

Smart Helmet with Integrated Alcohol Detection for Two-Wheeler Safety

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Abstract: *Two-wheeler road accidents are often triggered by the lack of helmet usage and driving under the influence of alcohol. This paper proposes the design and development of a smart helmet with an alcohol detection feature to improve the safety of two-wheeler riders. The proposed system uses an MQ-3 gas sensor installed within the helmet to detect the concentration of alcohol in the rider's breath and an IR sensor to check if the helmet is properly worn. A camera module with a YOLOv8 model running on a Raspberry Pi is used as an additional feature to provide visual confirmation of helmet usage. The ESP32 is used for initial sensor data acquisition and communication with the Raspberry Pi, which serves as the main controller to analyze safety conditions and control the relay ignition interlock system. A buzzer is used for real-time notification of helmet and alcohol usage, and the system is powered by a rechargeable lithium-ion battery with an integrated charging circuit. The experimental results of the proposed system prove its effectiveness in accurate detection and prevention of unsafe ignition of vehicles, and the proposed system is a cost-effective solution to prevent accidents triggered by rider negligence and drunk driving.*

Keywords: Alcohol Detection, ESP32, Ignition Interlock, Raspberry Pi, Road Safety, Smart Helmet, YOLOv8

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1. Introduction

Two-wheeler riders are prone to severe injuries and death due to the lack of helmet usage or driving under the influence of alcohol. Even though traffic rules enforce the use of helmets and do not allow driving under the influence of alcohol, it is difficult to enforce these rules in real time. Recent developments in embedded systems and computer vision open new avenues for the design of intelligent safety systems that can automatically detect rider behavior and enhance road safety. This paper presents a Smart Helmet with Integrated Alcohol Detection system that integrates an MQ-3 sensor, IR based helmet detection, and YOLOv8 based visual verification using a Raspberry Pi. The system employs ESP32 for sensor processing and a relay-controlled ignition interlock to prevent dangerous driving, along with buzzer notifications and a rechargeable lithium-ion power module. The proposed methodology provides a feasible and economical solution to improve two-wheeler safety.

The key contributions of this work are as follows:

- **Hybrid Helmet and Alcohol Detection:** To track rider safety in real time, we create an integrated smart helmet system that combines MQ-3 breath alcohol analysis with infrared helmet sensing.
- **Multimodal Verification Framework:** To increase robustness against false detection and bypass attempts, we employ a dual-stage verification pipeline in which an ESP32 conducts sensor-level screening and a Raspberry Pi YOLOv8 model provides visual confirmation.
- **Ignition Interlock with Portable Power:** To enable a low-cost, standalone, and useful deployment for two-wheeler safety, we design a relay-controlled ignition lock that is supported by buzzer alerts and a rechargeable lithium-ion battery with a charging module.

In this context, the proposed smart helmet system aims to provide an intelligent and automated solution for enhancing two-wheeler safety by integrating sensor-based monitoring with vision-based verification. By combining alcohol detection, helmet usage validation, and ignition control within a unified framework, the system addresses key limitations of conventional safety enforcement methods. The use of embedded systems and deep learning techniques enables real-time decision-making and reliable operation under practical conditions. This approach contributes to the development of smarter and safer transportation systems by

ensuring compliance with essential safety measures.

2. Methodology

The proposed methodology comprises four main components, including system architecture, helmet integration, camera-based verification, and vehicle ignition interlock.

2.1. System Architecture

The proposed system integrates ignition control, vision-based verification, and helmet sensing into a comprehensive safety system. The IR sensor and MQ-3 alcohol sensor integrated into the helmet enable real-time data transmission to the ESP32, which in turn sends the processed status information to the Raspberry Pi. When alcohol is detected, a buzzer is activated when the measured value exceeds the threshold. The status of helmet wear is indicated through an LED powered by the IR sensor output. The Raspberry Pi executes the decision-making algorithm to control the relay-based ignition interlock system and employs the YOLOv8 model for vision-based helmet verification. A rechargeable lithium-ion battery with a charging circuit integrated into the helmet powers the entire helmet system, ensuring reliable portability.

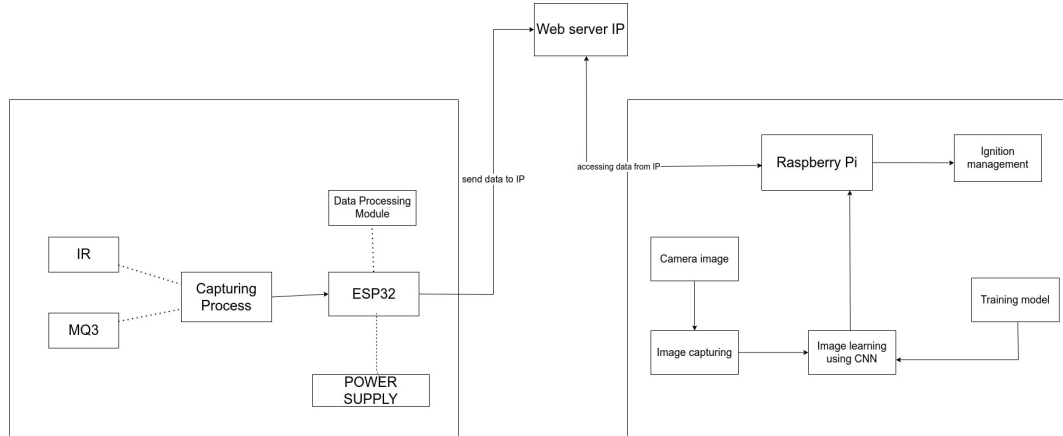


Figure 1: System Architecture

2.2. Helmet Integration

The real-time usage of the helmet and sobriety of the rider is managed by the helmet integration module. When the helmet is in the correct position, an infrared sensor fixed inside the helmet detects the blocking of the infrared ray path. Depending on the infrared sensor signal, an LED provides a visual indication of helmet compliance. To quantify the amount of alcohol in the rider's breath, a MQ-3 alcohol sensor is also fixed close to the rider's breathing area. The sensor readings are processed, and status signals are generated by the ESP32 microcontroller for further decision-making. A lithium-ion battery with a charging module is used to power the entire helmet system.

2.3. Camera-Based Verification

To increase system dependability and thwart helmet bypass attempts, the camera-based verification module offers an extra degree of validation. Following initial clearance from the sensor unit, a camera module interfaced with the Raspberry Pi takes real-time pictures of the rider. The YOLOv8 object detection model, which was trained for helmet recognition, is used to process the recorded frames. The model produces confidence scores and bounding boxes that show whether a helmet is being worn correctly. The Raspberry Pi assesses compliance based on a predetermined confidence threshold and transmits the outcome to the ignition control logic. This multimodal verification significantly enhances robustness under real-world conditions such as improper helmet wearing, partial occlusion, and sensor manipulation.

2.4. Vehicle Ignition Interlock

The ignition interlock module for the vehicle ensures safety compliance by controlling the ignition system of the motorcycle according to the joint decision of the sensing and vision modules. The Raspberry Pi module produces the final enable signal, which actuates a relay module connected to the vehicle ignition circuit. The ignition circuit is kept in the default off state and is turned on only when both helmet safety compliance and

alcohol safety conditions are met. In case of any safety violation, the relay is kept open, preventing the vehicle from being started, and a buzzer is used to alert the rider.

3. Implementation Setup

3.1. ESP32 Pin Configuration

The ESP32 microcontroller interfaces with the MQ-3 alcohol sensor, IR sensor, LED indicator, and buzzer through its GPIO pins to acquire sensor data and generate alert signals.

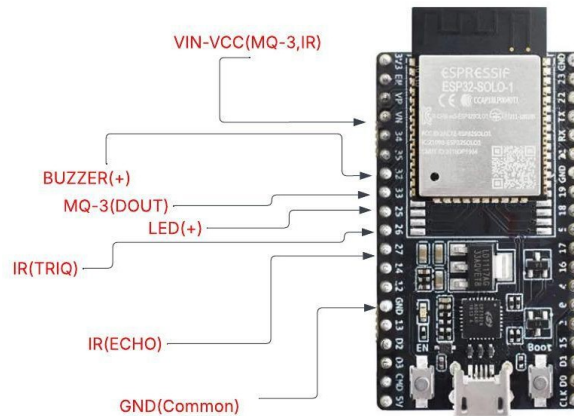


Figure 2: ESP32 pin connectivity for sensor and alert modules.

The ESP32 pin connections used in the proposed smart helmet system are described below.

- The VIN pin of the ESP32 powers the MQ-3 alcohol sensor and the IR sensor via their VCC pins.
- The digital output (DOUT) of the MQ-3 alcohol sensor is connected to one of the ESP32 GPIO pins to indicate the presence of alcohol.
- The output of the IR sensor is connected to the GPIO pins to indicate the status of wearing the helmet.
- For user indication, an LED is connected to a digital output pin to indicate the status, and a buzzer is connected to another GPIO pin to produce an audible signal when alcohol is detected.
- The components have a common ground (GND) for stable operation of the sensing and alert modules.

3.2. Sensor Integration

The sensing module comprises an MQ-3 alcohol sensor and an IR sensor that is integrated inside the helmet to check the rider safety conditions. The MQ-3 sensor is placed close to the rider's breathing zone to sense the alcohol concentration from the breath samples. The IR sensor is placed inside the helmet to check if the helmet is properly worn by the rider. The ESP32 module continuously reads the sensor values through its GPIO pins and checks the signals to determine the helmet compliance and alcohol presence before sending the information to the Raspberry Pi module for further verification.

4. Experimental Results and Discussion

4.1. MQ-3 Sensor Evaluation

Parameter	Value
Sensor model	MQ-3
Alcohol Threshold Value	0.08% BAC
Sensor Response Time	3–5 sec
Buzzer Activation	When BAC > 0.08%

Table 1: Alcohol Detection Parameters

Table 1 lists the major operational parameters set for the alcohol detection module that is integrated into the smart helmet system. It identifies the MQ-3 gas sensor as the component that is responsible for the rider's breath alcohol concentration level measurement. The table draws attention to the predefined Blood Alcohol Concentration (BAC) threshold level of 0.08%, which is used as the decision-making criteria for the rider to be classified as either sober or intoxicated. The table further indicates the standard response time of 3-5 seconds, which represents the time taken by the sensor to provide a stable output after being subjected to alcohol vapor. Moreover, the table outlines the system's alert mechanism, which automatically turns on the buzzer as soon as the measured BAC value exceeds the standard threshold level.

Test Number	BAC Detection (Actual)	BAC Prediction (System)	Prediction Accuracy (%)
1	0.00% (No Alcohol)	0.00% (No Alcohol)	100%
2	0.03% (Low BAC)	0.03% (Low BAC)	100%
3	0.08% (Thresh- old BAC)	0.08% (Thresh- old BAC)	100%
4	0.11% (Above Thresh- old)	0.11% (Above Thresh- old)	98%
5	0.12% (High BAC)	0.11% (Slight Differ- ence)	95%
6	0.15% (Severe BAC)	0.14% (Slight Differ- ence)	93%

Table 2: Bac Detection Performance Results

The performance analysis of the proposed alcohol detection and vehicle control system has been summarized in Table 2. The table compares the actual BAC values with the predicted values, along with the prediction accuracy and response time of the vehicle control system. The results show that the system provides high accuracy in alcohol detection, especially at and below the threshold level, with minor deviations at higher BAC levels. The response times recorded during the experiments confirm that the system is capable of making decisions in real-time ignition control to ensure rider safety.

4.2. IR Sensor Evaluation

Test No.	Actual Distance	IR Detection	LED Status	Detection Accuracy
1	3(within range)	Helmet Detected	OFF	100%
2	6(beyond range)	Helmet Not Detected	BLINK	98%
3	8(far from sensor)	Helmet Not Detected	BLINK	96%

Table 3: IR Sensor Detection Performance

Table 3 shows the performance analysis of the IR-based helmet detection module with a detection threshold of 5 cm. The table lists the actual distance of the helmet from the IR sensor, the system detection output, and the corresponding LED indication. If the helmet is within the specified range (5 cm), the system detects the presence of the helmet and maintains the LED indicator OFF, indicating normal and safe conditions. However, if the distance is beyond the threshold, the system detects that the helmet is not properly worn and generates an LED blinking alert for the rider. The data clearly indicates accurate detection at all distances, ensuring that the IR sensor is able to effectively distinguish between proper helmet wear and improper wear. This confirms the efficacy of the helmet verification system based on proximity for real-time safety enforcement in the proposed smart helmet system.

4.3. YOLO-Based Helmet Detection Results

The helmet verification part of the proposed system uses a YOLO object detection algorithm to visually verify the usage of helmets in real-time scenarios. The proposed model was trained using a dataset with two classes: helmet and non-helmet, which allows the system to identify helmet users and non-users. The training process was carried out for 100 epochs to enable the system to learn the relevant visual features of helmets, including their shape and color patterns, as well as the head region of the riders. During the testing process,

real-time images taken by the Raspberry Pi camera module were used to test the proposed system. The detection algorithm used in the system analyzes the images and creates bounding boxes around the head region of the riders while assigning class labels and confidence scores. The experimental results show that the proposed system was able to achieve a maximum detection accuracy of about 0.84 when trained using portrait-oriented images of riders wearing helmets. The system achieved an average inference time of around 0.8666 milliseconds per image on the Raspberry Pi platform, which allows the efficient frame-by-frame analysis of the model. Based on the existing hardware setup, the system analyzes around two frames per second, which is adequate for helmet validation before allowing the ignition of the vehicle.

The result obtained shows the successful classification of both helmet and non-helmet cases, as shown in the detection output. If the helmet is detected, the system determines the rider as compliant and proceeds with further verification. However, upon detection of the non-helmet case by the model, the system detects the violation and inhibits ignition activation. The combination of the vision-based detection system in the proposed safety system enhances its reliability, as it supplements the sensor-based helmet detection module and minimizes the chance of avoiding safety verification. In summary, the YOLO-based detection outcome verifies that computer vision can efficiently contribute to the development of intelligent transportation safety systems by ensuring accurate and automated helmet usage monitoring in real-world scenarios. Experimental observations confirm that the model can accurately distinguish between helmet and non-helmet cases under practical conditions. This visual verification mechanism strengthens the reliability of the proposed safety system by providing an additional layer of validation before enabling vehicle ignition.

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Figure 3

Figure 3 shows Output of the YOLO-based helmet detection system showing the rider wearing a helmet, where the system correctly displays the status “HELMET PRESENT.”



Figure 4

Figure 4 shows Output of the helmet detection system showing the rider without a helmet, where the model correctly displays the status “NO HELMET.”

Figures 3 and 4 illustrate the performance of the YOLO-based helmet detection model during real-time testing. The model is able to identify riders wearing helmets and those not wearing helmets by producing

bounding boxes and classification results. The experiment has proven that the trained model is capable of distinguishing between helmet and non-helmet situations to provide a reliable visual verification for the proposed smart helmet safety system.

5. Conclusion

This paper has discussed the design and development of a smart helmet system that incorporates sensor-assisted alcohol detection and vision-assisted helmet verification to improve the safety of two-wheeler riders. The proposed system combines several hardware and software components such as an ESP32 microcontroller for sensor data acquisition, an MQ-3 alcohol sensor for breath analysis, an IR sensor for helmet detection, and a Raspberry Pi platform for vision processing and system control. The camera module connected to the Raspberry Pi supports helmet verification through a YOLO-based object detection algorithm trained to classify riders into helmet and non-helmet classes. The system also includes an ignition interlock system based on a relay circuit, which ensures that the ignition of the vehicle is possible only when helmet safety and alcohol safety standards are met. Experimental results demonstrated the effectiveness of the proposed system. The YOLO model was trained for 100 epochs with a maximum accuracy of 0.84 when trained on portrait-oriented images of riders wearing helmets. Real-time processing on the Raspberry Pi platform took an average time of approximately 0.8666 ms per image with a processing speed of about 2 frames per second based on the existing system configuration. The experimental results prove that the vision module is capable of accurately identifying helmet and non-helmet situations, and the MQ-3 and IR sensors are successfully detecting the presence of alcohol and helmet use. The system, which combines sensor-based detection with computer vision verification, is a robust and intelligent safety system that can be used to reduce the number of accidents resulting from helmet misuse and drunk driving. This approach is feasible to develop using embedded systems, IoT devices, and deep learning concepts for improving road safety in two-wheeler transport.

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Authors' Contributions

Abdulla Anas contributed to the design and development of the smart helmet system and hardware integration. Albin P Binu contributed to circuit design and implementation of sensor modules. Hanna Thomas contributed to software development, documentation, and manuscript preparation. Sheffin G Shaju contributed to data analysis and system testing. Ms. Leena Y supervised the project and provided technical guidance throughout the research work. Dr. Reji Ravi contributed to methodology design and critical review of the manuscript. Mr. Rupesh Ravi contributed to project coordination and final editing of the paper.

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Conflicts of Interest: The authors declare “No conflict of interest”.