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Mine Monitor IoT Based Environmental Oversight System

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Abstract: ***Mining is an essential sector for economic growth and industrial development; however, it often poses significant environmental challenges, including air and water pollution, soil degradation, biodiversity loss, and increased greenhouse gas emissions. The Mine Monitor IoT Based Environmental Oversight System is proposed as a comprehensive solution designed to ensure sustainable mining through advanced environmental monitoring, data analytics, and automated oversight mechanisms. This system integrates modern technologies to continuously assess and manage the environmental impacts associated with mining operations. The system's user interface provides a dynamic dashboard accessible to multiple stakeholders, including mine managers, environmental officers, government regulators, and local communities. Through visualizations, automated alerts, and report generation tools, stakeholders can monitor real-time environmental performance, assess compliance with environmental standards, and make informed decisions to minimize ecological impact.***
Keywords: Microcontroller, IoT

I. INTRODUCTION

The Mine Monitoring: IoT-based Environmental Oversight System is a comprehensive safety and surveillance solution designed to continuously monitor critical environmental parameters inside mines. Mining environments are inherently hazardous due to factors such as gas emissions, moisture accumulation, poor ventilation, and structural instability. To mitigate risks and ensure worker safety, real-time monitoring and responsive alert systems are essential.

By integrating cutting-edge technology with environmental management principles, the MMEOS not only enhances regulatory compliance but also promotes transparency and accountability within the mining industry. It serves as a vital tool for achieving a balance between economic productivity and ecological preservation. Ultimately, the Mine Monitor Environmental Oversight System represents a forward-thinking approach to sustainable mining, supporting responsible resource extraction while safeguarding the surrounding environment and communities.

A. Motivation and Significance

Mining operations, especially underground mining, pose severe risks to human life. Hazards such as gas poisoning, tunnel collapse, equipment failure, and flooding are ever-present. Traditional safety checks rely on periodic manual inspections, which can be slow, dangerous, or subject to human error. By deploying an IoT-based monitoring system, continuous real-time surveillance becomes possible, improving response time during emergencies, minimizing manual inspection needs, and enhancing overall mine safety. The system can also support preventive maintenance and structural health monitoring of the mine infrastructure.

B. Objectives

1) Design and prototype a sensor network capable of measuring gas concentrations and moisture levels reliably in mining conditions.
2) Implement a camera-based visual inspection module suited for underground (low light, dust, vibrations).
3) Develop firmware and networking protocols to transmit data from sensor nodes to a centralized server or cloud backend.
4) Build a user interface/dashboard to visualize environmental readings, images, alerts, and historical trends.
5) Evaluate system performance under simulated mine conditions (e.g. variable gas, humidity, lighting) and assess accuracy, latency, robustness, and false alarm rates.

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C. *Problem Statement*

As a means of reducing the intensity of the accidents due to high temperature, humidity, release of harmful gases our present work focuses on sensing these environmental parameters from different locations in the mines and sends alert to the mine control room operator who uses a IOT based Application whenever there seems to be dangerous situation.

D. *Future Scope*

1) Integration with Artificial Intelligence (AI) and Machine Learning (ML) Predictive Analytics: AI algorithms can analyze IoT sensor data to forecast potential hazards like gas leaks, equipment failure, or ground instability before they happen. Intelligent Decision-Making: AI-driven systems can autonomously adjust ventilation, temperature, or machinery operation in real time.
2) Enhanced Environmental Sustainability Carbon Footprint Monitoring: IoT can be used to track emissions and optimize operations to reduce greenhouse gases.
3) Use of 5G and Edge Computing Ultra-Low Latency Communication: 5G networks will enable faster, more reliable real time data transfer from deep underground mines. Edge Processing: Local data processing near the sensor reduces delays and dependency on cloud connectivity, allowing for faster response in emergencies.

II. WORKING PRINCIPLE

A. *Component's Used:*

1) ESP32 Development Board: is a powerful, low-cost microcontroller used for building IoT and embedded systems projects. It comes with built-in Wi-Fi and Bluetooth, making it ideal for wireless applications like smart home devices and sensor networks. With a fast dual-core processor, multiple GPIO pins, and support for platforms like Arduino IDE and Micro Python.
2) MQ-135 Gas Sensor: The MQ-135 gas sensor is used to detect air quality and harmful gases such as CO_2, ammonia, benzene, smoke, and alcohol. It works by measuring changes in resistance when gases are present in the air. The sensor provides both analog output (A0) for measuring gas concentration and digital output (D0) for threshold detection. It is commonly used in air pollution monitoring systems, smart homes, and safety devices, and can be easily connected to microcontrollers like Arduino or ESP32.
3) DHT11 Temperature Sensor: The DHT11 is a basic sensor used to measure temperature and humidity. It provides digital output, making it easy to connect with microcontrollers like Arduino or ESP32. It can measure temperature from 0°C to 50°C and humidity from 20% to 90% with moderate accuracy.
4) Flame Sensor: A flame sensor is used to detect the presence of fire or flames by sensing infrared light emitted from a flame (typically 760–1100 nm). It provides both analog and digital outputs, allowing it to detect flame intensity or simply trigger when fire is present. Flame sensors are commonly used in fire alarm systems, safety devices, and robotics projects for fire detection and prevention.
5) IR Sensor (for workers count): An IR (Infrared) sensor is used to detect objects or obstacles by emitting infrared light and measuring its reflection. It usually provides a digital output (object detected or not) and sometimes an analog signal.
6) L298N Motor Drive: The L298N motor driver is a module used to control DC motors and stepper motors. It is based on a dual H-bridge circuit, allowing you to control direction and speed of two motors. It works with motor voltages up to ~35V and provides PWM control for speed regulation.
7) Relay Module: It works as an electrical switch, allowing safe isolation between control and load circuits.
8) 4 BO Motors With Wheels
9) 12V Siren
10) OLED 0.96" Display (I2C)
11) Power Supply & Wires

B. *Working Principle*

The ESP32 continuously monitors sensor data from MQ-135, DHT11, Flame, and IR sensors. When gas, smoke, or flame is detected or temperature exceeds a safe limit, the ESP32 activates the relay which powers the siren. The IR sensor counts the workers entering the mine. Once 5 workers have entered, a 20-second timer starts, after which the siren alerts them to exit the mine. The robot can be moved manually using Bluetooth commands (F, B, L, R, S).

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C. Circuit Description

- MQ-135 sensor connected to analog pin 34 of ESP32.
- Flame sensor connected to GPIO 23.
- DHT11 temperature sensor connected to GPIO 4.
- IR sensor connected to GPIO 18 for worker counting.
- Relay module connected to GPIO 5 to control 12V siren.
- L298 motor driver connected as follows: IN1=26, IN2=27, IN3=12, IN4=13; ENA and ENB connected to 5V.
- OLED display connected to I2C pins: SDA=21, SCL=22.
- Power supply: ESP32 (5V), Motor Driver (12V), Common GND shared.

D. Software Implementation

Code is written in Arduino IDE using the following libraries:

- Wire.h and Adafruit_SSD1306.h for OLED display.
- DHT.h for temperature and humidity reading.
- BluetoothSerial.h for Bluetooth communication.

The code logic performs continuous sensor reading and controls the motors and relay based on safety conditions. If any danger is detected, all motor operations are stopped, and the siren is triggered.

E. Circuit Diagram

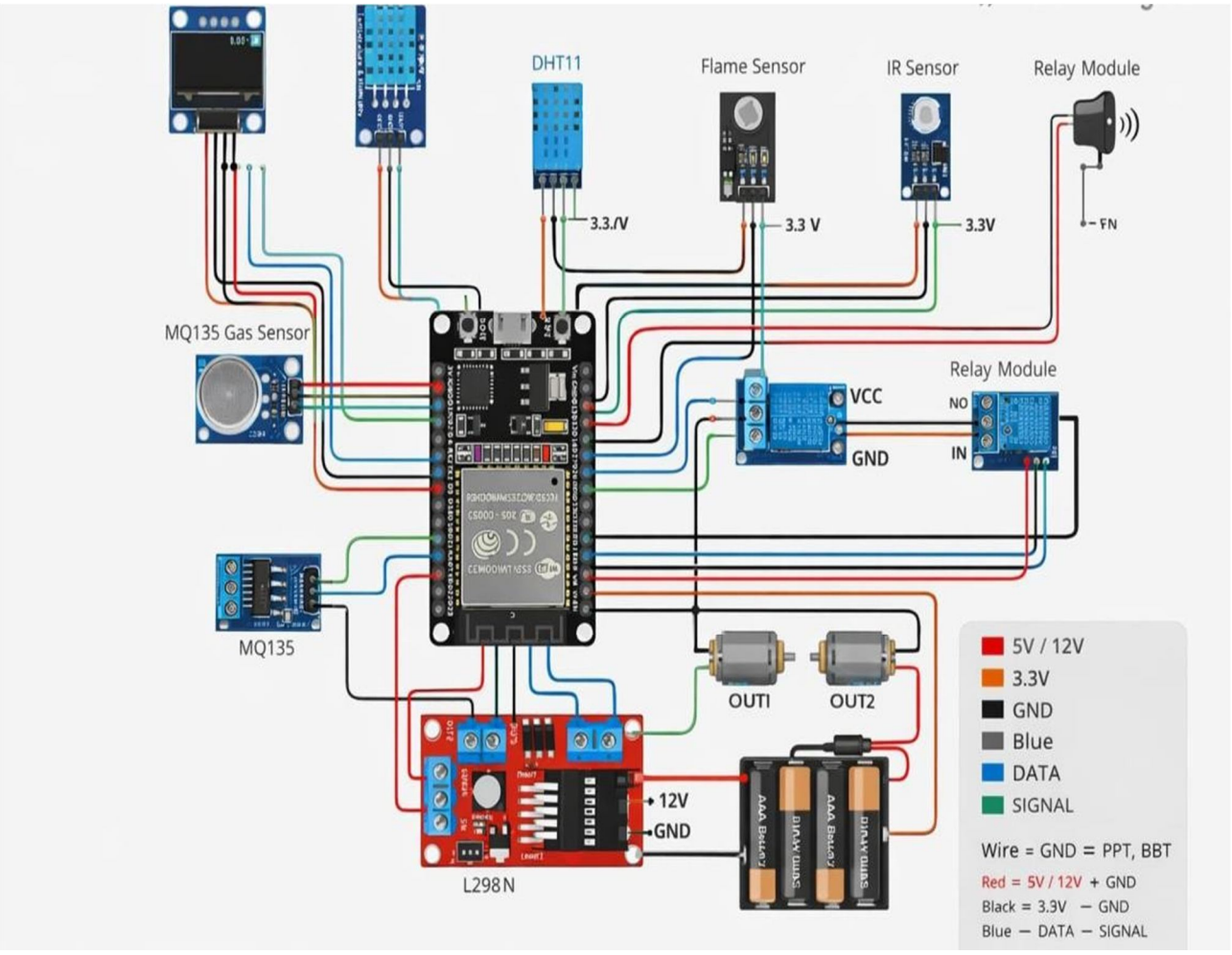


Fig.1 Circuit Diagram

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III. METHODOLOGY

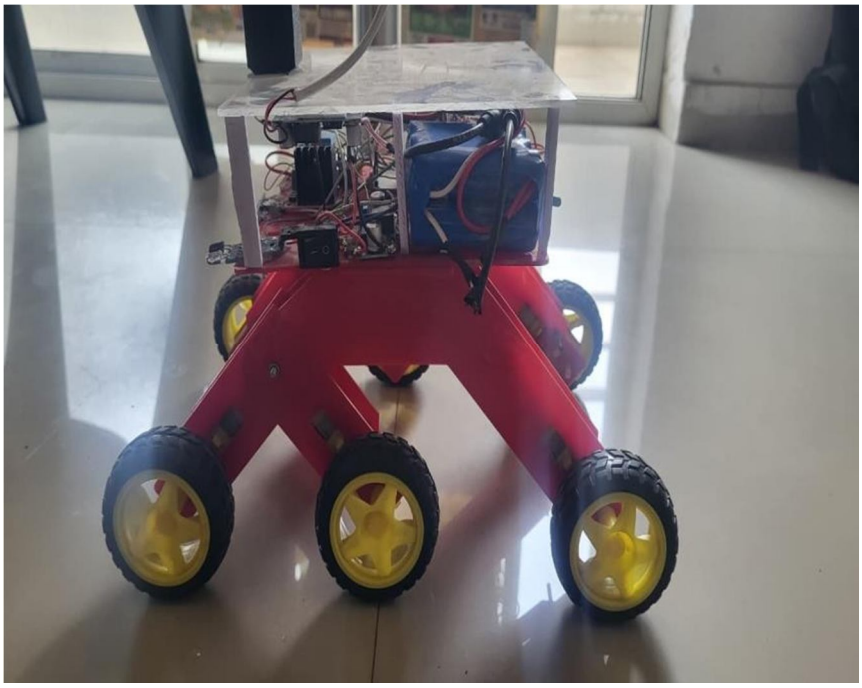


Fig. 2 System Photo

1) The ESP32 continuously monitors sensor data from MQ-135, DHT11, Flame, and IR sensors.
2) When gas, smokes, or flame is detected or temperature exceeds a safe limit, the ESP32 activates the relay which powers the siren.
3) IR Sensor counts the workers entering in the mine.
4) Once 5 Workers have entered, a 20 second timer starts, after which the siren alerts them to exit the mine.
5) The Robot can be moved manually using Bluetooth commands (F,B,L,R,S).

IV. RESULTS

1) The system successfully detected high gas concentration using MQ-135.
2) Temperature and flame detection worked accurately.
3) The siren was triggered instantly on danger detection.
4) Worker counting system accurately tracked the number of workers.
5) Bluetooth control commands operated the robot smoothly.

V. CONCLUSION

1) The hazardous nature of rescue missions in mines, compounded by factors such as explosions, toxic gases, and lack of environmental awareness, necessitates innovative solutions for enhancing safety and effectiveness. The introduction of a monitoring robot system designed for remote sensing of mine environments represents a significant step forward.
2) This multifunctional sensor-equipped system enables distant sensing, providing crucial data to alert rescuers of potential dangers and improve decision-making during rescue operations. Moreover, the development of this robot system serves as a valuable reference for the advancement of future search-and-rescue systems, ultimately contributing to the protection of lives in hazardous environments.

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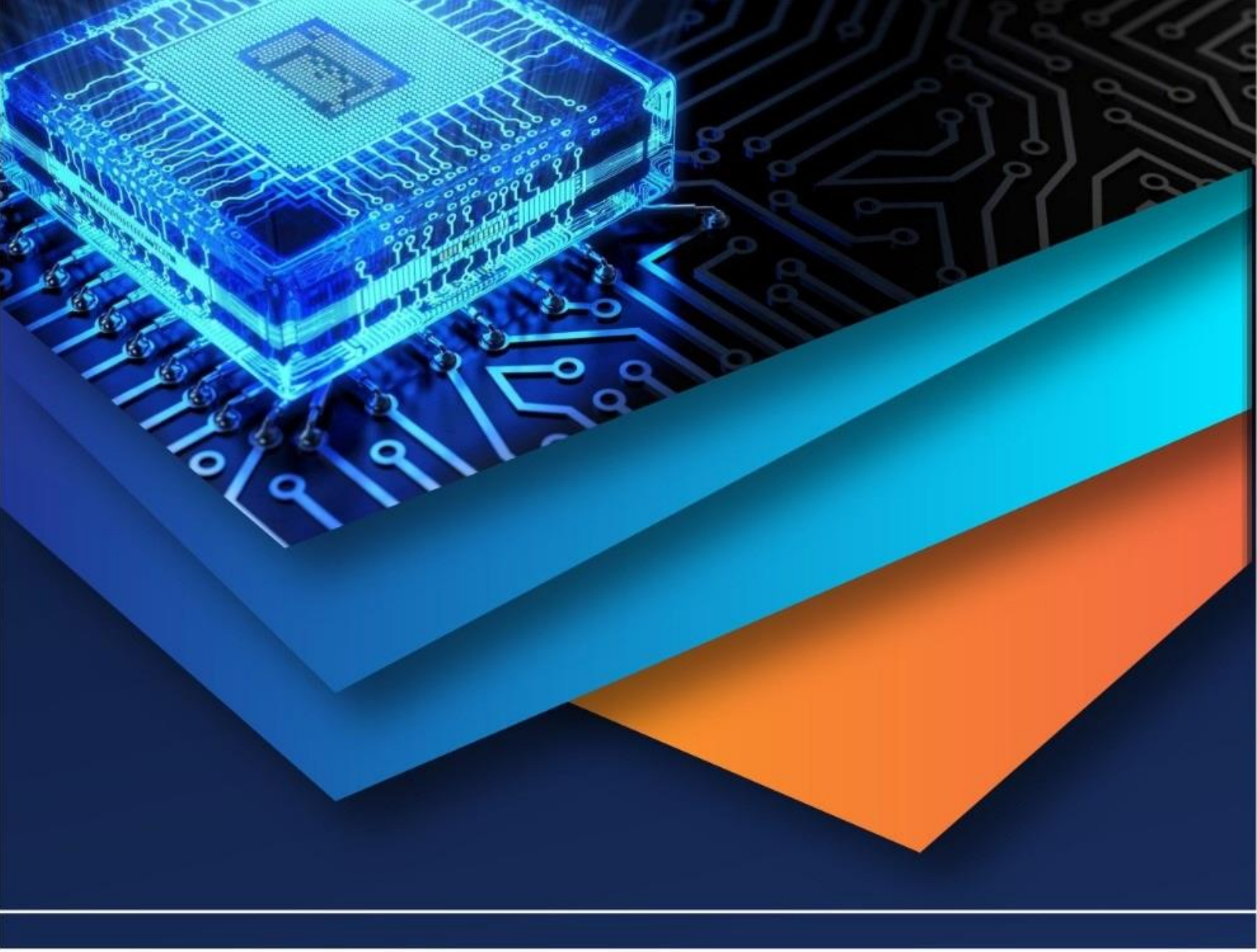
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