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Web-based Hazardous Gas Monitoring and Alerting Rover System

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Abstract—This paper states a remote gas monitoring and alert system designed for mining environments, where toxic gas causes severe risks to workers. The proposed system employs an IoT-based approach to detect, measure, and transmit gas concentration data in real-time while providing alerts through a web-based interface. The module integrates MQ-7 for detecting carbon monoxide (CO), MQ-135 for hydrogen sulfide (H_2S), and MQ-4 for methane (CH_4), ensuring comprehensive environmental monitoring. The hardware architecture consists of an ESP32-CAM, which is for the rover's control purpose and navigation, and an ESP32 responsible for gas data obtaining and transmission. Sensor readings are continuously sent to a web dashboard, enabling remote users to monitor hazardous gas levels and analyze trends. The web service is useful for data sharing and remote access, building situational awareness, and worker safety. Sensor readings are continuously sent to a web dashboard, enabling remote users to monitor hazardous gas levels and analyze trends. The system's web interface allows for data sharing and remote accessibility, enhancing situational awareness and worker safety. The benefit of this prototype is being cost-effective, scalable, and real-time gas monitoring capability and alerting system, and hence an efficient solution for occupational safety for underground mines.

Keywords—IoT, gas monitoring, mining safety, toxic gas detection, ESP32-CAM, real-time alert system, MQ-7, MQ-135, MQ-4, occupational safety, environmental monitoring, web-based dashboard.

I. INTRODUCTION

Mining remains one of the most hazardous industries, with exposure to toxic gases such as methane (CH_4), carbon monoxide (CO), and hydrogen sulfide (H_2S) posing severe health risks to workers. These gases, often odorless and highly combustible, contribute to fatal accidents such as explosions, suffocation, and long-term respiratory diseases. Traditional gas monitoring systems have fixed sensors, which need constant manual attention and are not useful in large-scale mining operations where gas accumulation may occur suddenly. Furthermore, limited accessibility to certain mining areas makes manual monitoring both challenging and dangerous.

Accidents like the China coal mine explosion in 2024, three people killed in at Mexico incident in 2024 and the Odisha mine gas leakage in 2023 have been fatal ones and these are the main reasons to have the safety system in real-time such as in the underground mining area.

Such calamities point to the drawbacks of traditional monitoring methods where one is likely to take time to detect the gas or where safety measures may not be effective enough to prevent an explosion. This is because there is no strong real-time alerting system that would warn miners when there is an occurrence of gas leakage or an explosion.

The conventional methods of monitoring gases have been enhanced with the new strategies in the recent past. One of them is the Smart Safety Helmet which is a helmet containing microcontrollers like ESP32 along with the integrated sensors that help in detecting hazardous gases. These helmets offer monitoring and notification to the miners, which adds to the safety aspect due to response features.[1]Another essential development is the IoT-Based Environmental Monitoring System that uses WSNs to monitor the gas concentrations in the mining areas. These systems offer information and alarms, which enable timely action to be taken in the event of a leakage of gas [2]. Optical Fibre Sensors can therefore be considered as a reliable solution for the detection of hazardous gases in mines and tunnels. The sensors include the advantages of nonelectrical transmission of signal, electromagnetic interference, corrosion, and miniaturization, and these make them suitable for challenging underground conditions[3].

This project proposes to eliminate these drawbacks by implementing an automated iot-based rover that can move through dangerous mining areas and simultaneously measure the concentration of poisonous gases. the rover is built around the esp32-cam module to provide live video feed and data visualization to the supervisors or safety officers who are away from the working area. this makes it possible to prevent human involvement, and thus lessen the chances of worker exposure to fatal conditions. furthermore, due to the rovers' capability of moving and performing scanning and mapping in complex and restricted mining areas, it is able to cover a larger area as compared to fixed sensors

Apart from safety improvements, the Ore Hazard Explorer presents a versatile and inexpensive method for the detection of potentially lethal gaseous mixtures in mining environments and the prevention of such hazards. This project of integrating IoT and real-time analytics in the mines paves the way for a much safer environment for the workers where the possible risks are reduced to the barest minimum and their lives valued. All these advancements in one way or the other mark significant progress in enhancing the safety of the workers in the mining sector eradicating the shortcomings that come with the conventional monitoring processes.

II. EXISTING METHODS

Much research has been conducted on the detection and monitoring of gases in the mines resulting in the design of sophisticated methods that incorporate sensor technology, communication components, and alerts. They seek to reduce the risk of accidents at the workplace and fatalities in mining and provide continuous monitoring of the environment in underground mining.

Smart mining to monitor dangerous gases such as (CH_4), (CO), and (H_2S) in the coal mine. This system uses gas sensors in conjunction with an MCU that collects data and transmits it to a remote server. Alarms are raised when the gas levels surpass certain set limits and send alerts to the supervisors using text messages and mobile applications. The system focuses on the real-time acquisition of data and enhanced interaction between the miners and control rooms. [4]

Employing the environmental sensors to detect the concentrations of the gaseous components and the subsequent transmission of the data to a control center. The system is intended to give the readings in real time and also give an alarm in the instance of leakage or fire outbreak. Data collected is displayed on an LCD screen in the control room while information dissemination is done through wireless communication channels to those concerned [5].

A proposed scheme for monitoring the gas levels in mining areas using the Bluetooth-based communication system. The system provides the miners with Bluetooth devices that sense toxic gases in the mining environment. These send information to a control station within the Bluetooth range thus allowing the supervisors to monitor the safety of each miner in the mine.[6].

Incorporating environmental sensors to monitor the levels of toxic gases in the coal mines. There is a loud beeping sound and flashing light to warn of high-level dangerous gases present in the area. For the purpose of data transfer, the system relies on a wired network in order to provide a reliable connection in confined spaces such as underground environments.[7].

Lone worker protection, including the use of tracking and monitoring of the surrounding environment. It is used for monitoring the gas levels and sends signals to a control room in case of the existence of dangerous levels of gases. Intended for use in the mobile setting, the system ensures the safety of a person when working alone. Although suitable for individual employees, this system is only helpful for personal protection tools and cannot cover vast mining space. This system provides a gas detection rover that can roam large areas and report visuals and environment data in real time to the supervisors. This increases the safety of the individual and the team and also provides a holistic coverage of mining activities.[8].

III. PROPOSED SYSTEM

The proposed system brings forward the idea of a rover that will be able to move independently in dangerous zones instead of being immobile and having only sensors. This mobility also helps achieve wider coverage within difficult mining conditions where the formation of gas pockets can be unpredictable. Also, the integration of ESP32-CAM augments the flow of real-time visualization of the scenario and even graphical representations of the gas concentrations.

This system has efficient data acquisition, the main disadvantage of this system is that it is highly dependent on the installation of the sensors, which can be difficult in some circumstances. This is done away with in this system through the use of a mobile rover that can manoeuvre in confined and unstable areas for complete area coverage. The ESP32-CAM also helps in streaming video in areas that can only be monitored physically, which is quite risky. The Bluetooth transmission is useful for short-range transmission, but it is not applicable to expansive mining areas.

This is achieved in this system through the use of a Wi-Fi-enabled ESP32-CAM for the transmission of data to a distant location. This makes it possible for data to be transmitted even in challenging environments such as

underground thus improving the flow of communication besides enhancing safety. Although the wired networks help a great deal in this case they are somewhat rigid, especially in large and unstable mining zones. This system employs wireless communication technologies for the efficient transfer of data over large mining terrains. It also has the capability of moving around independently, thus making it easier to collect data from areas that cannot be accessed by fixed sensors.

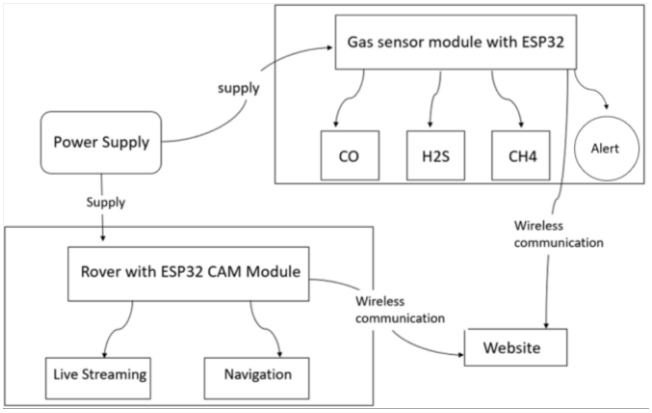

***Figure 1**. System Flow Diagram*

A. ROVER MODULE*:*

The rover module is the traveling and observation component of the Ore Hazard Explorer system. It is meant to be used in some dangerous areas, as it has the function of video streaming, remote control for the robot, and gas concentration measurement. The ESP32-CAM is mainly responsible for controlling the live video stream as well as serial communication with the motor driver board. The real-time video stream is provided through a web interface which can be used to control the rover and to monitor the conditions below the ground. This is safe for operation since it can be done without the need for a human to be in the vicinity of the danger zone.

Its mobility is attributed to four DC motors that are operated by an L298N motor driver. The ESP32-CAM receives directional commands through Wi-Fi and relays the commands to the motor driver to control the voltage signal to the motors so as to achieve the desired movements in different terrains. This makes the web interface enable real-time movement commands such as forward, backward, left, and right through a control panel. This is because the communication between the rover and the web application is very low latency hence making it suitable for applications such as mining, industrial inspections, and environmental monitoring.

The hardware components of the rover module include:

- Live video streaming comes with the help of ESP32-CAM and wireless communication.
- L298N motor driver to control the rover movement based on input signals given through Website.
- Four DC motors for propulsion, providing mobility in rugged environments.
- Rechargeable power supply through Lithium Batteries for uninterrupted operation in remote locations.
- Wheels are designed for stability and adaptability to uneven surfaces.

With Wi-Fi connectivity incorporated in it, the rover does not need close physical interaction and is very useful in exploration and monitoring. This capability is useful in safety assessments in mines, during disasters, and in monitoring hazardous areas where human intervention is dangerous.

B. SENSOR MODULE:

The sensor module of the Ore Hazard Explorer system is part of the system that monitors hazardous gases in real time. This module involves MQ-4, MQ-7, and MQ-135 sensors which are connected to the ESP32 microcontroller for monitoring air quality on a continuous basis. The collected data is then processed analyzed and presented on a web-based application interface as graphs to help the users to make an interpretation of the environmental gas concentrations. And can create a Buzzer alert.

The gas sensors used in the module are:

•**MQ-4** (Methane Sensor): Designed to sense methane (CH_4), which is usually present in underground mines and confined areas. Methane is highly combustible, and early detection is required to prevent explosions and cause skin irritation to the workers.

• **MQ-7** (Carbon Monoxide Detector): Designed for the detection of carbon monoxide (CO), an odorless and colorless gas that is poisonous to humans. Exposure at high concentrations results in serious poisoning and fatal mishaps so CO monitoring under steady conditions becomes imperative.

•**MQ-135** (Hydrogen Sulphide Sensor): Industrial multi-gas sensor capable of sensing ammonia, benzene, smoke, and other air contaminants. This provides the system with greater flexibility to be used for industrial safety, environmental monitoring, and pollution.

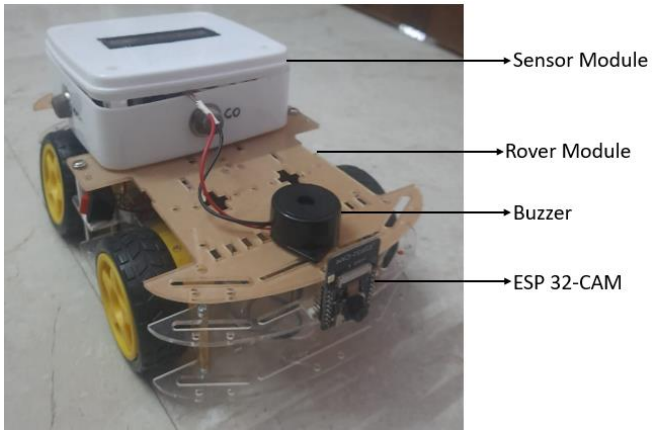

***Figure 2**. Prototype Overview*

Each sensor transmits analog data to the ESP32 microcontroller, which processes the readings using predefined threshold values. If the concentration of any detected gas exceeds safety limits, the system:

- User Activates buzzer alarms integrated to provide immediate on-site warnings.

The web-based dashboard presents sensor data using interactive elements, such as gauge meters, real-time graphs, and color-coded alerts, making the system user-friendly and easy to interpret. This feature ensures that miners, supervisors, or remote operators can quickly assess risks and take precautionary measures.

Moreover, through ESP32 the data transmission is done through Wi-Fi and so the sensor module can be controlled even when it is physically disconnected from the rover but can be accessed remotely. This capability makes the system ideal for long-term monitoring of the environment in underground mines, tunnels, and other industrial structures with hazardous gases that endanger the lives of workers.

C. WEBSITE:

The Ore Hazard Explorer has a web application that is used for monitoring gas concentration data, rover position, and video stream. It is made simple, interactive, and available from any location to allow for remote operation and constant environmental monitoring.
The Website link is https://orehazardexplorer4.netlify.app/

Key Features of the Web Interface

1. Real-Time Gas Monitoring Dashboard
    - Displays live data from MQ-4, MQ-7, and MQ-135 sensors.
    - Representation of gas concentration for detailed analysis.
2. Rover Control Panel
    - Live video feed streamed from the ESP32-CAM.
    - Directional control buttons for navigating the rover remotely.
    - Speed adjustment and movement logs for improved maneuverability.
3. Alerts and Notifications
    - Sound alarms are triggered by a switch button on the website.

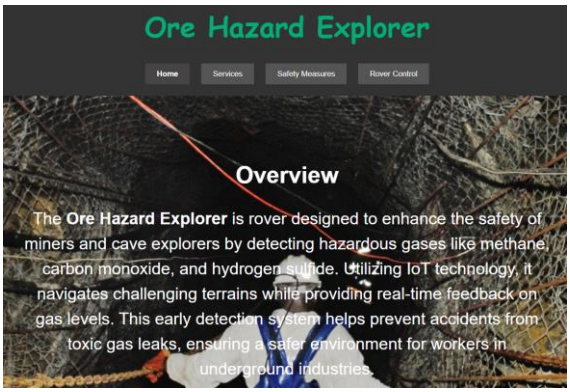

***Figure 3**. Home page of the website*

The backend system, powered by , guarantees the continuous data transmission and processing. The web server is designed to be lightweight so as to minimise latency and to provide communication between the sensors, the rover and the users.

This approach of integrating the Ore Hazard Explorer into a web-based system means it can be effectively used as an industrial safety tool and in disaster management as well as for autonomous monitoring of the environment. Remote evaluation of dangerous conditions and the ability to control robotic modules also minimise the risk levels for people while increasing productivity.

The Ore Hazard Explorer website was therefore developed as an easy to use and fully equipped tool that improves user safety, rover control and system management. Real-time monitoring of the gas situation, remote control of rovers, and available maintenance resources make the work of the website fast, problem-oriented, and safe. It is self-explanatory, allowing professionals and researchers to control the environment and make decisions from a distance based on the information received.

D. Safety Measures Page

The primary focus of the Ore Hazard Explorer is the safety of the people working in the mining industry, due to which

the platform is equipped with MQ-4, MQ-7, and MQ-135 sensors to monitor hazardous gases constantly. In order to monitor the toxic gas levels in the atmosphere, the system alerts the users when the concentration of the toxic gases is high. The system detects and alerts users to toxic gas accumulations before they reach dangerous levels. In case of elevated gas concentrations, can we trigger an alarms from the web interface, allowing for swift intervention.

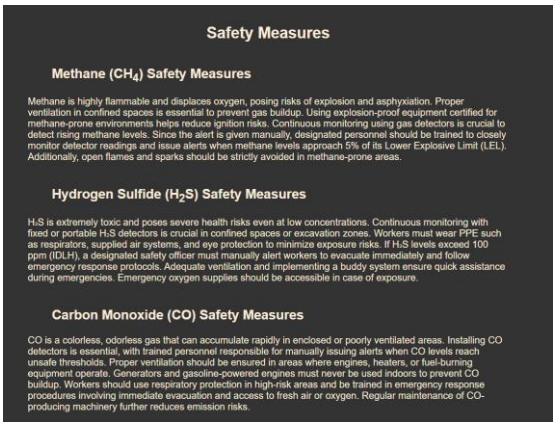

Figure 4*. Safety measures webpage*

Also, for safety, the platform includes a safety guideline section that outlines the emergency response procedures, gas concentrations, and suggested evacuation procedures to enhance the user's ability to take action in the event of an emergency. The system's data also allows for the storage of historical data on the concentration of the gas in order to determine trends and make maintenance and safety precautions in advance.

E. Service Page:

The Service Page is a separate section that provides all the necessary information on how to maintain, repair, and improve the rover and its sensor units. It also provides step by step procedures on how to perform some of the basic maintenance including sensor calibration, motor cheque, connexion cheque, and software update to enhance the functionality and durability of the system.

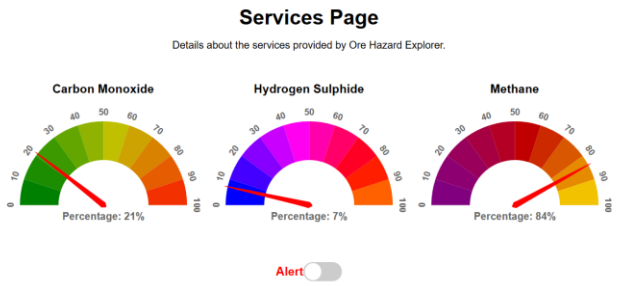

Figure 5*. Service web-page*

The service section outlines the different calibration processes that would be used to make sure that the gas sensors give accurate and reliable readings hence reducing the number of errors that might be present within the system. Through these guidelines, the users can maintain the Ore Hazard Explorer in its best condition and performance in hazardous areas.

F. Rover Control Page:

The Rover Control Page can be described as a web-based interface that provides easy and efficient means for controlling the rover and viewing its data feeds. It has a control panel that includes directional controls that will help the user maneuver the rover in any terrain including underground mines, tunnels, and industrial areas. Also, the control panel includes the data obtained from the gas detection module and the state of the environment, to enable the users to make rational decisions concerning the route. The system also includes options for automated path planning and avoidance of various obstacles, thereby minimizing the number of instances that require human intervention during exploration. Also, the page has data logging and history where the users can monitor the movements of the rover, the readings of the sensors, and the concentration of the gases to improve the evaluation of the area and research.

These critical features incorporated in the Ore Hazard Explorer website enable the user to monitor the hazardous conditions, control the rover, and manage the system with maximum efficiency, and least possible downtime. Connectivity, easily navigable interface, and strong safety features make it an essential tool in mining and industrial safety and environmental threat identification for the more effective and safer means of gas detection and remote exploration.

The source code for the implementation presented in this paper is made available at the following GitHub repository https://github.com/leelasudarshan-git.

Experimental Results:

The Ore Hazard Explorer is tested to check its effectiveness in identifying toxic gases, mobility in difficult terrains, and data relaying in real-time. It was used to assess the performance of the MQ-7, MQ-136, and MQ-4 sensors in detecting desired mine-like concentrations of CO, H_2S, and CH_4, respectively. Also, the ESP32-CAM module allowed for continual data transmission and live streaming through the rover-remote monitoring system interface. Gas Detection Accuracy and Sensor Validation

In order to determine the efficiency of the gas detection, specific amounts of toxic gases were introduced into a chamber that simulated the conditions of underground mining. This showed that the MQ-7, MQ-136, and MQ-4 sensors were sensitive and had a quick response in detecting hazardous gases in an average of 5 seconds. The

recorded gas concentration levels were then compared with the readings of commercial gas detection devices and it was found that the difference was less than 5% of the actual reading proving the efficiency and reliability of the system. It was also effective in raising alerts when the concentrations of the gases were beyond the permitted levels hence underlining the system's efficiency as a hazard prevention tool.

The mobility of the rover was tested in a scenario that depicted a mining environment that entails rough surfaces, low light conditions, and many barriers. The results indicated a 92% pass rate on obstacle avoidance indicating the efficiency of the rover in manoeuvring through complex terrains. It proved to have a steady movement on gravel, sand, and rocky terrains to guarantee its functionality in a real mining environment. Also, the experiment involved using the web interface to take manual control of the rover in case it was needed to override the autonomous mode of the rover. This allows the Ore Hazard Explorer to have both autonomous motion and the ability for manual control in case of encountering unexpected and potentially dangerous conditions.

The ESP32-CAM was tested to check the capability to stream live using data transmitted from the rover to a remote monitoring center. The system was able to display the monitor's high-quality image and the real-time gas concentration with very low delay in order for constant environmental monitoring to take place. In terms of the efficiency of the communication module, the data loss rate was less than 3% even in the zones with low density of Wi-Fi signals. For improved performance in low signal areas, the system is capable of data buffering and retransmissions thus minimizing on data loss of crucial information. It also had a very effective interface for presenting sensor data and data logs as well as live streaming video for giving users a real-time awareness of the situation.

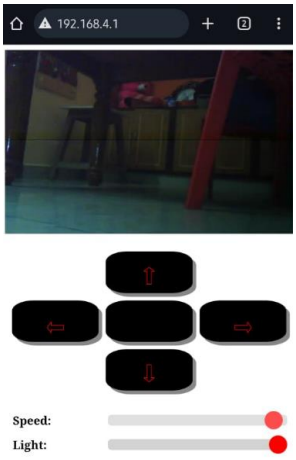

***Figure 6**. Rover control interface*

The results of the experiment also supported the hypothesis of the proposed system that is efficient for monitoring and exploration of the gases and for detecting toxic gases, avoiding errors in navigation through terrains and transmitting data in real time. Some of the future advancements may include the incorporation of 5G for better data transfer, AI for real-time hazard identification and better battery management for longer use. All these improvements will bolster the Ore Hazard Explorer's position as a premier solution for mining safety and hazardous environment detection.

CONCLUSIONS:

The experimental values confirm that the Ore Hazard Explorer is an effective low-cost and safe tool for the detection of toxic gases and environment analysis in dangerous and hard-to-reach areas. Through the use of real-time gas detection, obstacle avoidance, and remote monitoring, the system improves safety measures in mines and offers a technological advantage in industrial risk management. It has also been able to identify toxic gases with a high level of precision, avoid obstacles on its path on its own, and send relevant information about the surroundings to the control center with little delay through its wireless connections. This makes it easier for mine workers, researchers, and safety personnel to make fast decisions on whether or not the environment is safe to venture into, or whether the identified dangers are safe to approach.

The mobility in any environment allows the rover to be used in hazardous areas where the involvement of humans is either risky or inconceivable. Its portable and portable structure makes it suitable for use in industrial, scientific, and even exploration such as mining, disaster management, and environmental studies. The inclusion of wireless communication modules as a part of the device enables real-time hazard evaluation and monitoring, and the measures to be taken in the event of an emergency can be taken without delay. Unlike other gas detection systems that are immovable, expensive, and fixed, the Ore Hazard Explorer is movable and cheaper and can be taken to areas with high risks for improved safety and productivity.

The rover's greatest asset is that it is highly flexible, with the ability to be built to order, and can be designed and built to suit the needs of a particular operation. The platform can be expanded with more sensors for additional purposes, AI analysis, and new forms of communication, which makes it a future-oriented solution for the development of the industry. In the future, more efforts will be made to enhance the performance of the sensors, increase the battery capacity to support the longer operation time and develop an AI-based decision-making system for more intelligent navigation in various terrains.

Possible advancements may include the use of 5G to ensure constant data transmission by means of connexion,

the enhancement of the precision of the sensors through sensor fusion and the application of machine learning algorithms that could predict future leakage or hazardous conditions before they occur. When it comes to ensuring safe working conditions, minimizing the human factor, and popularising hazardous environment navigation, the Ore Hazard Explorer has the potential to become an indispensable tool due to its constant development in terms of functionality, accuracy, and real-time response systems.

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