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CRASH SHIELD: AN ADVANCED AIRBAG SYSTEM FOR ENHANCED RIDER SAFETY

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Abstract: Two-wheeler riders are exposed to severe injury because motorcycles and scooters lack the passive protection available in enclosed vehicles. This paper presents an integrated smart helmet that combines preventive, protective, and responsive safety functions. Arduino Uno acts as the central controller. An MQ-3 alcohol sensor evaluates ethanol vapor, while an infrared sensor verifies helmet usage. A relay-based ignition interlock permits vehicle operation only when the helmet is worn, and the alcohol reading is below a preset threshold. During riding, an MPU6050 inertial sensor measures three-axis acceleration and angular velocity to identify a high-impact event followed by orientation change and post-impact inactivity. After accident confirmation, a second relay drives a DC geared motor that opens a compressed-gas cylinder valve to inflate a protective airbag. A GSM module simultaneously transmits an emergency SMS to predefined contacts. The proposed architecture therefore addresses prevention of unsafe riding, impact protection, and emergency response in one low-cost embedded platform.

Keywords: Smart helmet, Alcohol detection, Helmet detection, Accident detection, MPU6050, Airbag deployment, Arduino Uno, GSM, Rider safety.

I. INTRODUCTION

Two-wheelers are widely used because of their affordability, accessibility, and suitability for congested roads. However, riders have limited physical protection during a collision. The source project identifies helmet non-usage, alcohol-impaired riding, absence of passive protection, delayed emergency response, and lack of integrated safety functions as major challenges. The proposed system treats rider safety as a three-stage problem: prevention before the ride, protection during a crash, and response after a crash.[1],[2] The system uses an Arduino Uno as the central embedded controller. The helmet contains an infrared sensor for wear detection, an MQ-3 alcohol sensor positioned near the rider's mouth, and an MPU6050 accelerometer/gyroscope for crash detection. Relay 1 controls ignition, while Relay 2 controls the airbag actuator. A GSM module provides automatic emergency messaging. The design is intended to be modular, affordable, and adaptable to different two-wheeler platforms.[2]

II. RELATED WORK

Research on motorcycle rider safety systems has investigated the use of motorcycle-mounted airbags, wearable airbag jackets, accelerometer-based crash detection, and intelligent sensor-based protection mechanisms. Honda developed a motorcycle airbag system designed to reduce rider injuries during frontal collisions by limiting forward movement during an impact of:

[1] Dainese introduced the D-Air wearable airbag system, which uses electronic sensors to detect accident conditions and provide protection to the rider’s upper body.
[2] Alpinestars developed the Tech-Air airbag system, incorporating electronic sensors and algorithms to detect crashes and automatically activate protective airbags
[3] Other research has examined accelerometer- and gyroscope-based accident detection techniques for identifying abnormal motorcycle movements, sudden impacts and rider falls
[4] Studies have also explored multi-sensor crash detection methods to improve detection accuracy and reduce false triggering in motorcycle airbag systems.
[5]GPS- and GSM-based accident detection systems have been investigated for transmitting emergency alerts and sharing accident locations with predefined contacts

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III. PROPOSED SYSTEM AND METHODOLOGY

A. System Architecture

The proposed system consists of five functional subsystems: helmet detection, alcohol detection, ignition control, accident detection with airbag deployment, and emergency alerting. The vehicle's 12 V battery supplies the system, with regulated 5 V power for the Arduino and low-voltage sensors. The MPU6050 is mounted on the helmet to capture rider-head motion, while the controller and relay circuitry may be placed in a protected enclosure on the vehicle.

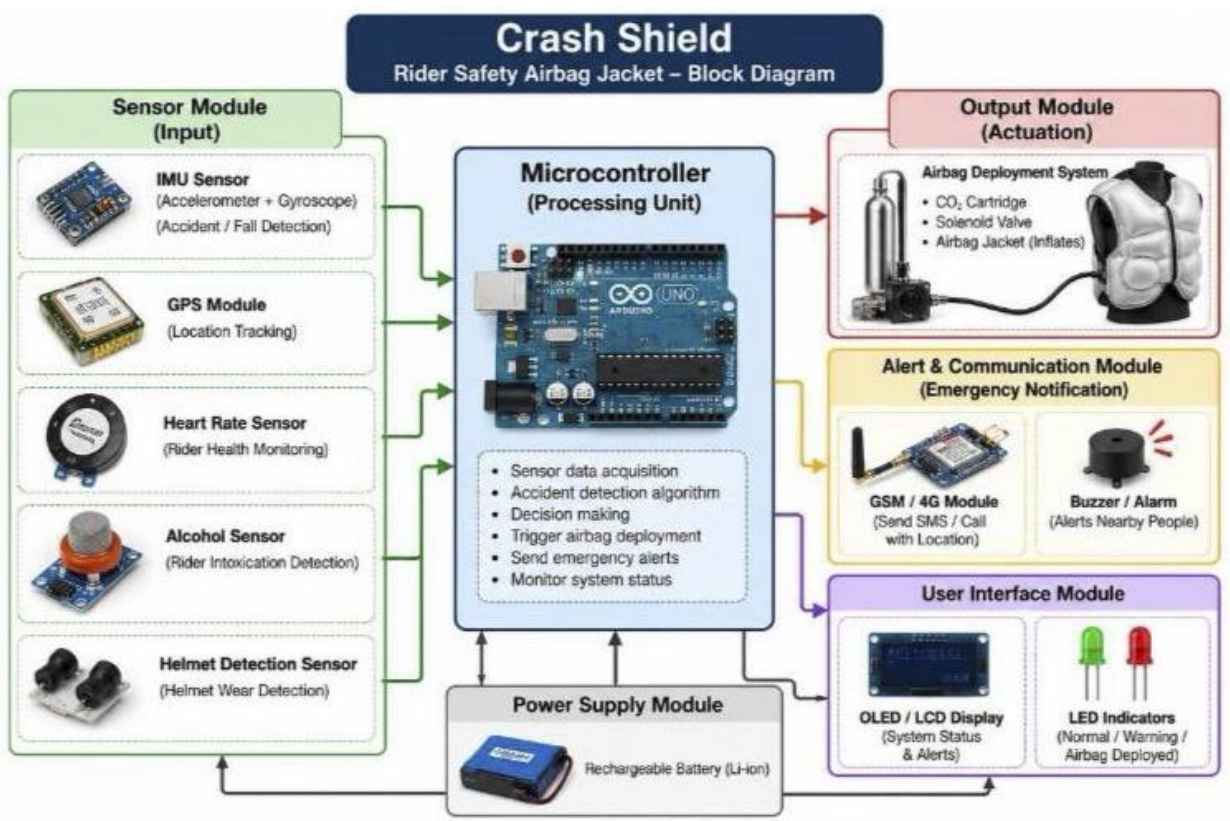


Fig. 1 Overall system architecture of the proposed Airbag system

1. SENSING UNIT

The sensing unit continuously monitors the rider's movement and surrounding conditions to identify abnormal events. An accelerometer and gyroscope can be used to measure linear acceleration, sudden deceleration, tilt, angular velocity, and changes in body orientation. An impact or vibration sensor can provide additional information during a collision. The sensor data is continuously transferred to the microcontroller for real-time analysis.

2. PROCESSING UNIT

The processing unit acts as the central controller of the system. An ESP32, STM32, or Arduino based microcontroller receives data from the sensors and processes it using a programmed accident detection algorithm. It evaluates parameters such as acceleration, angular velocity, impact intensity, and orientation to determine whether the rider has experienced a potentially serious accident.

3. DECISION AND SAFETY LOGIC

The decision and safety logic are responsible for distinguishing an actual accident from normal riding conditions such as sudden braking, turning, or small bumps. The controller compares sensor readings with predefined thresholds and evaluates multiple parameters before initiating deployment. This multi-parameter approach helps reduce false triggering and ensures that the airbag is activated only when a significant crash condition is detected.

4. AIRBAG UNIT

The airbag unit provides physical protection to the rider during a collision. When an accident is confirmed, the controller activates the airbag deployment mechanism, which rapidly inflates airbags positioned around critical areas such as the

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chest, back, shoulders, and neck. The inflated airbag helps absorb impact energy and reduces the possibility of severe injury to vital body regions.

5. LOCATION UNIT

The location unit uses a GPS module to determine the rider's geographical position. During an emergency, the GPS obtains the rider's latitude and longitude coordinates and makes this information available to the communication system.

6. COMMUNICATION UNIT

The communication unit enables the jacket to transmit emergency information to external devices or contacts. A GSM/LTE communication module can send an emergency SMS or data notification containing the accident status and GPS coordinates. Bluetooth or smartphone connectivity can also be incorporated to communicate with a mobile application for monitoring and emergency notifications.

7. ALERT UNIT

The alert unit provides immediate indication of an accident or emergency condition. It can include a buzzer, LED indicators, and smartphone notifications. After detecting a possible accident, the system can provide an audible or visual warning and, depending on the system's design, allow a short cancellation period to prevent false emergency alerts. If the accident is confirmed, an emergency notification can be transmitted automatically.

8. POWER SUPPLY UNIT

The power supply unit provides electrical energy to the sensors, microcontroller, GPS, communication module, and other electronic components. A rechargeable lithium-ion battery with suitable protection and voltage-regulation circuitry can be used. The power-management system ensures that each component receives the required voltage while incorporating battery protection against conditions such as overcharging, over-discharge, and short circuits.

9. MANUAL EMERGENCY AND SAFETY UNIT

The manual emergency unit provides the rider with an additional method of requesting assistance. A dedicated SOS button can be integrated into an easily accessible position on the jacket. When pressed, the system can send an emergency notification along with the rider's GPS location. The overall safety architecture should also incorporate fail-safe design principles, secure electrical isolation of the deployment circuit, and reliable system-status indication to improve operational safety

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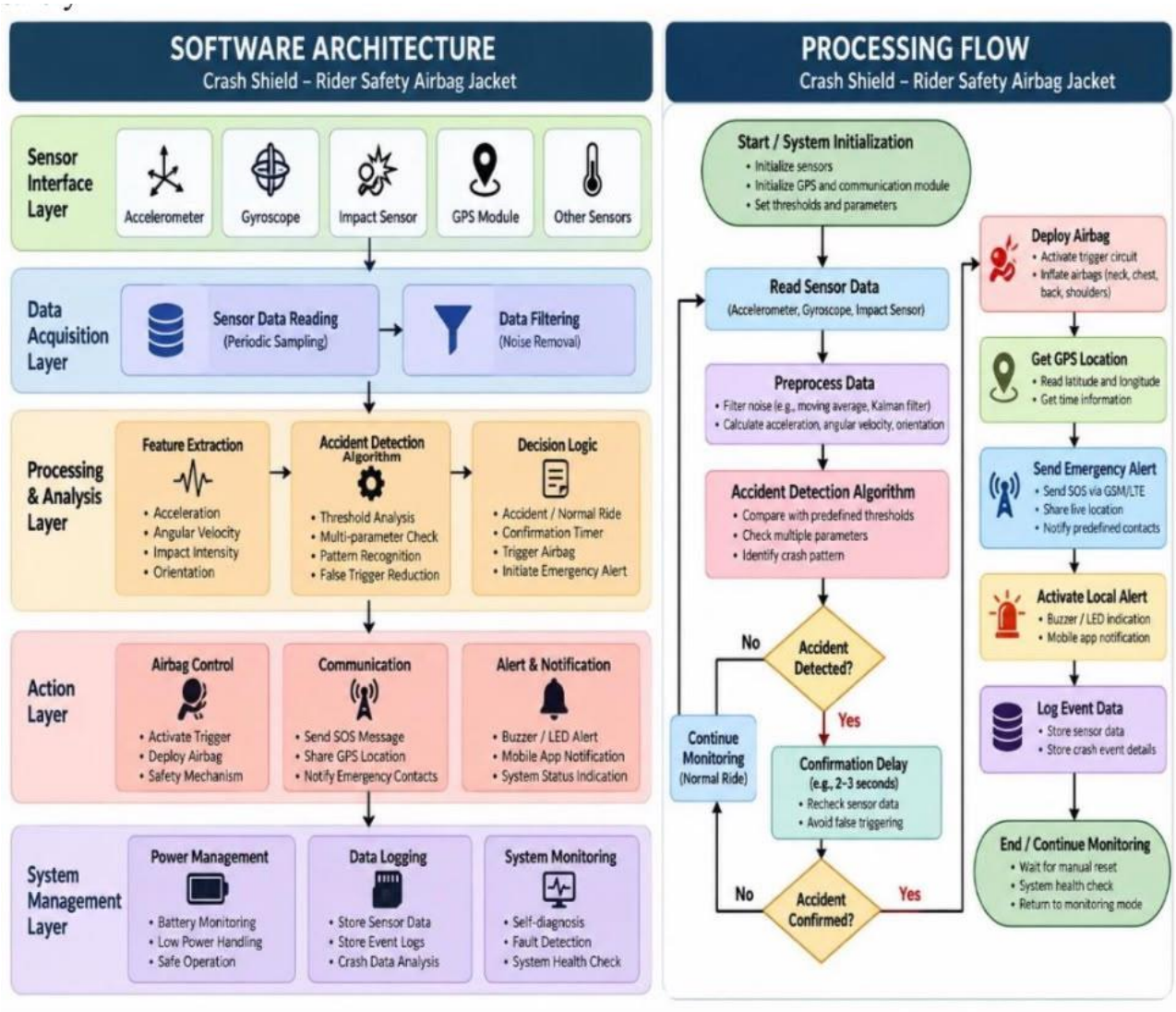


Fig. 2 Software architecture and processing flow of the proposed airbag system.

IV. RESULTS AND DISCUSSION

The airbag system successfully detected sudden crash conditions using the MPU6050 sensor and automatically triggered airbag deployment through the relay mechanism. The prototype demonstrated a quick response and provided additional protection to the rider's chest, back, and neck. The results show that the system can enhance motorcycle safety, although further testing is needed to improve accuracy and reduce false deployment.

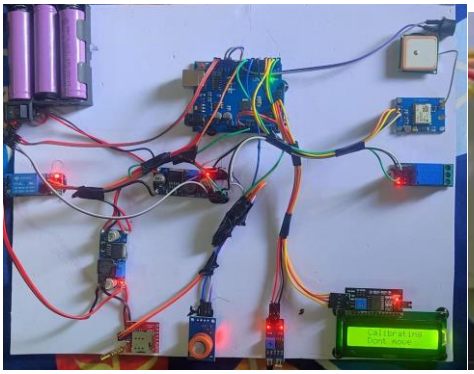


Fig (a)



Fig (b)

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Fig (c)



Fig (d)



Fig (e)



Fig (f)



Fig. 5 g



Fig 5.h

C. Fig.5 Real-time display outputs of the airbag system

Fig.(a)&(b) elaborates that the complete Crash Shield electronic prototype is assembled with the Arduino Uno as the main controller. The sensors, GPS, communication module, relay, LCD, and power management circuits are interconnected. The battery supplies power to the system, and all modules are activated for operation. The prototype is ready for initialization and functional testing, and the system enters the sensor calibration stage after power-up. The LCD displays “Calibrating - Don’t move”, indicating that initial motion and acceleration values are being recorded. Baseline values are established under stationary conditions. This calibration prepares the system for reliable accident detection.

Fig.(c)&(d) describes the LCD display “Wear Helmet & No - Alcohol”, indicating that the system has completed its initial checks and is verifying rider safety conditions. The rider is prompted to wear the helmet before the system becomes

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fully active, while the alcohol detection sensor checks for alcohol presence. If the conditions are satisfied, the system proceeds to safety monitoring and enables the airbag protection mechanism and after successful calibration, the LCD displays "Safety Mode ON", indicating that the system has entered active monitoring mode. The controller continuously receives data from the motion sensors and compares the readings with predefined safety thresholds. Under normal conditions, the airbag remains in standby. The system is ready to detect abnormal motion associated with an accident.

Fig.(e)&(f) shows the LCD displays "ACCIDENT DETECTED", indicating that the system has identified a condition corresponding to a possible accident based on the sensor readings. The Arduino processes the detected motion data and initiates the programmed emergency response. This event can trigger the airbag inflation mechanism to provide protection to the rider. The system can also activate the GPS and communication modules for emergency location tracking and alert transmission, and the photograph shows the complete integration of the electronic control system with the rider's safety airbag jacket. The Arduino processes sensor information and controls the relay and inflation mechanism. The GPS and communication modules provide location and emergency-alert functionality. The integrated prototype is ready for accident detection and airbag deployment testing.

Fig.(g)&(h) briefs the photograph shows the rider safety airbag jacket in its normal deflated condition. The inflatable chambers are folded within the protective textile covering and secured using the harness and straps. The inflation mechanism and tubing are connected to the airbag assembly. The jacket remains compact during normal riding and is prepared for deployment when an accident is detected. and the photograph shows the airbag jacket and its inflation mechanism used for rider protection. When a valid accident condition is detected, the controller can activate the inflation mechanism through the triggering circuit. Air is supplied to the inflatable chambers, causing them to expand around the rider's upper body. The inflated structure is intended to provide additional protection during an accident.

V. CONCLUSION AND FUTURE SCOPE

The EXG-Based Smart Wheelchair with ESP32 and IoT Control combines bio signal acquisition, embedded processing, wireless communication, motor actuation, obstacle detection and smartphone-based control. The Bio Amp EXG Pill module acquires electrical signals through electrodes, the transmitter ESP32 identifies predefined commands, and ESP-NOW transfers these commands to the receiver ESP32. The receiver operates the DC motors through the L298N driver and uses an ultrasonic sensor to stop movement when an obstacle is within the configured safety distance. Blynk provides an additional manual control and monitoring interface.

The project establishes a prototype platform for assistive mobility. Future work identified in the report includes AI-based signal processing, additional obstacle sensors, battery-level monitoring, voice control, emergency alerts, improved battery management, and ergonomic improvements. Further testing should quantify signal-recognition performance, obstacle response, communication reliability, operating time, and safe operation with representative users.

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