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Iot Based Smart Helmets For Mining Workers

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Abstract: - This project presents the development of a smart helmet system tailored for mining workers, aimed at enhancing safety, health monitoring, and communication in hazardous industrial environments. The helmet integrates advanced sensors, including a pressure sensor and MPU6050 motion sensor, powered by a NodeMCU microcontroller and a 3.7V Li-Ion rechargeable battery. Real-time monitoring of critical parameters, such as helmet wear status, worker movement, and environmental conditions, ensures timely feedback and proactive safety management. The system transmits sensor data to an IoT platform like Blynk for remote supervision while providing local alerts through a buzzer for immediate wearer notifications.

Designed with portability and comfort in mind, the helmet detects falls and hazardous conditions, notifying supervisors promptly. Future enhancements are envisioned, including gas detection, heart rate, and oxygen level monitoring, integration of AI for predictive safety, and augmented reality (AR) features for hazard visualization. Scalable and adaptable, the system is suitable for diverse industries such as construction, oil and gas, and firefighting. This comprehensive solution aims to revolutionize worker safety through innovative technologies, facilitating proactive risk management and accident prevention in high-risk environments.

I. INTRODUCTION

Mining is a critical industry that provides essential raw materials like metals, minerals, and coal, underpinning various sectors of the global economy. However, it is also one of the most hazardous occupations, with workers facing significant risks such as falling debris, exposure to hazardous gases, unstable environmental conditions, and accidental falls. These dangers often lead to severe injuries or fatalities, underscoring the urgent need for advanced safety solutions. While technological advancements have improved mining equipment and processes, ensuring worker safety in such high-risk environments remains a persistent challenge.

The **IoT-based Smart Helmet for Mining Workers** addresses these safety concerns by offering an intelligent, wearable solution tailored to the unique needs of mining personnel. This innovative helmet integrates cutting-edge sensor technologies with Internet of Things (IoT) capabilities to enable real-time monitoring of both the worker's condition and the surrounding environment. By facilitating proactive responses to potential hazards, the system aims to significantly reduce workplace accidents and improve overall safety standards.

Key components of the smart helmet include a pressure sensor to ensure proper helmet usage, an MPU6050 module (combining an accelerometer and gyroscope) for detecting falls and abnormal movements, and a buzzer for immediate auditory alerts in unsafe conditions. Environmental monitoring is achieved through a temperature sensor that tracks ambient conditions, helping to prevent heat stress or hypothermia. The collected data is transmitted to the Blynk IoT platform, allowing supervisors to remotely monitor worker safety, receive real-time alerts, and respond quickly in emergencies, thereby reducing response times and improving incident management.

By leveraging compact, cost-effective components, the proposed smart helmet offers a scalable, practical solution that can be implemented across mining operations of various scales. Beyond its practicality, the system is designed for ease of use, ensuring accessibility for workers and supervisors alike. This project highlights the transformative role of IoT in enhancing occupational safety and aims to set a benchmark for safety innovations in high-risk industries.

II. LITERATURE SURVEY

This literature survey reviews previous work related to IoT-based safety systems, emphasizing significant contributions in the fields of IoT and knowledge-based expert systems. These systems demonstrate the potential of IoT technologies to address critical challenges in safety, monitoring, and efficiency across various domains.

- **Real-Time Monitoring Gaps:** Delays in hazard detection and response due to dependency on IoT connectivity.
- **Environmental Monitoring Limitations:** Lack of advanced sensors for comprehensive environmental parameter monitoring, such as toxic gases or structural integrity.
- **Data Processing Speed:** Slower processing speeds in some systems reduce the effectiveness of real-time monitoring.
- **Cost Barriers:** High initial setup and implementation costs make adoption challenging for smaller mining operations.
- **Predictive Analytics Absence:** Lack of AI or machine learning integration for predictive safety measures and proactive risk management.
- **User Comfort:** Some designs lack ergonomic

considerations, making them less suitable for extended use.

➤ Proposed System

Following the problems identified in the existing system, the solutions proposed are:

Parameter	Paper 1: IoT-based Smart Security Helmet for Miner's Safety (P. Kunekar et al., 2023)	Paper 2: IoT-based Smart Helmet for Automated Monitoring (S. Karna et al., 2022)	Paper 3: Smart Helmet with Enhanced Protection (A. Banik et al., 2023)	Paper 4: Tracking System for Coal Miners Using IoT (S. Venkatesh Kumar et al., 2022)
Technology Used	IoT, real-time monitoring, wireless communication	IoT-based automated health hazard monitoring	IoT communication, multi-sensor integration	IoT and GPS-based tracking system
Sensors	Gas sensors, temperature sensors, pressure sensors	Gas sensors, temperature sensors, heart rate sensors	Gas sensors, temperature sensors, accelerometers	Gas sensors, temperature sensors, GPS
Microcontroller Used	Arduino UNO	Arduino Nano	Arduino UNO	Arduino-based system
Data Processing	Sensor data processed to detect hazardous gases and unsafe conditions	Multi-parametric monitoring with real-time data analytics	Real-time sensor data processing	Data processing to integrate GPS tracking and safety monitoring
Output Format	Alerts (visual and auditory) via wireless communication	Real-time alerts for health and environmental hazards	Visual and auditory alerts	GPS-based location tracking and safety alerts
Advantages	Real-time safety monitoring, efficient hazard detection	Comprehensive health monitoring for miners	Robust Safety and Monitoring features	Real-time tracking and enhanced situational awareness
Limitations	Limited scalability and underground connectivity challenges	Power consumption issues and dependency on IoT connectivity	High initial implementation cost	Connectivity challenges in underground environments

TABLE 1: Comparative Study of Research Papers

➤ Problems Identified

From the Literature Survey carried out, several problems were identified. They are:

- **Connectivity Issues:** Difficulty in maintaining reliable communication in underground mining environments due to limited network coverage.
- **Scalability Constraints:** Limited capacity for widespread implementation in large-scale mining operations.
- **Power Consumption:** High power requirements reduce operational lifespan and increase maintenance needs.
- **Sensor Integration Challenges:** Difficulty in integrating multiple sensors while maintaining system efficiency and compactness.

Key Features:

- **Helmet Wear Detection:** Embedded pressure sensor (push button) ensures the helmet is worn. Triggers an audible alarm and sends notifications to supervisors via Blynk IoT platform if the helmet is removed for over 15 seconds.
- **Fall Detection:** Uses the MPU6050 sensor (accelerometer and gyroscope) to monitor helmet orientation. Detects falls or abnormal movements, triggering alarms and real-time alerts for quick intervention.
- **Environmental Monitoring:** Measures temperature with the MPU6050 sensor to prevent heat stress or hypothermia. Provides real-time data for preventive action.

- Real-time Alerts and Monitoring: Integrated with the Blynk IoT platform for supervisors to monitor helmet status, fall alerts, and environmental conditions via smartphones or computers.

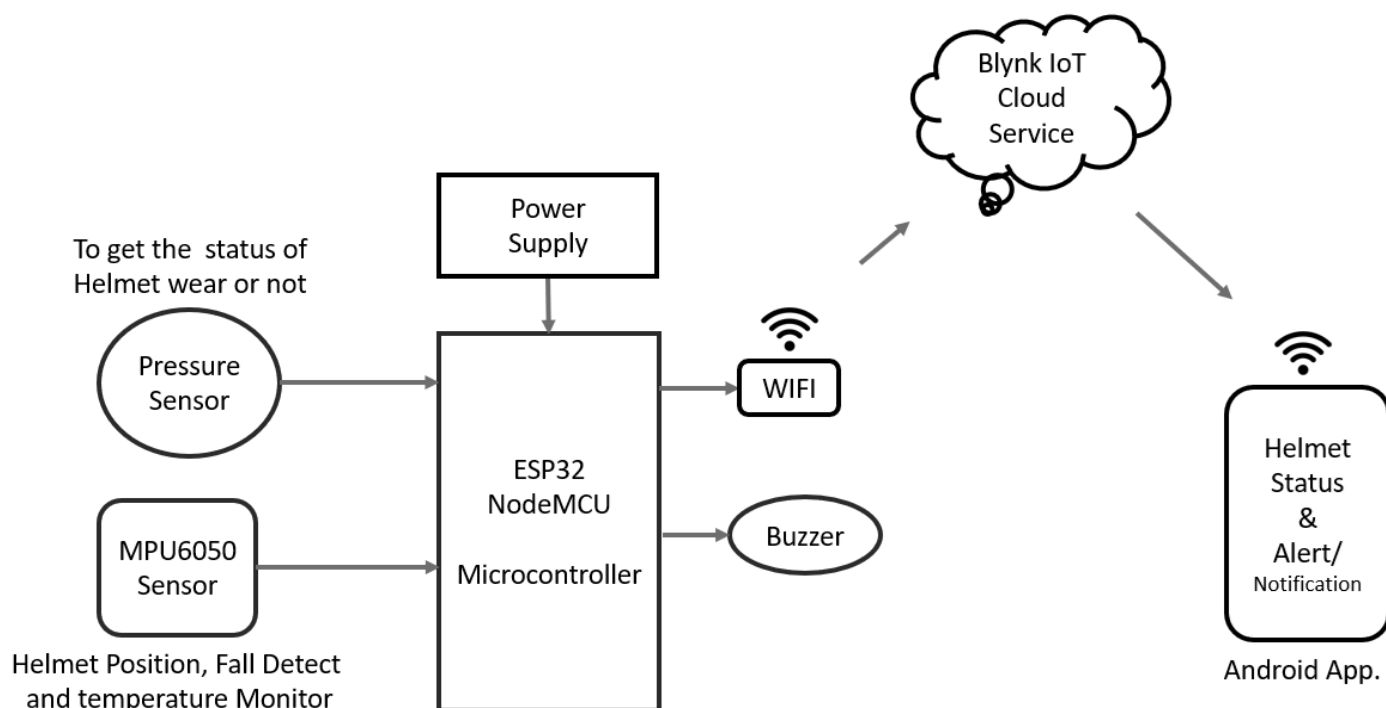


Fig. 1: Block diagram of Iot-based Smart Helmet for Mining Workers

- Power Supply:** Powered by a rechargeable 3.7V Li-Ion battery, ensuring portability and uninterrupted operation.

Advantages:

- Automated Monitoring:** Reduces human error by automating safety inspections.
- Real-time Alerts:** Enables faster emergency responses.
- Enhanced Compliance:** Promotes consistent helmet usage, reducing preventable injuries.
- Cost-effective:** Affordable components make it scalable for large mining operations.
- Worker Confidence:** Creates a safer working environment, boosting morale and productivity.

➤ Hardware and Software Requirements

The block diagram of the components are shown in Fig. 1

- The Hardware Components of the Project are:
 - ❖ NodeMCU ESP32
 - ❖ Pressure Sensor (Push Button)
 - ❖ MPU6050 Sensor
 - ❖ Buzzer
 - ❖ Connecting wires
 - ❖ Breadboard
 - ❖ Power supply
- The Software Components of the Project are:
 - ❖ Arduino IDE
 - ❖ Blynk IOT Cloud and its Android application.

III. METHODOLOGY

The methodology of implementing the IoT-based Smart Helmet for Mining Workers consists of several layers that function cohesively to enhance worker safety in hazardous environments. The structure of the system can be broken down into three primary layers: the Input Layer, Processing Layer, and Output Layer.

1. Input layer

The input layer involves the integration of sensors that capture vital data about the mining worker's safety status and environmental conditions. The two primary sensors used in this project are:

- Pressure Sensor:** This sensor detects whether the helmet is being worn properly by the worker. If the helmet is removed or improperly worn, it sends a signal to the NodeMCU, indicating the unsafe condition.
- MPU6050 Sensor:** This is a motion tracking device consisting of a 3-axis accelerometer and a 3-axis gyroscope. It helps in detecting any abrupt movements, such as falls or sudden head tilts, which could indicate an accident or emergency. The MPU6050 also collects data on the worker's orientation, helping to determine whether the worker is in a vulnerable position that requires immediate attention.

These sensors work in tandem to collect data in real time, which is essential for monitoring the worker's status in the mining environment.

2. Processing Layer

Once the data is captured by the sensors, it is sent to the NodeMCU microcontroller for processing. The NodeMCU, a Wi-Fi-enabled development board, serves as the brain of the system, responsible for analyzing the sensor inputs and making decisions based on predefined conditions. The processing layer handles the following:

- **Helmet Wear Status:** The NodeMCU checks the data from the pressure sensor to determine if the helmet is being worn correctly. If the helmet is not worn, it triggers an alert to notify the worker and the monitoring system.
- **Fall Detection:** The data from the MPU6050 accelerometer and gyroscope is processed to detect any abnormal or sudden movement, such as a fall or an unexpected head motion. If a fall is detected, the system classifies the situation as an emergency and takes appropriate action.
- **Environmental Monitoring:** The NodeMCU is capable of processing environmental data, such as temperature or humidity (if additional sensors are included), to ensure that the worker is not exposed to dangerous conditions. If the environment becomes hazardous (for example, excessive heat or toxic gases), the system can issue a warning or trigger an alert.

The processing layer is where all the decision-making occurs. The microcontroller evaluates the inputs, performs safety assessments, and prepares the appropriate responses.

3. Output Layer

The output layer consists of two key components that act on the processed data and alert the worker and supervisors:

- **Local Alerts (Buzzer):** If an unsafe condition is detected, such as improper helmet wear or fall detection, the system triggers a buzzer. The buzzer serves as a local, immediate alert to the worker, notifying them of a potential danger, prompting them to take corrective action, or seeking help if necessary.
- **Real-Time Notifications (Blynk IoT Platform):** In parallel to the local alerts, the NodeMCU sends the processed data and any critical alerts to the Blynk IoT platform. This enables real-time monitoring of the worker's safety. Supervisors or remote personnel can monitor the status of each worker via the Blynk platform, receiving notifications about helmet wear status, fall detection events, and environmental conditions. The data sent to Blynk can include information such as worker location, helmet status, fall alerts, temperature, and any other relevant safety parameters.

This output layer ensures that the worker is immediately alerted to any safety issues, while also providing supervisors or emergency responders with vital information, allowing for quick action in case of an incident.

➤ Data Flow and Interaction

The data flow between the sensors, NodeMCU, and output components follows a logical sequence:

- **Data Collection:** The sensors continuously monitor the worker's condition and the environment, capturing relevant data such as whether the helmet is on, if a fall has occurred, and the surrounding environmental conditions.
- **Data Processing:** The NodeMCU processes this data to evaluate the safety status. It makes real-time decisions based on preset thresholds for helmet wear, fall detection, and environmental conditions.
- **Alert Generation:** Based on the processing outcome, the NodeMCU triggers alerts in two forms: a local buzzer alert for the worker and remote notifications sent to the Blynk IoT platform for monitoring and analysis.
- **Continuous Monitoring:** The IoT platform provides ongoing monitoring and ensures that any critical alerts or safety breaches are immediately visible to supervisors, enabling rapid intervention.

By using this layered approach, the system ensures continuous safety monitoring, allowing for prompt response to unsafe situations. The integration of IoT allows for seamless communication and real-time alerting, significantly enhancing the safety and security of workers in hazardous environments such as mine.

➤ Flowchart

Fig. 2 represents a smart monitoring system utilizing pressure and motion sensors integrated with IoT cloud services and a mobile application. The system begins by initializing the sensors, ensuring they are operational and ready to collect data. These sensors continuously monitor the environment, detecting physical pressure or movement.

Once data collection starts, the system evaluates the sensor readings against a predetermined safety threshold. If the threshold is exceeded, indicating a potential hazard or anomaly, the system triggers a series of immediate actions:

1. A buzzer is activated as a physical warning signal.
2. A notification is sent to the user's mobile application, ensuring the user is promptly informed, even if away from the device.

If the sensor readings remain within safe limits, the system follows an alternative process. It updates the mobile application in real time to display current sensor data, enabling continuous monitoring. Additionally, the data is uploaded to an IoT cloud platform. This cloud integration supports:

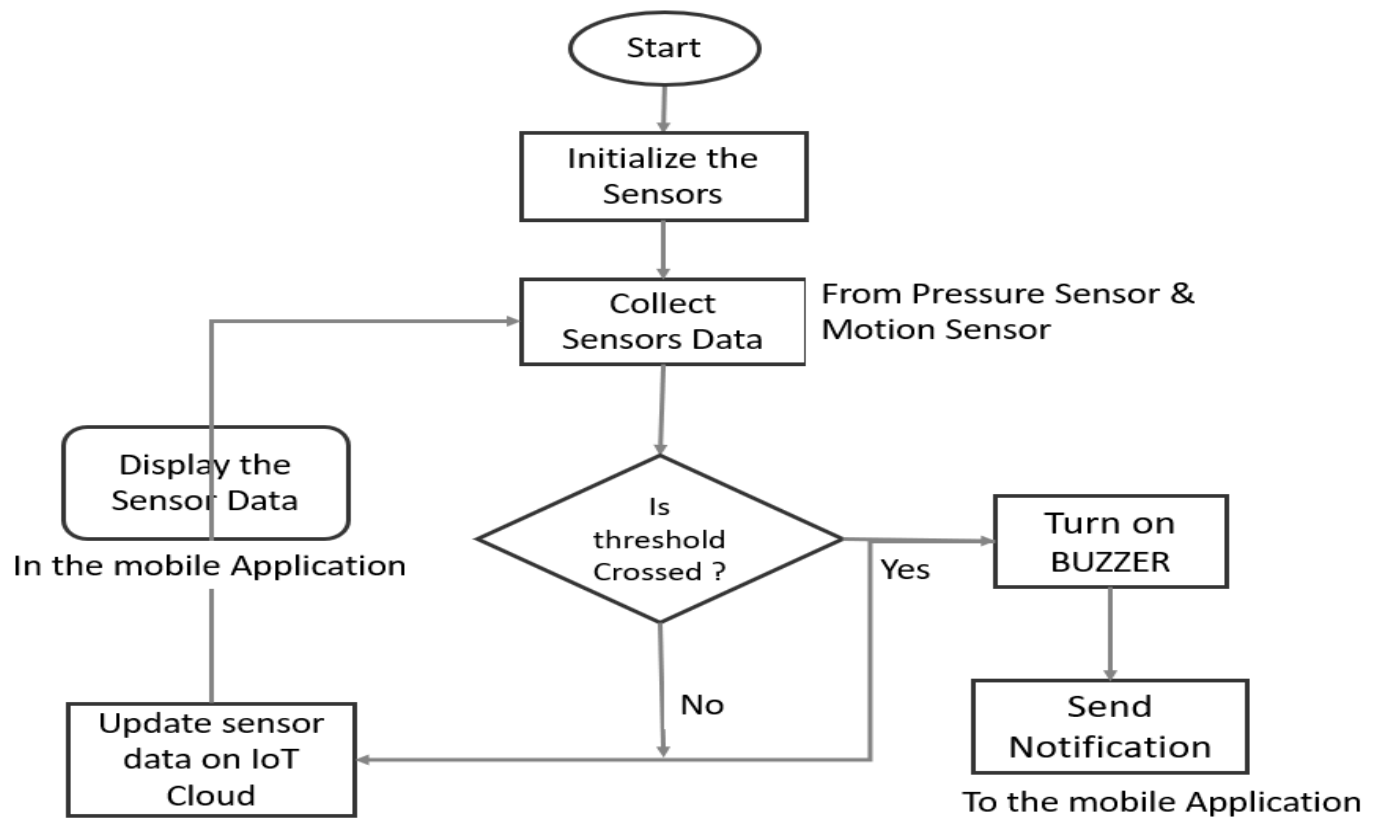


Fig 2: Flow chart of the IoT-based Smart Helmet for Mining Workers

- Remote access to historical sensor data.
- Advanced data analytics for pattern detection and optimization.
- System improvements through long-term data insights.

This system provides a comprehensive, real-time monitoring and alert solution. Immediate notifications and warning signals enhance user safety, while IoT cloud technology ensures efficient data management and advanced analytics. The mobile application adds convenience and accessibility, making the system versatile for applications in smart homes, industrial safety, and healthcare monitor.

IV. RESULTS

➤ The Helmet setup

Fig. 3 showcase the internal and Fig. 4 showcase the external setup of the smart helmet, providing a clear view of the system's design and components. The internal setup image illustrates how the various components, including the 3.7V Li-Ion battery, NodeMCU, MPU6050 sensor, pressure sensor, and buzzer, are securely integrated within the helmet, ensuring that all parts are efficiently connected and protected while maintaining the helmet's comfort and functionality. The external part of the helmet is also depicted, highlighting how the sensors are discreetly positioned for optimal performance, and the overall design remains sleek and ergonomic. These visual representations demonstrate the balance between practicality and user comfort ensuring that the smart helmet remains functional without compromising its usability in a real world working environment.

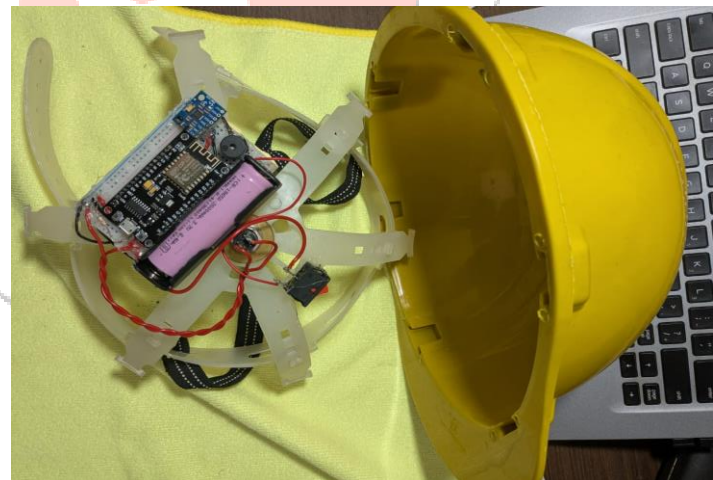


Fig. 3: Internal Setup of the Smart Helmet



Fig. 4: Outer set up of the Smart Helmet

Fig. 5 picture displaying the **Application Interface for Helmet Worn Status** provides a visual representation of how the system monitors and communicates the status of the helmet. This interface showcases the **real-time data** from the **helmet's sensors**, including whether the helmet is being worn by the worker. It likely features a simple, user-friendly layout with a clear indication of the helmet's wear status, perhaps through **color-coded notifications** or an **on/off indicator**. This allows for quick and easy monitoring of the helmet's condition remotely, ensuring that users or supervisors can instantly detect whether the helmet is properly worn. The interface might also display additional data, such as battery status or alert logs,



Fig. 5: Application Interface for Helmet Worn Status

offering a comprehensive overview of the helmet's operational status. This ensures both safety and efficiency in the workplace, making it easier to identify potential issues and take necessary action promptly.

Fig. 6 is the picture illustrating the **Application Interface for Fall Detection** highlights how the system monitors and alerts for any fall events detected by the smart helmet. This interface likely presents real-time data from the **MPU6050 sensor**, which detects sudden changes in motion or orientation, signaling a potential fall. The interface might feature **visual indicators** or **notifications** that immediately alert the user or supervisor when a fall is detected. It could include details such as the exact time of the fall event, its severity, and any additional context, ensuring a quick response to critical situations. The intuitive design allows for easy interpretation of fall detection alerts, providing peace of mind in environments where worker safety is a priority. Additionally, the interface might allow for **logging fall events** and displaying a **history of past detections**, helping supervisors track safety metrics and identify patterns that may require further attention.

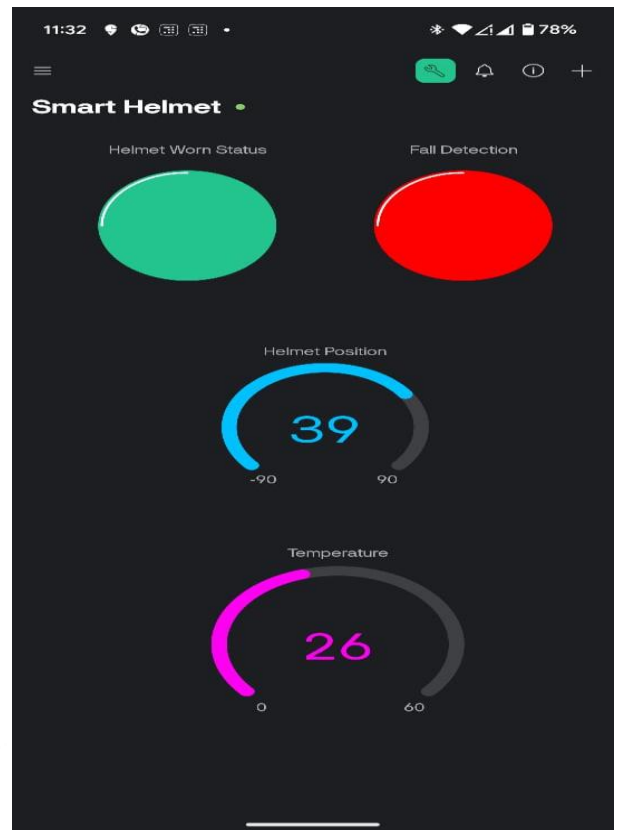


Fig. 6: Application Interface for Fall Detection

V. CONCLUSION

In conclusion, the IoT-based Smart Helmet for Mining Workers is an innovative solution designed to enhance the safety and well-being of workers in hazardous environments like mining. By integrating advanced technologies such as fall detection, helmet wear monitoring, and environmental sensing, the helmet provides real-time alerts and data transmission to supervisors, ensuring quick responses to emergencies. Its lightweight, portable design powered by a rechargeable Li-Ion battery ensures long operational hours without compromising comfort. The helmet not only reduces the risk of accidents but also contributes valuable data for improving safety protocols. Furthermore, its adaptability to other high-risk industries like construction and oil & gas makes it a versatile safety tool. Overall, the smart helmet serves as a comprehensive safety device, significantly improving worker protection and contributing to a safer working environment.

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