SMART HELMET FOR COAL MINING WORKERS USING LORA COMMUNICATION

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Keywords:

Smart Helmet, IoT-based Safety System, LoRa Communication, Gas and Health Monitoring, Coal Mining Safety.

Introduction:

Coal mining is a hazardous occupation where workers face risks such as toxic gas leakage, high temperatures, poor ventilation, and sudden accidents, often leading to serious injuries. Traditional safety systems rely on manual monitoring, which is not effective for real-time hazard detection. To improve safety, a Smart Helmet using IoT technology is proposed for continuous monitoring of workers and the environment. It uses sensors like MQ-135 for gas detection, DHT11 for temperature, MAX30102 for heart rate, and MPU6050 for fall detection. An ESP32 microcontroller processes the sensor data and compares it with predefined safety thresholds. If any abnormal condition is detected, alerts are generated through buzzers and display units. LoRa communication enables long-distance data transmission in underground mining environments. Additionally, the data is sent to the ThingSpeak cloud via Wi-Fi for real-time monitoring and faster emergency response.

Objectives:

1. Monitor the worker's heart rate, body temperature and fault/fall conditions continuously.
2. Detect harmful gases present in the mining area using the MQ-135 sensor.
3. Provide instant alerts through buzzers at both helmet and monitoring unit when any parameter crosses the safe limit.
4. Send the measured values wirelessly using LoRa communication to a receiver placed in the mining control room.
5. Display all real-time readings on LCD displays at both transmitter and receiver. Upload the sensor values to a mobile dashboard (ThingSpeak) so that the supervisor/manager can check the worker's status anytime

Methodology:

The proposed system consists of two main units: a transmitter unit (helmet module) and a receiver unit (monitoring station), along with cloud connectivity. The transmitter unit integrates sensors such as MQ-135 gas sensor, DHT11 temperature sensor, MAX30102 heart rate sensor, and MPU6050 motion sensor with the ESP32 microcontroller. Initially, all sensors continuously collect environmental and physiological data. The ESP32 processes

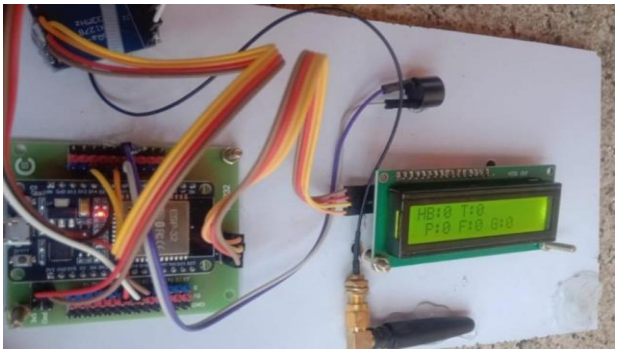
these inputs at regular intervals and compares them with predefined threshold values. The heart rate sensor operates only when proper contact is detected, preventing false alerts. If any abnormal condition occurs, such as high gas levels, increased temperature, abnormal heart rate, fall detection, or panic button activation, the system identifies it as an emergency. Immediately, alerts are generated through a buzzer and displayed on the LCD .The processed data along with alert status is transmitted wirelessly using the SX1278 LoRa module, which ensures reliable long-range communication even in underground mining environments. The receiver unit receives the transmitted data, displays it on an LCD, and activates alerts for supervisors if required. Additionally, the ESP32 uploads real-time sensor data to the ThingSpeak cloud platform using Wi-Fi, allowing remote monitoring through mobile or web dashboards. The system operates continuously in cycles to ensure uninterrupted monitoring. A minimal GPS tracking feature can be integrated in future to provide location information of workers during emergency situations.

Result and Conclusion:

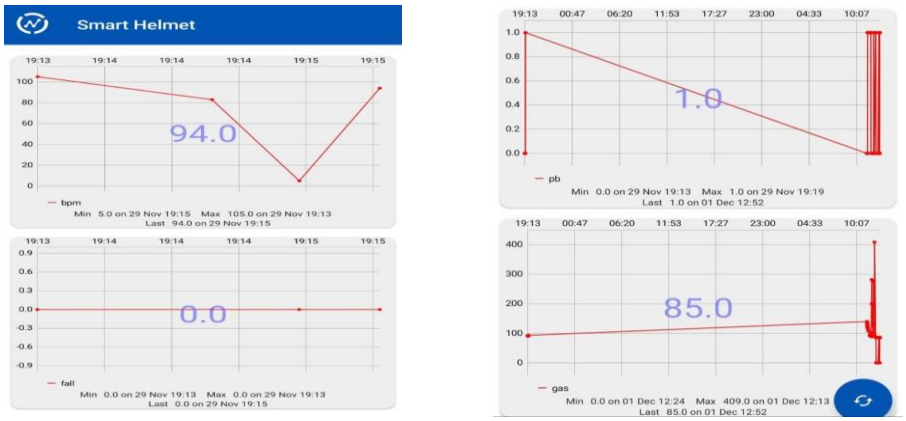
The developed Smart Helmet system was successfully implemented and tested under various conditions to evaluate its performance and reliability. The system effectively monitored environmental parameters such as gas concentration and temperature, along with physiological parameters like heart rate. The prototype demonstrated accurate sensing, real-time processing, and reliable transmission of data using LoRa communication. Experimental results showed that the system was capable of detecting hazardous conditions such as high gas levels, abnormal temperature, worker fall, and emergency panic situations. Upon detection of such conditions, alerts were generated instantly through buzzers and displayed on LCD screens at both transmitter and receiver units. The LoRa communication module ensured stable long-range data transmission with minimal delay, making it suitable for underground mining environments. Cloud integration through ThingSpeak enabled remote monitoring and visualization of real-time data via mobile applications.

Prototype Output Showing
Emergency Condition (Fall / Panic Button)

Prototype Output Showing
Normal Heart Rate and Gas Levels



Output Display When Heart Rate Sensor Is Not Working



ThingView Mobile Application Display

Project Outcome & Industry Relevance:

1. The project resulted in the successful development of a smart safety helmet capable of monitoring both environmental and physiological parameters of coal mining workers. It provides real-time alerts for hazardous situations such as toxic gas exposure, abnormal heart rate, falls, and emergency signals.
2. This system has strong relevance in industries like coal mining, oil & gas, construction, and other hazardous workplaces where worker safety is critical. The use of LoRa communication makes it highly suitable for underground and remote environments where traditional wireless systems fail.
3. The project contributes to the field of embedded systems, IoT, and industrial safety by integrating multiple sensors into a single wearable device. It demonstrates how modern technologies can be applied to improve occupational safety and reduce accidents.
4. In real-world applications, this system can be deployed to continuously monitor workers and provide centralized supervision, enabling faster response during emergencies and potentially saving lives.

Working Model vs Simulation Study:

1. This project is primarily a working model-based system rather than a simulation.
2. A physical prototype of the smart helmet was developed using hardware components such as ESP32, gas sensors, heart rate sensor, temperature sensor, MPU6050, and LoRa modules. The system was tested in real-time conditions to verify its functionality.
3. Unlike simulation-based studies, this project involved actual hardware implementation, sensor calibration, and real-time data transmission. The performance of the system was validated through module-wise testing and integrated system testing.
4. The working model provided practical insights into challenges such as sensor accuracy, communication delays, power consumption, and environmental interference.
5. Therefore, this project emphasizes real-world implementation and practical applicability rather than theoretical or simulated analysis.

Project Outcomes and Learnings:

1. The project successfully achieved its goal of developing a smart helmet for enhancing worker safety in coal mining environments. Key outcomes include real-time monitoring of gas levels, temperature, heart rate, and motion, along with reliable alert generation.

2. During the project, we learned how to integrate multiple sensors with a microcontroller and implement communication using LoRa technology. We gained hands-on experience in hardware design, circuit connections, and PCB-level understanding.
3. We also developed skills in embedded programming using Arduino IDE and implemented cloud integration using ThingSpeak for data visualization.
4. The project improved our problem-solving abilities, especially in debugging issues like sensor noise, communication errors, and false alerts.

References:

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Future Scope:

1. The proposed smart helmet system can be further enhanced with several advanced features to improve its functionality and scalability. One major improvement is the integration of GPS tracking to monitor the exact location of workers, although alternative positioning techniques may be required for underground environments.
2. The system can be upgraded with additional sensors such as oxygen level detection, pressure sensors, and advanced gas sensors for better environmental monitoring. Battery optimization techniques can be implemented to improve power efficiency and extend operational time
3. Integration of machine learning algorithms can help in predictive analysis of hazardous conditions, enabling early warning systems. The system can also be enhanced with mobile applications featuring real-time notifications and analytics dashboards.