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Coal Mine Monitoring System with Landslide Hazard Detection

Rashmi Shaligram Bhumbare[1*], Dr. Sudhir Paraskar[2], Prof. Yogesh Sushir[3], Prof. Tejal Kharche[4], Prof. Moiz Hussain[5]
[1*]Electrical engineering(E&P) VBK college of engineering Malkapur, India rashmisbhumbare@gmail.com
[2]Electrical engineering SSGM college of engineering Shegaon, India srparaskar@gmail.com
[3]Electrical engineering VBK college of engineering, Malkapur, India yogeshsushir@gmail.com
[4]Electrical engineering VBK college of engineering, Malkapur, India tejalkharche96@gmail.com
[5]Electrical engineering VBK college of engineering, Malkapur, India mymoiz2004@yahoo.co.in

Abstract—
Real-time monitoring of landslides is one of the challenging research areas now a days within the field of geophysical research. The event of an actual field deployment of a device network primarily based on a landslide detection system. This system uses sensor nodes and communication for efficient delivery of real-time data to the system for monitoring and provides warnings and risk assessments to the inhabitants of the area. This network will be used for understanding the capability and usability of sensor networks for critical and emergency applications. In this context, this project delves into the development of a sensor-based system that utilizes multiple sensors for landslide detection as well. We will explore how these sensors enhance the monitoring of surrounding environmental awareness in a coal mine, enabling it to relay data in dynamic and complex scenarios.
Keywords—*Temperature Sensor, Pressure Sensor, Gas Sensor, Buzzer*

I. INTRODUCTION

The cost of mining is expected to be the minimum price. The field of robotics is constantly evolving, with robots becoming increasingly sophisticated and capable of operating in complex environments. One key factor driving this advancement is the integration of multi-parameter observing sensors. Real-time monitoring of landslides is one of the challenging research areas available nowadays within the field of geophysical research.

A mine is considered to be a plant that produces useful minerals with a given percentage of ore and a given quantity, whereas the cost of mining is expected to be the minimum price. Geological conditions of any mine are determined by nature. They are unpredictable. The various environmental parameters of my system, including methane, carbon monoxide, temperature, and oxygen, are currently transmitted using traditional cable methods. Thus, truly, mine methane and carbon monoxide gas accumulation areas in mechanized mining faces, such as the dead gob cable security parameters, cannot be monitored, so they cannot predict the alarm. Mining project activity is subject to high risks because of its size, uncertainty, complexity, high costs, and mine worker safety; the emission of toxic gases from the coal seam in turn leads to air pollution in the mine area. These conditions can be monitored using a robotic device.

II. LITERATURE SURVEY

Zhang, Huili, et al. [1] reviews modern IoT applications in underground mining, focusing on safety, environmental monitoring, and production efficiency. It explores wireless sensor networks, real-time data analytics, and smart monitoring systems that help detect gas leaks, temperature fluctuations, and equipment failure. By integrating IoT into mining operations, the study demonstrates how real-time monitoring and automation can enhance worker safety, reduce risks, and streamline operations. The authors also discuss challenges like network coverage, sensor durability, and energy efficiency. This work emphasizes the potential of IoT in transforming mining into a safer and more intelligent industry.

U. Chandra mouli, M. Namratha et.al [2] a low-cost IoT-based system to monitor coal mine environments and ensure worker safety. It utilizes sensors to detect harmful gases, temperature, humidity, and track worker locations. Data is transmitted wirelessly to a control center where thresholds are analyzed. In emergencies, the system triggers real-time alerts via alarms or messages to mitigate risks. The paper focuses on cost-effectiveness, ease of deployment, and responsiveness in hazardous underground settings. By offering continuous monitoring and immediate alerting, the system reduces chances of accidents and enhances safety in coal mining operations.

Dr. N. Sambasiva Rao, Mr. Gangisetty Devanand et.al[3] an IoT-powered system for improving safety in coal mines through real-time monitoring and automated alerts. It integrates gas, temperature, and motion sensors with wireless communication modules to detect hazards and instantly notify workers and authorities. The system supports proactive risk mitigation by identifying unsafe conditions early. Designed for low power consumption and high reliability, the solution emphasizes quick response to fire, gas leaks, or structural collapses. The authors demonstrate how IoT can enhance traditional safety systems, improving awareness, operational efficiency, and worker protection in underground mining environments.

Bagwari, Swapnil, et al. [4] review explores the potential of using low-cost sensors and LoRaWAN networks for landslide detection and monitoring. The authors discuss sensor types that measure soil moisture, vibration, and movement, highlighting their integration with long-range, low-power LoRaWAN for data transmission. The paper emphasizes the need for scalable, affordable, and energy-efficient systems for deployment in remote landslide-prone regions. Various architectures and case studies are analyzed to identify best practices and technical gaps. The study concludes that combining IoT and LoRaWAN can provide a viable solution for early warning systems, saving lives and reducing infrastructure damage.

Indukala, P. K., U. G. Gosh et.al [5] a microseismic-based IoT system to detect and monitor landslides in real time. It employs sensitive seismic sensors connected to a cloud-based platform that analyzes data continuously. When abnormal micro-vibrations are detected, alerts are sent to concerned authorities. The system uses wireless networks to ensure accessibility even in remote terrains. The authors focus on integrating data science with hardware for accurate prediction and early warnings. This proactive approach enables fast evacuation and infrastructure protection. The paper demonstrates how combining microseismic sensing with IoT can revolutionize landslide risk management.

Mrunal Jawalkar, Nikita Malviya et.al [6] a practical, sensor-based IoT solution for landslide detection using soil moisture, vibration, and tilt sensors. The collected data is transmitted wirelessly to a central system that analyzes patterns to predict landslides. When a potential threat is identified, the system sends alerts via messages or alarms. The solution is designed to be affordable and easy to implement in landslide-prone areas. It emphasizes real-time monitoring and community safety. By offering early warnings, the system minimizes loss of life and property. The study validates its effectiveness through simulations and small-scale field tests.

Mousavi, Milad, et al. [7] present a framework combining IoT sensor networks with Bayesian inference to monitor real-time environmental safety risks in mining. Using data from gas, temperature, and humidity sensors, the model applies probabilistic reasoning to detect unsafe conditions. Tested with datasets from Polish and Chinese mines, the system demonstrates early hazard prediction and robust decision-making under uncertainty. This fusion enables intelligent, remote mine monitoring, enhancing workplace safety and risk prevention in complex environments.

Ray Chowdhury, Ankita Pramanik et al. [8] design an IoT system using LoRaWAN for deep underground coal mine monitoring. The system detects hazardous gases, temperature, and humidity, transmitting data through LoRa-enabled nodes. A Mine Environment Safety Index algorithm evaluates safety in real-time. Field-tested in Indian mines, the solution overcomes signal propagation issues underground and ensures efficient early warning capabilities. Its low-power, long-range design makes it suitable for large-scale mine deployments to enhance safety and operational awareness.

Scalambrin, Luca, Andrea Zanella et al. [9] propose a synchronized TDMA-based multi-hop LoRa network for reliable underground mine communication. The system ensures time-synchronized packet transfers with ultra-low latency and energy efficiency. Analytical models and real-world tests confirm the system's scalability, robustness, and suitability for harsh subterranean environments. This approach improves wireless sensor network stability for mine safety and environmental monitoring, overcoming challenges of low connectivity and signal distortion underground.

Kartik and Manimaran present [10] a smart helmet embedded with IoT sensors to detect hazardous conditions in real time. The helmet monitors gas levels, temperature, motion, and worker location, transmitting data to a central server. Alarms are triggered when predefined thresholds are exceeded. This wearable system enhances personal safety, supports early risk detection, and provides location-based assistance in emergencies. Its lightweight, wireless design makes it ideal for use in dangerous mining environments.

III. METHODOLOGY

The project basically comprises of two parts, one part covers development of a robotic device the monitors various environmental entities inside the coal mine and in the vicinity of the same and another part that covers development of lad slide detection system again inside or in the vicinity of a coal mine.

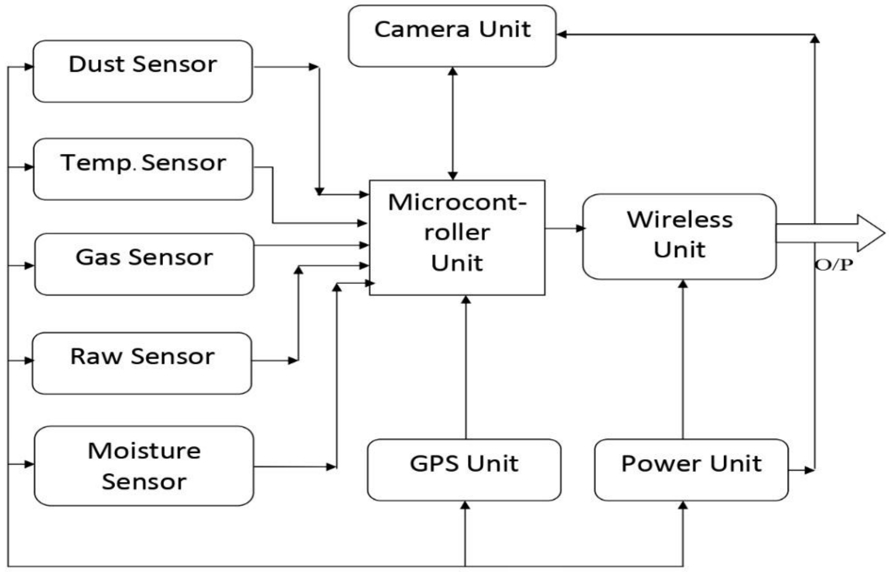

Figure1. Proposed Block Diagram of coal mine monitoring robot

This section outlines the key steps involved in developing a robotic system that utilizes multi-parameter observing sensors.

1. Define Project Goals and Requirements:

Identify the Application: Clearly define the purpose of the robot and the environment it will operate in. (e.g., environmental monitoring, land slide detection, coal mine inspection and rescue as well)

Specify Environmental Parameters: Determine the critical environmental factors the robot needs to be aware of for successful operation. (e.g., Temperature, pressure, obstacles, presence of chemicals)

2. Sensor Selection and Integration:

Research Sensors: Explore various sensor technologies capable of measuring the chosen environmental parameters. Consider factors like range, accuracy, size, power consumption, and cost.

Choose Appropriate Sensors: Select the most suitable sensor for each parameter, considering the application requirements and robot platform limitations.

Sensor Integration: Physically integrate the chosen sensors onto the robot platform, ensuring proper placement and secure connections.

Calibration and Testing: Calibrate each sensor for accurate readings and thoroughly test the integrated sensor suite for functionality and communication with the robot controller.

3. Data Acquisition and Processing:

Data Acquisition System: Develop a system to collect raw data from all sensors at a specified sampling rate. This may involve an embedded controller or dedicated data acquisition hardware.

Feature Extraction: Extract relevant features from the preprocessed data that best represent the environmental parameters for decision-making. (e.g., Average temperature, range to obstacle, presence of specific chemicals)

4. Testing and Evaluation:

Real-World Testing: Conduct real-world testing in a controlled environment that mimics the target application. This allows for evaluation of the robot's performance with actual sensor data.

Iterative Improvement: Based on testing results, refine sensor selection, data processing methods, or decision-making to optimize performance.

5. Documentation and Reporting:

- Document the Design Process: Detail the sensor selection, integration techniques, data processing algorithms, and decision-making strategies.
- Present Results: Report the performance of the robot in simulations / real-world testing, highlighting the effectiveness of the multi-parameter sensor approach.

Additional Considerations:

- Power Management: Optimize power consumption of sensors and data processing to ensure sufficient battery life for the robot.
- Safety Measures: Implement safety protocols to ensure the robot operates safely in its intended environment, especially when dealing with hazardous conditions or materials

A. Hardware Components

- Dust Sensor
- Temperature Sensor
- Gas Sensor
- Moisture Sensor
- GPS Sensor
- GSM Sensor
- Arduino UNO

IV. RESULT ANALYSIS

The monitoring system is designed to track key environmental parameters, each with defined normal ranges and alert thresholds. Gas value should remain between 0 and 30 units; any value exceeding 50 indicates a potential hazard and triggers an alert. Moisture value is considered normal when below 150 units, but readings above 200 signify abnormal conditions requiring attention. Temperature is expected to stay within 25–30°C, while any temperature exceeding 40°C raises an alert for possible overheating or fire risks. Similarly, dust density should be less than 5 units, and any value above 10 indicates a critical air quality issue that demands immediate action.

Table 1 Comparing Normal vs. Alert values

Parameter	Normal Range	Alert Threshold
Gas Value	0–30	> 50
Moisture Value	< 150	> 200
Temperature (°C)	25–30	> 40
Dust Density	< 5	> 10

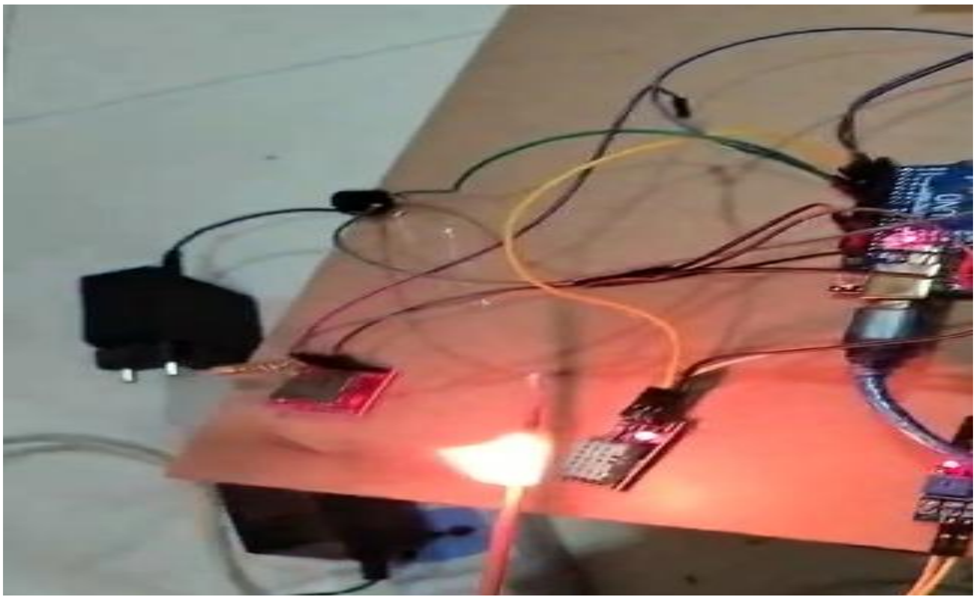

Figure 2 Hardware Image

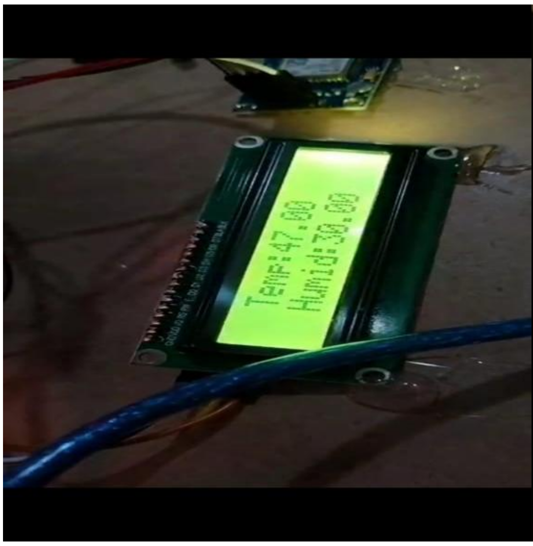

Figure 3 Hardware LCD Show Values

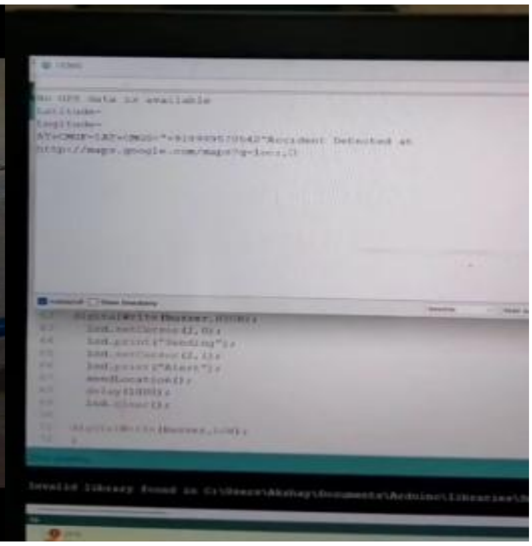

Figure 4 Codes and Output

V. CONCLUSION

In this project, we have developed and demonstrated a real-time landslide monitoring and alert system using a multi-sensor, microcontroller-based approach. The core technique employed is the integration of a Wireless Sensor Network (WSN) consisting of environmental sensors (gas, temperature, humidity, dust, moisture) and a GPS module, all coordinated by an Arduino-based embedded system. This setup enables the continuous and autonomous collection, analysis, and transmission of real-time environmental data from landslide-prone areas, particularly coal mines. The deployment of a device network in the field primarily relies on a landslide detection system. This system uses sensor nodes and communication for efficient delivery of real-time data to the system for monitoring and providing warning and risk assessments to the inhabitants of the area. This network will be used for understanding the capability and usability of sensor networks for critical and emergency applications. In this context, this project delves into the development of a sensor-based system that utilizes multiple sensors for landslide detection as well. We will explore how these sensors enhance the monitoring of surrounding environmental awareness in a coal mine, enabling it to relay data in dynamic and complex scenarios. By successfully integrating multi-parameter sensors, this project aims to create a more versatile and adaptable robotic system capable of tackling challenging tasks in coal mine environments.

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