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Research on Smart Helmet for Coal Miners with Locking System

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Abstract

This paper introduces an IoT-based Smart Helmet designed to enhance the safety of coal miners by combining helmet-lock detection, gas monitoring, automatic work-time tracking, and real-time communication. The system uses NodeMCU (ESP8266) as the main controller, which collects information from the connected components, processes the received data, and communicates the required updates to a web server. The helmet is equipped with a strap-lock detection mechanism that checks whether the safety strip has been properly fastened before the system becomes active. Once the helmet is securely locked, an automatic timer starts and records the miner's working duration. This recorded time can be useful for maintaining attendance details and supporting accurate payroll calculation based on the actual time spent at work. The system also continuously monitors the surrounding mine environment using an MQ gas sensor to identify hazardous and flammable gases that may pose a serious risk to workers. The DHT11 sensor is positioned inside the helmet to monitor the worker's body temperature rather than the surrounding ambient temperature. The complete system is powered by a rechargeable lithium-ion battery, allowing the helmet to operate without depending on a direct power connection during the miner's working shift. At the same time, the NodeMCU enables real-time communication with the web server, where supervisors or authorized personnel can receive information and alerts regarding the helmet status and hazardous conditions.

Keywords: Smart Helmet, Coal Miner Safety, IoT Monitoring.

Introduction

Mining is one of the most demanding and hazardous occupations, where workers are constantly exposed to challenging underground conditions. The presence of toxic and flammable gases, limited visibility, and the possibility of accidents make safety a major concern in coal mines. Although conventional safety helmets provide protection against physical injuries, they are unable to monitor environmental conditions or assist in ensuring worker safety during mining operations. These limitations highlight the need for a smarter and more reliable safety solution. To address these challenges, this paper proposes a Smart Helmet for Coal Miners with Locking System, designed to improve safety through continuous monitoring and real-time communication.

The proposed helmet is equipped with a locking detection mechanism that verifies whether the helmet strap has been fastened properly before use. Once the helmet is securely locked, an automatic timer begins recording the miner's working duration, which can be used to maintain attendance records and support payroll calculation. An MQ gas sensor continuously monitors the surrounding environment for hazardous and flammable gases. If the gas concentration exceeds the safe limit, the system immediately activates an LED indicator and a buzzer to alert the worker. We've also added the DHT11 sensor not for ambient temperature this time, but strategically positioned inside the helmet to detect the worker's body temperature. A green LED indicates that the environment is safe, while the buzzer increases its alert intensity as the gas level rises, helping miners respond quickly to dangerous situations. To ensure uninterrupted operation throughout the work shift, the helmet is powered by a rechargeable lithium-ion battery. In addition, a NodeMCU (ESP8266) module sends real-time notifications through the web server, allowing supervisors outside the mine to receive immediate updates whenever unsafe conditions are detected.

By combining helmet-lock verification, gas monitoring, timely alerts, work-time tracking, and IoT-based communication into a single device, the proposed system offers a practical and reliable approach to improving the safety and well-being of coal miners.



Literature Review

Zhang et al. (2019) conducted a comprehensive survey on smart helmet systems aimed at enhancing worker safety in underground coal mines. Their study focused on the integration of real-time monitoring technologies, gas sensors, and wireless communication systems into helmet designs. They concluded that such systems significantly improve accident mitigation and create safer work environments. However, the authors noted that their research lacked large-scale implementation validation to confirm real-world effectiveness.

Sharma et al. (2020) explored the integration of IoT and wearable technologies in coal mining safety systems. Their review analyzed various IoT-based solutions that utilize Zigbee and Wi-Fi communication to improve hazard detection and worker monitoring. The study found that IoT integration greatly enhances real-time safety management and hazard prevention in mining operations. Nonetheless, issues such as signal interference and sensor reliability were identified as key limitations.

Chen et al. (2018) reviewed advancements in modern sensor technologies for smart helmets in coal mining. Their paper highlighted the use of accelerometers, gyroscopes, and gas detectors to improve real-time hazard awareness and worker protection. The study emphasized that modern sensors can significantly reduce accidents by continuously detecting unsafe conditions. However, they pointed out that the technology had not yet been extensively field-tested across diverse mining environments.

Gupta et al. (2017) focused on wireless communication systems designed for smart helmets in underground coal mines. Their survey compared protocols such as Zigbee, Wi-Fi, and Bluetooth, analyzing their performance in facilitating rapid emergency communication. The authors found that such systems enable timely alerts and coordination during hazardous situations. Still, they noted that signal loss and attenuation in deep mine zones remain major challenges for wireless communication reliability.

Garcia et al. (2024) studied risk reduction in coal mines using sensor-integrated smart helmets. Their research emphasized the role of advanced gas sensors and GPS tracking in creating a real-time safety monitoring framework. The findings revealed that integrating these technologies reduces accident probabilities and enhances situational awareness in hazardous environments. However, they reported that battery life and maintenance requirements limit the long-term usability of such helmets.

Johnson et al. (2024) presented an enhanced safety system using smart helmets embedded with biometric and alert modules. Their system design emphasized real-time monitoring of workers' vital signs, coupled with automated alerts for proactive accident prevention. The research demonstrated that biometric data could play a crucial role in early detection of worker fatigue or health risks. Yet, the study acknowledged that ergonomic factors and user comfort were not sufficiently addressed.

Zhang et al. (2023) focused on improving the energy efficiency of smart helmets for prolonged mining operations. Their research proposed the use of low-power sensors and optimized communication systems to extend battery life during long shifts. The study showed that energy-efficient designs can ensure continuous operation without frequent recharging. However, they noted that reducing power consumption might affect the frequency of sensor data updates, potentially impacting responsiveness.

Johnson et al. (2023) examined real-world applications of smart helmets in hazardous mining environments through multiple case studies. Their research showcased how integrating gas leak detectors and stability sensors enhanced worker safety and provided reliable field performance. The study confirmed the practical benefits of smart helmets in reducing accidents and ensuring continuous monitoring. Nevertheless, they highlighted that large-scale deployment and scalability of these systems remain areas requiring further exploration.

Methodology

The proposed Smart Helmet for Coal Miners with Locking System is designed to improve miner safety by combining sensor-based monitoring and IoT communication. The system uses NodeMCU (ESP8266) as the main controller, which works as the central unit for collecting sensor data, processing information, and sending real-time updates. The working process begins with the helmet locking detection mechanism, which checks whether the safety strap is properly fastened. If the helmet is not locked correctly, the system remains inactive to ensure that safety procedures are followed. Once the helmet is securely locked, an automatic timer starts to record the miner's working duration, which can help in maintaining accurate work-hour records and payroll calculation.

The system continuously monitors the underground environment using an MQ gas sensor to detect the presence of hazardous and flammable gases. When the gas level exceeds the safe limit, the system immediately activates a warning through an LED indicator and



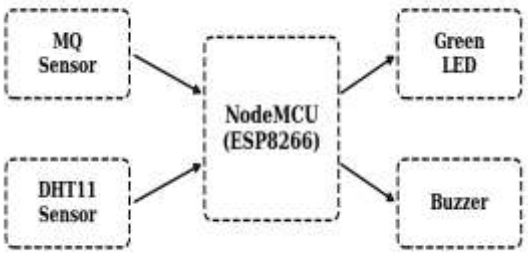
buzzer. A green LED indicates that the surrounding environment is safe, while the buzzer alert intensity increases as the gas concentration rises, allowing miners to recognize the level of danger. In addition, the DHT11 sensor, positioned inside the helmet, captures the body temperature of the miner. Sudden temperature spikes can indicate heat stress or illness, which are critical in underground scenarios. The complete setup is powered by a rechargeable lithium-ion battery, providing reliable operation during long working hours.

For remote safety monitoring, the NodeMCU module transmits the collected information through the web server, enabling supervisors outside the mine to receive real-time alerts during emergency conditions. By integrating helmet-lock verification, work-time tracking, gas detection, alert mechanisms, and wireless communication, the proposed system provides an effective solution for improving safety and reducing risks faced by coal miners in underground environments.

Block Diagram

Figure 1

Block Diagram of the System



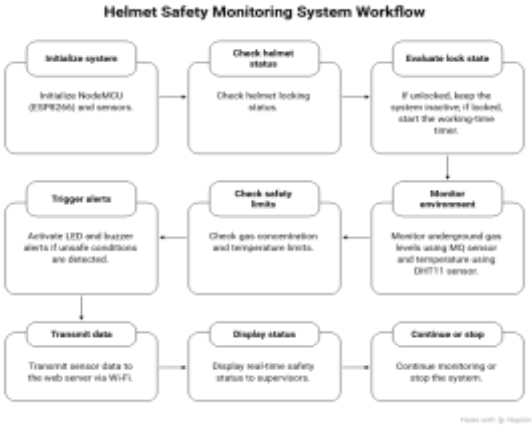
Description

The block diagram represents the overall architecture of the proposed smart helmet system, which uses a NodeMCU microcontroller to monitor environmental conditions and provide safety alerts. The MQ sensor detects the presence of harmful gases in the surrounding environment, while the DHT11 sensor measures temperature and humidity. These sensors continuously collect environmental data and transmit it to the NodeMCU for processing. The NodeMCU acts as the central processing unit, analyzing the sensor readings and comparing them with predefined threshold values to identify potentially hazardous conditions. Based on the processed data, the microcontroller controls the output devices, including a green LED and a buzzer. The green LED indicates that the environmental conditions are within the acceptable safety limits, while the buzzer generates an audible warning when harmful gas concentrations or abnormal temperature levels are detected. This alert mechanism enables workers to recognize potential hazards and take appropriate precautions. The integration of environmental sensors, a microcontroller, and alert devices provides an efficient and cost-effective approach to real-time hazard detection. Overall, the proposed system aims to enhance workplace safety by continuously monitoring environmental conditions and providing timely warnings in hazardous industrial environments.

Flow Chart

Figure 2

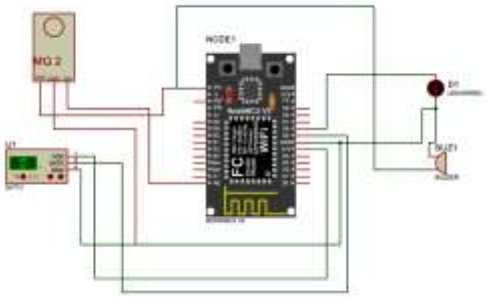
Flow Chart of the System



Circuit Diagram

Figure 3

Circuit Diagram of the System



Working

The Smart Helmet for Coal Miners with Locking System operates through the NodeMCU (ESP8266), which coordinates helmet-lock detection, working-time tracking, gas monitoring, and alert generation. When the helmet strap is properly secured, the timer starts recording the miner's working duration. Meanwhile, the MQ gas sensor continuously monitors the surrounding air for hazardous gases. If the gas concentration exceeds the predefined threshold, the system activates the buzzer and LED indicators to warn the miner. The DHT11 sensor measures body temperature inside the helmet to detect heat stress. The NodeMCU also transmits the



collected data and alerts to a web server through Wi-Fi, enabling remote monitoring by supervisors. The entire system operates using a rechargeable lithium-ion battery, providing a portable safety monitoring solution for underground coal mining environments.

System Requirements

Hardware Requirements

1. NodeMCU
2. MQ Gas Sensor
3. LED × 2
4. Buzzer
5. Battery × 2
6. DHT11 Sensor

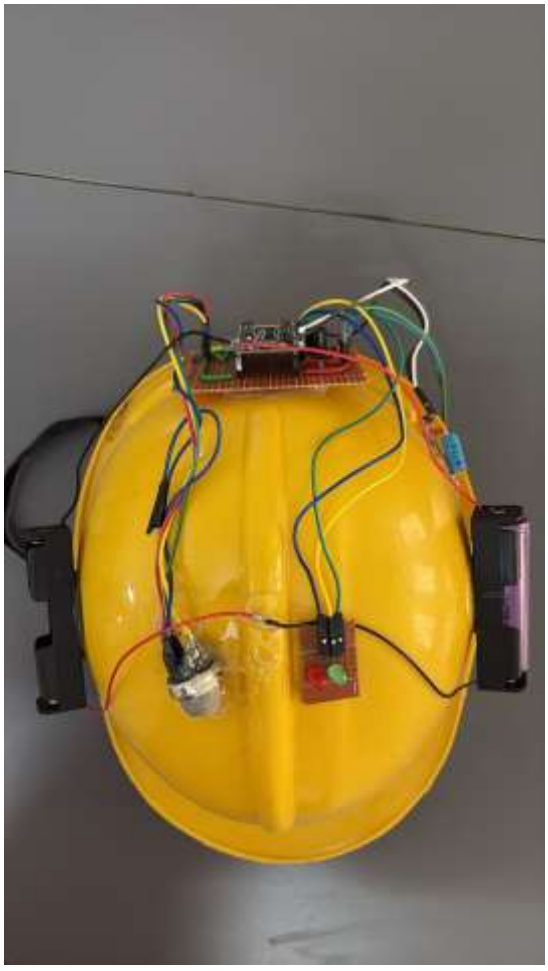
Software Requirements

1. Arduino IDE
2. Proteus

Experimental Setup

Figure 4

Top View of the Hardware Setup



Results

The Smart Helmet for Coal Miners with Locking System provides a safety monitoring mechanism that combines helmet security, gas detection, and remote alert communication. The system helps ensure that working-time tracking begins only after the helmet is properly secured and identifies hazardous gas conditions through sensor readings. The LED and buzzer alerts notify the miner when gas levels exceed the set limit, while the web server allows supervisors to receive safety-related updates remotely. Overall, the system supports improved monitoring of miners' working conditions and helps reduce the risks associated with hazardous underground environments.

Discussion

The proposed Smart Helmet for Coal Miners with Locking System integrates helmet-lock detection, gas monitoring, working-time tracking, and IoT-based communication to improve miner safety. The MQ gas sensor detects hazardous gases and activates the LED and buzzer when predefined limits are exceeded. The DHT11 sensor monitors temperature and humidity inside the helmet, while the NodeMCU (ESP8266) transmits safety-related information to a web server for remote monitoring.

The system encourages proper helmet fastening and supports working-time records. However, its practical effectiveness depends on sensor accuracy, battery life, and reliable communication in underground mines. Further testing under realistic mining conditions is required to evaluate its reliability and overall performance.

Conclusion

The Smart Helmet for Coal Miners with Locking System represents a practical and effective approach to improving worker safety in underground mining environments. The system combines helmet-lock detection, hazardous gas monitoring, automatic work-time recording, and real-time communication into a single wearable device, making it more than just a conventional safety helmet. The paper contributes to creating a safer and more organized working environment while encouraging better compliance with workplace safety practices.

The proposed smart helmet demonstrates how affordable IoT technology can be integrated with personal protective equipment to improve workplace safety, reduce operational risks, and support better monitoring in hazardous environments. It offers a reliable foundation for smarter mining practices and highlights the importance of combining technology with safety to protect workers in challenging underground conditions.



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