Coal Mine Safety Monitoring and Alerting System with Smart Helmet

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Abstract. Traditional monitoring systems in coal mines are difficult to install, hazardous, and difficult to power. Because of the complexity of the mining environment and the wide range of operations performed in coal mines, it is vital to monitor and maintain the parameters in the background t increase the efficiency and safety of mineworkers. As a result, traditional monitoring methods cannot be relied on to ensure coal workers'safety. This research represents a ZigBee-based wireless monitoring system using a smart helmet. The presented wireless monitoring system is capable of detecting and transmitting critical parameters in coal mines such as methane gas, high temperature, humidity, and fire. In an emergency, this monitoring system transmits distress signals. A buzzer will sound if emergency conditions are detected, and the monitored variables will be displayed on the user interface machine. Moreover, the Parameters are wirelessly transmitted to the control room, allowing people to determine the safety situation of the mine. This model is easily reprogrammable. Experiments have demonstrated the system's reliability and stability.

Keywords - Coal mine Safety, Monitoring system, IoT, ZigBee, Smart helmet.

1 Introduction

An accident that occurs while mining minerals or metals is known as a mining accident. Each year, tens of thousands of miners die in mining accidents, most of which occur in underground coal mining, while accidents also happen in mining [1]. Due to rock strata that are plain, typically incompetent rock, presence of CH4 gas, and coal powder, Coal mining is considered significantly more dangerous than hard rock mining. Most deaths nowadays occur in underdeveloped nations and rural areas of wealthy countries when safety precautions are not properly implemented [2].

As a result, it is critical to maintaining track of circumstances that might contribute to an accident to protect human safety. This project introduces a device used to keep track of the conditions within a coal mine, which might pose a threat to human life. The sensors and Zigbee are employed for monitoring in this system. This system also incorporates a smart helmet with a panic button that each worker may activate individually. All sensors are linked to specific applications and send an alert signal when it exceeds a particular value. The alarm message is sent to the control room to take the necessary action quickly. If coal mine accidents are not adequately controlled, it may result in massive human fatalities. A monitoring system has been built to record the readings of dangerous gases and risky working conditions. The information gathered is subsequently forwarded to professionals for analysis and action.

Over the years, it has been observed that coal mine contributes significantly to the country's rapid economic and social development. Scholars from around the world have undertaken substantial research to improve the degree of safety. Coal mines are an essential source of energy for human growth. Development. Mining failures may be exploited to increase security in the industry. Industrial series of failures or flaws are typically the cause of an accident. There are a number of practical measures available. Initiatives involving mines, such as the construction of safety lamps, can significantly impact. Law and creating a self-contained coal mine safety monitoring system are both in the works. The trajectory of China coal mine accidents over the last ten years were investigated, and the human elements involved in these accidents were investigated using multi-dimensional statistical analysis. The number of significant coal mine accidents and the number of people killed were constantly reducing, but occasional death accidents still accounted for most deaths. Human factors accounted for 94.09 percent of the causes of these incidents, with the willful violation, mismanagement, and flawed design accounting for 35.43 percent, 55.12 percent, and 3.54 percent, respectively [3].

A round penetrating synthetic pulse radar device to probe through a coal pillar in search of hidden structures or abnormalities was employed. To produce a velocity picture of the inside of the pillar, direct matrix inversion was performed. The reconstructed picture revealed the presence and position of a substance with a low velocity. A clay vein in the cores corresponded to the low-velocity material shown in the tomogram [4]. Technology alone will not be adequate to address the difficulties for a substantial number of individuals

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The dangers of coal mining; proper education and training arealso essential for mine safety [5].

The research was conducted for safety monitoring of mine roof integrity and dangerous gases in coal mines, fibre optic sensors have been developed and implemented. The inherent safety, multi-location, and multi-parameter monitoring features of the FOS-based mine danger detection system are unmatched. They might be utilized to create expert systems for the early identification and prevention of mining hazards [6].
Underground mines are prone to serious safety incidents. The development of safe mining technologies is critical. This problem can be solved with smart mining. One of the most important components in smart mining is the unmanned electric locomotive [7].

The rest of the paper is organized as follows: In section2 methodology of the proposed system has been explained. In section 3, a brief description of the system is given. Section 4 comprises of working of the monitoring system and smart helmet. Output result analysis and discussion have been specified in section 5, and the end section tells us about conclusions and the future scope of the project.

2 Methodology

The Arduino microcontroller is used to detect and monitor variables in a coal mine. Live readings are provided by the temperature sensor, humidity sensor, IR flame sensor, and gas sensor. A microcontroller and a transceiver are connected to all of these sensors. The data is sent to the microcontroller, and communication between the gateway and the specific node is done via Xbee WPAN IEEE 802.15.4. As mentioned previously, the data is sent to the control room via the XBee protocol. In an abnormal situation, an alert message is sent to the system, which is also displayed on an LCD screen connected to Arduino at the coalfield's entrance. A buzzer is also programmed and controlled with the help of Arduino, which activates at any abnormal reading detected by the above sensors.

A smart helmet is also computed with a microcontroller which simply has a push button connected to it. The microcontroller is also comprised of a ZigBee transceiver. This measure has been taken to maximize the safety of workers in coalfield. Whenever a worker needs medical attention or has any discomfort, a panic button can be used, which transmits a message in the control room about an emergency so that medical attention can be given to that worker.

3 Description of System

3.1 Block diagram

As shown in Fig.1, This block diagram is of a prototype that includes some sensors that would be needed in a coalfield and are connected to a microcontroller to detect environmental conditions. The Arduino Uno microcontroller was used and connected to LM35

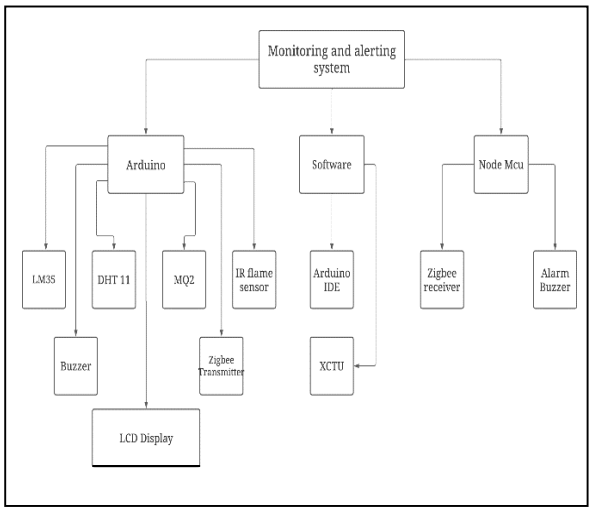

Fig. 1: Block Diagram Of Coal Mine Safety And MonitoringSystem.

(Temperature sensor), DHT11 (Humidity sensor), Mq2 (Gas sensor), and an IR flame sensor. With the help of these sensors, continuous readings of temperature, humidity, and gases present in the coalfield can be taken, as well as air density, and we've programmed the Arduino board in such a way that any abnormality in the parameters as mentioned above will trigger an alert, and the buzzer will be activated.

A 16x2 LCD display was added, which will display all of the readings. Workers will be able to monitor the live circumstances of the coalfield and take necessary action using this LCD, which will be installed at the coalfield's entrance. To create safe and dependable communication to the control room, the ZigBee Protocol has been employed. The environmental parameters of the coalfield are communicated with the aid of the XBee transmitter and receiver, which are coupled together with the help of XCTU software so that necessary measures may be done in time in critical situations.

Fig.2 below is a block diagram. Another safety gadget is a smart helmet equipped with a push-button, buzzer, and a ZigBee transmitter. At any sudden point of time, if any worker feels uneasiness or needs medical attention, that worker can use the push button, which will trigger thebuzzer and transmit an emergency message to the controlroom via ZigBee.

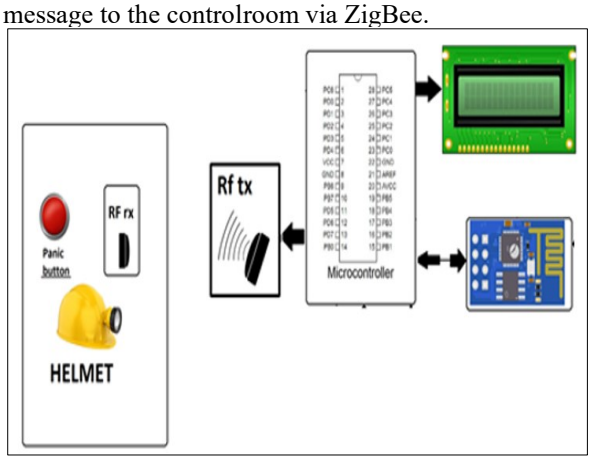

Fig. 2: Block Diagram of Smart Helmet

3.2 Sensors Specifications

This prototype is intended to monitor and measure environmental factors such as temperature, gas concentrations such as CH4, CO2, and humidity, as well as to detect inflammation or fire. Table 1 shows the sensors utilized in the prototype and their parameters. The LM35 sensor measures temperature since it is small and accurate to within 3°C [8]. An MQ2 gas sensor is used to detect gas concentration with an accuracy of 85%, while a DHT11 sensor is used to measure humidity with an accuracy of ±5% RH. Another sensor used in the prototype is an infrared flame sensor, which is used for fire detection and has a higher sensitivity and better accuracy than other types of flame sensors. These sensors are long-lasting, can withstand the harsh environmental conditions of the coalfield, and are cost- effective.

For wireless M2M and IoT networks that are low-cost and low-power, Zigbee is a wireless technology that is based on standards. In comparison to a WIFI network, ZigBee provides significantly lower data rates and use a mesh networking protocol to eliminate hub devices and build a self-healing architecture. This allows for the potential mixing of implementations from different manufacturers; however, it has been changed and improved. Zigbee is a standard protocol with a modest data rate and consumes less power [9].

Table 1: Specification table for selected sensors

Sr no.	Parameters	DHT11 Humidity sensor	MQ2 Gas sensor	LM35 Temperature sensor	IR Flame sensor	ZigBee Module
1	Sensing variable/Uses	Humidity	Gas concentration	Temperature	Fire	Transceiver
2	Operating Voltage	3.5V to 5.5V	5V	+4V to 30V	3.3V to 5V	2.1V to 3.6V
3	Operating Current	0.3 mA	800 mW	60 micro-A	15 mA	45 mA
4	Output Voltage	5.5 V	0 to 10 V	10 mV	Digital output (0 or 1)	–
5	Operating Temperature Range	0 to 50 degrees Celsius	-20 to 70 degree Celsius	-55 to 150 degrees Celsius	-25 to 85 degrees Celsius	-40 to 85 degree Celsius
6	Output/sensing Range	20% - 90%	300 to 10000 ppm	-55 to 150 degrees Celsius	760 to 1100 nm	4000 ft

3.3 Flowchart

Fig. 3 shows the operational flow of the monitoring system. Begin by connecting the prototype circuit to a power source. Now we'll have to keep track of all of the sensors' values attached to the Arduino UNO. Set a threshold value for each sensor after evaluating the readings and determining when environmental circumstances become aberrant.

The condition will be true if the sensor output is greater than the defined threshold value, and a buzzer will sound,readings will be displayed on the LCD screen with an alert message, and data will be transferred through Zigbee protocol to the control room. The Buzzer will not turn on if the sensor value is less than the defined threshold value, but the sensor readings will be shown on the LCD and relayed to the control room. This is when the flow of the procedure comes to a stop.

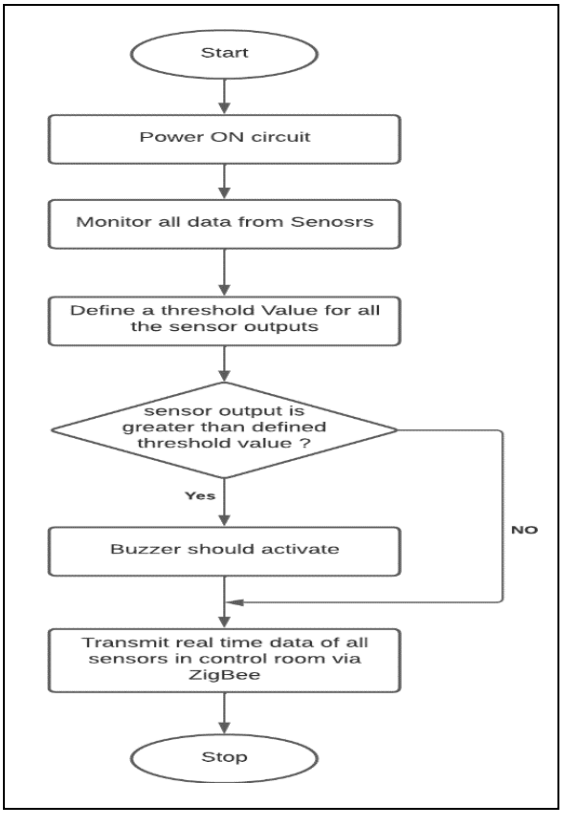

Fig. 3: Flow Chart For Controller Programming

4 Working

Arduino Uno is the central component, and it sends the information on the internet via the Zigbee module. DC power supply is used for supplying voltage to the circuit.This is the circuit diagram for the smart helmet's monitoring and alerting system. This system will be builtusing Arduino, ZigBee modules, and sensors such as the DTH11 humidity sensor and the IR flame sensor, among others. The sensors we'll use will detect changes in the coal miner's environment, and variables like temperature, gas concentration, and fire detection will be continuously monitored. It will also have an extension that will connect to an LCD display, which will be placed at the entrance tothe coal minefield. Also, the data which will be recorded by sensors will be transmitted via the Zigbee module to the control room so that proper actions can be taken effectively in minimum time. Fig.4 shows the representation of the circuit diagram designed.

A push-button, a buzzer, and a ZigBee transmitter will be included in another safety device, the smart helmet. If any worker becomes uneasy or requires medical attention at any time, that worker can use the push button to activate the buzzer and send an emergency message to the controlroom via ZigBee.

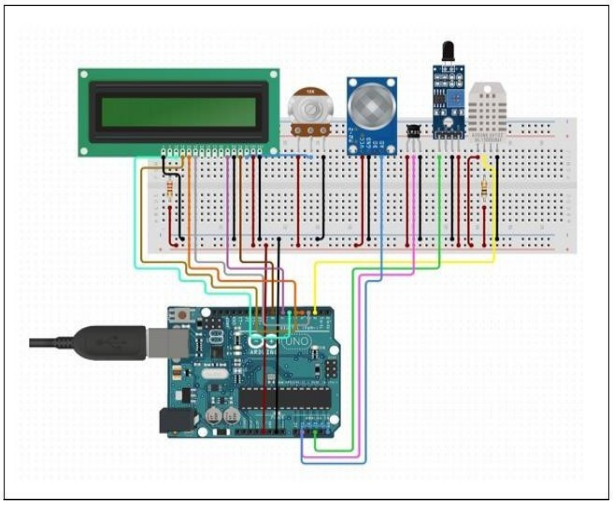

Fig. 4: Circuit Diagram of Coal Mine-Side Monitoring System.

5 Result and Discussions

IoT concepts and sensors are used to create a small, effective, and cost-efficient prototype. The temperature was successfully measured using LM35 sensors during the testing phase, and the output was satisfactory. The DTH11 sensor was also used to monitor humidity accurately. The MQ2 gas sensor detected gas concentrations in the area and successfully displayed a warning message on the screen. The IR flame sensor also detected fire and displayed an alert message informing the user of its presence. For wireless communication, the Zigbee Protocol was developed and tested in various locations and distances. Wireless communication was functional, and Zigbee delivered the best results and was fully functional. Prototype in coal mine can be seen in Fig.5, and prototype of control room can be seen in Fig 6. Smart helmet, on the other hand, was working correctly and displaying a help message on the screen.

During an emergency, the smart helmet communicates signals to the control room. The smart helmet is fitted with a push-button and a ZigBee module, as illustrated in fig.8. When the amount of carbon dioxide or methane in a coalfield rises, miners begin to feel dizzy. In this case, they can hit the panic button on their helmet, which alerts the workers in the control room and effectively reduces the time it takes for individuals to be rescued.

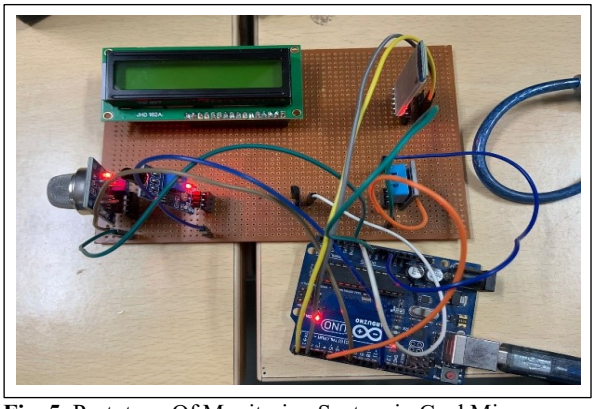

Fig. 5: Prototype Of Monitoring System in Coal Mine

Fig. 6: Prototype Of Monitoring System in Control Room.

The result obtained via the monitoring system has been analyzed and represented in Table 2 and Table 3, respectively, whereas results obtained are shown in fig 7. Whereas Table 2 describes the output of the monitoring system when conditions are under control, compares the output from all the sensors with their respective thresholds set and shows the hardware changes and their current state. Whereas table 3 describes output in an emergency situation and what hardware changes will take place in that situation. Fig.7. shows the actual readings obtained from the monitoring system prototype. Arduino UNO is programmed so that the readings of all the sensors are displayed on the user interface at an interval of 5 seconds. When the threshold value has crossed, warnings like 'high gas concentration', 'close fire', 'high humidity' and 'high temperature' are displayed.

Table 2 : Result analysis of monitoring system

Sr no.	Parameter	Threshold value set	Sensor reading	Hardware changes	remark
1	Temperature (degree Celsius)	25	21.09	Buzzer off	Safe condition
2	Gas (PPM)	600	518.2	Buzzer off	Safe condition
3	Humidity(%RH)	45	33	Buzzer off	Safe condition
4	IR flame sensor (digital output)	0	0	Buzzer off	Safe condition

Table 3 : Result analysis of monitoring system

Sr no.	Parameter	Threshold value set	Sensor reading	Hardware changes	remark
1	Temperature (degree Celsius)	25	31.05	Buzzer on	unsafe condition
2	Gas (PPM)	600	694.1	Buzzer on	unsafe condition
3	Humidity(%RH)	45	48.3	Buzzer on	unsafe condition
4	IR flame sensor (digital output)	1	1	Buzzer on	unsafe condition

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temperature: 21.09 °C
gas density: 561.00
Humidity = 33.5
* Close Fire *
temperature: 21.14 °C
gas density: 561.00
Humidity = 33.5
* Close Fire *
temperature: 21.19 °C
gas density: 563.00
Humidity = 33.5
* Close Fire *
temperature: 21.14 °C
gas density: 561.00
Humidity = 33.5
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Fig. 7: Result of Monitoring System

Fig. 8 shows the final prototype image of the smart helmet. During an emergency, the smart helmet communicates signals to the control room. The smart helmet is fitted with a push-button and a ZigBee module.When the amount of carbon dioxide or methane in a coalfield rises, miners begin to feel dizzy or Any feeling of uneasiness in health or injury in the body, they can hit the panic button on their helmet, which alerts the workers in the control room and effectively reduces the time it takes for individuals to be rescued as help will reach fasterdue to quick action.

Figure 8: Prototype of Smart Helmet

Table 4 does the analysis of results transmitted through ZigBee. A push-button can have only two possible outputs, 0 or 1. When the push button is pressed, the output will be 1, and so the buzzer will get activated, whereas if the push button is not pressed by default, the output will be 0, and the buzzer will be in the deactivatedstate.

Table 4: result analysis of smart helmet

Sr.no	Sensor reading	Hardware changes	remark
1	0	Buzzer OFF	Safe condition
2	1	Buzzer ON	emergency

6 Conclusion

This paper presents a Zigbee-based coal mine monitoring system. The proposed system is used to monitor the subsurface characteristics of a coal mine and will aid in the prevention of mine disasters. ZigBee technology features a simple and adaptable networking concept, is tiny in size, and consumes little power. Additionally, the proposed system addresses all of the problems associated with wired connections. As a result, this is an advancement above the traditional coal mine safety system. Furthermore, a distress signal from the smart helmet is useful in abnormal environmental conditions or when a person needs medical attention. This system has applications in securities of industries as well. It is easy to upgrade and modify further as innovations arise.

References

[1] Y. Shi, J. Chen, J. Hao, J. Bi, M. Qi and X. Wang, "Statistical Analysis of Coal Mine Accidents of China in 2018," *2019 Prognostics and System Health Management Conference (PHM-Qingdao), (2019)*.

[2] Ericsson, M., Löf, O. Mining's contribution to national economies between 1996 and 2016.

[3] Hong Chen, Hui Qi, Ruyin Long, Maolong Zhang, Research on 10-year tendency of China coal mine accidents and the characteristics of human factors, *Safety Science, Volume 50, Issue 4, (2012)*.

[4] Dennen, R S, and Stroud, W P. Radar hazard Detection in a coal structure. *United States : N.p., (1991).*

[5] Hebblewhite, Bruce. (2009). Mine safety–through appropriate combination of technology and management practice. *Procedia Earth and Planetary Science. 1. 13-19. 10.1016*/j.proeps.2009.09.005, (2009).

[6] T. Liu et al., "Advances of optical fiber sensors for coal mine safety monitoring applications," 2013 International Conference on Microwave and Photonics (ICMAP), (2013).

[7] Jiang Y, Li Z, Yang G, Zhang Y, Zhang X. Recent progress on smart mining in China: Unmanned electric locomotive. *Advances in Mechanical Engineering. March 2017.*R. K. Kodali, T. Devi B. and S. C. Rajanarayanan, "IOT Based Automatic LPG Gas Booking and Leakage Detection System," 2019 *11th International Conference on Advanced Computing (ICoAC),(2019).*

[8] T. H. Nasution and L. A. Harahap, "Predict the Percentage Error of LM35 Temperature Sensor Readings using Simple Linear Regression Analysis," (2020) *4rd International Conference on Electrical, Telecommunication and Computer Engineering(ELTICOM),(*2020).

[9] V. Kadam, S. Jadhav, M. Parihar and A. Karande, "Development of wireless embedded automation system for a batch process," (2015) *5th Nirma University International Conference on Engineering(NUiCONE),(2015)*.