OXYGEN LEVEL MONITORING SYSTEM FOR COAL MINING WORKERS

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Abstract

The proposed smart helmet is designed to enhance the safety and well-being of coal mine workers by integrating real-time oxygen level monitoring. Coal mines pose significant risks due to the potential presence of hazardous gases and low oxygen levels, which can lead to life-threatening situations. The smart helmet addresses this issue by incorporating advanced sensors capable of continuously measuring the oxygen concentration in the surrounding environment. The helmet features a compact, lightweight design to ensure comfort and ease of use for the workers. It includes a built-in display and auditory alerts that notify the wearer if the oxygen levels fall below a safe threshold, prompting immediate evacuation or other safety measures. Additionally, the helmet can transmit real-time data to a central monitoring system, allowing for remote supervision and rapid response in case of emergencies. By combining state-of-the-art technology with practical safety measures, the smart helmet aims to reduce the incidence of accidents and health issues in coal mines, thereby improving overall workplace safety and productivity.

Keywords: Arduino UNO, Bluetooth module, Pulse oximeter (MAX30100)

1.Introduction:

The coal mining industry is one of the oldest and most significant sectors in the global economy, providing essential energy resources. However, the harsh and often perilous conditions encountered in underground mines present numerous challenges to worker safety and health.Among these challenges,low oxygen levels and the potential for exposure to harmful gases such as methane and carbon monoxide are of paramount concern. Prolonged exposure to these hazardous conditions can lead to severe respiratory issues, unconsciousness, and, in extreme cases, fatalities. Despite advancements in safety protocols and technology, incidents still occur, illustrating the urgent need for innovative solutions to better protect miners.

In light of these critical safety concerns, this project introduces the development of a Smart Helmet equipped with an integrated Oxygen Level Monitoring System specifically designed for coal mining workers. The primary goal of this Smart Helmet is to enhance the safety of miners by providing real-time air quality management and ensuring that workers are immediately alerted to any fluctuations in oxygen levels or exposure to toxic gases.The significance of real-time monitoring cannot be overstated; it empowers workers to make informed decisions regarding their environment and enhances their situational awareness while on the job.

Hence this paper focuses on the design and implementation of a Smart Helmet for Coal Mine Workers, integrating real-time oxygen level monitoring and IoT-based automation to enhance worker safety. Section 2 reviews existing safety mechanisms, highlighting the need for continuous monitoring. Section 3 details the proposed system, incorporating oxygen sensors,

a pulse oximeter (MAX30100), Bluetooth communication, and real-time alerts. Section 4 covers system implementation, including sensor deployment and wireless data transmission. Section 5 evaluates the system's effectiveness through real-world testing. Section 6 concludes with key findings and future enhancements like AI-driven hazard prediction and integration with mine safety systems.

2. Literature review and Motivation:

Recent studies emphasize smart helmets with real-time monitoring and alert systems to enhance miner safety. Vishwakarma et al. (2023) introduced a helmet with environmental monitoring, GPS tracking, and a panic button for emergencies. Talpur et al. (2021) focused on secure communication for hazardous gases like methane and carbon dioxide, ensuring real-time tracking to prevent accidents. Sandaruwan and Hettige (2023) advocated for wireless over wired communication to improve underground mining efficiency and safety. Advanced solutions include IoT and AI-driven helmets by Jadhav et al. (2014) with real-time sensor data, Jiang et al. (2024) with 5G communication and UWB positioning, and Kanda (2021) with sensors detecting temperature, humidity, and toxic gases, offering timely alerts through buzzers and vibrations. These innovations highlight the ongoing evolution of smart mining helmets, prioritizing safety and emergency response through advanced technology.Mining is a hazardous occupation with risks like toxic gases, explosions, and collapses. Existing safety measures often fail due to a lack of real-time monitoring and delayed emergency response. Advancements in IoT, sensors, and wireless communication provide an opportunity to enhance worker safety. This paper aims to develop a smart helmet with real-time environmental monitoring, GPS tracking, and emergency alerts to reduce accidents and improve rescue operations.

3.Proposed methodology:

The proposed system integrates a Bluetooth communication module, microprocessor, and oxygen sensors. The system uses SpO2 sensors to continuously check the workers' oxygen levels, and when those levels fall below a set threshold, it warns mobile devices. The approach consists of several major components and processes, which are described below.

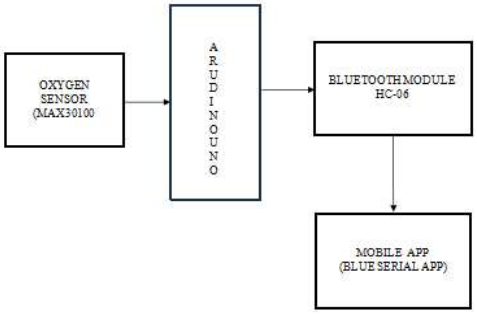

Fig1: Block Diagram

Design Flow :

- **Sensor Integration**: The sensor connects to the microcontroller's analog input. Calibration ensures accurate oxygen concentration readings.
- **Data Acquisition & Handling**: The microcontroller converts the analog sensor data to digital using its ADC. Digital sensors like MAX30100 use I2C or SPI interfaces for

direct data reading.

- **Data Processing**: The system sets safety thresholds (e.g., oxygen <19.5%, SpO2 <90%) and triggers alerts if levels drop below safe limits.
- **Bluetooth Communication**: Upon detecting a low oxygen level, the microcontroller transmits data serially to the paired mobile device via the bluetooth module. The message includes:

Fig2: Bluetooth Module

i) The current oxygen level (or SpO2 percentage).

ii) A warning that the level is below the safe threshold.

iii) The worker's ID or location, if applicable.

- **Mobile Application**: Using the BlueSerial app, the mobile device displays real-time data and issues visual/auditory alerts. The app can send push notifications or SMS alerts to supervisors and log data for future reference and to improve safety protocols.

Fig3:Blueserial App

- **Software Implementation**: Arduino IDE is an open source software program that allows users to write upload code within a real-time work environment. As this code will thereafter be stored within the cloud, it is often utilize by those who have been searching for an extra level of redundancy. The system is fully compatiible with any arduino software board.

Working Principle of MAX30100 Oxygen Sensor

The MAX30100 sensor uses two LEDs—red and infrared—to measure pulse rate and blood oxygen levels (SpO2). When the heart pumps, the volume of oxygenated blood increases, absorbing more infrared light and allowing more red light to pass through. Conversely,deoxygenated blood absorbs more red light and passes more infrared light. The sensor detects these absorption levels and stores them in a buffer, accessible via the I2C interface.

Fig4:max30100

7. 4.Results & Discussions:

- Normal Range: 20.9-23.1%
- Low: 15-20.9% (may indicate oxygen depletion or sensor issues)
- Critical: <15% (life-threatening, immediate attention required)
- High: >23.1% (may indicate sensor errors or abnormal environmental conditions)

Before connecting the Bluetooth module:

The output indicates the current oxygen level and status. Users can monitor the readings to ensure safe and healthy oxygen levels.

```
07:41:08.900 -> Initializing pulse oximeter..SUCCI
07:41:09.920 -> Heart rate:0.00bpm / SpO2:0%
07:41:10.903 -> Heart rate:0.00bpm / SpO2:0%
07:41:11.940 -> Heart rate:0.00bpm / SpO2:0%
07:41:12.925 -> Heart rate:0.00bpm / SpO2:0%
07:41:13.909 -> Heart rate:0.00bpm / SpO2:0%
07:41:14.253 -> Beat!
07:41:14.953 -> Heart rate:18.76bpm / SpO2:0%
07:41:15.374 -> Beat!
07:41:15.930 -> Heart rate:30.82bpm / SpO2:0%
07:41:16.941 -> Heart rate:30.82bpm / SpO2:0%
07:41:17.948 -> Heart rate:0.00bpm / SpO2:0%
07:41:18.030 -> Beat!
07:41:18.951 -> Heart rate:37.52bpm / SpO2:0%
07:41:19.336 -> Beat!
07:41:19.952 -> Heart rate:41.06bpm / SpO2:0%
07:41:20.746 -> Beat!
07:41:20.918 -> Heart rate:42.56bpm / SpO2:98%
07:41:21.527 -> Beat!
07:41:21.949 -> Heart rate:58.59bpm / SpO2:98%
07:41:22.263 -> Beat!
07:41:22.867 -> Beat!
07:41:22.941 -> Heart rate:84.47bpm / SpO2:97%
07:41:23.841 -> Beat!
```

Fig5: Output of Serial Monitor

After Connecting the Bluetooth Module:

The BPM and SpO2 values on the serial monitor can also monitor the same values on the android cell phone application.

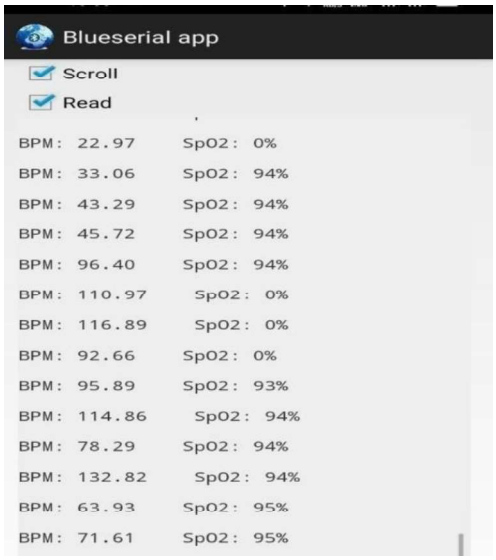

Fig6: Output of Blueserial App

5. Conclusion:

The oxygen level detector for coal mining workers is a vital safety tool designed to enhance safety in hazardous underground environments. By providing continuous real-time monitoring of oxygen concentration, the system ensures immediate alerts when oxygen levels drop below safe thresholds. This proactive approach minimizes the risk of hypoxia, suffocation, and accidents due to reduced alertness. The integration of Bluetooth technology enables wireless monitoring, significantly improving on-site safety. The system also offers a robust foundation for future enhancements, such as adding environmental sensors and introducing remote-control features for emergency responses like ventilation system activation or equipment shutdowns.

6. Future Scope:

Hybrid Communication Protocols: Integrating Bluetooth with other wireless technologies like LoRa, Zigbee, or Wi-Fi to enhance range and reliability in complex underground environments.

Geofencing Alerts: Implementing location-based alerts through the mobile app to provide personalized and context-specific notifications for workers in hazardous conditions.

7. References

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