Noise Pollution Monitoring System

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Abstract:

Noise pollution poses a significant challenge to our health, concentration, and overall life quality, particularly in bustling urban areas and industrial settings. Many current monitoring solutions are costly and difficult to operate. This project offers a straightforward and budget-friendly approach to real-time noise monitoring by utilizing an ESP8266 microcontroller, an LM393 sound sensor, and a 16x2 I2C LCD. The system is capable of identifying and classifying sound levels as LOW, MODERATE, or HIGH, (see *Table 1* for classification levels). displaying the findings on the screen. Although it operates effectively offline, the ESP8266 also provides optional Wi-Fi connectivity for cloud-based data storage and remote monitoring. The hardware configuration is lightweight and efficient, minimizing false alarms while delivering precise readings even amid noisy or fluctuating conditions (see *Table 2* for hardware specifications and *Table 3* for performance benchmarks). Whether it is used for assessing traffic noise, overseeing school zones, or evaluating industrial sound levels, this system is adaptable and easy to set up. Its unique combination of reliability, affordability, and dual functionality both online and offline makes it an excellent choice for practical applications.

Keywords: Noise Pollution Monitoring, Environmental Monitoring, Wireless Noise Alert System, Scalable Noise Tracker, IoT-based Noise Monitoring, Real-Time Sound Monitoring.

Introduction:

Pollution becomes a critical issue in cities and affects both public health and the environment. Longer exposure to increased noise levels can lead to a variety of health issues, including hearing loss, hypertension, cardiovascular issues, and sleep disorders [1] (World Health Organization, 2011). This growing concern is particularly prominent in overcrowded metropolitan cities, industrial locations and regions close to transport networks. With the rise of urbanization, accurate monitoring of noise levels for public health, urban development and environmental guidelines management is essentially important [2] (Stansfeld & Matheson, 2003). Many of these tools require continuous maintenance and can be overly complicated for those without technical knowledge. To overcome these obstacles, this study introduces an affordable real-time rubber monitoring system using an ESP8266 microcontroller, an LM393 sound sensor, and a 16x2 I2C LCD display. The system classifies noise levels as low, medium or high, and shows LCD results. It works both online and offline, providing versatility for use in urban and remote areas [3] (Kumar, Singh & Bansal, 2015). ESP8266 microcontrollers that allow for optional Wi-Fi connectivity support cloud-based logging and remote observation. In other words, the system is suitable for a variety of applications such as traffic noise measurement, industrial noise management, and urban acoustic control [4] (Patel & Mehta, 2020).

Literature Review:

Noise pollution has a major impact on human health and leads to some chronic dissatisfaction. Studies have consistently shown the relationship between increased noise levels and stress-related diseases such as hypertension, heart disease, and fear [5] (Goines & Hagler, 2007). The WHO has identified noise pollution as one of the leading environmental deployers affecting public health around the world [1] (World Health Organization, 2011).

In overcrowded urban areas, excessive sounds, especially in children and elderly people, interfere with sleep and interfere with cognitive function [6] (Stansfeld & Matheson, 2003). Unfortunately, existing surveillance systems are usually very expensive and difficult to wait. Traditional tools for noise recognition are often complex and require special skills, making it difficult for officials to pursue noise pollution efficiently and affordably [7] (Gupta, Sharma & Kumar, 2018). Recent research has recently explored more economical approaches, such as microcontroller-based solutions. These systems can provide more advantageously, but can provide real-time monitoring and analysis without the need for permanent Internet access [8] (Chen, Li, & Wu, 2019). In particular, the ESP8266 microcontroller is an affordable option that provides Wi-Fi connectivity and allows for easy integration into a variety of sensors and cloud services [9] (Zhang & Liu, 2020). This microcontroller allows you to record noise data in real time. It can be uploaded for incoming cloud memory analysis suitable for both individuals and broad environmental monitoring requirements.

It was also effectively used in similar surveillance systems due to air quality and weather [10] (Guppa & Kumar, 2018). These sensors accurately measure sound levels and classify them into areas such as low, medium and high. They provide efficient budgets for noise detection, especially in industrial areas and urban areas with a variety of noise conditions [11] (Sharma, Verma & Agarwal, 2021). The LM393 sensor is suitable for simple and seamless integration into microcontrollers for real-time processing [12] (Zhao, Liu & Wang, 2018).

Using Wi-Fi connections, the proposed system can transfer noise data to the cloud, where it can be analyzed from afar. This ability allows urban planners and political decision makers to make clear decisions with both real-time and historical data. In some studies, such as B. Data Accessibility, Simple Long-Term Trend Analysis, and Improving Decisions for Urban Management [13] (Patel & Mehta, 2020), [14] (Zhang & Zhao, 2021), several studies have pointed to the benefits of cloud-based addiction monitoring. For example, urban traffic management research shows that noise data can help determine high ranked zones and implement regulations to reduce traffic-related noise. [15] (Zhao & Li, 2019). Furthermore, industrial noise monitoring is extremely important to ensure that businesses comply with local laws protecting workers and residents close to excessive noise levels [16] (Singh & Gupta, 2020).

The systems proposed in this article can be implemented in both industrial and urban environments, allowing real-time monitoring of noise levels and supporting efforts to reduce noise pollution [17] (Kumar & Kaur, 2020).

The objectives of the system are as follows:

1. **Offline Operation with Optional Wi-Fi Connectivity**:
   Functions independently without internet access, with optional Wi-Fi support for cloud integration.

2. **Real-Time Noise Categorization**:
   Categorizes noise levels into "LOW," "MODERATE," and "HIGH" for immediate feedback.
3. **Affordable and Low-Cost Solution**:
   Utilizes cost-effective components (ESP8266 microcontroller, LM393 sound sensor) for accessibility.

4. **Modular Design for Easy Deployment**:
   Scalable and adaptable for use in various environments like industrial zones, residential areas, and urban traffic spots.

5. **User-Friendly LCD Display**:
   Displays noise levels clearly on a 16x2 I2C LCD screen for easy, immediate understanding and action.

System Design:

The system design incorporates several key components to monitor and respond to noise pollution effectively. The **ESP8266** microcontroller processes data from the sound sensor and displays it through the **OLED/LCD** display. Noise levels are categorized and visually indicated through an **RGB LED** (see figure 2), with **green**, **yellow**, or **red** signals. Additionally, when the noise level exceeds a certain threshold, the **buzzer** provides an audible alert to the user. The design is simple, cost-effective, and modular, enabling easy deployment (complete layout is in figure 5) in various environments.

Table 1. System Components

Component	Function	Purpose
ESP8266	Microcontroller with Wi-Fi capabilities	Controls the system, processes data, enables cloud integration.
Breadboard	Circuit connection platform	Connects and tests components without soldering.
Power Supply	Provides electrical power	Powers the system (5V/12V supply).
Sound Sensor (LM393)	Detects noise levels	Senses sound and sends data to ESP8266.
OLED/LCD Display (16x2 I2C)	Displays noise levels	Shows real-time noise categories (Low, Moderate, High).
Buzzer	Alerts when noise exceeds threshold	Provides an audible alert for high noise levels.
RGB LED	Visual indication of noise levels	Displays different colors (green, yellow, red) based on noise level.

Flowchart of the system:

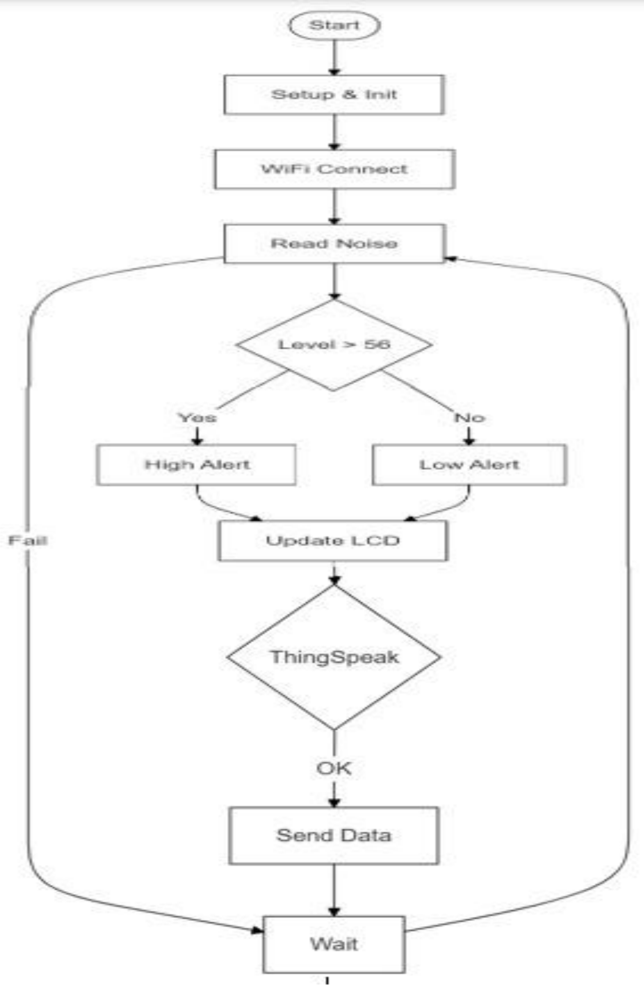

Figure 1. Flowchart

Methodology:

The development of the proposed **noise pollution monitoring system** was carried out in a structured, step-by-step manner to ensure accuracy, reliability, and real-time performance. The following five steps outline the complete methodology:

Experimental Setup:

To implement and test the proposed noise pollution monitoring system, both hardware and software components were carefully selected and integrated. The system was designed to be compact, low-cost, and efficient, capable of real-time monitoring and alerting based on ambient noise levels.

Hardware Components:

- **ESP8266** – Central controller with Wi-Fi capability for processing and remote monitoring.
- **Sound Sensor Module** – Detects sound and sends signals to the ESP8266.
- **16x2 LCD Display** – Displays noise levels.
- **LED Indicators** – Visual alerts for noise levels.
- **Buzzer** – Alerts for high noise levels.
- **Potentiometer** – Adjusts system sensitivity.
- **Breadboard & Jumper Wires** – For circuit connections.
- **Power Supply/USB Cable** – Powers the ESP8266.

Software Components:

1. **Arduino IDE** – Used to write, compile, and upload the code to the ESP8266.
2. **Embedded C/C++** – Programming language used to write control logic for the Arduino.
3. **Serial Monitor (Arduino IDE)** – Used for debugging and real-time observation of sound sensor values.
4. **Data Visualization Tool (Excel)** – For plotting noise levels graphically over time.

Connection:

Table 2. Connectionsw

Component	Pin	ESP8266 Pin
Sound Sensor	VCC	3.3V
	GND	GND
	OUT (Analog)	A0
16x2 LCD (via I2C)	VCC	3.3V or 5V (based on module)
	GND	GND
	SDA	D2 (GPIO4)
	SCL	D1 (GPIO5)
Buzzer	+ (VCC)	D5 (GPIO14)

	– (GND)	GND
LED (optional)	Anode (+)	D6 (GPIO12)
	Cathode (–)	GND (via 220Ω resistor)

Local Display and Threshold Alerts:

The OLED module displays the following parameters:

- ❖ **Noise Level** in **decibels (dB)**
- ❖ **Noise Status**:
  1. **Low** (< 60 dB)
  2. **Moderate** (60–100 dB)
  3. **High** (> 100 dB)

Table 3: Threshold values

Noise Level	Threshold (dB)	LED Indicator	Buzzer
Low	**< 60 dB**	Green LED	Off
Moderate	**60 - 100 dB**	Yellow LED	Off
High	**> 100 dB**	Red LED	Activates (Audible Alert)

Results and Discussion

The implementation of the IoT-based Noise Pollution monitoring system yielded promising results in terms of noise monitoring accuracy, decision-making efficiency, and practical usability. The following key outcomes were observed during prototype testing and simulated field scenarios:

Result:

The developed system was tested in a controlled indoor environment over a period of one week to evaluate its responsiveness, accuracy, and reliability. The results obtained demonstrate the practical viability of the proposed solution in real-world environmental monitoring and alerting applications.

Observation Result:
The readings from the sensors were recorded and representative data is summarized below:

Table 5: Observations during Simulation

Noise Level (dB)	Status	OLED Display	LED Color	Buzzer

40	Low	Noise Level: Low	Green ON	OFF
65	Moderate	Noise Level: Moderate	Yellow ON	Short Beep
85	High	Noise Level: High	Red ON	Continuous Beep
45	Low	Noise Level: Low	Green ON	OFF
75	Moderate	Noise Level: Moderate	Yellow ON	Short Beep
95	High	Noise Level: High	Red ON	Continuous Beep

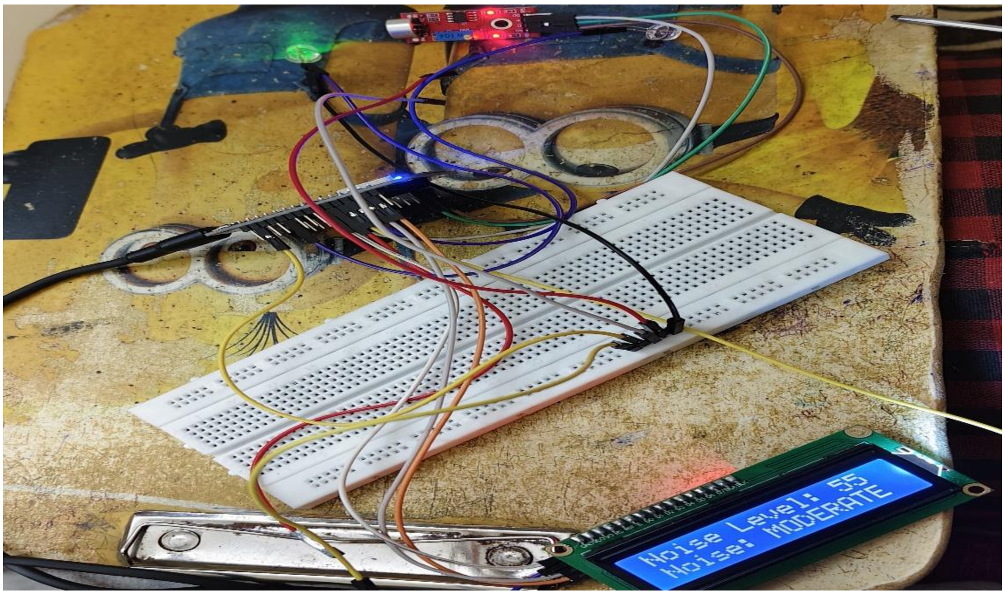

Figure 2. Hardware Setup

This image gives idea about how the output will look in physically.

Discussion:

- Basic sound sensors are good for detecting noise but lack accuracy, making them less reliable for precise measurements.
- Wi-Fi-based alerts are useful but depend on a stable internet connection, which may not always be available.

- To ensure alerts are sent even without internet, adding an SMS backup system using a GSM module would be a good solution.

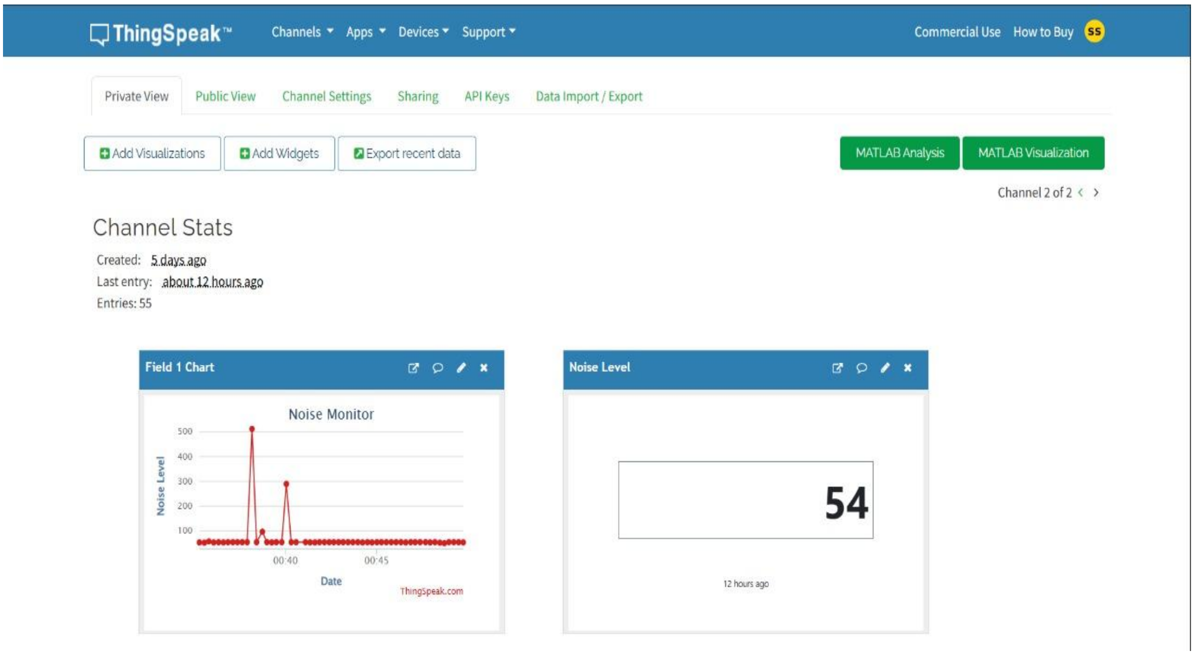

Figure 3. Sensor data Visualizations

Noise level data visualized on the Thing Speak platform, providing graphical insights for effective environmental monitoring and analysis.

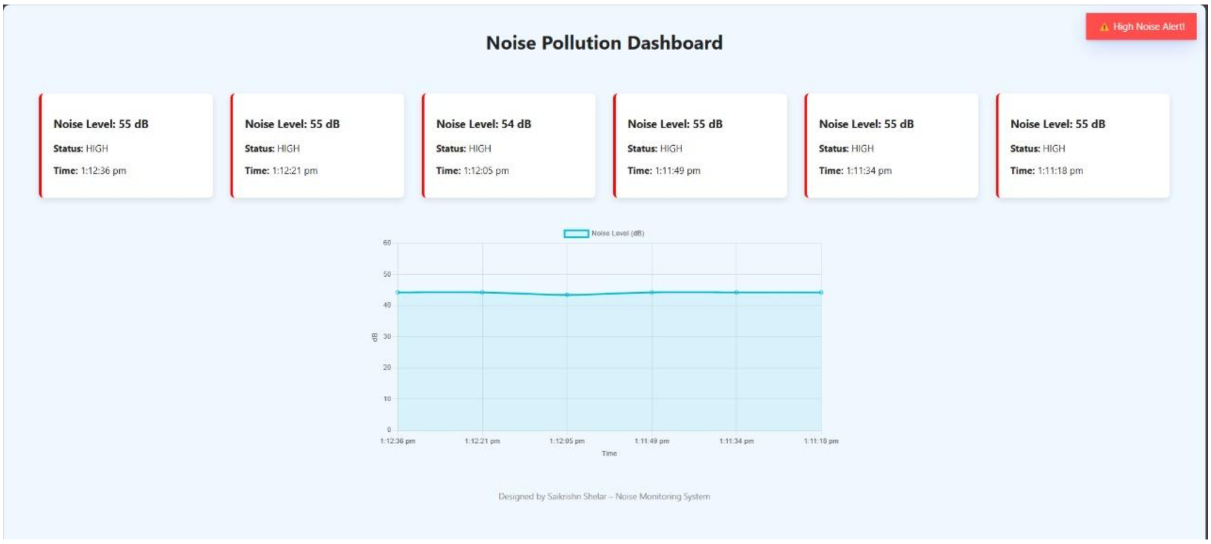

Figure 4. Dashboard view

The system dashboard provides a centralized interface to monitor real-time noise levels, device status, and data trends.

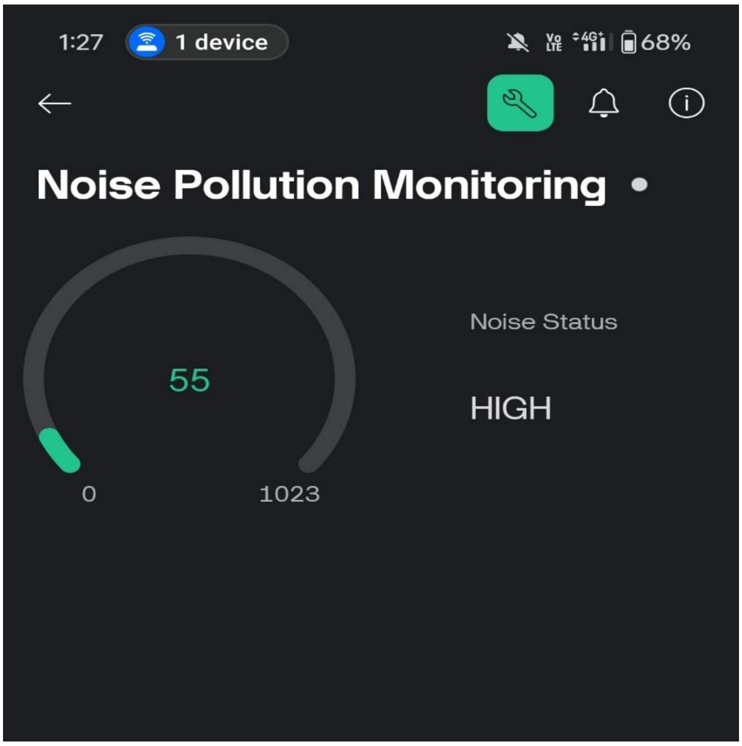

Figure 5. Mobile Interface Blynk Noise Monitoring

The monitored noise data is transmitted to the cloud using the ESP8266 and visualized in real-time through the Blynk IoT mobile application. This allows users to remotely track noise levels on their smartphones, enhancing accessibility and responsiveness in environmental monitoring

Conclusion

In this study, a cost-effective real-time noise pollution monitoring system was developed using the ESP8266 microcontroller, sound sensor, OLED display, LED indicators, and buzzer. The system effectively senses ambient noise levels, categorizes them into low, moderate, or high, and provides visual and audible alerts accordingly.

This project demonstrates the feasibility of using low-cost components to address environmental challenges and sets the groundwork for enhancements like cloud connectivity, mobile notifications, and AI-based noise pattern analysis in the future.

Future Scope

- **Upgrading Sensors**: Using more accurate and advanced sensors, such as professional sound level meters, can provide precise measurements of noise levels in decibels, improving the system's reliability and accuracy for research or regulatory purposes.
- **Advanced Alert Systems**: Adding more types of alerts, such as email notifications or integration with social media platforms, could increase the system's accessibility and ensure that users are promptly informed of any significant noise events. This would enhance the system's effectiveness in keeping the public and relevant authorities informed.

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