Smart Helmet for Drunk Driving Prevention and Safety Monitoring Using IoT

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***Abstract*—Road accidents caused by drunk driving are a serious concern globally. Our proposed Smart Helmet aims to reduce such incidents by integrating alcohol detection and safety mechanisms into the rider's helmet. This hardware-based system is built using Arduino Uno and sensors to prevent the bike from starting if the rider is intoxicated. The helmet integrates real-time GPS and GSM modules for tracking and alerting during emergencies. Additional features include an IR sensor to detect helmet usage, an ultrasonic sensor for obstacle detection, and environmental sensors to monitor riding conditions. All data collected is visualized on a user interface website to support monitoring and potential future enhancements. The system automatically prevents ignition upon alcohol detection, sends emergency alerts only during confirmed accidents, and enables real-time sensor data monitoring via a dedicated UI platform.**

***Index Terms*—Smart Helmet, Drunk Driving Prevention, Arduino Uno, Alcohol Sensor, GPS, GSM, IoT, Safety Monitoring**

I. Introduction

Drunk driving remains one of the major causes of road accidents globally of traffic fatalities globally. Statistics globally show that thousands of lives are lost annually due to drunk driving, indicating the need for proactive and intelligent safety measures. Awareness campaigns and regulations have not yet been enough to eliminate the menace entirely, hence the need for incorporating technology in personal protective equipment.

To meet this challenge, we introduce a Smart Helmet system that utilizes embedded hardware and sensors to identify and discourage drunk driving. The primary goal of the system is to stop the bike from starting when the rider is detected to be drunk. This is achieved using an MQ-3 alcohol sensor integrated into the helmet that examines the rider's breath. If the alcohol content crosses a previously set level, the system switches on a relay module, which controls a gear motor to disable the ignition circuit and thus immobilize the vehicle.

Aside from alcohol detection, the helmet features built-in real-time GPS and GSM modules to facilitate location tracking and emergency alert messaging. In case of an accident, the GSM module sends the rider's location to pre-set emergency contacts, allowing for instant response and what could be life-saving actions. Notably, the alerts are only sent during confirmed accidents to avoid false alarms.

To further provide user safety, the helmet comes with an IR sensor that confirms the helmet is on before ignition is allowed. The system also incorporates an ultrasonic sensor that will detect objects around the vehicle, which would alert the rider to potential collisions. Environmental sensors like temperature and humidity modules provide situational information, giving information on riding conditions.

All sensor data from the helmet are sent to a user interface (UI) website that we built, enabling real-time tracking and historical visualization of data. This platform not only enables future enhancements through analytics but also represents a step toward scalable smart mobility solutions. Currently, our system exists mainly through hardware implementation, with the user interface serving as a dashboard for sensor feedback and notifications.

In short, this Smart Helmet system is a combined safety solution for preventing alcohol-related road accidents, providing real-time tracking, and paving the way for intelligent, connected transport.

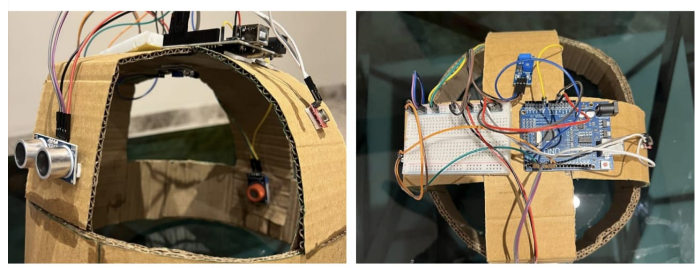

Fig. 1. Helmet overwiew

II. Related Work

The research in intelligent helmet systems for riders' safety has been an important research area in recent years. The methodologies have varied from simple alcohol detection to sophisticated AI-based road accident prevention. The current research is reviewed in this section with the research grouped under major subsections: Alcohol Detection Systems, IoT-Based Ac-cident Detection, AI-Powered Safety Mechanisms, and Edge Computing in Smart Helmets

A. Alcohol Detection Systems

Initial research on smart helmets dealt mostly with alcohol detection for avoiding drunk driving. Conventional systems, including those in [6], were based on threshold-based alarms and ignition cut-off. Subsequent developments combined MQ-3 alcohol sensors with microcontrollers such as Arduino

[6], supporting immediate detection but with the need for manual intervention. Bluetooth-based detection was subsequently developed [7], with wireless transmission to smartphone applications, albeit subject to external dependencies. Our system enhances these limitations with the combination of alcohol detection and real-time accident alerts as well as helmet compliance.

B. IoT-Based Accident Detection and Tracking

IoT-upgraded smart helmets utilize GPS/GSM-based crash notifications [4]. More sophisticated systems employ accelerometer-based fall detection using cloud analytics [6], although internet reliance may create latency.

C. AI-Powered Safety Mechanisms

ML models provided predictive crash detection through sensor fusion [3]. Edge AI made it more reliable by eliminating cloud reliance [4], but lacked important features such as obstacle detection and helmet condition. Our solution addresses this through multi-sensor data and local decision-making.

D. Edge Computing and Real-Time Processing

Edge computing enabled real-time processing on platforms such as Raspberry Pi and Jetson [9], although not optimized for low-cost systems. Arduino-based alerts were suggested [5] but did not have complete safety integration. We offer a full low- power solution with real-time UI support.

E. Comparative Analysis and Research Gap

Existing works concentrate on individual safety features, but they tend to lack multi-sensor fusion, rely on external servers, and are power-hungry. Our system:

- Removes dependence on the cloud through Edge AI
- Implements alcohol detection, helmet compliance, and obstacle sensing
- Maps data in real-time on a local UI using Edge AI processing
- Eliminates cloud dependency via Edge AI
- Integrates alcohol detection, helmet compliance, and obstacle sensing
- Visualizes data in real-time on a local UI

F. Helmet-to-Bike Communication and Ignition Control

The smart helmet is designed to communicate directly with the bike's ignition system to ensure rider safety. A crucial feature implemented is blocking the vehicle operation unless the helmet is in use. This is done by employing an **Infrared (IR) sensor** internally within the helmet, which senses the rider's head. A wireless communication module like a **433 MHz RF transmitter** is employed to transmit a digital signal from the helmet to a receiver module on the bike. The logic operates as follows:

- When the rider is wearing the helmet, the IR sensor detects presence and causes the RF module to output a `HIGH` signal.
- The receiver module on the bike picks up this `HIGH` signal and turns on the relay circuit wired to the ignition system.
- When the helmet is taken off, the IR sensor state becomes `LOW`. This `LOW` signal is sent wirelessly to the bike, which makes the receiver turn off the relay.
- Turning off the relay removes the power from the ignition and thus kills the engine.

This system prevents the rider from starting or continuing to ride the vehicle unless the helmet is worn correctly, mandating compliance with safety procedures.

The ignition control logic can be defined as:

$$\text{Ignition} = \begin{cases} \text{ON}, & \text{if Helmet = Worn} \\ \text{OFF}, & \text{if Helmet = Not Worn} \end{cases}$$

This aspect not only encourages safe riding habits but also serves as a theft deterrent, since the vehicle cannot be driven without the helmet in place and functioning.

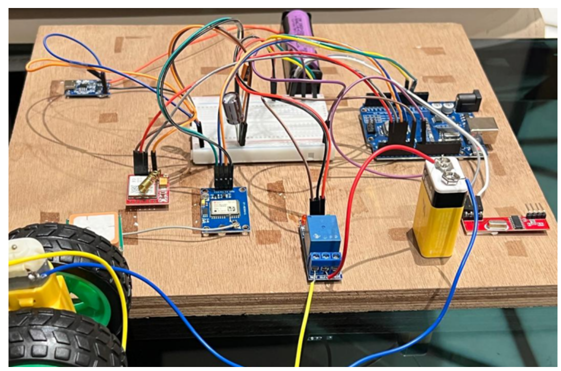

Fig. 2. Bike unit

III. System Architecture

This intelligent helmet system integrates an *Arduino Uno* with various sensors and communication modules to significantly improve rider safety. Unlike conventional helmets, this solution enforces *helmet compliance*, detects *alcohol consumption*, provides *accident alerts*, and notifies *real-time hazards*—all while processing data locally for reliability, speed, and low cost.

A. Working Principle and Methodology

The system follows a clear *safety-first methodology*. First, an *IR sensor* checks helmet compliance. If not detected, ignition is disabled. Next, the *MQ-3 sensor* measures alcohol levels. If they exceed a safety threshold, ignition is blocked and a buzzer alert is triggered. Once cleared, real-time hazard detection through the *ultrasonic sensor* begins. If a crash is detected, *GPS coordinates* are sent via *GSM* to emergency contacts. The *DHT11 sensor* monitors internal temperature and humidity to ensure rider comfort.

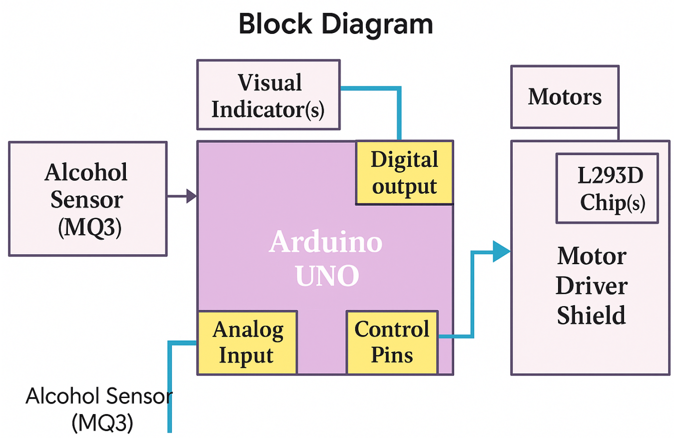

Fig. 3. Overview of Smart helmet system. [9]

B. Sensor Modules and Calculations

B.1 Alcohol Detection (MQ-3 Sensor)

The MQ-3 sensor measures ethanol concentration in the rider's breath. The estimated Blood Alcohol Content (*BAC*) can be calculated using:

$$\text{BAC} = A \times \left(\frac{V_{\text{out}}}{V_{\text{ref}}}\right)$$

where:

- *BAC* is the Blood Alcohol Content
- V_{out} is the sensor's output voltage
- V_{ref} is the reference voltage (typically 5V)
- A is an experimentally determined calibration constant

B.2 Obstacle Detection (Ultrasonic Sensor)

The *HC-SR04 ultrasonic sensor* detects nearby objects. The distance to an object is computed as:

$$\text{Distance} = \frac{\text{Time} \times \text{Speed of Sound}}{2}$$

where:

- *Time* is the total time taken for the echo
- *Speed of Sound* is 343 m/s at room temperature

B.3 Environmental Monitoring (DHT11 Sensor)

The *DHT11* sensor provides direct digital readings. Ideal comfort conditions are maintained as:

$$22^\circ C \leq T \leq 28^\circ C \quad \text{and} \quad 40\% \leq RH \leq 60\%$$

where:

- T is the temperature in Celsius
- RH is Relative Humidity

C. Decision Logic

The logical condition for enabling ignition is expressed as:

$$\text{Ignition} = \begin{cases} \text{Enabled,} & \text{if Helmet = Worn AND BAC} < \text{Threshold} \\ \text{Disabled,} & \text{otherwise} \end{cases}$$

This ensures that the system only allows ignition if all safety conditions are satisfied.

D. Communication Modules

The *GPS module (Neo-6M)* tracks the rider's location in real time. If a crash is detected or the helmet is removed mid-ride, the *GSM module (SIM800L)* sends alerts with location details to pre-registered emergency contacts. An optional *433MHz RF module* provides short-range wireless communication between the helmet and the bike.

E. Power Supply and Controls

The system is powered using a *9V battery* on a breadboard. A *push button* allows manual override for maintenance or emergency use. Power can also be upgraded using a *rechargeable battery* or *solar module* for long trips.

IV. Future Enhancements

To enhance the smart helmet system, the following upgrades can be considered:

- *Edge AI Object Recognition* using TinyML on *ESP32-CAM* or *Raspberry Pi Zero* enables obstacle classification (e.g., cars, pedestrians), enhancing hazard detection beyond ultrasonic range.
- A *solar-powered battery* with *5V/2W solar panels* and a LiPo battery extends ride time by harvesting solar energy.
- *Bluetooth 5.0 with a smartphone app* (via *HC-05/HM-10*) enables BAC monitoring, ride analytics, and emergency SOS alerts—improving user interaction.
- Bluetooth integration using HC-05 (Bluetooth 2.0) or HM-10 (Bluetooth 4.0) modules provides backward compatibility and supports essential safety features.
- *Voice alerts* via a *bone conduction speaker (DFPlayer Mini)* deliver hands-free safety notifications, reducing distraction.
- An *airbag system* using *MPU6050* and a CO_2 cartridge provides neck protection during crashes.
- *Night vision and thermal sensors* (e.g., *MLX90640*, Pi HQ Camera) improve visibility in dark or foggy conditions.
- *V2X communication* (via *LoRa RA-02* or DSRC) allows bike-to-vehicle alerts, aiding in collision prevention.
- *Biometric sensors* like *MAX30102* track rider vitals, enabling fatigue or health-related alerts.
- An *AR display* (e.g., *Vufine+ HUD*) can show speed/navigation data directly on the visor for heads-up guidance.
- Lastly, *piezoelectric harvesting* using *LTC3588* converts ride vibrations into power, ensuring continuous energy supply.

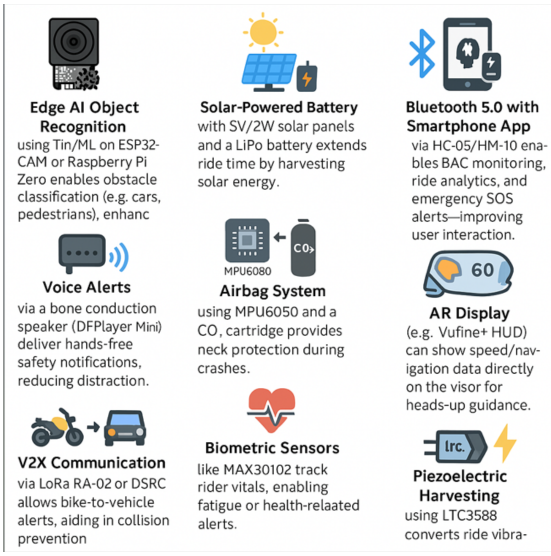

Fig. 4. Future enhancements reference image.

V. Long-Term Vision

Smart helmets can evolve into advanced safety systems through next-gen upgrades. Autonomous Emergency Braking (AEB) via LiDAR/radar and Edge AI can reduce collisions, while 5G-V2X communication enables real-time alerts from traffic infrastructure. Holographic AR navigation projects onto the rider's view or the road surface, and predictive crash analytics assess risks based on riding patterns. Graphene-based impact sensors and quantum dot solar charging enhance durability and power efficiency. Neuromorphic AI learns rider behavior with low energy use, and a drone-based emergency response system can deliver aid via GPS. Additional features like a self-repairing visor and brain-computer interface (BCI) for fatigue detection move helmets from passive gear to intelligent life-saving devices.

Challenges: Ensuring data privacy, providing manual override options, and meeting global safety regulations (FCC/NHTSA/EU).

VI. Applications

- **Alcohol Detection & Ignition Lock**
  - MQ-3 sensor detects BAC from breath.
  - Ignition cut-off if BAC $> 0.05\%$.
  - LED/buzzer warnings; ignition locked until sober.
- **Accident Detection & Emergency Alerts**
  - MPU6050 detects crash via G-force threshold.
  - Auto-SMS with GPS (Neo-6M) to emergency contacts.
  - Backup alert if helmet is removed post-crash.
- **Real-Time GPS Tracking**
  - 1Hz GPS logging; last location stored in EEPROM.
  - Live tracking and geofencing via mobile app.
- **Proximity Warning System**
  - Dual HC-SR04 sensors (2–400cm range).
  - Alerts via LED/buzzer/vibration based on distance.
  - 360° coverage with adjustable sensitivity.
- **Environmental Monitoring**
  - DHT11 tracks temperature (0–50°C) & humidity (20–90% RH).
  - Anti-fogging alerts and ventilation suggestions.
- **Data Visualization & UI**
  - Web dashboard with real-time stats, history, and alerts.
  - Responsive design; local server (no cloud needed).
- **Technical Highlights**
  - Alerts triggerd under 100ms response time for alerts.
  - 12-hour battery life; extendable via power bank.
  - IP65-rated water-resistant modules; modular hardware.

VII. User Interface Website

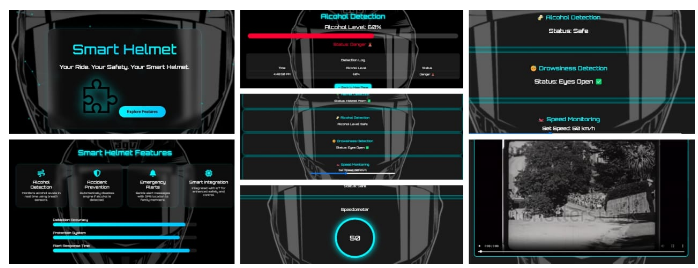

Fig. 5. User interface website design

VIII. Block Diagram

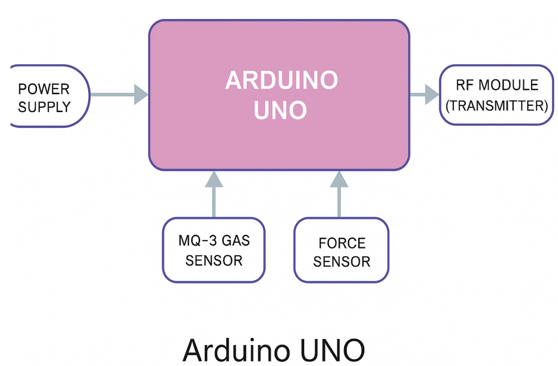

Fig. 6. Smart Helmet block diagram [7]

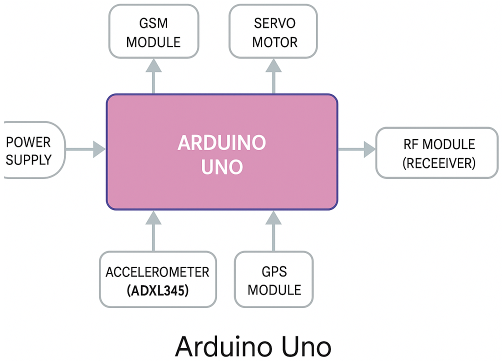

Fig. 7. The implementation in bike block diagram. [7]

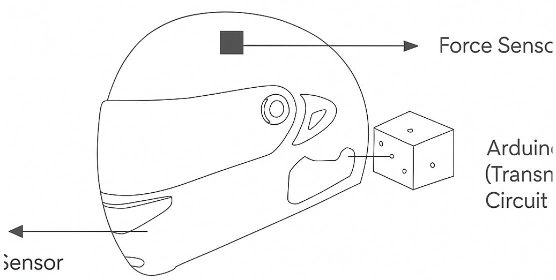

Fig. 8. The complete helmet implementation. [7]

IX. Conclusion

This intelligent helmet system improves rider safety through the integration of alcohol detection, crash notification, obstacle warning, and environmental sensing—all locally processed for low-latency, reliable performance. Features like ignition lock, GPS-based emergency messaging, and helmet compliance form a comprehensive safety solution for two-wheeler riders. With its modular design and real-time UI, the system is a scalable, intelligent step towards minimizing road fatalities and enabling smarter mobility.

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