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IoT based Smart Helmet with Motorbike Unit for Rider's Safety

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Abstract. Studies shows that 87% of road accidents lead to major brain injuries when riders ride the bikes without helmets. When standard helmets are made intelligent by providing an enhanced safety to the rider, giving alerts on emergency contacts when accidents occur could reduce the accidents by 74%. Smart helmets not only alert during accidents but also helps in construction sites, mining areas supporting industrial workers and medical fields by providing real-time information saving peoples lives. In this paper, a similar smart helmet is developed by integrating various sensors to identify if the person has consumed alcohol, if the rider does not wear helmet and corelate it with bikes ignition ON or OFF. These key functionalities are achieved by employing suitable sensors in the helmet thereby alerting the rider or emergency contacts linked to alert about accidents occurred and current condition of the rider. In addition to this, another feature with helmet is to detect rain and act upon wiping the helmet visor making the riders visibility for safe driving. Rigorous testing was done to analyse the models performance achieving an accuracy of 96% with precision of 96%, recall of 97% and f1-score of 96.4% ensuring riders safety by detecting if rider is alcoholic or non-alcoholic and integrating it with ignition status.

1 Introduction

Nowadays youth prefer to ride bikes and motorbikes than use public transport because obsession with motorcycles is growing. 70% of India's annual total of around 1.34 lakh road accident deaths are attributed to drunk driving, according to studies. Non-standard helmets [1] and errors caused due to external factors such as riders health condition leads to many deaths yearly. Awareness programs were being organised by NGO's and government organisations in all major cities to provide importance on usage of standard helmets by the bikers. Campaigns done in public could create more impact on people when drink and drive could cause serious accidents and also share awareness on stringent laws posed on such traffic violators if helmets were not worn. Furthermore, as of late, helmet use has been mandated by legislation, as per Motor Vehicle Act Section 128. It is legally mandated that all riders on two-wheelers wear protective helmets. This prevents riders from engaging in the worst forms of carelessness, such riding without the required understanding of the laws or the state of the bike. Delay in response and poor care during accidents and not responding quickly to alert police is the critical reason in rise of deaths.

The increase in road accidents due to alcohol-impaired driving is a major concern globally. As a remedy, a smart helmet system that can identify alcohol is being developed using Internet of Things (IoT) technology. In order to prevent accidents caused by intoxicated driving, this device ensures that the rider can only start the vehicle if their blood alcohol content is within a safe limit. Traffic accidents remain a significant global concern, contributing to millions of injuries and fatalities each year. According to estimates from the World Health Organisation (WHO), yearly million loose their lives and monthly thousands suffer with injuries. Low and middle-income countries bear the brunt of these accidents, accounting for about 93% of all road fatalities despite having fewer registered vehicles. Vulnerable road users, such as motorcyclists, pedestrians, and cyclists, are at the highest risk, especially in countries where helmet use is low. Motorcyclists, in particular, face a higher risk of severe injury or death in accidents. Lack of helmet [2] use or improper helmet wearing significantly increases the risk of brain trauma injuries, that is to say often fatal or lead to long-term disability. Despite regulations mandating helmet use in many countries, non-compliance remains widespread due to lax enforcement or rider negligence.

The introduction of smart technologies, such as IoT-based safety systems for motorcyclists, aims to mitigate accident risks and enhance rider protection. Intelli-helmets built with efficient sensors such as alcohol sensor, communication module, rain sensor should be made mandatory for all riders which react smartly heling riders during their ride avoiding many major accidents. The development of the smart helmet system focuses on improving rider safety by integrating advanced sensors and IoT technology. The research begins with embedding an ultrasonic sensor in the helmet, which detects whether the rider is wearing it properly and is within the necessary proximity to the motorbike. If both conditions are met, a signal is sent to the bike's ignition system, allowing it to start. This ensures that the bike

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cannot be operated without the helmet being worn, promoting safety compliance.

In addition to the core function of helmet detection, the system includes a rain sensor to monitor weather conditions. This sensor provides alerts to the rider during rainfall, allowing them to take necessary precautions. A microcontroller processes real-time data from these sensors, ensuring smooth communication between the helmet and the motorbike. The system also features an LED indicator on the helmet to display its status, whether the helmet is properly worn and whether the bike is ready for ignition. This paper also explores expanding the smart helmet's capabilities through IoT connectivity, enabling the helmet to send alerts or data to a mobile device or cloud platform for further monitoring and safety analysis.

The rest of the paper includes literature survey indicating the limitations and future work to be carried out in different papers. Section-3 provides the methodology carried out indicated through flow charts and threshold values set for the sensors. Section-4 incorporated the implementation and results obtained with respect to alcohol detection connecting to vehicles ignition ON and OFF, also monitoring the working of visor automatically when it rains. A Comparative analysis is done on performance of the sensors used in the model for riders safety. Finally, conclusion provides the key findings obtained.

2 Literature review

An integration of IoT into smart helmets, emphasizing real-time monitoring systems that enhance motorcyclists' safety through advanced data transmission techniques like delve into accident prevention, focusing on sensor-based technologies that detect falls and immediately alert emergency services, a concept further expanded by who provide an in-depth review of the smart helmet ecosystem, highlighting various features such as accident detection, health monitoring, and real-time communication.

The authors proposed a comprehensive system that not only monitors rider health and safety but also leverages wearable IoT devices for continuous rider tracking and emergency responses. This paper [3] take this further by developing a road safety system where accident detection algorithms analyze data from accelerometers and GPS modules to notify authorities in real-time. These studies collectively emphasize the importance of integrating IoT with sensor technology to create intelligent systems that can predict and prevent accidents, monitor rider health, and ensure rapid communication in emergencies. The literature [4] highlights the growing trend toward the development of smart helmets as an essential tool for rider safety, with an increasing focus on reliable data communication, real-time alerts, and user-friendly interfaces. These research efforts provide a foundation for future advancements [5] in wearable technology, aiming for broader adoption in everyday motorcycling safety applications.

The key findings, limitations and future works of each reference paper are listed in the Table 1.

Table 1. Limitations and key findings.

Research Focus	Key Findings	Limitations	Future Work
IoT-enabled helmet for monitoring rider behavior and accident alerts	Kolapkar [6] Real-time notifications improve response time to accidents; IoT enhances safety through constant monitoring	Limited testing in real-world conditions	Expanding accident detection to cover more riding scenarios and environmental factors
Multi-sensor helmet for accident and environmental monitoring	This paper [7] Comprehensive safety system using sensors for accident detection and environmental hazards	Complexity of integrating diverse sensors into a unified system	Improving sensor accuracy and system integration for real-time monitoring in challenging environments
Health monitoring features in smart helmets	Choudhary [8] Incorporation of heart rate and body temperature sensors provides additional rider safety beyond accident detection	Lack of longitudinal health data monitoring	Extending health monitoring to include other vitals and linking with emergency health services
Prototyping and real-world testing of smart helmets	Evaluates, this paper [9] smart helmet functionality in real-world scenarios; challenges in deployment highlighted	Limited deployment and small-scale testing	Large-scale field testing and refining the prototype for mass production
Data security and privacy in smart helmet IoT systems	Encryption in this paper Patil [10] ensures secure transmission [11] of rider data; maintains balance between safety features and data privacy	Data security increases system complexity and may slow performance	Enhancing data encryption methods to improve security without compromising real-time system performance

This paper [12-14] explore novel features in smart helmets, introducing advancements that leverage IoT capabilities for improved safety. Their research highlights how integrating smart technology can significantly enhance user experience and safety, ultimately leading to broader acceptance of these systems among riders. This focus on innovation is critical for maintaining relevance in a rapidly evolving technological landscape which detects real time accident detection using GPS and GSM technology.

This paper [15] incorporates ML algorithms on the data collected from sensors and predict the maintenance in advance in real time. The accuracy results were compared with traditional methods to enhance the usability of smart helmets. AI and ML algorithms [16] have created an automated approach to detect and process penalties up on detecting riders without helmets. AI algorithms such as YOLO and OCR for number plate details extraction have played a key role in maintaining the traffic rules in turn enhancing road safety ML algorithms [17] have also helped in preparing an optimised helmet which causes less damage to the bran during accidents. Authors [18] have proposed a novel approach integrating ML algorithms, IoT sensors and cloud computing to enhance safety by 30% to workers in construction sites.

3 Methodology

The system design shown in Figure 1 for the IOT based smart helmet with motor bike unit for riders' safety involves a comprehensive integration of hardware, software, and IoT components to create a reliable and efficient safety solution. An automated mechanism with sensors integrated with communication module is the key feature for an intelligent helmet. Firstly, bike would not start unless the rider would not wear the helmet and indicate through a buzzer. Secondly, ignition would be OFF if the biker is found alcoholic. Thirdly, helmet is integrated with another feature with visor when it rains. The helmet s visor would automatically wipe the screen and maintains the speed of the wiper depending on how the rain is, light, moderate or heavy. Suitable sensors such as ultrasonic sensor, alcohol sensor (MQ-3), rain sensors integrated with helmet and microcontroller which analyses the data and send messages to the rider to act up on for his safety. Further, it also acts up on vibration in bike to verify if the vehicle is met with an accident.

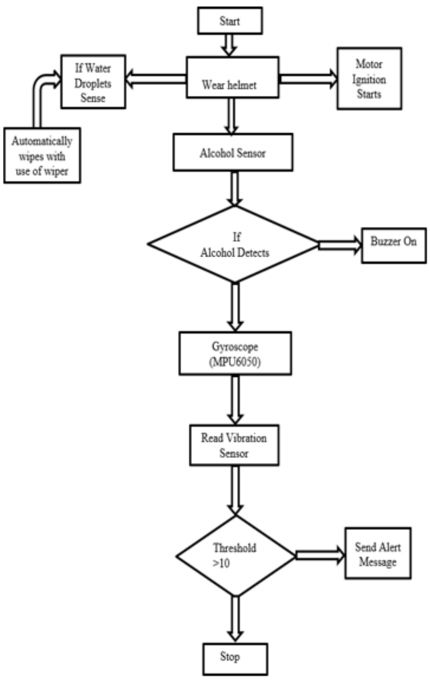

Fig. 1. Flow of the proposed model.

3.1 System requirements

3.1.1 Hardware requirements

The hardware used to design the model includes

- Arduino Mega 2560 (Transmitter) connecting Raindrop Sensor, Alcohol Sensor (MQ-3), Ultrasonic Sensor (HC- SR04), Actuators for Servo Motor (Wiper), Buzzer and Communication with Software Serial for UART communication with ESP8266.
- Arduino Nano (Receiver) connects the devices like Relay Module, DC Motor, Gyroscope (MPU6050), ESP8266(WIFI Module), Communication with Software Serial for UART communication with Arduino Mega, and functionality for checking helmet wear status, controlling the relay for the motor, reading gyroscope data, sending SMS via Twilio.

3.1.2 Software requirements

Arduino IDE is used in programming and uploading data to microcontroller to develop smart helmet. Sensors, control devices and wireless modules are interfaced with libraries which supports C and C++. Libraries such as Wire.h, SoftwareSerial.h were used to communicate the with GSM for high-speed data transfer. Another key library is EEPROM.h was used to store th information to enable wireless communication making helmet function smartly. Servo library was also used in the process of development to integrate servo motor for proving alerts through buzzers or LED displays.

3.2 Alcohol detection system

The main component of the intelligent helmet, which detects the amount of alcohol consumed by the rider through his breath. The ignition will be switched OFF once the rider is detected with alcohol consumption through alcohol sensor (MQ-3) installed in the when the limit is exceeding standard limit ensuring riders safety. Alcohol Sensor (MQ-3) is a highly sensitive sensor used to detect alcohol concentration in the rider's breath. Micro-controller (Arduino/ESP8266) then would receive data through central processing unit from the alcohol sensor, processes it, and takes action (preventing vehicle ignition). The buzzer will emit an audible signal to the rider upon detecting alcohol, strongly indicating that they should refrain from attempting to start the bike. Ignition Control Unit connected to the bike's engine prevents the vehicle from starting if alcohol is detected beyond a certain threshold.

Notifications are sent to those contacts through communication modules to get real time alerts if found alcoholic. The system also logs the data for future reference.

3.3 Helmet fit and proximity detection

This module enhances rider safety by ensuring the helmet is worn correctly before the vehicle would start, preventing potential misuse. Ultrasonic Sensor used in helmet measures the distance between the rider's head and the helmet, ensuring it is properly worn and alerts the rider with a message. Additionally, it checks the rider's proximity to the vehicle. Microcontroller would then analyzes data from the ultrasonic sensor to confirm proper helmet fit. Ignition will change the status as OFF once it detects that helmet is not wore correctly. Helmet Status Indicator gives a visual alert (LED) informs the rider whether the riders protection head gear is secured and if the model is ready for vehicle ignition.

3.4 Rain detection and visor control

Another feature which helmet incorporates is detection of rain through rain sensor and alert the model to start the visor working automatically. When the sensor detects moisture or rain, it triggers an automatic response within the helmet system. Rain Sensor will detect moisture on the helmet visor to identify rainy conditions like light rain, moderate, heavy rain and starts the servo motor to control the opening and closing of the helmet visor. Once rain is sensed, the servo motor lowers the visor automatically to protects the user from the rain with clear visibility on the road.

3.5 Accident detection and emergency response

This module is developed to identify mishaps and notify emergency contacts or authorities in a case that a fall or collision. It utilizes both a gyroscope and accelerometer to monitor the helmet's position and movement.

Fig. 2. Alcohol and rain sensor values recorded.

Gyroscope and Accelerometer (MPU6050): Monitors the helmet's orientation and motion, enabling the system to detect irregularities like crashes or sudden falls. Microcontroller: Interprets information from the gyroscope and accelerometer to ascertain if an incident has occurred. Upon detection, the system initiates an emergency response. Emergency Communication Module (GSM/Wi-Fi): Sends real-time alerts, including the rider's location, to important contacts or authorities.

4 Implementation and results

The implementation of an IoT-based smart helmet for rider safety encompasses multiple crucial phases such as hardware integration, software development, and system testing.

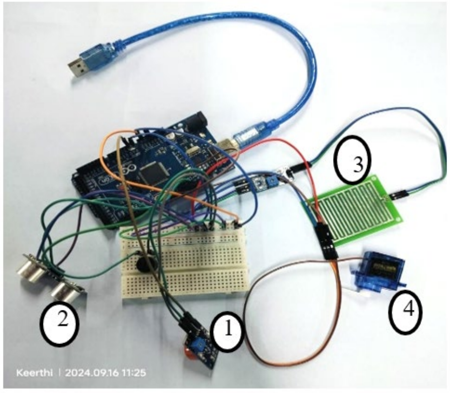

Fig. 3. Helmet (transmitter).

In the above Figure 3 Component-1 is Alcohol Sensor which detects the alcohol in the rider's breath and alerts him with buzzer after disabling the vehicle's ignition. Component-2 is Ultrasonic Sensor which measures distance between riders head and helmet using ultrasonic waves to detect whether the helmet is being worn properly by the rider. Component-3 is Raindrop Sensor that Senses moisture and rain to enable automatic visor adjustments for improved visibility in wet conditions to wipe off the water and makes the screen clear. Component-4 is a Servo Motor that precisely controls the position or movement of helmet visor and mechanical components in the system.

The MQ-3 alcohol sensor detects alcohol concentration with a threshold as shown in Figure 2 around 300-400 analog value to trigger alerts. The ultrasonic sensor measures distance, which is set between 5-10 cm, to confirm if the helmet is worn. The rain sensor senses rain, with a threshold between 300-400 analog value to indicate moisture presence.

The correlation with alcohol consumed and bikes ignition state is evaluated in terms of accuracy, precision, recall and F1-score. A total of 210 test were performed to identify if the biker is alcoholic or non-alcoholic consisting of 100 alcoholic cases and 110 non-alcoholic cases. The system has provided an accuracy of 96% comprising a precision of 95.2% recall of 95.0%, and an F1-score of 95.52% indicating false alarms and missing detections. These results confirm that the smart helmet effectively blocks ignition in the presence of alcohol while reliably allowing ignition when the rider is non-alcoholic, thereby ensuring both safety compliance and usability. Following are the 2 cases to verify if presence of alcohol and wore helmet or not. Below mentioned are metrics used to analyse the efficiency of the intelligent helmet. i) Alcohol presence detection (when positive = "alcohol present") on a sample size of 210. Confusion matrix if formed with following metrics:

- True Positive (TP, alcohol present and system detect alcohol and ignition is blocked) = 98
- False Positive (FP, detected as non-alcoholic but system wrongly detects as alcohol and ignition is blocked) = 4
- False Negative (FN, alcohol is detected but system wrongly detects and ignition is allowed) = 3

- True Negative (TN, is non-alcoholic and system detects correctly and ignition is allowed) = 105.

Following are the metrics applied using confusion matrix as given in Equations (1), (2), (3) and (4) to computer accuracy, precision, recall and f1-score respectively:

$$Accuracy = \frac{TP+TN}{N} = \frac{98+105}{210} = 0.96 \quad (1)$$

$$Precision = \frac{TP}{TP+FP} = \frac{98}{98+4} = 0.960 \quad (2)$$

$$Recall = \frac{TP}{TP+FN} = \frac{98}{101} = 0.970 \quad (3)$$

$$F1 - score = 2.\frac{(Precision \times Recall)}{(PRecision+Recall)} = 0.964 \quad (4)$$

Similarly, tests were conducted in different scenarios to check the proximity between helmet worn or not and suitably ignition is allowed to be ON or its blocked.

Functionality of smart helmets is assessed in relation with alcohol analyser is compared with previous works and mentioned as below Table 2:

Table 2. Comparative analysis of breath analyzer and its correlation with vehicles ignition.

Authors	Accuracy	Precision	Recall	F1-Score
Choudhary & Singh [8]	91%	89.5	92	90.7
Patil et al. [10]	93.4%	92.1	93.8	92.9
Sharma & Jain [12]	94.6%	93.8	94.2	94
Proposed System	96%	96%	97%	96.4%

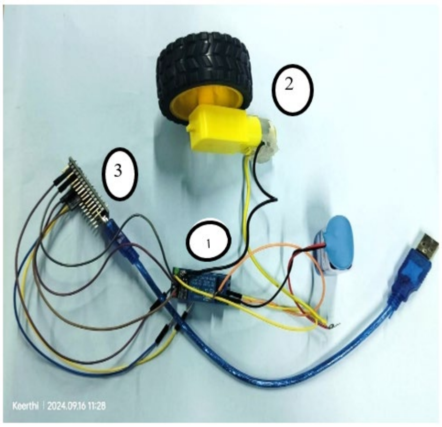

Fig. 4. Bike (receiver).

In the above Figure 4, 1- is a Relay Module acting as an electrical switch to control high-power devices, allowing the microcontroller to turn the motorbike's ignition system on or off. 2- is a BO Motor is a small battery-operated DC motor commonly used in low-power applications like robotic systems or for controlling mechanical movements. 3- Arduino Nano is a compact microcontroller board used for processing input from sensors and controlling outputs like motors or communication modules in the system.

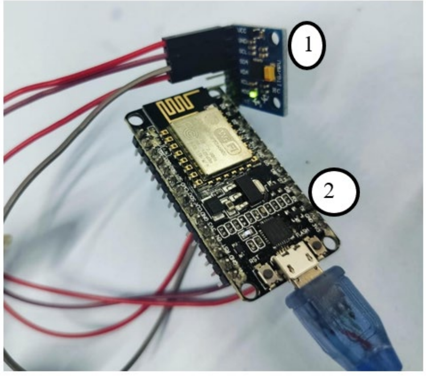

Fig. 5. Accident detection.

In the above Figure 5, component-1. Gyroscope: Measures the orientation and angular velocity of the helmet, providing data on the rider's head movements for enhanced safety monitoring. Component-2. Node MCU is a Wi-Fi-enabled microcontroller board that facilitates wireless communication and data transmission in IoT-based systems, allowing the helmet to connect to a network. Figure 6 depicts the working model of smart helmet portraying both receiver and transmitter.

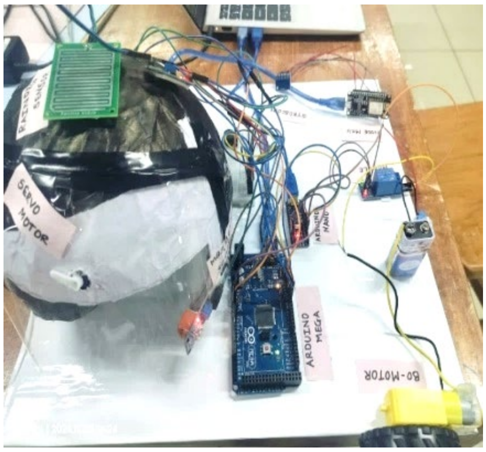

Fig. 6. Working model of both transmitter & receiver.

Results are tabulated in Table 3 below to show how rain sensors are working with respect to visor integrated to helmet.

Table 3. Actuation time with working of visor.

Type	Accuracy	Actuation time in seconds
Light rain	95%	1.5
Moderate rain	93%	2.0
Heavy rain	92%	2.2

The system gave correct results when operated for more than 100 actuation cycles without failure, demonstrating that it is practically useful in the real-world riding conditions.

Accident detection is evaluated with the metrics such as Event Detection Rate (EDR) that measures the system's ability to correctly detect actual accident events and False Alarm Rate (FAR) which quantifies how often the system falsely triggers an accident alert during normal riding.

5 Conclusion

The IoT-based smart helmet designed for rider safety represents a significant advancement in motorcycle safety technology. By integrating various sensors and communication modules, this innovative system aims to address critical safety challenges faced by riders today. The inclusion of an alcohol sensor ensures that riders are sober before operating their motorbikes, while the ultrasonic sensor detects whether the helmet is securely worn, preventing the bike from starting without proper safety gear. Additionally, the rain sensor plays a vital role in adjusting the helmet's visor automatically, thus main-training optimal visibility during adverse weather conditions. In the event of an accident, the GPS and GSM modules can quickly relay the rider's location to emergency contacts, facilitating prompt assistance. This smart initiative not only enhances rider safety but also provides peace of mind for both riders and their families. As the number of motorbike riders continues to rise, the requirement for efficient safety precautions becomes even more critical. The results demonstrate that the smart helmet system achieved high accuracy of 96% in helmet detection and alcohol sensing. Thus, key sensors integrated with an intelligent helmet caters to the needs of riders on safety and security for real world situations.

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