IoT Based Smart Helmet for Coal Mining and Safety Monitoring System

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Abstract:

Energy production still depends heavily on the coal mining sector, but doing so comes with a number of occupational risks for miners, such as exposure to poisonous gases, cave-ins, and accidents. The IoT-based Smart Helmet for Coal Mine Workers is a creative solution that was developed and put into use in this research study. It has a number of sensors, including, temperature and humidity sensors, gas sensors for identifying dangerous substances, and other types. These sensors continually gather real-time data and send it via a wireless network to a centralised control system.

The design, features, advantages, and underlying IoT architecture of the Smart Helmet are all thoroughly covered in this research paper. With the help of this model, the coal mining sector will get one step closer to adopting safer and more environmentally friendly mining techniques.

Keywords: Smart helmet, coal mining, IoT, safety, environmental monitoring.

1. Introduction

Coal is an essential resource to every nation as it has many commercial operations. Coal Mining is a very large industry which includes complicated operations carried within tunnels, underground etc [1]. There are lot of dangerous accidents which cause more death of miners are reported from mines located in different countries. The major reason for those hazards are, the concentration of the gases like methane gas and CNG (compressed natural gas) and other harmful gases which expose from underneath of earth while excavation, next main reason is the removal of helmet by miners and it increases chances of head injuries.[2][10] The mining operations with unsafe manners are due to different methodologies utilized by the miners for extricating diverse minerals. The longer the mine, the more prominent is the hazard [3]. The safety measures execution is very poor, especially in the coal mine industries. The process of mining creates a highly unsafe scenario for the human laborers where the risk increases with the increase in distance from the ground [5]. Safety measures are executed very poorly in the coal mining industries [4]. It is quite hard to analyse to all the environmental conditions constantly in a coal mine manually. The most integral employments of coal are in the production of thermal power, cement, and steel production and as a fuel for numerous applications [6]. The coal mines have numerous risky stipulations that include high temperature and humidity, discharge of destructive gases that make unsafe surroundings for miners working there [7]. Many employees are taking off their occupations in coal mines or no longer inclined to pick such

employments as mining [8]. This creates a lot of challenges in the accessibility of employees for the coal mining industry. To address the safety concerns associated with coal mining, there is a growing need for innovative solutions that can improve the working conditions for laborers. One such solution is the development of IoT-based smart helmets designed specifically for coal mining operations [9]. The IoT sensors that are embedded in the smart helmets can continuously monitor the environmental conditions within the mine. This includes live tracking levels of harmful gases carbon monoxide, as well as monitoring temperature, humidity etc. With the use of different sensors, the smart helmet will be able to identify catastrophic situations such as harmful gases like Carbon-Monoxide, CH4, LPG, and natural gases and there will be alerting system through the use of buzzer.

2. Literature Review

A smart helmet to prevent noise induced hearing loss by adding feed forward and feedback active noise cancellation in the helmet with microphones to measure external noise and air velocity and according to that it will change the measure of ANC so that the rider will be secure from a hearing aid caused due to noise while driving. Tested using wind tunnel and freeway experiments [11]. Smart helmet equipped with gas sensors, collision sensors. By using Arduino they have made a system such that it will detect the harmful gases, whether the miner is wearing the helmet or not, and location of the miner. It is connected to the cloud via Wi-Fi so that whenever the gas or temperature increases over a limit it will notify using a buzzer and notification on the app [12]. To overcome the lack of safety features in traditional coal mine monitoring systems ZigBee-based wireless monitoring system using a smart helmet is made. The helmet detects harmful gases like methane, High temperatures, Humidity, and fire. In case of any emergency it alerts the user by triggering the buzzer and sending the notification to control room for ensuring real time safety of miner [13]. Due to increasing accidents in mines due to safety concerns this smart helmet with sensors for collision detection, gas leakage, and a Wi-Fi-based monitoring system that communicates with all sensors to provide data. This smart helmet sends out an alert using buzzer and cloud-based monitoring to the user in case of potential hazards [14]. The primary goal of this helmet is to ensure safety of miners while working in coal mines. This system continuously monitors factors like temperature, humidity, harmful gases, miner is wearing the helmet, and damaged caused to helmet using various sensors. Based on the readings of sensors the risk is calculated and alert is send whenever there is high risk [15]. A smart helmet for detecting harmful events both in mining and on roads. It considered three main types of hazards as Air Quality, Helmet Removal and Collision. In case of accident it sends alert message and location of user to provided contacts via GSM. The information is transmitted to control station like an ambulance, using Zigbee trans-receivers [16].

Developed a system that provides a wireless sensor network for monitoring real-time situation of underground mines from the base station. It keeps track of harmful gases like CO, CH4, and LPG. It also tracks temperature and humidity. It alerts when a miner falls due to any reason or removes helmet both to mines and base station using Zigbee technology [17]. A smart helmet system using Arduino technology to monitor various factors such as harmful gases, abnormal temperatures and humidity levels. The helmet has circuit with four sensors to monitor temperature, Humidity, gas, and Oxygen level in mines. If any unusual event occurs helmet activates safety measures like buzzer and send message to operator to exit the mine quickly [18]. A safety helmet designed for coal miners

with methane and carbon monoxide gas sensor which will detect the increase in level of hazardous gas concentration. If the value goes above critical value the information is transmitted to control room using X-Bee who activates the alarm ensuring the safety of workers avoiding any accident [19]. This system consist of two key components one is to monitor miner and another is overall monitoring of surrounding environment. For miner's safety some sensors like smoke sensors, gas sensors are used. When level of harmful gases exceeds a given value it triggers the system and alerts the miner through buzzer and sends data to control room via LoRaWAN [20]. Employing autonomous vehicles within underground coal mining. Developed shuttle cars for coal mine so that the operator can be removed from hazardous place to safe locations ensuring the safety of people working in mines. The user only needs to supervise the vehicle instead of operating it by going inside the mine which may be risky in many cases [21].

A smart helmet with various features such as two-way communication, detection of harmful gases, notification in case of helmet removal, collision detection, panic button for emergency situation and GPS is provided to track the location of miners. A small oxygen cylinder is integrated in case of poisonous gas detection the helmet seals automatically and oxygen is provided to miner. The alert is then sent to control room with the miner's location [22]. A smart helmet for miners to provide at least same level of protection for miners as the MSHA requirements. Considering the relative level of protection of miners. They have tried to provide at least the minimum level of protection for miners. Also explores advantage of incorporating entity concept which will be cost effective and more streamlined pathway for better technology [23]. A smart and flexible helmet designed for construction workers to ensure their safety while working on dangerous sites. Helmet contains sensors like accelerometer and gyroscope sensor to detect the orientation of person which are used for fall detection and if there orientation is changed the sensor sends signal to microcontroller and gives alerts contractor via mobile notification ensuring their safety [24]. The development of smart helmet for resolving issue of safety. Created an intelligent system with sensors and modules to ensure the safety of rider. Vibration sensors to detect collisions and GPS so that the location of rider can be sent to contacts on detection of an accident using the sensors. The helmet has a Bluetooth module for transferring data between sensors and mobile phones as well as noise suppression technology. [25].

3. Methedology

This system uses Node MCU module which detects variables in a coal mine and a cloud-based monitoring is provided. Live readings are provided by the temperature and humidity sensor, IR flame sensor, and MQ135 sensor. The data is sent to the microcontroller, and communication between the gateway and the node is done via Wi-Fi. In an abnormal situation, an alert message is sent to the system, which is also displayed on an LCD screen and an application and an alert through buzzer.
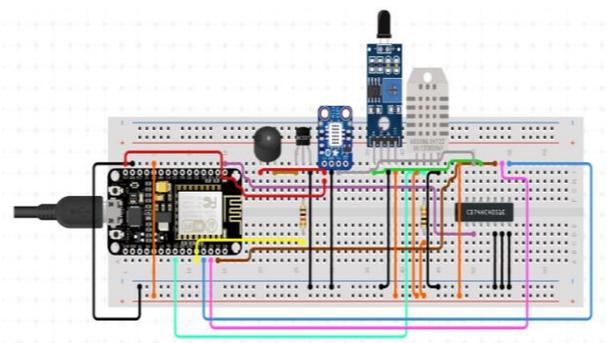
Fig. 1. Circuit diagram of Smart Helmet

In fig.1, node mcu is connected to the breadboard and it is given a power supply. DHT11 and IR Flame sensors have 3 pins GND connected to ground of the microcontroller, D0 connected to digital output pin and Vcc connected to 5V power supply. Whereas, MQ135 sensor also has one analog pin in addition to these 3 pins which is connected to analog A0 output pin for measuring the gas in PPM. Buzzer and LCD are also connected to give an alert and display message respectively when there is an abnormal situation.

MQ135 Sensor:

$$VRL = I \times RL = VC/(RS+RL) \times RL = 5/(RS+RL) \times RL$$

VC is used to maintain constant DC voltage at one of the electrodes, and load resistor RL and VRL is the output voltage of the sensor which is in series with the sensor. VRL is produced due to a change in the resistance of the sensing element which alters the current flow. The change in load resistance affects the output characteristic of MQ135. Here the change in RS, the resistance of the sensor depends on the concentration of gas. Sensor resistance RS and load resistance RL form a voltage divider. From the equation, it is clear that the output voltage of the sensor depends on load resistance.

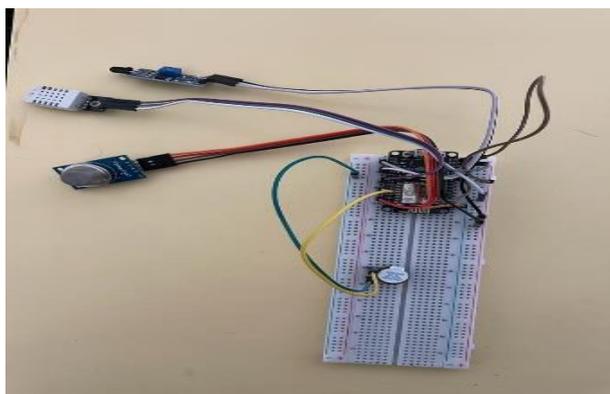## 4. Results-System Demonstration

Fig. 2. Hardware Setup

The fig.2 shows the hardware setup of the overall system. We have used DHT11 sensor which takes the temperature and humidity readings, IR flame sensor which detects the presence of fire and MQ135 sensor which detects the level of CO gas.

Fig. 3. Graph of Humidity vs Time

Fig. 3 shows the variations in the humidity based on readings taken by dht11 sensor.

Initially humidity is constant at 26 percentage upto a certain time. Then it increases where it attains the maximum value of 27 percentages and it decreases to again initial value of humidity and remains constant for some period of time. Overall, this graph shows the change in humidity over time in the room.
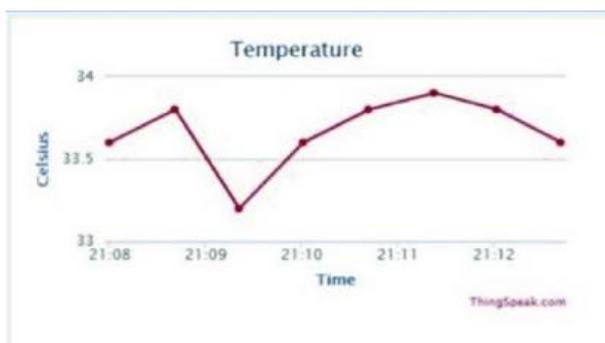

Fig. 4. Graph of Temperature vs Time

Fig. 4 shows the variation in temperature based on readings taken by dht11 sensor where it shows a slight upward trend over time, with some fluctuations. The temperature starts at 72 degrees Fahrenheit and gradually rises to 75 degrees Fahrenheit over the course of the graph. There are few small fluctuations along the way, but the overall trend is upward. Overall, the graph shows that the temperature in the room is gradually changing over time.

Table 1. Sensors used in the system.

Sensor	Range (ppm)	Response Time(seconds)
DHT22	-40 to 125	<=5
IR	0.76 to 1.1	<=30
MQ135	10 to 1000	<=1

During the testing phase, the system detected rapid temperature and humidity changes.

Also from the results we come to know that the IoT based safety helmet system is the robust and effective solution for enhancing safety in coal mining operations. Also its ability to detect and respond to uncertain conditions in real-time, along with its ease of use and reliability, positions it as a valuable asset in the pursuit of minor safety and well-being.

4. Conclusion

The IoT-based smart helmet for coal mining and safety monitoring system is a ground-breaking advancement, fusing state-of-the-art technology with the harsh environment of coal mines. The innovation utilizes an array of sensor, real-time data analysis, and communication capabilities to provide critical information to miners, including toxic gas levels, temperature, and location tracking. This not only ensures their safety but also enables quick responses to potential hazards. The system's proactive monitoring of working conditions and miner's health serves to prevent accidents, reduce fatalities, and significantly improve overall safety in coal mines.

Beyond safety, it optimizes resource utilization, contributing to cost savings and increased operational efficiency. It not only protects the lives of miners but also holds the promise of elevating productivity and sustainability in this traditionally challenging industry. As a testament to the transformative power of technology, this innovation demonstrates that safety and efficiency can go hand in hand , paving the way for a brighter and safer future for coal mining.

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