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Environment Monitoring System: Air Quality and Noise Pollution Monitoring

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Abstract— The rapid industrialization and urbanization in modern society have led to significant environmental challenges, including air pollution and noise pollution. Continuous monitoring of these parameters is essential to ensure public health and sustainable urban planning. This paper presents an IoT-based *Environment Monitoring System* that utilizes the ESP32 microcontroller integrated with MQ135 (gas sensor), DHT11 (temperature and humidity sensor), and MAX4466 (sound sensor) to collect real-time environmental data. The collected data is analyzed using a Support Vector Machine (SVM) classifier with a Radial Basis Function (RBF) kernel to categorize air quality and noise levels into multiple predefined classes. Experimental results demonstrate that the system achieves 92% accuracy in air quality classification and 98% accuracy in noise level classification. The proposed system offers a low-cost, scalable, and intelligent solution for smart cities, industrial monitoring, and research applications, enabling timely interventions and informed decision-making for environmental management.

Keywords— Environmental Monitoring, IoT, Air Quality, Noise Pollution, ESP32, MQ135, DHT11, MAX4466

I. Introduction

The increasing levels of air and noise pollution in urban and industrial areas have become a major concern for public health and environmental sustainability. Poor air quality can lead to respiratory illnesses, cardiovascular problems, and environmental degradation, while high noise levels can affect human concentration, sleep patterns, and overall quality of life. Real-time monitoring of these environmental parameters is therefore critical to enable proactive measures and policy-making.

This study proposes an IoT-based *Environment Monitoring System* that leverages the ESP32 microcontroller interfaced with multiple sensors to continuously monitor air quality, temperature, humidity, and noise levels. The system uses MQ135 gas sensor for detecting air pollutants such as CO_2, NH_3, and NOx, DHT11 for temperature and humidity measurements, and MAX4466 sound sensor for capturing environmental noise levels. The data collected by the sensors is processed locally on the ESP32 and analyzed using a Support Vector Machine (SVM) classifier with Radial Basis Function (RBF) kernel, providing intelligent classification of environmental conditions.

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II. Components Used

Table 1: Hardware Components of the Environmental Monitoring System

Component	Description
ESP32	Wi-Fi/Bluetooth microcontroller for data acquisition
DHT11	Temperature and humidity sensor
MQ135	Gas sensor for air quality detection
MAX4466	Sound sensor for noise measurement
Breadboard	For connecting sensors and ESP32
Power Source	5V USB or adapter for powering the system

III. Sensors Overview and Description

The Environmental Monitoring System employs a combination of advanced sensors to continuously measure and record various environmental parameters in real time, including air quality, ambient temperature, relative humidity, and noise levels. Each sensor is specifically chosen for its accuracy, sensitivity, and compatibility with the ESP32 microcontroller to ensure precise data acquisition. These sensors work together to provide a comprehensive overview of the surrounding environment, enabling real-time monitoring, analysis, and classification of environmental conditions. Detailed descriptions of each sensor, along with their corresponding images, are provided below to illustrate their functions and roles within the system.

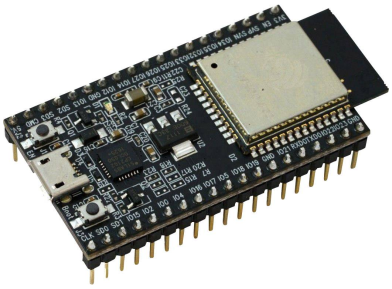

Fig. 1: ESP32 Microcontroller used for data acquisition and wireless communication. It acts as the central processing unit and transmits sensor data to the cloud or dashboard.

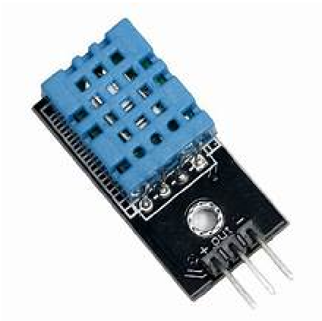

Fig. 2: DHT11 Temperature and Humidity Sensor. This digital sensor provides ambient temperature and humidity readings for environmental monitoring.

Fig. 3: MQ135 Gas Sensor for Air Quality Monitoring. It detects harmful gases such as CO, NH, NOx, and benzene, providing analog outputs proportional to the concentration of pollutants.

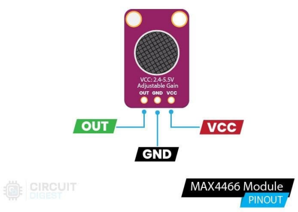

Fig. 4: MAX4466 Sound Sensor. Measures environmental noise levels and provides analog output voltage corresponding to sound intensity, allowing detection of quiet to loud conditions.

IV. System Architecture and Block Diagram

The Environmental Monitoring System is built around the ESP32 microcontroller and integrates three key sensors:

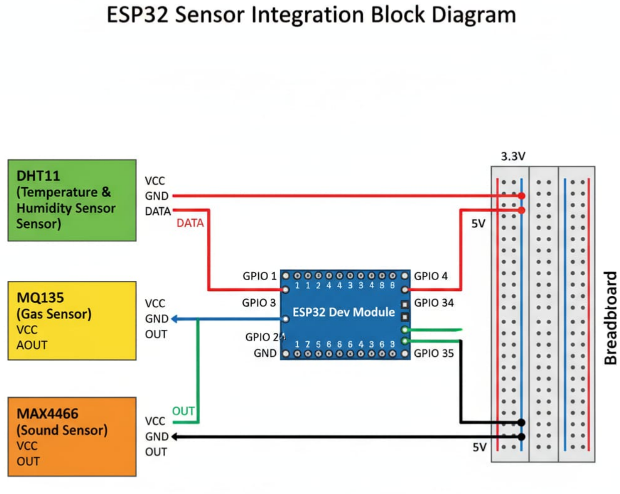

Fig. 5: Block diagram of the Environmental Monitoring System showing ESP32 and connected sensors.

DHT11 for measuring temperature and humidity, MQ135 for detecting air pollutants, and MAX4466 for monitoring environmental noise levels. The DHT11 sensor provides digital readings of temperature and humidity through GPIO 1, while the MQ135 outputs an analog voltage corresponding to gas concentrations, connected to GPIO 34. The MAX4466 sound sensor measures noise intensity and sends an analog signal to GPIO 35. All sensors share power and ground connections through a breadboard for convenient wiring. The ESP32 collects the sensor data, performs preprocessing, and can either process it locally or transmit it to cloud platforms for real-time monitoring and intelligent analysis of environmental conditions. This setup allows continuous tracking of air quality, temperature, humidity, and noise levels, making it suitable for smart city applications, industrial monitoring, and research purposes.

V. Working Principle

a. Data Acquisition

The Environmental Monitoring System collects real-time data using three primary sensors:

- **DHT11:** Measures ambient temperature and humidity, providing digital data to the ESP32. This data helps monitor indoor and outdoor environmental conditions.
- **MQ135:** An analog gas sensor that measures air pollutants such as CO_2, NH_3, NOx, and benzene. The sensor outputs an analog voltage proportional to the concentration of these gases.
- **MAX4466:** A sound sensor that detects environmental noise levels and outputs an analog voltage proportional to the sound intensity.

The sensors are connected to the ESP32 through appropriate GPIO pins. Data is sampled at regular intervals to ensure accurate monitoring of dynamic environmental changes.

The ESP32 also provides real-time timestamping to each data record for logging and historical analysis.

b. Data Processing

Once the sensor readings are collected, the ESP32 performs preprocessing:

- **Normalization:** Sensor values are scaled to a common range to ensure uniformity and compatibility with the machine learning model.
- **Noise Filtering:** Minor fluctuations or sensor noise are filtered using simple smoothing or moving average techniques.
- **Feature Extraction:** Relevant features are extracted from raw sensor signals, such as average pollutant concentration, humidity trends, and peak noise levels, which help improve classification accuracy.
- **Data Storage:** Processed data is temporarily stored locally on the ESP32 or transmitted to cloud storage for further analysis and visualization.

c. Machine Learning Classification

After preprocessing, the data is fed into a Support Vector Machine (SVM) with Radial Basis Function (RBF) kernel to perform intelligent classification:

- **Air Quality Classification:** The system classifies air quality into six predefined categories: Good, Moderate, Unhealthy, Very Unhealthy, Hazardous, and Unknown. This helps in identifying pollution levels and potential health risks.
- **Noise Level Classification:** Noise levels are categorized into five classes: Quiet, Very Quiet, Moderate, Loud, and Very Loud. This is useful for detecting environmental noise pollution and planning mitigation measures.
- **Decision Making:** Based on the classification results, the system can trigger alerts or notifications if air quality or noise levels exceed predefined safe thresholds.

d. Data Visualization and Alerts

The classified data can be displayed on an LCD screen, a web interface, or a mobile application for real-time monitoring. Alerts and notifications can be sent via Wi-Fi or cloud platforms when thresholds are exceeded. Historical data visualization allows trend analysis, helping authorities and researchers make informed decisions on pollution control and environmental management.

e. Overall System Flow

The overall workflow of the system can be summarized as follows:

1. Sensors collect temperature, humidity, gas concentration, and noise data.

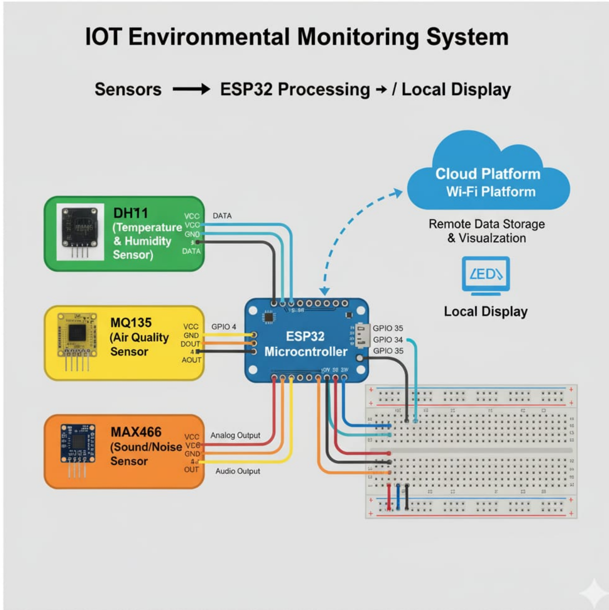

Fig. 6: System Flow

2. ESP32 preprocesses the data by filtering, normalization, and feature extraction.
3. Preprocessed data is input to the SVM-RBF classifier.
4. Environmental conditions are classified into predefined categories.
5. Data is displayed in real-time and stored for historical analysis.
6. Alerts are triggered if pollution or noise levels exceed safe limits.

VI. ALGORITHM USED: SVM-RBF

a. Air Quality Classification

TABLE 2: AIR QUALITY CLASSIFICATION PERFORMANCE

Metric	Value
Accuracy	0.92
Classes	Good, Moderate, Unhealthy, Very Unhealthy

```
Confusion Matrix:
 [[21  0  0  0  0  0]
  [ 0 37  0  0  4  1]
  [ 2  0 36  1  0  0]
  [ 0  0  1 34  0  5]
  [ 0  0  0  0 20  0]
  [ 0  2  0  0  0 36]]
```

b. Noise Level Classification

```
Confusion Matrix:
 [[43  0  0  1  0]
  [ 0 40  0  0  0]
  [ 0  3 44  0  0]
  [ 0  0  0 41  0]
  [ 0  0  0  0 28]]
```

TABLE 3: NOISE LEVEL CLASSIFICATION PERFORMANCE

Metric	Value
Accuracy	0.98
Classes	Quiet, Very Quiet, Moderate, Loud, Very Loud

VII. SYSTEM PERFORMANCE COMPARISON

TABLE 4: COMPARISON WITH TRADITIONAL SENSOR SYSTEMS

Parameter	Traditional System	SVM-RBF System
Data Processing	Threshold-based	AI-based classification
Accuracy	70–80%	92–98%
Adaptability	Limited	Learns from data
Scalability	Moderate	Highly scalable
Real-time Monitoring	Yes	Yes with prediction

VIII. ADVANTAGES AND APPLICATIONS

a. Advantages

- Low-cost and compact IoT-based design.
- Real-time air quality and noise monitoring.
- Intelligent prediction using SVM-RBF machine learning.
- Wireless data communication through ESP32 Wi-Fi.
- Scalable solution suitable for smart cities and industrial applications.
- Energy-efficient operation with low power consumption.
- Easy integration with cloud platforms for remote monitoring.
- Provides early warning alerts for hazardous conditions.
- Modular design allows addition of more sensors in the future.
- User-friendly interface for monitoring and analysis.
- Data logging capability for trend analysis and research purposes.

b. Applications

- Smart city environmental monitoring.
- Industrial emission and noise control.
- Agricultural and greenhouse environmental monitoring.
- Academic and research-based environmental studies.
- Monitoring air quality in schools, hospitals, and public areas.
- Pollution assessment near highways and urban centers.
- Supporting governmental policies for environmental protection.
- Integration with mobile apps for real-time citizen alerts.
- Disaster management through monitoring hazardous gas leaks.
- Enhancing indoor air quality in offices and residential buildings.

Fig. 7: Expected product in production.

IX. CONCLUSION

This paper presents a detailed and comprehensive IoT-based *Environment Monitoring System* that integrates multiple sensors, including the ESP32 microcontroller, MQ135 gas sensor, DHT11 temperature and humidity sensor, and MAX4466 sound sensor, to continuously collect real-time environmental data. The system is designed to monitor key parameters such as air quality, temperature, humidity, and noise levels, which are critical indicators of environmental health and public safety. By employing a Support Vector Machine (SVM) classifier with a Radial Basis Function (RBF) kernel, the collected data is analyzed and categorized into specific classes for both air quality and noise intensity, achieving high accuracy and reliability. The proposed system provides a cost-effective and scalable solution, making it suitable for deployment in a variety of scenarios, including urban areas, industrial environments, and academic research projects. Additionally, the intelligent processing and wireless communication capabilities of the ESP32 enable real-time monitoring, data logging, and remote access, allowing policymakers, environmentalists, and researchers to take timely and informed actions. Overall, this system represents a practical, intelligent, and adaptable approach to continuous environmental monitoring, contributing to public health, environmental sustainability, and the development of smart cities.

X. FUTURE SCOPE

- Integration with cloud platforms such as ThingSpeak or Blynk for remote visualization.

- Development of mobile apps for real-time alerts on pollution levels.
- Use of solar-powered ESP32 for sustainable operation.
- Addition of PM2.5 and CO sensors for comprehensive air quality monitoring.
- Implementation of deep learning algorithms to improve prediction accuracy.

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