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IOT-ENABLED WORKER PROTECTION AND EMERGENCY ALERT SYSTEM FOR MINING INDUSTRIES

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ABSTRACT

Mining is one of the most hazardous occupations, with workers frequently exposed to dangerous gases, high temperatures, low oxygen levels. This project presents an advanced **IoT-based mining safety system** that integrates smart helmets and jackets to ensure real-time monitoring. The **Smart helmet** is equipped with sensors such as **IR, MQ2, MQ135, DHT11, LDR, Flame, O2 sensors, RFID Tag, RFID** and **Vibration sensor** along with an **ESP32 Microcontroller** and a **RF transmitter**. It continuously monitors environmental parameters including gas levels, temperature, humidity, light intensity, dust concentration, and fire presence to detect hazardous conditions. The **Smart Jacket** incorporates a **Gyroscope, Heart Rate Monitor, SPO2 sensor, SOS button, ESP32,** and **RF transmitter t**o track worker health and emergency signals. Both devices communicate wirelessly with the **Control room**, where **RF receivers** (one for helmets and one for jackets) interface with an **ESP32, LCD display, LED, Buzzers,** and the **Blynk IoT platform** for real-time visualization, alerting, and data logging.

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I. Introduction

This project proposes an IoT-based wearable safety and health monitoring system for mining workers, in which environmental conditions are monitored using IR, MQ2, MQ135, DHT11, LDR, Flame, Oxygen, RFID Tag, RFID and Vibration sensors, while worker health and movement are tracked using a Gyroscope, Heart rate sensor, SPO_2 sensor, and SOS button. separate RF transmitters are used in the wearable units to send real-time sensor data wirelessly to the control room, where RF receivers pass the received signals to a Control room ESP32 for processing. The processed data are displayed using an LCD, LEDs, and a Buzzer, and are also sent to the Blynk IoT platform for remote monitoring, enabling quick detection of hazards and timely emergency response to improve mining worker safety.

II. Literature Review

Recent advancements in wearable safety systems
have significantly improved worker protection in hazardous environments. A smart helmet system integrating gas, temperature, and humidity sensors with real-time alert mechanisms using LoRa communication was proposed to enhance mining safety. This system effectively detects environmental hazards and ensures timely alerts, thereby reducing accident risks.In another study, IoT-based worker health monitoring systems were developed using wearable sensors to track physiological parameters such as heart rate and body temperature. These systems transmit data to cloud platforms, enabling remote monitoring and early detection of health abnormalities.

Furthermore, fall detection systems utilizing accelerometers and gyroscopes have been widely implemented to identify sudden worker accidents and trigger emergency alerts. Such systems improve response time during critical situations. However, most existing systems focus either on environmental monitoring or health monitoring independently. The lack of an integrated approach limits overall safety efficiency. To address this gap, the proposed system combines both smart helmet and jacket modules to provide comprehensive real-time monitoring of environmental and physiological conditions, ensuring enhanced worker safety in hazardous industrial environments.

III. Methodology

The proposed system is designed to enhance worker safety in hazardous environments through an integrated smart helmet and jacket equipped with multiple sensors and real-time monitoring capabilities. Initially, various sensors such as gas sensors, temperature sensors, humidity sensors, and heart rate sensors are embedded into the helmet and jacket to continuously collect environmental and physiological data. These sensors are interfaced with an ESP32 microcontroller, which acts as the central processing unit of the system. The collected data is processed in real time and compared against predefined safety thresholds. If any abnormal condition is detected, such as the presence of toxic gases, high temperature, or irregular heart rate, the system immediately triggers an alert mechanism. This includes activating a buzzer and sending notifications to the concerned authorities. For communication, the system utilizes wireless technologies such as Wi-Fi or LoRa to transmit data to a remote monitoring platform. The transmitted data is displayed on a dashboard, enabling supervisors to continuously monitor the worker's condition and environmental status. The overall system operates in a continuous loop of sensing, processing, transmitting, and alerting, ensuring timely detection and prevention of potential hazards in industrial environment

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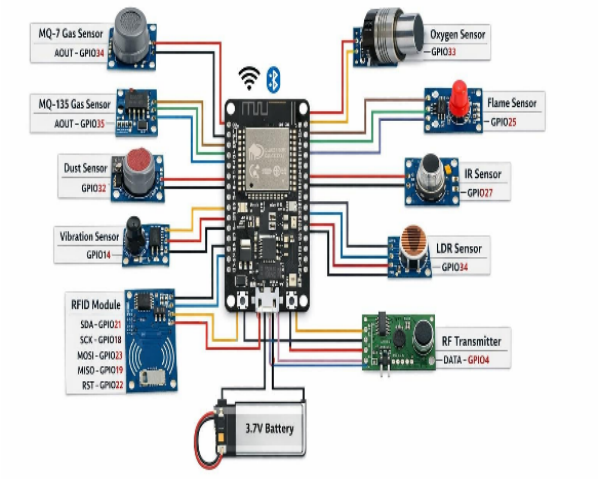
IV. SOFTWARE DASHBOARD

V Hardware Dashboard



Circuit diagram of helmet module **V** .

Methodology with Formula

1. Sensor Data Acquisition

The system collects environmental and physiological parameters:

Gas concentration (CO, CH_4, etc.)

- Temperature (°C)
- Humidity (%)
- Heart rate (BPM)
- Body temperature (°C)
-

2. Signal Processing & Normalization

The raw sensor values are normalized for analysis:

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Where:

- X= sensor reading
- X_{min}, X_{max}= minimum and maximum thresholds

3. Threshold-Based Decision Making

Safety conditions are evaluated using threshold limits:

$$D = \{1,\ if\ X > T_{threshold}\ 0,\ otherwise$$

Where:

- D= danger detection flag
- $T_{threshold}$= predefined safety limit

4. Risk Level Estimation

Overall risk is calculated by combining multiple parameters:

$$R = w_1 G + w_2 T + w_3 H + w_4 HR + w_5 BT$$

Where:

- R= Risk core
- G, T, H, HR, BT= normalized gas, temperature, humidity, heart rate, body temperature
- w_1, w_2,...= weighting factors

5. Alert Generation

An alert is triggered when risk exceeds a critical level:

Outputs include:

- Buzzer alarm
- LED indication
- Notification to mobile/cloud

6. Data Transmission (IoT Communication)

Data is transmitted using IoT protocols such as Wi-Fi / LoRa:

$$Data_{transmitted} = f(Sensors, Network)$$

S. No	Feature	Existing System	Proposed System

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1.	Monitoring type	Manual or limited monitoring	Real time continuous monitoring
2.	Safety equipment	Basic helmet only	Smart helmet+ smart jacket
3.	Health monitoring	Not available	Heart rate and body temperature monitoring
4.	Gas detection	Limited or absent	Advanced gas sensors
5.	Alert system	Manual alert	Automatic alert
6.	Communication	No remote access	IoT based
7.	Data storage	No data recording	Dashboard data storage
8.	Response time	Slow	Instant real time response
9	Worker tracking	Not available	Possible with GPS integration
10	Accuracy	Low	High due to sensor integration

Table I Performance Analysis

VII. Result and Discussion

The proposed Integrated Smart Helmet and Jacket System was successfully implemented and evaluated for real-time monitoring of environmental and physiological parameters, including gas levels, temperature, humidity, heart rate, and body temperature. The system demonstrated accurate data acquisition and efficient transmission using IoT technologies such as Wi-Fi/LoRa. Alerts were generated instantly through buzzer signals and mobile notifications whenever the sensed values exceeded predefined safety thresholds, ensuring quick response to hazardous situations. The integration of multiple sensors in both helmet and jacket provided comprehensive monitoring, improving overall worker safety compared to traditional systems.

The results indicate that the proposed system offers significant advantages such as continuous monitoring, reduced response time, remote accessibility, and cost-effectiveness. It enables better decision-making through real-time data visualization on a centralized dashboard and enhances safety in high-risk environments like mining and construction. However, the system performance may be influenced by network dependency and sensor accuracy under extreme conditions. Despite these limitations, the proposed solution is reliable, scalable, and efficient for improving worker safety and health monitoring in hazardous industrial environments.

VII. Conclusion & Future work

The proposed Integrated Smart Helmet and Jacket System provides an effective solution for enhancing worker safety in hazardous industrial environments. By integrating multiple sensors with IoT technology, the system enables real-time monitoring of both environmental and physiological parameters such as gas levels, temperature, humidity, heart rate, and body temperature. The implementation using ESP32 ensures efficient data processing and communication, while the alert mechanism provides immediate warnings during critical situations. Compared to existing systems, the proposed model offers improved accuracy, faster response time, and continuous remote monitoring. Overall, the system is cost-effective, scalable, and capable of significantly reducing workplace risks and accidents.

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