DEPARTMENT OF COMPUTER & SOFTWARE ENGINEERING

COLLEGE OF E&ME, NUST, RAWALPINDI

PROJECT REPORT

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1 Problem Statement

Road accidents involving two-wheeler riders are a significant cause of injuries and fatalities worldwide, often due to the non-usage of helmets, delayed emergency response, and rider impairment. Despite the availability of safety gear, many riders fail to wear helmets consistently. In a crash, there is often no immediate system to detect the accident or prevent further harm. Additionally, traditional bike systems do not assess the rider’s condition before allowing ignition, increasing the risk of accidents caused by impaired or unfit riders.

There is a critical need for an intelligent helmet-based safety system that can:

- Ensure the rider is wearing the helmet before starting the bike.
- Detect potential crashes in real time.
- Immediately respond by disabling the bike ignition if necessary.
- Be scalable and adaptable to future safety enhancements like alcohol detection and real-time alert systems.

This project aims to address these challenges by designing and implementing a smart helmet system using the ESP32 microcontroller and sensor technologies to improve road safety for two-wheeler users.

2 Objectives

Helmet Detection System

Ensure the helmet is being worn before the bike can be started.

Crash Detection

Monitor real-time acceleration and angular velocity to detect sudden impacts or accidents.

Wireless Ignition Control

Disable the bike's ignition system upon crash detection or when the helmet is not worn.

Reliable Communication

Implement Bluetooth-based wireless communication between the helmet and bike modules.

User Interaction

Provide manual override capability via a capacitive touch sensor for safety and convenience.

3 Project Overview

The **ESP-32 Smart Bike Helmet** is a microcontroller-based safety system aimed at reducing motorcycle accidents by ensuring safer riding practices. The project integrates an **ESP32 microcontroller**, **MPU6050 motion sensor**, **capacitive touch sensor**, and a **relay module** to create a smart, responsive system that actively monitors the rider's status and responds to hazardous conditions.

The project is divided into two main units:

Helmet Unit (Sensor & Control Module)

This unit, mounted on the helmet, uses the **MPU6050** to continuously track the rider's motion, detecting abnormal accelerations (jerk) that may indicate a crash. A **capacitive touch sensor** is added to allow manual control or override. The data is processed by the **ESP32**, which then transmits relevant signals wirelessly via **Bluetooth** to the bike unit.

Bike Unit (Response Module)

The bike module also consists of an **ESP32**, which receives the Bluetooth signal from the helmet. If a crash is detected or the helmet is not worn, this unit activates a **relay** to disable the ignition system, preventing the bike from starting or continuing operation. This helps prevent further accidents and ensures the rider's safety.

The system is **powered by LiPo batteries** in the helmet and regulated through a buck converter. On the bike side, it is currently powered by the same architecture as the helmet, although for future commercialisation bike's internal battery could be used to power the system. This project not only addresses current safety challenges but is also designed to be **scalable and upgradable**, with the possibility to incorporate **alcohol detection**, **CAN communication** for better vehicle integration, and **GPS-enabled emergency alerts**.

WHY WE USE ESP32:

The ESP32 microcontroller is ideal for implementing this smart bike helmet due to its built-in Wi-Fi and Bluetooth. It offers high performance at a low cost, with a dual-core processor capable of handling tasks like gesture recognition, voice commands, and obstacle detection. Its compatibility with the Arduino IDE and strong community support simplifies development and integration with sensors and motor drivers. Additionally, the ESP32's support for advanced peripherals ensures scalability for future upgrades, such as adding a camera or offline voice control.

4 Hardware Implementation

Sensor & Detection Module (Helmet Unit)

- **ESP32 Microcontroller**: Serves as the central processing unit, managing sensor data acquisition, processing, and wireless communication.
- **MPU6050 IMU Sensor**: Combines a 3-axis accelerometer and a 3-axis gyroscope to measure acceleration and angular velocity. The system calculates jerks (the rate of change of acceleration) to detect sudden impacts indicative of a crash.
- **Capacitive Touch Sensor**: Provides manual input capabilities, allowing the rider to interact with the system or override certain functions.
- **Power Supply**: Utilises dual 3.7V LiPo batteries, regulated through a buck converter to provide a stable 5V supply to the ESP32 and sensors.
- **Bluetooth Communication**: Enables wireless data transmission to the response module, facilitating real-time monitoring and alerts.

Response Module (Bike Unit)

- **ESP32 Microcontroller**: Receives data from the helmet unit via Bluetooth and processes it to determine appropriate responses.
- **Relay Module**: Controls the bike's ignition system. In the event of a detected crash or if the helmet is not worn, the relay can disable the ignition to prevent operation.
- **Power Supply**: Powered by the bike's electrical system, regulated to provide a stable 5V supply to the ESP32 and relay module.

System Operation

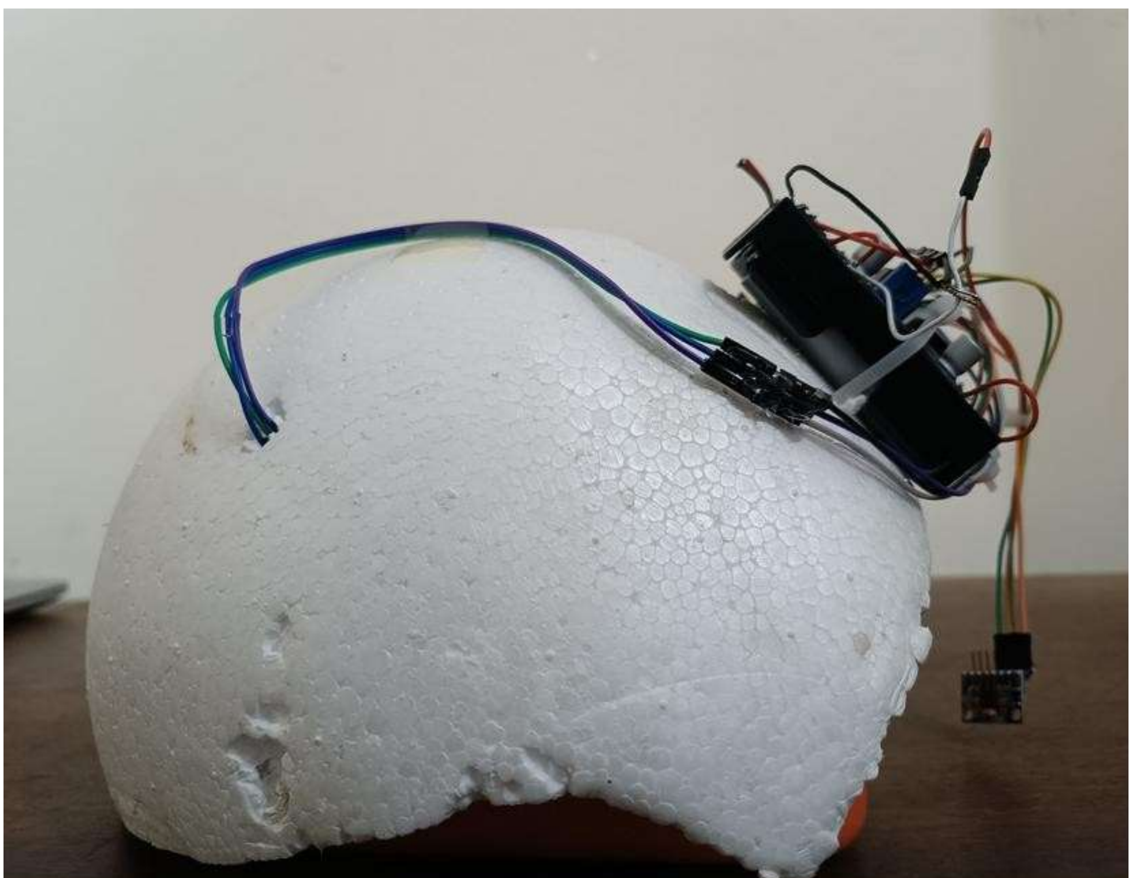
1. **Data Acquisition**: The MPU6050 sensor continuously monitors the rider's movements, capturing acceleration and angular velocity data.
2. **Crash Detection**: The ESP32 processes sensor data to calculate jerks. If the calculated jerk exceeds a predefined threshold, indicating a potential crash, the system triggers an alert.

3. **Wireless Communication**: Upon detecting a potential crash, the helmet unit sends a signal via Bluetooth to the bike's response module.

4. **Ignition Control**: The response module processes the received signal and, if necessary, disables the bike's ignition system through the relay module to prevent further operation.

5. **Manual Override**: The capacitive touch sensor allows the rider to manually interact with the system, providing the ability to override automatic functions if needed.

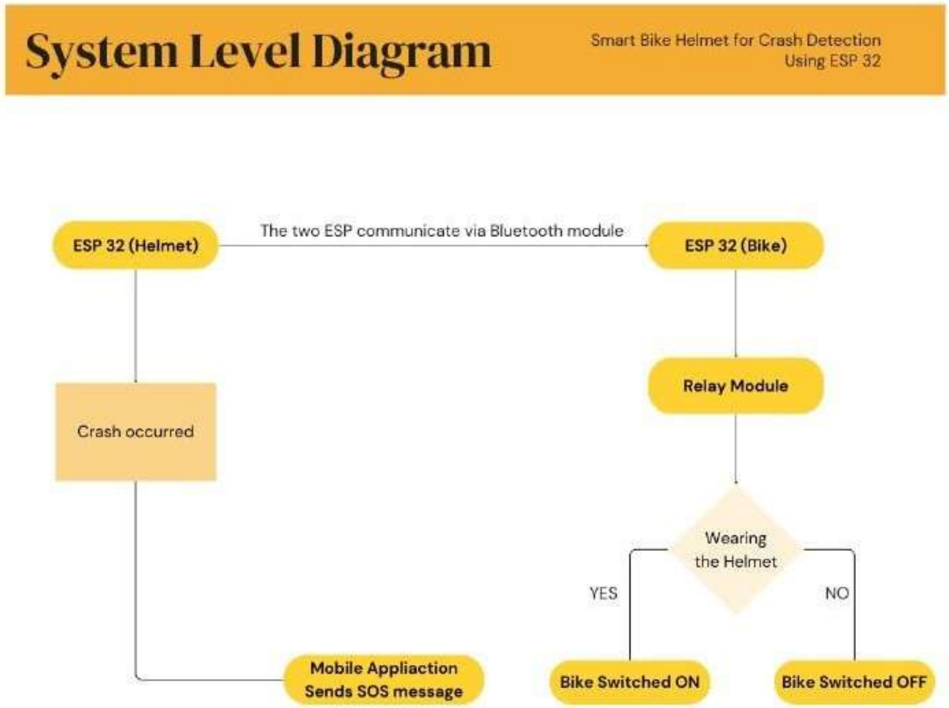
This hardware implementation enhances rider safety by integrating real-time crash detection with automatic bike control mechanisms. The use of ESP32 microcontrollers and MPU6050 sensors provides a cost-effective and efficient solution for monitoring and responding to potential accidents.



-- Helmet's Side View --

-- Helmet's Front View --

5 System Level Diagram



6 Features

- **Real-time Crash Detection:**

  Detects crashes using thresholds on resultant acceleration, angular velocity, and calculated jerk for accurate impact assessment.

- **Wireless Bluetooth Communication:**

  Two ESP32 modules communicate wirelessly—one for helmet sensing (MPU6050 + capacitive touch), the other for bike relay control.

- **Mobile App Integration:**

  A custom smartphone app connects via Bluetooth to receive speed, longitude, latitude, and crash status in real-time.

- **Crash Notification System via GSM:**

  Upon crash detection, the app uses the mobile phone's GSM and GPS modules to send an SMS to a pre-saved emergency contact with the location details.

- **Helmet Fit Verification:**

  A capacitive touch sensor ensures the helmet is worn before allowing engine ignition, enforcing safe riding practices.
- **Safe and Rechargeable Power Supply:**

  Each ESP32 is powered by dual 3.7v LiPo batteries, regulated to ~4.5v via a buck converter and TP4056 charging module, ensuring stability and rechargeability.
- **Compact and Portable Design:**

  Lightweight, LiPo-powered modules suitable for integration directly into helmets or mounted on bike frames

7 Future Enhancements:

Alcohol Detection Module

To further enhance rider safety, an alcohol detection sensor (such as the MQ-3 gas sensor) can be integrated into the helmet unit. This module detects the rider's breath alcohol concentration and disables the bike ignition via the relay if alcohol is detected above a certain threshold. This addition would help prevent drunk driving incidents.

CAN Communication Instead of Bluetooth

The current system relies on Bluetooth for communication between the helmet and bike units. While functional, Bluetooth has limitations in terms of range, latency, and interference. Implementing **CAN (Controller Area Network) communication** would provide:

- **Faster and more reliable data transmission**
- **Robustness against noise/interference**
- **Support for multi-node communication**, allowing integration with other bike electronics (e.g., dashboard, ECU)

  CAN communication is widely used in the automotive industry, making it a more suitable and scalable option for real-world deployments.

Battery Monitoring System

Adding voltage and current sensors can help monitor battery health and alert the rider in case of low power or charging issues, ensuring system reliability.

8 Conclusion:

The ESP-32 Smart Bike Helmet presents an innovative and practical solution to enhance rider safety through real-time crash detection and automated bike control. By integrating the ESP32 microcontroller with the MPU6050 sensor, the system efficiently monitors rider motion and detects potential accidents. The addition of a response module Being able to disable the bike's ignition system adds a critical layer of protection, ensuring the rider is wearing the helmet and is safe to operate the vehicle.

With its modular design and potential for further expansion, such as alcohol detection, CAN communication, and GPS-based emergency response, the system lays the foundation for a smarter and safer riding experience. This project not only addresses common safety concerns for motorcyclists but also demonstrates the effective application of embedded systems in real-world scenarios.

9 References:

Github-ESP-32-Smart-Helmet

Bhatti F., A Novel Internet of Things-Enabled Accident Detection and Reporting System for Smart City Environments (2019), https://doi.org/10.3390/s19092071

Kauai Labs, Inc., Collision Detection (FTC), (2023), Link to the article

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