Working Mechanism

Machine Learning-Enhanced Portable Gas Detection System for Mines

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The portable gas detection system is designed to monitor the presence of harmful gases and environmental parameters in mines. It uses an array of sensors, machine learning models, and communication technologies to ensure real-time detection, alerting, and data logging.

1. Key Objectives

- **Real-time Detection:** Monitor gas concentrations and environmental conditions like temperature, humidity, and light intensity.
- **Risk Assessment:** Classify gas levels as Safe, Moderate, or Hazardous based on pre-defined thresholds.
- **Alert Mechanism:** Provide visual and audible warnings using LEDs and a buzzer during hazardous situations.
- **Automation:** Trigger exhaust fans to mitigate harmful gas levels.
- **Data Logging & Communication:** Log data locally on an SD card and communicate wirelessly via LoRa and Wi-Fi.
- **Machine Learning Integration:** Utilize a trained machine learning model to predict unsafe conditions.

2. Working Mechanism

Stage 1: Sensor Data Acquisition

- **Gas Sensors (MQ-135, MQ-7, MQ-2, TGS2600, TGS822):**
    - Detect various gases, including CO2, CO, smoke, hydrogen, and alcohol.
    - Provide analog signals proportional to gas concentrations.
    - ESP32 reads these signals and converts them into digital values.
- **Environmental Sensors (BME280, BH1750):**
    - Measure temperature, humidity, pressure, and light intensity.
    - Data is acquired via the I2C protocol and sent to the ESP32.

Stage 2: Data Processing

- **Data Calibration:**
    - Raw sensor readings are calibrated using pre-defined sensor characteristics.

    - This ensures accurate gas concentration levels in ppm (parts per million).
- **Threshold Classification:**
    - Gas levels are classified into three categories:
        - **Safe:** Below defined safety limits.
        - **Moderate:** Approaching harmful levels (cautionary).
        - **Hazardous:** Exceeding safety limits, requiring immediate action.

Stage 3: Alert System

- **LED Indicators:**
    - **Green LED:** Safe levels.
    - **Yellow LED:** Moderate levels.
    - **Red LED:** Hazardous levels.
- **Buzzer Activation:**
    - Emits a loud alarm during hazardous conditions.
    - Helps in notifying workers in the vicinity.
- **Exhaust Fan Control:**
    - Activated via a relay module when gas levels reach hazardous thresholds.
    - Aims to reduce gas concentration to safe levels.

Stage 4: Machine Learning Prediction

- **Model Integration:**
    - A trained ML model predicts unsafe conditions based on multi-sensor inputs (gas levels, temperature, and humidity).
    - The ESP32 sends sensor data to the ML model, which classifies the environment as Safe, Moderate, or Hazardous.
- **Prediction Output:**
    - Overrides manual threshold classification for better accuracy.
    - In case of potential risk, alerts and mitigation mechanisms are triggered.

Stage 5: Data Logging and Communication

- **Data Logging:**
    - Real-time sensor data is stored on a micro-SD card for analysis.

    - Logged data includes gas concentrations, environmental parameters, and timestamps.

- **Wireless Communication:**
    - **Wi-Fi Module:** Sends alerts to nearby personnel via mobile applications or web dashboards.
    - **LoRa Module:** Sends data to the central control room over long distances for remote monitoring.

Stage 6: Display System

- An OLED display shows real-time data, including:
    - Gas concentrations (ppm)
    - Environmental conditions (temperature, humidity, pressure, light intensity)
    - Alert status (Safe, Moderate, Hazardous)

3. Machine Learning Workflow

- **Data Collection:**
    - Historical gas sensor data and environmental parameters are collected during initial operation.
- **Model Training:**
    - Data is labelled (Safe, Moderate, Hazardous) based on pre-defined thresholds.
    - A supervised machine learning model (e.g., Decision Tree, Random Forest) is trained using Python libraries like TensorFlow or scikit-learn.
- **Deployment:**
    - The trained model is converted to a lightweight format (e.g., TensorFlow Lite).
    - The model is uploaded to the ESP32, where it predicts unsafe conditions based on sensor inputs.

4. Safety Features

- **Ventilation Control:**
    - Automatically turns on exhaust fans to reduce gas levels.
- **Redundancy:**
    - Manual thresholds serve as a fallback in case of ML model failure.
- **Robust Communication:**

- LoRa ensures uninterrupted communication even in low-connectivity areas.

5. Applications

- **Mining Operations:**
  - Detects toxic gases like CO and CH4 in underground mines.
- **Industrial Environments:**
  - Monitors gas leakage in chemical plants and refineries.
- **Disaster Management:**
  - Helps in evacuating personnel during hazardous conditions.