

# Coal Mine Monitoring System with Landslide Hazard Detection

**Rashmi S. Bhumbare, Mr. Yogesh Sushir, Dr. Moiz Abdul Hussain, Mrs. Tejal Kharche**

Department of Electrical Engineering (Electronics and power), Padm. Dr. V. B. Kolte College of Engineering, Malkapur Dist. Buldhana 443101

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## ABSTRACT

*Coal mining operations, especially in geologically unstable areas, face significant challenges from both hazardous gas emissions and potential landslides. Traditional monitoring systems fail to offer the real-time, multi-parameter awareness necessary for effective risk mitigation. This paper presents a practical robotic solution designed to monitor coal mine environments through an array of basic environmental sensors, including those for gas concentration, temperature, and ground stability. The system also incorporates a landslide hazard detection module, capable of early warnings based on terrain shifts and vibrations. The integration of real-time data acquisition with local alerts provides a cost-effective framework for enhancing miner safety and operational continuity.*

*Keywords: Coal mine monitoring, landslide detection, robotic surveillance, gas sensors, vibration detection, low-cost prototype.*

## 1. INTRODUCTION

Coal mining continues to be a major contributor to energy production globally. However, these operations are frequently exposed to hazardous conditions such as toxic gas leaks, high temperatures, and the threat of landslides. Traditional safety mechanisms often fall short of providing real-time data and early warnings, putting the lives of workers at risk.

With advancements in microcontrollers and basic sensors, intelligent monitoring systems now offer the capability to collect multi-parameter data. A robotic system equipped with environmental sensors can autonomously navigate a coal mine, detect abnormalities, and transmit data for local monitoring. This paper proposes a robotic monitoring system that provides real-time awareness of environmental conditions and early detection of landslides, using simple, low-cost hardware.

## 2. LITERATURE REVIEW

Several efforts have been made to enhance safety in coal mining through automated systems. Zhang et al. (2023) discussed trends in underground mine monitoring, highlighting the industry's shift toward sensor-based technologies. Chandra Mouli et al. (2024) proposed wearable sensor-based devices for workers, but lacked an integrated robotic platform. Rao et al. (2023) focused on standalone wireless gas monitoring systems.

In the context of landslides, Indukala et al. (2024) presented a microseismic sensing platform, and Bagwari et al. (2022) reviewed sensor characteristics for slope monitoring. However, most of these solutions are either complex or focus on a single hazard. This paper integrates multiple sensors into a mobile, low-cost robotic system capable of both mine and landslide monitoring using accessible hardware.

## 3. PROPOSED SYSTEM

The proposed system is a mobile, sensor-based robot that monitors environmental parameters in coal mines and detects early signs of landslides. It avoids the use of complex IoT technologies and instead relies on simple microcontroller-based processing with basic communication modules.

Key components include:

- Robot platform using DC motors and chassis
- Gas sensors (methane, carbon monoxide)
- Temperature and humidity sensor
- Vibration and tilt sensors
- Microcontroller (e.g., Arduino Uno)

- Short-range communication (wired or RF modules)
- Buzzer and LED indicators for local alerts

The robot navigates predefined routes, collects sensor data, and activates alerts in case of hazard detection. Data can be monitored on a nearby computer or display unit.

#### **4. METHODOLOGY**

The development process follows these simplified steps:

##### 4.1 Requirements Analysis:

- Define environment: Simulated coal mine or terrain model
- Identify key parameters: Gas levels, temperature, vibrations, tilt

##### 4.2 Hardware Development:

- Select and integrate sensors with Arduino
- Calibrate using known test inputs (e.g., gas lighters)

##### 4.3 Data Collection:

- Collect sensor readings via microcontroller
- Display data on LCD or send to PC via serial
- Trigger local buzzer/LED alert on unsafe readings

##### 4.4 Testing and Evaluation:

- Test on mock setups for gas leaks and vibrations
- Record sensor performance and system responsiveness

This methodology supports a practical and educational approach suitable for real-time lab implementation and field adaptation.

#### **5. RESULTS AND DISCUSSION**

Initial testing was conducted in a lab-scale environment using simulated hazards. The performance of each component was evaluated based on responsiveness, accuracy, and reliability.

- Gas sensors effectively detected methane and carbon monoxide at small concentrations using gas lighters.
- Temperature and humidity sensors provided consistent readings compared with commercial devices.
- Tilt and vibration sensors responded within seconds to artificially induced slope changes or tremors.
- Buzzer and LED indicators triggered alerts instantly when thresholds were crossed.

Communication using RF modules maintained stable connections over a short range (up to 20 meters). Wired communication showed excellent reliability. The system proved to be effective for detecting common hazards and provides a reliable platform for educational and prototype purposes.

#### **6. CONCLUSION**

This paper presents a practical, low-cost robotic system for monitoring coal mine environments and detecting landslide risks. By integrating basic sensors on a mobile platform, the system effectively detects hazardous gases, temperature changes, and terrain instability. Its simple design avoids complex IoT architectures, making it feasible for academic projects and initial field trials. The system's modularity and affordability allow for easy customization and expansion. In the future, enhancements such as GPS integration and wireless data logging can improve coverage and real-time decision-making capabilities.

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