Design And Implementation Of A Helmet Recognition System For Motorcycle Safety

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Abstract- This study presents the design and implementation of a helmet recognition system aimed at improving motorcycle safety by ensuring that riders wear helmets before the motorcycle ignition is activated. The proposed system integrates both hardware and software components to detect helmet usage and prevent engine ignition when a helmet is not worn. The system was initially designed and simulated using Proteus Design Suite to evaluate its performance prior to physical implementation. Experimental testing was conducted to measure voltage across key components, and the resulting data were analyzed in Microsoft Excel to assess system performance and electrical characteristics. The results demonstrate that the developed system effectively enforces helmet usage by linking helmet detection to the motorcycle ignition control to prevent accidents. However, certain limitations were identified, including scenarios involving multiple riders where the system detects only a single helmet, as well as the possibility of bypassing the ignition system. Despite these limitations, the proposed system provides a practical approach to enhancing rider safety and promoting compliance with helmet regulations. Future improvements may include surge protection, alarm integration, and enhanced battery management for improved reliability.

Index Terms: Accident Prevention, Motorcycle, Safety, Helmet, Head, Proteus Software,

I. Introduction

Motorcycle riders are at considerably greater risk of severe injury or death in road traffic crashes than occupants of enclosed vehicles, due to limited structural protection and direct exposure to impact forces. Correct and consistent helmet use has been shown to significantly decrease the risk of fatality and serious head injury in crashes, with standard helmet use associated with reductions in head injury severity and death [1] [2]. Moreover, despite this, helmet usage rates remain low in many regions, motivating research into automated helmet recognition systems that can detect non-helmeted riders and support safety reinforcement and compliance [3].

The increasing use of two-wheelers has made them a common mode of transportation due to their affordability and convenience. However, the growing popularity of motorcycles has also contributed to a rise in road accidents involving two-wheelers. Despite the well-known safety benefit of helmets, many riders neglect to wear them, thereby exposing themselves to significant risk. This lack of compliance with helmet safety regulations, combined with high-speed riding, significantly increases the likelihood of accidents, which frequently result in serious head injuries and fatalities [4]. Moreover, helmets play a critical role in protecting cyclists during accidents by reducing the severity of head injuries. The rigid outer shell of a helmet helps prevent skull fractures, while the inner cushioning material absorbs impact energy and reduces head motion upon impact. This structural design distributes the force generated during impact, thereby lowering the likelihood of severe head trauma. Additionally, the helmet serves as a protective barrier that shields the rider's head from potential injury during accidents [5]

Studies have reported that the rapid increase in motorcycle usage has contributed to a rise in road accidents, particularly where helmet use is neglected. Traditional monitoring methods, such as roadside inspections and manual analysis of CCTV footage, are often inefficient and require significant human effort. Recent research has therefore explored automated helmet detection systems using deep learning techniques, including the YOLO Darknet framework, to classify riders as helmeted or non-helmeted from images. Findings indicate that such systems can support intelligent traffic monitoring and improve enforcement through automated alerts and integration with traffic management technologies such as Automatic Plate Recognition (ANPR) [6].

In [7], the authors proposed a smart helmet system designed to enhance motorcycle safety and enable accident detection. The system consists of three main components: a helmet unit, a motorcycle unit, and a mobile application. The helmet unit incorporates infrared and alcohol sensors to verify helmet usage

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and detect alcohol consumption before the motorcycle ignition is activated. The motorcycle unit includes a load sensor, relay, Bluetooth module, and a three-axis accelerometer for crash detection. In the event of an accident, the accelerometer detects the impact, and the mobile application automatically transmits the accident location to emergency contacts and relevant authorities.

Meanwhile, a smart helmet system was proposed in [8] to improve motorcycle safety and reduce accident-related injuries. The system consists of a helmet unit and a mobile application designed to monitor riding conditions. The helmet unit integrates components such as a NodeCUM controller, an alcohol sensor, a crash sensor, and a motion sensor to detect unsafe riding conditions. In addition, a tachometer is used to monitor the motorcycle's speed. Sensor data are transmitted to a mobile application where the rider can monitor the system status, including alcohol detection, motion, and overspeed conditions. In the event of abnormal conditions or accidents, the application automatically sends alerts to nearby emergency services and predefined contacts.

Road traffic accidents have become a major public safety concern in many societies. The rapid growth in population and vehicle usage has contributed to a significant rise in road accident fatalities, with official statistics reporting approximately 60 deaths per 10,000 motor vehicles. However, a considerable number of motorcycle riders lose their lives in road crashes each day, often due to delays in obtaining timely assistance after accidents occur. Moreover, in many cases, the lack of immediate information about the accident location further reduces the chances of prompt rescue. Meanwhile, the increasing popularity of motorcycles as a convenient and affordable means of transportation has led to a continuous rise in their presence on roads and urban streets. [9].

In [10], the smart Helmet was shown to enhance motorcycle safety by monitoring helmet use and alcohol consumption. The system employed a touch sensor to verify whether the rider was wearing a helmet and a gas sensor to detect alcohol. The motorcycle ignition was disabled if helmet use was not detected or if alcohol was present, ensuring safer operation. The integrated sensors enabled real-time monitoring and contributed to accident prevention.

II. MATERIALS AND METHODS

A. Design Concept

The proposed helmet recognition system aims to enhance motorcycle safety by ensuring ignition activation only when a helmet is worn. At its core, the system uses a microcontroller that processes signals from a helmet detection sensor. Upon confirming helmet usage, the microcontroller enables the motorcycle ignition system. If the helmet is absent, ignition remains disabled, preventing unsafe operation. An LCD provides real-time feedback on the system status, clearly indicating whether the helmet is detected. This design enforces safety compliance in a convenient and user-friendly manner. The system architecture, including the transmitter and receiver modules, is illustrated in Figure 1. Moreover, to ensure intuitive analysis, the circuit diagram is presented in Figure 2.

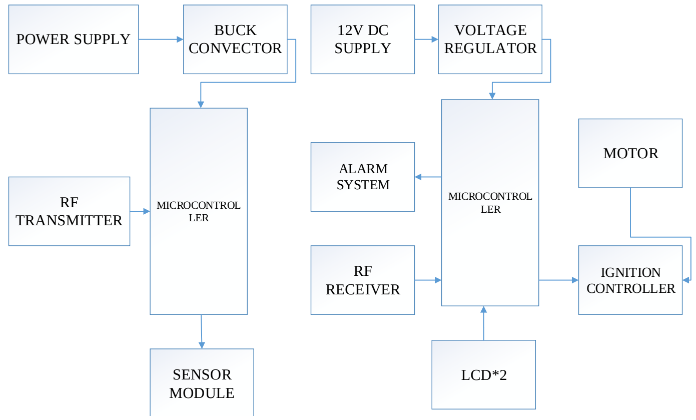

Figure 1. The Block Diagram of the Proposed Helmet Recognition System

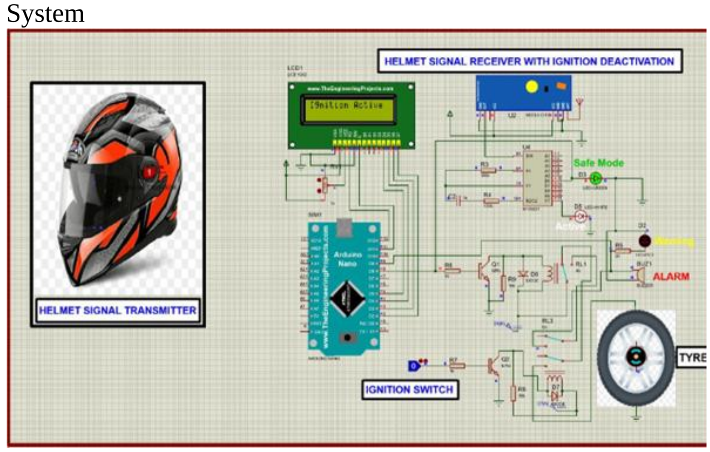

Figure 2. The circuit diagram of the proposed Helmet Recognition System

B. System Operation

The system integrates helmet detection with ignition control to prevent motorcycle operation without protective gear. The helmet sensor serves as the primary detection unit, transmitting signals to the microcontroller, which functions as the central control unit. A regulated 5 V power supply ensures stable operation of the microcontroller. The microcontroller communicates with a transmitter module, which wirelessly sends data to a receiver module. The receiver forwards this information back to the microcontroller. When a helmet is detected, the circuit activates, enabling ignition. If the helmet is not worn, the circuit disables the ignition, preventing the motorcycle from starting. LED indicators provide clear visual feedback, green for safe operation, white for system activation, and red for helmet absence. Additionally, a relay facilitates low-voltage switching to control both the ignition and alarm systems. A buzzer issues an audible warning if the helmet is not detected, alerting the rider and further enforcing compliance.

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III. RESULTS AND DISCUSSION

A. Simulation Results and Analysis

The designed system was simulated in Proteus to verify helmet detection and ignition control prior to hardware implementation. The startup interface shown in Figure 3 displays “Smart Helmet”, confirming system initiation and readiness. As illustrated in Figure 4, when no helmet signal is detected, the Arduino Nano disables the ignition through a relay, activates the red warning LED and buzzer, and displays “warning, Helmet not Detected” on the LCD. This confirms proper signal monitoring and fault response. When a valid helmet signal is received, the RF433 MHz module and decoder transmit it to the microcontroller, which then enables the ignition relay. As shown in Figure 5, the LCD depicts “Helmet Detected, and ignition active,” and the green LED (safe mode) turns on, and all warning indicators remain off. Figure 6 demonstrates the system’s response when the helmet is removed during operation. Loss of the RF signal causes immediate ignition deactivation, activation of the red LED and buzzer, and display of a warning message. This confirms that the system consistently enforces helmet compliance under all simulated conditions.

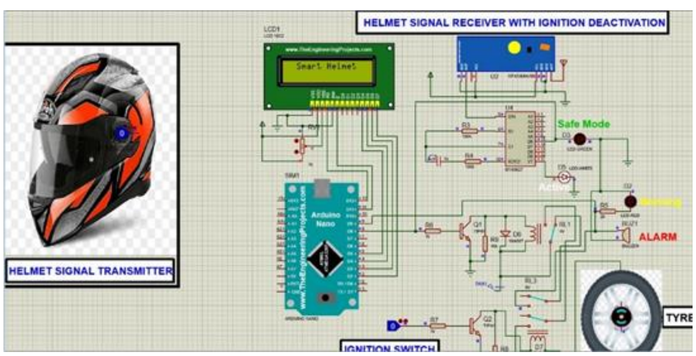

Figure 3. The Simulation Result of the Initial User Interface of the Proposed System

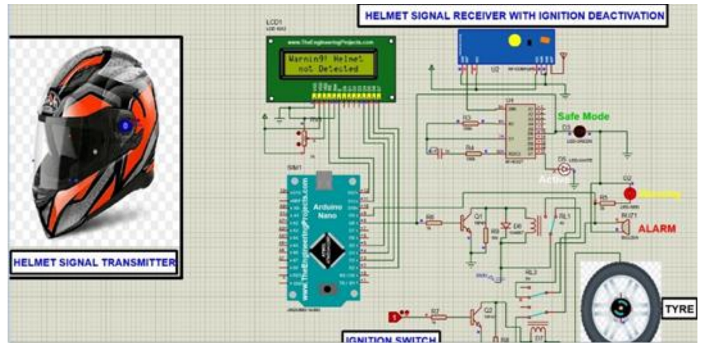

Figure 4. The Simulation Result of the Proposed System when the Helmet is not Detected

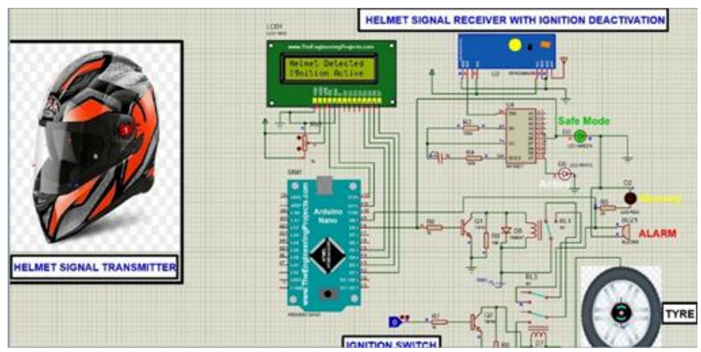

Figure 5. The Simulation Result of the Proposed System when a Helmet is Detected

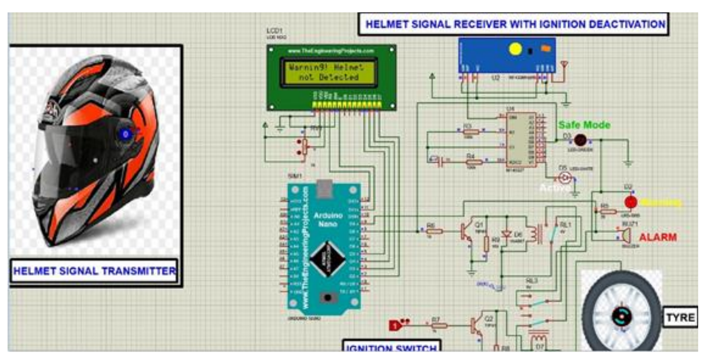

Figure 6. The Simulation Result when the Helmet is Removed After Starting the Proposed System

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IV. CONSTRUCTION PROCEDURE

The proposed system was constructed in two main sections: the helmet unit and the receiver unit. The helmet unit comprised a back converter for voltage regulation, a sensor for helmet detection, a microcontroller for signal processing, and an RF transmitter for wireless communication. The module was tested to ensure accurate detection and signal transmission. The receiver unit incorporated an RF receiver, a regulated 5 V supply, and a microcontroller to process incoming signals and control the ignition system. An LCD provided operational feedback. Relay and alarm circuits, driven by transistor switches, were integrated to manage ignition control and warning indicators. All components were enclosed in a prospective casing as shown in Figure 7, and the completed system was tested and calibrated to ensure reliable performance as presented in Figures 8 to 12. Moreover, the experimentally measured values are reported in Table 1, with their graphical representation shown in Figure 13 to facilitate clearer analysis.

Figure 7. The construction of the Proposed System

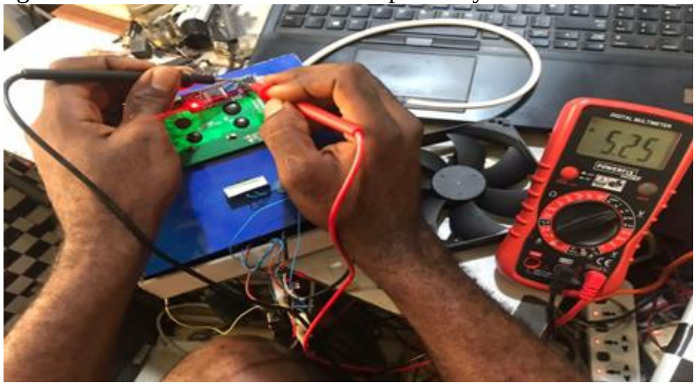

Figure 8. Screen Voltage testing Analysis

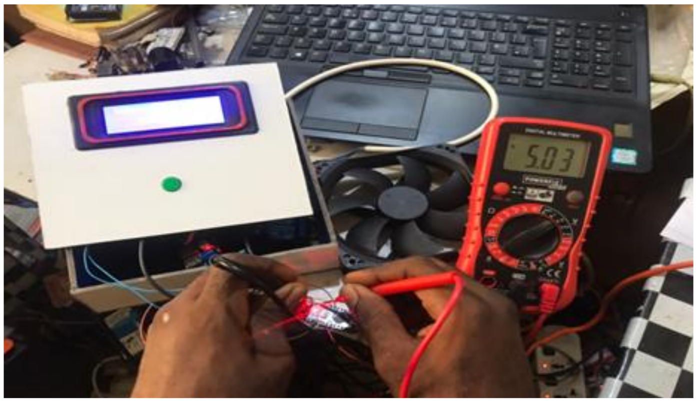

Figure 9. Signal Voltage Testing Analysis

Figure 10. Buzzer Voltage when Helmet was not Recognized

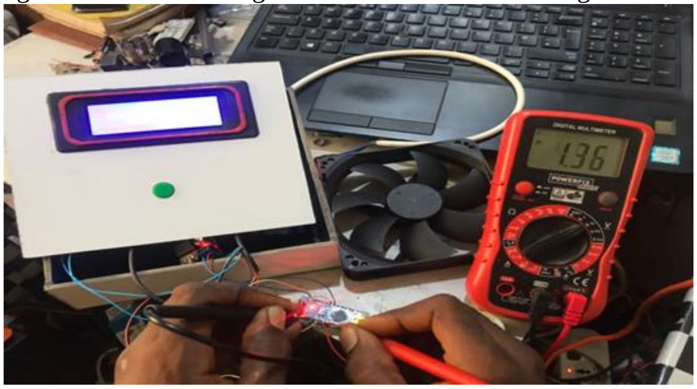

Figure 11. Received Signal Voltage from the Helmet

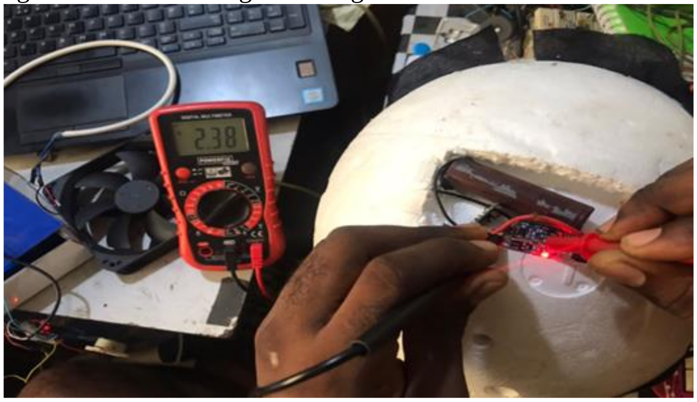

Figure 12. Helmet Transmission Signal Voltage

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Table 1. Experimental Testing Results Analysis

Number of Experiments	Experiments	Voltages	LCD Display
1	Screen voltage	5.25	Helmet recognition system Engine off
2	Switching signal voltage	5.03	Helmet recognition system Engine off
3	Buzzer voltage	3.31	Helmet recognition system Engine off
4	Received signal voltage	1.36	Helmet recognition system Engine on
5	Helmet transmission signal voltage	2.38	Helmet recognition system Engine on

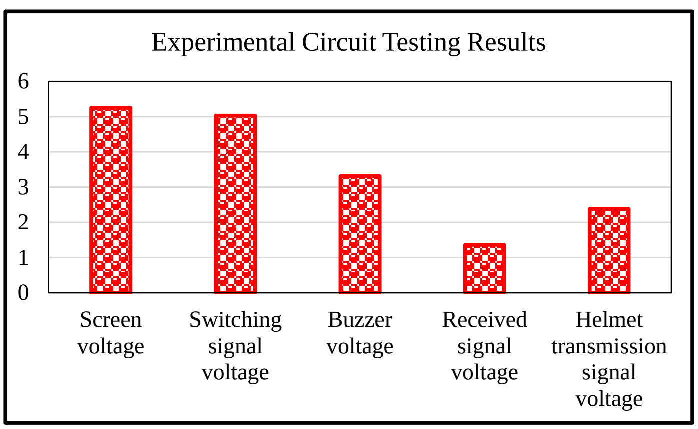

Figure 13. The Experimental Testing of the Proposed System

V. EXPERIMENTAL RESULTS AND ANALYSIS

Following the hardware integration and clarification, experimental testing was conducted using a digital multimeter to verify system performance. The results confirmed that the helmet recognition system functioned as designed. When the helmet-mounted transmitter sends a wireless signal, the receiver forwards it to the Arduino Nano for processing. Upon confirming the presence of the helmet, the microcontroller activates the ignition system and displays a confirmation message on the LCD, as shown in Figure 14. Conversely, if no helmet signal is detected, the controller disables the ignition and triggers a warning indication, as illustrated in Figure 15. This continuous monitoring mechanism ensures that the motorcycle operates only when the helmet is worn, thereby enforcing rider safety.

Figure 14. The Proposed System when Helmet was Detected

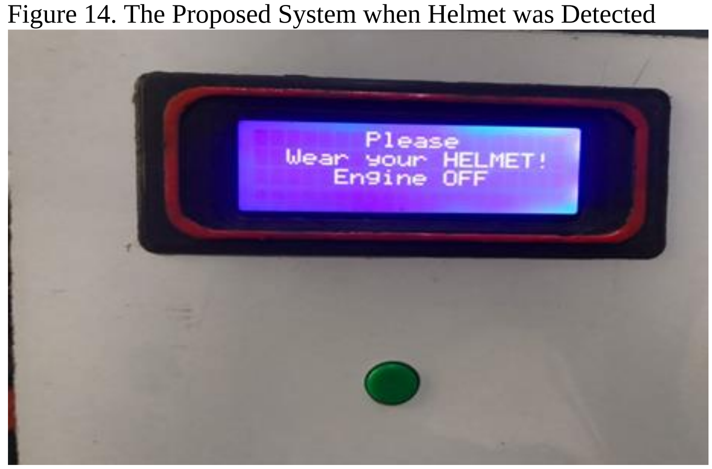

Figure 15. The Proposed System when the Helmet was not Detected

VI. DISCUSSION

The simulation results for the proposed system are presented in Figures 3-6. Figure 3 confirms successful system initialization with the LCD displaying “Smart Helmet,” indicating operational readiness. As shown in Figure 4, the absence of a helmet signal keeps the ignition relay open, and the display indicates an inactive status to prevent engine startup. Figure 5 depicts the result of the proposed system when a helmet is detected, while Figure 6 demonstrates the result when no helmet is detected during an ignition attempt; the system disables ignition and activates visual and audible warnings. Moreover, Figures 8 to 12 present the experimental test values of the system, as shown in Table 1 and graphically in Figure 13, to facilitate intuitive analysis. Conversely, the experimental results are illustrated in Figures 14 and 15. Detection of a valid helmet signal enables the ignition relay, updates the LCD to confirm, and activates the safe-mode indicator, as shown in Figure 14. Figure 15 further verifies continuous monitoring; removal of the helmet during operation immediately triggers ignition cutoff and warning alerts. These results confirm reliable helmet detection, controlled ignition switching, and effective safety enforcement under all tested conditions.

VII. CONCLUSION

The helmet recognition system with integrated ignition control effectively enhances motorcycle safety by enforcing helmet usage before engine activation. Utilizing a sensor, microcontroller, and wireless communication, the system reliably detects helmet presence and enables or disables ignition accordingly, providing visual feedback to the rider. Experimental testing confirmed that the system performs as intended, ensuring safe operation through automation, and that the system performs as indicated, ensuring safe operation through automated ignition management. For further improvement, it is recommended to integrate an alarm to reinforce helmet compliance in case the ignition is bypassed, introduce a brief delay between helmet detection and ignition activation to prevent abrupt starts, and implement a battery management system to safeguard against power fluctuation, ensuring reliable and durable operation.

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