**Reinforcing Coal Mine Safety through IoT – Based Automated Detection and Immediate Rescue Robots**

**Abstract:**

The global economy depends heavily on the coal mining sector. In coal mines, tens of thousands of miners were employed. Numerous sectors, including coal mines, are in grave danger. Due to the release of dangerous gases, roofs collapsing, cornerstone ruptures, explosions, and flames, coal miners are killed. Industries experience severe health problems as a result of temperature expansion and gas evaluation. Since hazardous gases have no scent, it is impossible for humans to predict when they will be present. Serious problems are caused by the harmful gases' continuous infusion. Thousands of miners were killed in coal mines, according to surveys from those mines. It is not safe to examine the coal mines with human assistance. The suggested study teaches the robot equipped with various sensors can be able to infiltrate the coal mines to detect the presence of coal and to protect the safety in the coal mines, industries, and to defend the lives of workers. It has a special ability to detect methane and carbon monoxide gas breakouts. Additionally, the effort that helps save coal miners, individuals in times of need, and gestures are examined on the website.

**Introduction**

The safety of coal mining operations has long been a paramount concern due to the inherent risks and challenges associated with working in underground environments. As the demand for coal continues to support various industries, it becomes increasingly crucial to adopt innovative technologies that can proactively address safety concerns and safeguard the lives of miners. In response to this pressing need, a pioneering solution emerges, promising to revolutionize coal mine safety – IoT-Based Automated Detection and Immediate Rescue Robotics.

This cutting-edge system leverages the transformative potential of the Internet of Things (IoT) to create a comprehensive safety framework within coal mines. By seamlessly integrating smart sensor networks and intelligent algorithms, the system aims to fortify safety measures and empower miners with enhanced protection and risk mitigation. Its primary objectives are twofold: first, to detect potential hazards in real-time through automated hazard detection and second, to provide immediate assistance and rescue capabilities through the deployment of autonomous rescue robots.

This paper delves into the key features and functionalities of the IoT-Based Automated Detection and Immediate Rescue Robotics system, exploring how it bolsters coal mine safety and contributes to a more secure and efficient mining environment. We will delve into the smart sensor networks that continuously monitor crucial environmental factors, the real-time data analysis that swiftly identifies anomalies and danger zones, and the advanced algorithms that automate hazard detection. Additionally, we will explore the capabilities of the immediate rescue robots, equipped with state-of-the-art sensors and communication tools, ensuring swift response and support in emergency scenarios.

As we explore deeper into this groundbreaking technology, we uncover the numerous benefits it offers – from heightened safety and rapid emergency response to informed decision-making and cost-effectiveness. Furthermore, we will discuss the system's remote monitoring and control capabilities, providing centralized access and expert support during critical rescue operations.

It is undeniable that with the deployment of IoT-Based Automated Detection and Immediate Rescue Robotics, coal mines can embrace a new era of safety and efficiency, significantly reducing the risks faced by miners while simultaneously ensuring the sustainable growth of the coal industry. As we journey through the various aspects of this transformative system, we recognize its potential to reinforce coal mine safety and protect the invaluable human capital working beneath the surface, thereby ushering in a safer and more secure future for coal mining operations.

**LITERATURE SURVEY**

Lightweight assortment intermediate layer is used in the suggested study in [1] to check the automation and security of coal mines. The main goal of the proposed work is to use the zigbee a wireless sensor network (WSN) to improve the current process in coal mine examination and command automation [1]. As it lowers the cost of checking the coal mines by connecting to the internet, open service gateway goal is dependent on uniform device ingress and aiding visualization technology, break down the data with a cost-effective system. The system will not participate in any rescue operations.

The work done in [2] ignores the rover-dangerous areas, small habitats, or coal mines. The system aids in investigating the identification of motions and pathogenic gas exhausts in coal mines [2]. It specifically detects the presence of poisonous carbon monoxide gas in coal mines, large habitats, caves, and other places where there are frequently accidents brought on by the release of poisonous gases. As it includes a rover finder, the device also calculates the site's distance and temperature. The suggested effort uses a low-cost rover to analyze the locations. The system doesn't quickly issue alerts.

With the use of multiple gas sensors, Andiry Holovatyy in their suggested study [3] identifies the presence of poisonous chemicals in the target habitat. The mechanism checks the virulent gases' attentiveness. The system continues to operate in the conventional or regular mode if hazardous gases do not exist or if their attentiveness is in an acceptable or non-virulent level [3]. The system will switch to the alerating mode if there is a rapid rise in the status temperature. It activates the alarm while also activating the buzzer, projects the status on the LCD, and sends the alert message through GSM.

The proposed inspection and alerting system to ensure coal mine safety is found in [4]. The work is helping coal mines incorporate safety systems to withstand accidents, deterioration, and eruptions.

The technology uses wireless sensor networks to keep an eye on the habitat's condition [4]. Focus on the coal mines' pathogenic gas concentration, internal temperature, and wet frameworks when inspecting them. If the specification deviates from the established norms, the work warns. The technique is effective in helping to keep coal mines safe and prevent accidents.

The task suggested in [5] is to guarantee the security of coal mines, including the security of coal miners. The system includes heart rate sensors to check the pulse of the coal miners and smoke sensors to check the higher hazards like carbon monoxide, sulphur dioxide, and nitrogen dioxide. the miners' respiration rates using the respiratory sensor. The suggested project makes use of LoRa technology to upload coal mine and miner status data to the cloud. Through GSM, the superior is informed of the miners' health state.

The suggested work [6] disassembles the system responsible for fire detection. Fire is caused by the burning of coal in coal mines. The suggested research looks at the gas emissions from burning coal. It does away with the need to check whether dangerous gases are present and how attentively they are being monitored in coal mines [6]. The method uses LSTM to dissect the gases released during coal production in order to identify the gases responsible for coal mine fires. It helps resolve rigorous accuracy problems in the ongoing task.

The quick coal mine inspection aiding smart helmet is suggested in [7]. The smart helmet has sensors to check for poisonous gases, temperature, and moisture. The helmet also has an RF component to transmit to the ground control station the situation in the coal mines. Instead of sulfur dioxide, the system focuses on methane, which is the most dangerous gas [7]. Choking and explosions are caused by the toxic gas in coal mines. When pathogenic gases spontaneously release, the mechanism activates the bell on the ground unit that is providing assistance.

The issues that coal mine miners face are examined in [8]. The system looks at a number of factors that might affect the health of coal miners. Inside coal mines, temperature, the presence of hazardous gas, and moisture levels are all part of the framework under research [8]. The system uses the MQTT protocol to send mail notifications about the emergency scenario. Unexpected alerts are delivered by the system via buzzers. Coal employees' lives are protected.

The work done in [9] involves incorporating different sensors to guarantee the safety in coal mines. The sensors examine a variety of structures, including humidity, virulent gas levels, temperature, and quivering. To protect their safety, the miners will receive the alarm via GSM. When the framework exceeds the set limit, the mechanism activates the buzzer and the led to warn the miners [9]. The miners are warned prior to the explosion. To ensure the safety of the mine workers, the system can be used in all sectors of the mining industry.

In [10], deep learning approaches are suggested for monitoring factors to ensure the safety of miners. The coal mines provided the dataset used to train the machine to examine the frameworks. The model is trained using the LSTM to examine coal mine specifications. The system informs with a buzzer and a led when the gas level rises or when vibrations are sensed [10]. The miners in the coal sector might be informed of the advance warning used to protect mine workers' lives.

**EXISTING WORK**

The existing approaches to coal mine safety involve installing gas, temperature, and moisture detection systems inside the coal mines. In case of an emergency, wireless sensor networks are used to transmit signals, triggering alarms if there is a sudden increase in levels of dangerous gases, temperature, or moisture. These alarms alert both the supervisor and the coal miners working in the mines about the current status of the mine during critical situations. Given that coal mines are highly susceptible to fires due to their flammable nature, the fire detection methods employed in the existing work may not be entirely effective.

In the proposed work, a novel robot-based monitoring system is outlined, which aims to monitor the coal mines before allowing miners to enter. The purpose of this system is to enhance safety by proactively assessing potential hazards and conditions inside the mine.

The proposed study entails evaluating the state of a coal mine using a robot fitted with gas, temperature, moisture, and vibration sensors. This robot pattern is intended to identify and keep tabs on the conditions inside coal mines. Additionally, the system uses Bluetooth technology to continuously relay data about gas levels, temperature, wetness, vibration, and fire status to the supervisor's mobile device. You can direct the robot's path by giving it orders. Additionally, the suggested work retains the gathered data on an SD card so that it may be later uploaded to the cloud for remote monitoring of the condition of the coal mine from any location.

The robot is a crucial component of the rescue system because its main duty is to examine the coal mines following mishaps in order to avoid further mishaps. The robot, which is fitted with a sound sensor, may detect the presence of any trapped miners who are still alive and can communicate this vital information to the supervisor in time to aid in their timely rescue and save their lives.

**METHODOLOGY**

The proposed work aims to guarantee the welfare of the coal miners at the mines. The system dispatches a robot equipped with a variety of sensors, including a gas sensor. sensor, temperature sensor, vibration sensor, and sound sensor to the ESP32 controller inside the coal mines. Before allowing them to work in the mines, the controller in turn evaluates the sensor values to determine the condition present there. The robot contains a variety of sensors, including temperature, vibration, gas, and moisture sensors. The exhaust of harmful gases, such as methane and carbon monoxide responsible for health problems, is monitored by gas sensors. The temperature sensor used to check the mines' temperature range. Using a temperature and gas sensor in combination, a fire can be detected. The earth tremors are predicted by the vibration sensor. The inspected frameworks are automatically transmitted to the supervisor using GSM and Bluetooth wireless technology. By communicating commands to the robots, the supervisor may be able to control them. The SD card connected to the controller stores information about the conditions present inside the coal mines that are included. The thing talk receives the motions from the SD card.

MOBILE

ALARM MODULE

**ESP32**

**CONTROLLER**

MQ 135 GAS SENSOR

MQ 4 GAS SENSOR

BLUETOOTH MODULE

SOUND SENSOR

CLOUD

VIBRATION SENSOR

TEMPERATURE SENSOR

GSM MODULE

HUMITITY SENSOR

Fig 1. Block Diagram of coal mine detection and rescue robot

The main objective of the proposed work is to ensure flexibility and remote monitoring of the conditions inside the coal mines from any location. This remote monitoring capability allows supervisors and authorities to assess the state of the coal mines and ensure they are safe for work before permitting miners to enter.

Once the coal mines are deemed appropriate and safe by the supervisors, the miners are granted permission to start their work inside the mines.

Figure 1 illustrates the block diagram of the proposed work, depicting the various components and functionalities of the system.

The primary focus of this proposed work is to prioritize the safety of coal miners and take preventive measures to avoid fire accidents within the mines. By incorporating flexibility and remote monitoring, the system aims to provide a comprehensive safety framework that enhances the overall safety and security of coal mining operations.

The proposed system also plays a crucial role in inspecting the coal mines after incidents like fire accidents or earth tremors, as well as addressing other potential issues. Vibration sensors are utilized to determine whether vibrations are still present within the mine. Moreover, sound sensors are employed to detect human sounds.

In the event that miners are trapped inside the coal mines, the robot can rescue them by responding to the sounds produced by the trapped individuals. This capability serves as a vital aspect of the proposed work, enhancing the safety measures and improving the chances of saving lives during emergencies.

Overall, the system functions as both an inspection tool to examine the conditions within the coal mines and as a rescue system to safeguard the lives of miners. By utilizing advanced sensors and robotics, the proposed system offers a comprehensive approach to enhancing safety and minimizing risks in coal mining operations.

Gas detected

High Temperature

Humidity Detected

Vibration detected

Fire Detected

Alert Message

Alarm

Yes

No

Yes

No

No

No

Yes

Yes

Yes

Fig 2. Flow Diagram of coal mine inspecting robot

The supervisor is notified when pathogenic gases are detected inside the coal by gas sensors, which also determine whether the temperature is within a certain range. To forecast fire starts in coal mines, the suggested method compares the data from temperature and gas sensors. If there is a discrepancy, the alarm goes off. For the purpose of detecting earth tremors, vibration sensor data is computed.

No

Yes

Yes

Yes

Yes

Yes

No

No

No

No

Sound detected

Alert Message

Fire detected

Humidity Detected

Vibration detected

High Temperature

Gas detected

Alarm

Fig 3. Flow Diagram of coal mine rescue robot

The humidity level in mines is predicted by moist sensors, and if it surpasses that level, an alarm sounds. Figure 2 depicts the flow diagram for the robot that will inspect coal mines.

The proposed work aids in the emergency extraction of miners from coal mines. The system also enables the robot to inspect coal mines following mishaps or other problems. Figure 3 shows the flow diagram for the coal mine rescue robot. The rescue robot investigates coal mine vibrations, temperature increases, fire occurrences, and the release of poisonous gas. It also analyzes the miners' sound. It alerts the superior to save the miner from coal mines if it hears the sound of miners in distress.

**RESULTS AND DISCUSSION**

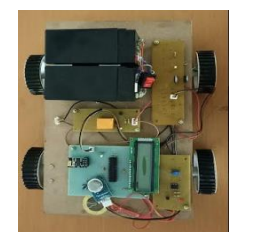


Fig. 5 Hardware Implementation

The system employs robot to examine the status of coal mine. The work analyzes numerous frame work like virulent gases, temperature, fire detection, humidity, vibration and sound. The hardware implementation of the proposed work is shown in figure 5.



Fig 6. Status of the coal mine updated in webpage

The projected work immensely assists in ensuring the safety of coal miners. Whenever there is an exigency the system glows the buzzer and sends the alert message to secure the lives of coal miners in the coal mines. The work done to rescue the miners in risk by inspecting the coal mine after calamity. The results updated to the cloud after the examination of robot through the webpage created is shown in figure 6.

**CONCLUSION**

The coal mining industry serves as a significant source of income for many nations, providing employment to numerous workers. However, the mortality rate in coal mines remains a pressing concern due to various hazardous factors, including virulent gases, high temperatures, fire accidents, earth tremors, and moisture. Therefore, ensuring the safety of miners is a crucial task in the coal mining industry.

The proposed system addresses this critical issue by implementing a robot pattern equipped with various sensors such as gas sensors, temperature sensors, humidity sensors, vibration sensors, and sound sensors. This robot is granted permission to examine the coal mines before miners enter to ensure a stable and safe environment.

In addition, the robot acts as a rescue system, helping secure miners in case of calamities. By inspecting the mines after an incident, the rescue system detects sounds that may indicate trapped miners and assists in their timely rescue. This proactive approach significantly reduces the risk of further accidents in the coal mines.

Overall, the projected system provides a comprehensive solution to ensure the safety of miners in coal mines. By leveraging robotics and advanced sensors, the system aims to minimize risks and enhance security, ultimately creating a safer working environment for coal miners.

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