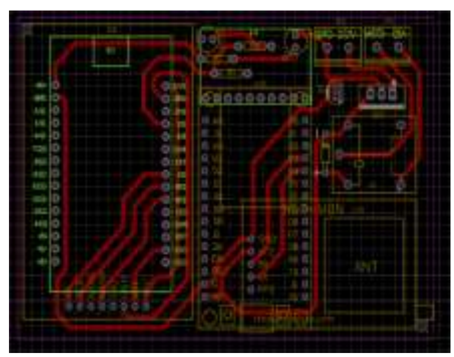

Fig. 9. Receiver Circuit PCB layout

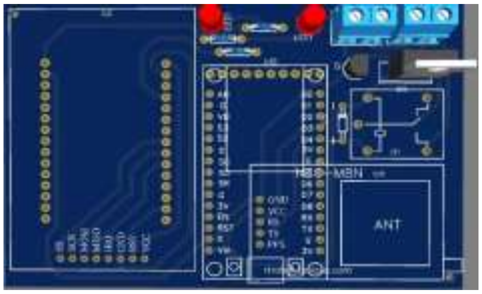

Fig. 10. 3D View of the Receiver PCB layout

The final prototype of the smart helmet combines wireless technology into a sleek design. An ESP32 microcontroller manages communication with the FSR sensor and communication module, triggering a 5V relay to control the ignition. A back camera, paired with a display, improves safety, while the 3D-printed PETG housing securely holds all components, ensuring reliable operation.

Fig. 11. Front view Photograph of Smart Helmet

Fig. 12. Back view Photograph of Smart Helmet

TABLE I.

DETAILED SPECIFICATION OF SMART HELMET

Metric	Parameter
Battery Specification	5V 1A Power Bank Module
Battery Capacity	1800–3500 mAh
Transmitter Microcontroller	ESP32
Receiver Microcontroller	ESP32
Helmet Detection	Force Sensing Resistor (FSR)
GPS Module	Neo-6M Ublox
Accident Detection Sensor	MPU6050 Accelerometer
RFID Reader	MFRC522, 13.56 MHz
Helmet Material	High-impact plastic
3D-Printed Parts Material	PETG

IV. TESTING OF PROTOTYPE SMART HELMET

A. Aerodynamic Optimization for Helmet Ventilation in Extreme Heat

In regions where temperatures routinely exceed 40°C, adequate ventilation within motorcycle helmets becomes a critical safety and comfort concern. Prolonged exposure to such extreme heat can lead to physiological strain, cognitive impairment, and an increased risk of accidents. To address this challenge, a comprehensive aerodynamic analysis was conducted to optimize the helmet's design for maximum airflow and heat dissipation.

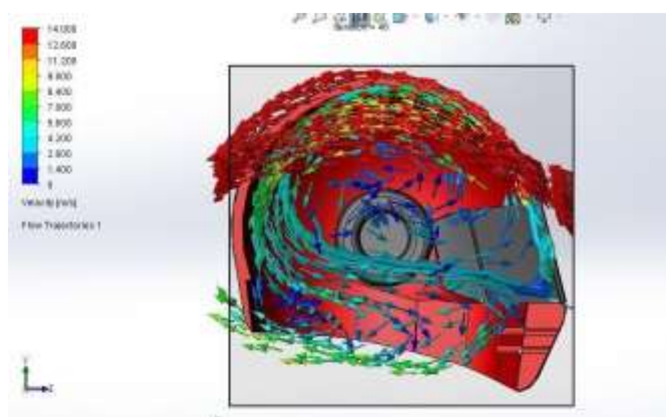

Fig. 13. CFD simulation

The CFD simulation in Fig 12. illustrates the intricate flow trajectories and velocity magnitudes surrounding the helmet. The color-coded visualization reveals areas of high-velocity airflow in red, predominantly concentrated at the frontal region and sides of the helmet. These high-speed airstreams are essential for effective air intake and ventilation, ensuring a continuous supply of fresh air into the helmet's interior. By adding a ventilation hole in frontal part of the helmet provides better ventilation to overall system.

B. Discharging of Discharging of Battery during Operation

The graph in Figure 11 illustrates the battery discharging over a 12-hour period under normal usage scenarios. The battery capacity followed an exponential decay pattern, starting at 3500 mAh. After 6 hours, the capacity dropped below 2000 mAh, and by the 10-hour mark, it dipped below 1000 mAh. Near the 12-hour mark, the battery approached depletion. This gradual decline highlights the need for efficient power management to ensure prolonged operation during regular use.

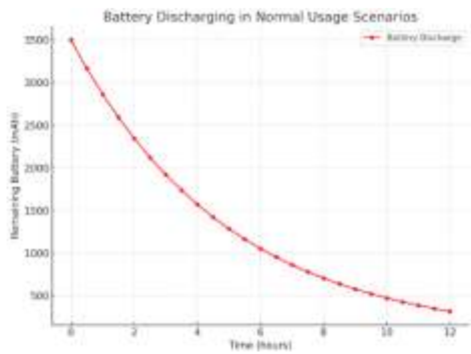

Fig. 12. Graph of battery discharge in normal operations

V. CONCLUSION

The study focused on designing and developing a smart helmet prototype that enhances motorcycle safety and convenience by integrating advanced technologies. The helmet communicates seamlessly with the motorcycle's receiver module via MQTT, ensuring secure ignition control. Additionally, the integration of a GPS tracker and accelerometer allows for accurate accident detection and emergency alert notifications, providing prompt assistance in case of incidents. The smart helmet's power management, utilizing 3.7V 18650 Li-ion cells, ensures stable operation during various scenarios, balancing functionalities such as MQTT communication, GPS tracking, and camera usage. Comprehensive testing validated the smart helmet's operational consistency and efficiency, making it a reliable safety solution for motorcyclists. The successful integration of multiple technologies in a compact, comfortable form factor highlights the potential of the smart helmet as a user-friendly, secure, and environmentally sustainable solution for motorcycle riders.

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