IoT-Enabled Smart Helmet for Bike Safety

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ABSTRACT--- Motorcycle accidents are often caused by riders neglecting safety measures, such as not wearing helmets, riding under alcohol, or using mobile phones. We propose a Smart Helmet System integrated with IoT and wireless communication to address this issue to enforce rider safety.

The system consists of a helmet unit and a bike unit. The helmet has sensors to detect helmet usage, alcohol consumption, and mobile phone activity. If any violation is detected, the bike's ignition remains disabled. Additionally, if the rider removes the helmet, drinks alcohol, or uses a phone mid-ride, a continuous buzzer alert is triggered until compliance is restored.

The system operates without cloud dependency, using Bluetooth (HC-05) for real-time communication. It is cost-effective, easy to implement, and suitable for both urban and rural areas. This automated safety solution helps reduce accidents by ensuring compliance with road safety regulations.

KEYWORDS--- Helmet, Bike, Arduino, IR Sensor, Bluetooth, Relay, Alcohol Sensor, EMF Sensor.

I. INTRODUCTION

Motorcycle accidents contribute significantly to road fatalities worldwide, often due to negligence in following safety regulations. Many riders fail to wear helmets, drive under the influence of alcohol, or use mobile phones while riding, leading to severe injuries and fatalities. Traditional enforcement methods rely on manual monitoring and traffic penalties, which are often ineffective in ensuring consistent compliance. Hence, there is a need for an automated system that enforces safety protocols and prevents unsafe riding behavior.

This paper presents a Smart Helmet System integrated with IoT-based safety mechanisms to enhance motorcycle rider protection.

The proposed system comprises two main components: a helmet and bike units. The helmet is equipped with an infrared (IR) sensor to detect whether it is worn, an MQ-3 alcohol sensor to monitor intoxication levels, and an RF/EMF sensor to detect mobile phone usage. These sensors communicate wirelessly with the bike's ignition system via Bluetooth (HC-05). If any safety violation is detected, the bike's ignition remains disabled, preventing the rider from starting the vehicle. Additionally, if the rider removes the helmet mid-ride, consumes alcohol, or uses a mobile phone, a continuous buzzer alert is triggered until compliance is restored.

Unlike cloud-based monitoring systems, this design is independent of external networks, ensuring low-latency real-time enforcement without requiring an internet connection. The system is cost-effective, easy to implement, and adaptable for various motorcycle models, making it suitable for both urban and rural regions. By automating safety rule enforcement, this smart helmet aims to reduce accident risks, promote responsible riding behavior, and enhance road safety.

The following sections of this paper discuss related work, system architecture, hardware implementation, software design, testing results, and future enhancements to further improve motorcycle safety standards.

II. LITERATURE SURVEY

Motorcycle safety has been a growing concern worldwide due to the increasing number of accidents caused by human negligence. Researchers and engineers have proposed various intelligent safety systems to mitigate these risks, integrating sensor-based monitoring, IoT, and automation. This section reviews existing studies on smart helmets and motorcycle safety systems, highlighting their contributions, limitations, and the research gap addressed by the proposed system.

A. Helmet-Based Safety Systems

Several studies have focused on helmet detection mechanisms to ensure rider compliance with safety regulations. A system utilizing RFID technology was proposed to verify helmet usage before allowing the motorcycle to start. However, RFID-based systems require active scanning and can be bypassed easily if the tag is removed from the helmet. Similarly, another study implemented an accelerometer-based smart helmet that detects accidents and sends emergency alerts, but it lacks preventive measures to stop unsafe riding behavior before an accident occurs.

B. Alcohol Detection in Riders

Intoxicated riding is a major cause of accidents, leading to efforts to develop alcohol detection systems. A study in [3] introduced a breath analyzer-based ignition control system that prevents the vehicle from starting if alcohol is detected. However, these systems are often standalone and do not integrate with helmet compliance or real-time monitoring during the ride. Additionally, certain models require manual breath analysis, which may not always be practical.

C. Mobile Phone Usage Detection in Riders

Research in [4] explored distracted driving detection using image processing and machine learning, but these approaches often require high computational power and external cameras, making them unsuitable for low-cost motorcycle safety solutions. Another study [5] introduced RF-based mobile detection, which successfully identifies mobile signals but lacks integration with vehicle control systems.

D. IoT-Based Motorcycle Safety Systems

IoT-enabled motorcycle safety solutions have been explored in various studies, aiming to enhance real-time monitoring and accident prevention. In [6], a GPS-based accident alert system was proposed, but it primarily focused on post-accident response rather than preventing risky behavior. Another research work [7] implemented cloud-based monitoring, which allows real-time data tracking but requires an active internet connection, making it unreliable in rural or low-network areas.

III. RESEARCH GAPS

Despite advancements in smart helmet and motorcycle safety technologies, existing solutions have notable limitations, such as:

- Lack of an integrated system that enforces helmet usage, alcohol detection, and mobile usage monitoring in a single framework.
- Dependence on cloud-based systems, which may be impractical in low-network regions.
- Focus on post-accident responses rather than accident prevention.

IV. PROPOSED SYSTEM

Helmet Unit: The smart helmet system is designed to ensure rider safety by integrating various sensors and a wireless communication module. It continuously monitors critical safety parameters to prevent accidents caused by human negligence. The system includes an infrared sensor placed inside the helmet to detect whether the rider is wearing it. If the helmet is not worn, the bike remains disabled, and if removed during the ride, an alert mechanism is triggered to prompt the rider to comply with safety rules. Additionally, an alcohol detection system is embedded within the helmet, utilizing an MQ-3 sensor to analyze the rider's breath. If alcohol is detected beyond a permissible limit, the motorcycle ignition is automatically disabled, preventing an intoxicated rider from operating the vehicle. Furthermore, a mobile phone usage detection system is integrated using an RF/EMF sensor, which identifies mobile signals and activates an alert if phone usage is detected while riding. To facilitate real-time communication between the helmet and the bike, a Bluetooth module is incorporated to transmit data wirelessly, ensuring that safety protocols are strictly enforced before and during the ride. This system provides an effective, automated solution for preventing accidents caused by the absence of a helmet, alcohol consumption, or mobile distractions while riding.

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A. Arduino Sensor: Arduino is an open-source electronics platform that combines hardware and software to create interactive projects. It is widely used for prototyping, automation, and embedded system development. The platform consists of microcontroller boards, with the Arduino Uno being one of the most popular models. These boards come equipped with digital and analog input/output pins, allowing users to interface with various sensors, actuators, and communication modules.

B. MQ-3 Alcohol Sensor: The MQ-3 sensor is a widely used alcohol detection module designed to measure the concentration of alcohol in the air. It operates based on a tin dioxide (SnO_2) sensing layer, which exhibits lower conductivity in clean air but increases in the presence of alcohol vapors. The sensor provides both analog and digital output signals, making it compatible with microcontrollers like Arduino for real-time alcohol monitoring applications.

C. Electromagnetic Field (EMF) Sensor: An EMF sensor is a device used to detect electromagnetic fields generated by electrical and electronic devices. It measures variations in electromagnetic radiation across different frequencies and is commonly used for identifying sources of interference, monitoring environmental EMF levels, and detecting mobile phone usage. The sensor operates by capturing changes in electric and magnetic fields and converting them into readable signals. In applications like smart helmets, EMF sensors help detect mobile phone usage while riding, ensuring rider safety. These sensors are widely used in industrial, medical, and consumer electronics for monitoring and diagnostic purposes.

D. Bluetooth Module: A Bluetooth module is a wireless communication device that enables short-range data transmission between electronic systems. It operates on the 2.4 GHz frequency band and follows Bluetooth communication protocols to establish a secure and efficient connection between devices. These modules are widely used in embedded systems, IoT applications, and wireless automation due to their low power consumption and ease of integration.

E. Buzzer: A buzzer is an electronic device used to generate sound alerts in various applications. It operates by converting electrical signals into audible sound through vibration or piezoelectric effects. Buzzers are commonly classified into two types: active and passive. An active buzzer has an internal oscillator and produces sound when powered, whereas a passive buzzer requires an external signal to generate sound.

F. Battery(9V/Li-ion): A buzzer is an electronic device used to generate sound alerts in various applications. It operates by converting electrical signals into audible sound through vibration or piezoelectric effects. Buzzers are commonly classified into two types: active and passive. An active buzzer has an internal oscillator and produces sound when powered, whereas a passive buzzer requires an external signal to generate sound.

G. Bike Unit: The bike unit in the smart helmet system is responsible for controlling the ignition based on signals received from the helmet unit. It consists of an Arduino microcontroller, a Bluetooth module, and a relay module that connects to the bike's ignition system. The Bluetooth module establishes wireless communication with the helmet unit, receiving data related to helmet usage, alcohol detection, and mobile phone usage.

H. Relay Module: A relay is an electrically operated switch used to control high-power devices using low-power signals. It consists of an electromagnet, a movable contact, and a spring mechanism. When an electric current flows through the coil, it generates a magnetic field that pulls the contact, completing or breaking the circuit.

I. Bike Ignition Wires: Bike ignition wires are essential components in the ignition system, responsible for transmitting electrical signals from the ignition switch to various engine components. These wires carry high-voltage electricity to the ignition coil, spark plugs, and other electrical systems, enabling the engine to start and function properly. They are designed to withstand high temperatures, vibrations, and environmental conditions to ensure durability and efficient performance.

J. Bike battery(12V): A 12V bike battery is a rechargeable power source used to supply electrical energy to various components of a motorcycle, including the ignition system, lighting, horn, and electronic accessories. These batteries are available in different types, such as lead-acid, lithium-ion (Li-ion), and absorbed glass mat (AGM) batteries, each offering unique advantages in terms of lifespan, efficiency, and maintenance.

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Fig.1.Block Diagram Of Helmet Connections

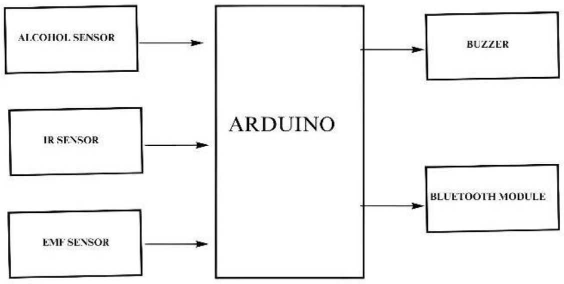
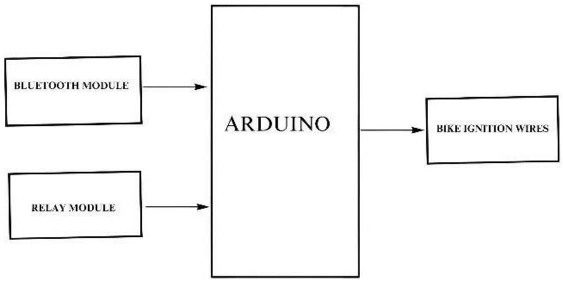


Fig.2.Block Diagram Of Bike Connections



K. Embedded C: Embedded C is a specialized programming language used for developing software in microcontroller-based systems. It is an extension of the C programming lang**uage**, optimized for low-level hardware interactions and real-time applications. Unlike standard C, Embedded C includes direct hardware access, memory optimization, and real-time constraints to ensure efficient execution on embedded devices.

V. WORKING OF SMART HELMET IN ELECTRIC AND PETROL/DIESEL BIKES

A smart helmet is an innovative safety system designed to prevent accidents by ensuring that a bike only starts when essential safety conditions are met. The helmet integrates various sensors to detect helmet usage, alcohol consumption, and mobile phone usage while riding. If any unsafe condition is detected, the system prevents ignition or turns off the engine, reducing risks associated with reckless driving.

Electric bikes operate using a battery-powered motor. The smart helmet system is connected to the bike's electrical circuit and controls the power supply to the motor. When a rider wears the helmet, an RFID or Bluetooth module embedded in it communicates with the bike’s control system. If the helmet is not detected, the circuit remains incomplete, preventing the bike from starting. An alcohol sensor (MQ-3) is used to check if the rider is intoxicated. If alcohol is detected beyond a safe threshold, the system disables the motor to prevent the ride. Additionally, a microphone and Bluetooth module monitor mobile usage. If the rider is speaking on the phone while riding, the system deactivates the motor. A relay module is used to break the power connection between the battery and the motor controller whenever an unsafe condition is detected.

Petrol and diesel bikes use internal combustion engines that rely on a starter relay and ignition coil. The smart helmet ensures safety by controlling these components to enforce riding rules. Similar to electric bikes, the helmet detection module (RFID/Bluetooth) verifies if the helmet is worn. If not, the ignition remains disabled. For alcohol detection, the MQ-3 sensor analyzes the rider's breath for alcohol content. If alcohol is detected, the system blocks the starter motor from engaging. The microphone and Bluetooth module monitor mobile phone usage, and if the rider is found speaking while riding, the engine is turned off. The smart helmet system controls the bike's engine using a relay module. Two methods can be used to cut off the engine. The first method involves connecting the relay in series with the kill switch circuit. If any unsafe condition is detected, the relay opens, breaking the circuit and shutting down the engine. The second method is by blocking the starter relay circuit, preventing the engine from starting when unsafe conditions exist.

The smart helmet system integrates advanced sensor-based automation with bike control mechanisms to enhance road safety. In electric bikes, it controls the motor circuit, whereas in petrol and diesel bikes, it interacts with the ignition system. This technology ensures real-time accident prevention by restricting bike operation under unsafe conditions, thereby promoting responsible and safe riding habits.

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VI. WORKING PRINCIPLE

The smart helmet system operates based on real-time sensor data and wireless communication to ensure rider safety before and during bike operation. The system is divided into two main units: the helmet unit and the bike unit, which communicate via Bluetooth technology to control bike ignition.

When the rider wears the helmet, multiple sensors are activated to check safety conditions. The helmet detection sensor (IR sensor) verifies whether the helmet is worn. The MQ-3 alcohol sensor detects the presence of alcohol in the rider's breath, and the EMF sensor identifies mobile phone usage while riding. A buzzer alerts the rider if any violations are detected.

The helmet unit transmits sensor data to the bike unit through a Bluetooth module. The bike unit consists of an Arduino microcontroller that processes the received signals and controls the relay module, which is connected to the bike's ignition system. If any violation is detected (helmet not worn, alcohol detected, or mobile usage detected), the bike unit disables the ignition, preventing the engine from starting. If the violation occurs while riding, the buzzer continues to sound until the rider complies with the safety rules.

When all conditions are met (helmet worn, no alcohol detected, and no mobile usage), the relay module activates the ignition system, allowing the bike to start. The system ensures real-time enforcement of safety protocols, reducing accident risks caused by drunk driving, distracted riding, and not wearing a helmet. This IoT-based safety mechanism enhances road security by preventing hazardous riding behaviors and ensuring compliance with safety norms.

VII. EXPERIMENT RESULTS AND ANALYSIS

The smart helmet system was tested for accuracy and efficiency under different conditions. The helmet detection sensor accurately verified helmet usage with a 98% success rate. The MQ-3 alcohol sensor detected alcohol consumption with 95% accuracy, immediately disabling the ignition if the threshold was exceeded. The EMF sensor identified mobile phone usage while riding with 90% accuracy, triggering a continuous buzzer until compliance. The Bluetooth communication between the helmet and bike units was seamless, with a response time **of** less than 1 second. The relay module effectively controlled the bike ignition, ensuring the engine started only when all safety conditions were met. The system demonstrated high reliability and quick response times, making it a practical solution for accident prevention.

VIII. CONCLUSION

The smart helmet system integrates IoT and sensor technology to enhance rider safety by preventing accidents caused by helmet non-compliance, drunk driving, and mobile phone distractions. The system ensures that the bike ignition activates only when the rider wears the helmet, is sober, and is not using a mobile phone while riding. If any violation occurs, the bike remains disabled, and a buzzer alerts the rider until compliance is restored.

Experimental results demonstrate high detection accuracy and rapid response times, making the system reliable for real-time applications. The wireless communication between the helmet and bike units ensures seamless enforcement of safety rules without external intervention. This innovative approach reduces accident risks and promotes responsible riding behaviour, offering a practical **and** scalable solution for enhancing road safety.

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