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HYPERLOCAL NOISE DETECTOR

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ABSTRACT

Noise pollution has become a major environmental issue, especially in urban and semi-urban areas. Continuous exposure to high noise levels can cause stress, hearing loss, and reduced productivity. This project aims to design and implement a Hyperlocal Noise Monitoring System that measures noise levels in real time at a specific location and alerts users when the sound exceeds a defined threshold. The system uses an ESP32 microcontroller with a sound sensor to collect local noise data, display the reading on an OLED screen, and upload it to an online platform (ThingSpeak) for visualization. When noise levels cross the safe limit, the device triggers an LED and buzzer alert. The project demonstrates how small, low-cost sensors can be used to monitor and control noise pollution at a community level.

I. INTRODUCTION

Noise pollution is a problem that affects millions of people worldwide. Different studies have shown that it is currently one of the greatest environmental threats to people's health, leading to increased risk of cardiovascular disorders, hypertension, sleep disturbance, stress, etc., and it is negatively influencing productivity and social behavior .Noise pollution refers to unwanted or harmful sound that disrupts normal activities such as communication, sleep, and concentration. In cities, common noise sources include traffic, industrial activity, and public gatherings. While government agencies monitor noise at a few central points, they often miss small local hotspots.

A hyperlocal monitoring system can bridge this gap by collecting fine-grained data from multiple points, such as near schools, hospitals, or residential areas.To address this gap, the concept of a Hyperlocal noise detector has emerged as a promising solution. A hyperlocal noise detector combines low-cost acoustic sensors, microcontroller-based processing, and networked data communication to monitor sound levels within very small geographic areas. Unlike conventional approaches, this system offers fine-grained spatial resolution, continuous data collection, and real-time reporting, enabling precise mapping of noise hotspots. The integration of advanced filtering algorithms and machine-learning techniques further enhances the system's ability to differentiate between noise sources and reduce measurement errors. This project develops one such low-cost, portable prototype using IoT (Internet of Things) principles.

Recent developments in Internet of Things (IoT) technologies have made it feasible to deploy dense networks of such detectors, providing scalable and affordable noise monitoring infrastructures. These systems support smart-city initiatives, empower communities with localized environmental information, and assist policymakers in designing effective noise control strategies. This research focuses on the design, implementation, and performance evaluation of a hyperlocal noise detection

II. LITERATURE REVIEW

1. Bello et al.(2019) developed one of the most advanced large-scale urban noise monitoring systems integrating low-cost sensors, machine-learning–based sound classification, and citizen reporting tools. The study demonstrated high classification

accuracy for diverse urban sound sources such as traffic, construction, and human activity. The sensors were designed to operate autonomously and transmit data to cloud servers for detailed analytics. However, the system required a robust supporting infrastructure, frequent sensor calibration, and higher computational resources for real-time analysis. These requirements increase deployment costs and complexity, making the system less suitable for small-scale, fixedlocation hyperlocal applications where simplicity and affordability are essential.

2.Picaut et al.(2020) - This review evaluated a wide range of low-cost acoustic sensors and highlighted their growing relevance in urban noise monitoring. The authors noted that, when combined with proper calibration techniques, inexpensive microphones can produce results comparable to professional-grade sound meters. The study emphasized the importance of sensor shielding, environmental compensation algorithms, and standardized calibration procedures. However, limitations such as susceptibility to temperature changes, humidity effects, electronic noise, and long-term sensor drift reduce reliability in long-duration outdoor deployments. These challenges are particularly critical in hyperlocal monitoring, where accuracy at very small spatial scales is required.

3.Yin et al.(2020) introduced a mobile sensing technique using smartphones and portable devices to generate fine-grained noise maps in dynamic urban environments. The system leveraged GPS tracking and machine-learning models to correlate noise patterns with spatial movement. This approach offered excellent spatial coverage, rapid data collection, and the ability to capture temporal variations across different city zones. However, mobile noise mapping lacks continuous monitoring capability, as data collection depends on the movement patterns of participants. This leads to inconsistent temporal resolution and potential data gaps, making the technique unsuitable for hyperlocal studies where constant noise-level tracking at a fixed location is required.

4.Saldana-Barrios et al.(2023)-The study presented an IoT-integrated noise monitoring prototype using low-cost microcontrollers, real-time cloud analytics, and wireless data transmission. The system demonstrated efficient data acquisition, remote monitoring, and scalability for urban noise assessment. Its modular design allowed integration with additional environmental sensors such as temperature and humidity sensors. However, the dependence on stable internet connectivity limited its applicability in bandwidth-constrained or highly dense environments. Furthermore, the study highlighted issues such as latency in data transmission, cloud dependency for long-term storage, and susceptibility to network outages, which can affect continuous hyperlocal monitoring.

5.KY-037 Classroom study (2023) -This research focused on evaluating the KY-037 sound sensor in classroom environments to monitor noise generated by students and activities. The sensor successfully detected relative changes in loudness and provided valuable insights for classroom management. It proved beneficial due to its affordability and compatibility with microcontrollers such as Arduino and ESP32. However, the KY-037 suffers from high sensitivity variability between units and limited linearity in its output, making it unreliable for precise decibel-level measurement.

Additionally, its performance is influenced by physical orientation, background interference, and lack of built-in calibration options. These shortcomings restrict its effectiveness for accurate hyperlocal noise quantification without additional signal conditioning or calibration circuits.

III. METHODOLOGY

1. Start

This is the beginning of the project or research work. The goal and purpose of the project are decided here.

2. Literature Review

In this step, you gather information related to your topic by:

- ✧ Reading research papers
- ✧ Studying books and articles
- ✧ Checking existing projects or products ✧ Understanding current technologies

Purpose:

- ✧ To avoid what already has been done
- ✧ To avoid repeating existing work
- ✧ To get new ideas and improve existing solution

3. Identifying Problems

Here you clearly define the main issue you want to solve.

You answer questions like:

- ✧ What is the problem?
- ✧ Who faces it?
- ✧ Why does it need a solution?

4. Finding Multiple Solutions

Brainstorm different ways to solve the problem:

- ✧ Different sensors
- ✧ Different methods
- ✧ Different technologies

You compare each possible solution based on:

- ✧ Rewrite code
- ✧ Cost
- ✧ Efficiency
- ✧ Feasibility
- ✧ Safety
- ✧ Ease of implementation Then select the best option.

5. New Design

- ✧ After choosing the best solution, you:
- ✧ Create a design or prototype plan
- ✧ Prepare circuit diagrams / mechanical drawings
- ✧ Select components
- ✧ Decide software and hardware requirements

This step turns ideas into a workable design.

6. Assembly

You build the actual prototype/model based on your design.

Examples:

- ✧ Connecting sensors and modules ✧ Writing the program
- ✧ Fabricating mechanical structure
- ✧ Integration of all parts

7. Testing

You check whether the prototype works as expected.

Testing includes:

- ✧ Functionality test
- ✧ Performance test
- ✧ Safety test
- ✧ Reliability test

8. Modification (If needed)

If testing shows problems or failure:

- ✧ Identify the issue
- ✧ Make improvements
- ✧ Change components or design ✧

Then repeat: Assembly → Testing → Modification until the design works correctly.

9. Report

After achieving successful results, you document:

- ✧ Objectives
- ✧ Methodology
- ✧ Design details
- ✧ Components used
- ✧ Results and graphs ✧ Conclusion

This report becomes proof of your work.

10. End

The project is completed after documentation and presentation.

IV. Material Selection

When doing a project, it is important to pay attention to the selection of materials. To prevent waste, the items selection process must be carefully welcomed. A precise selection of items is necessary to ensure that they are long-lasting and safe for usage.

- **Raspberry Pi Pico**: A microcontroller board, similar to Arduino but more powerful and cheaper.

Fig. 1 Raspberry pi pico

- **Analog Sound Sensor (MAX4466 / KY-037):** A small module containing a microphone + amplifier (and in some cases threshold comparator) that gives an analog or digital signal when sound is detected. To detect ambient sound/noise.

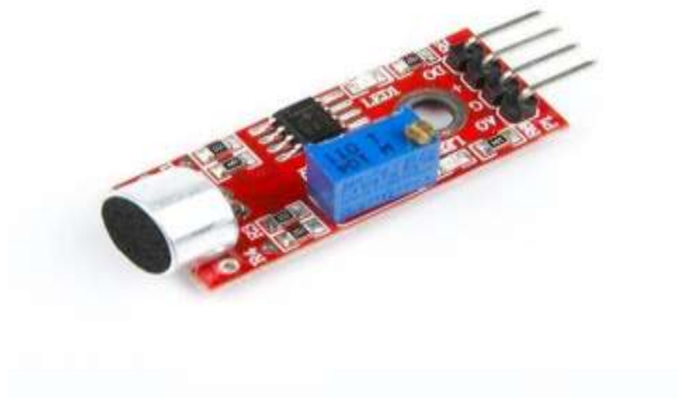

Fig. 2 Analog Sound Sensor

- **OLED Display (0.96," I2C):** It offers a 128×64-pixel resolution on a tiny 0.96″ screen — good for small displays, sensors, IoT dashboards, wearable-style output.

  Operates at 3.3 V or 5 V and is compatible with microcontrollers like ESP32 (which uses 3.3V logic) — ideal. Very low profile and low power, as OLEDs do not need a back-light like LCDs, giving high contrast. It shows current reading.

Fig. 3 OLED Displa

V. Results and Discussion

5.1 Working principle

The analog sound sensor converts air vibrations into corresponding voltage signals using its built-in microphone and amplification circuitry. These analog signals are then sampled . To derive a meaningful measurement, the ESP32 processes these readings by calculating an approximate RMS (Root Mean Square) value, which is commonly used to estimate sound intensity. This computed noise value is continuously updated and displayed on the OLED screen in real time, providing an immediate visual representation of the surrounding acoustic environment.

When the measured noise level exceeds a predefined threshold—for example, an estimated equivalent of 85 dB—the system triggers a visual and auditory alert by activating an LED and buzzer. This feature enables quick identification of excessive noise events. In addition to local alerts, the ESP32 uploads the processed noise data to the ThingSpeak cloud platform using its built-in Wi-Fi module. ThingSpeak stores and displays the incoming data on live graphs, allowing users to observe fluctuations, identify peak noise periods, and analyze long-term trends through time-series visualizations.

Furthermore, the cloud integration supports remote monitoring, enabling users to access noise information from any location. Historical datasets can be exported for deeper analysis or used to generate noise heatmaps for specific rooms or zones. This creates a “hyperlocal” understanding of sound patterns, where fine-grained acoustic variations can be tracked over short distances and time intervals. Such functionality is valuable for environments like classrooms, offices, libraries, or residential areas, where detecting localized noise disturbances helps in planning mitigation strategies and improving overall sound quality.

5.2 Software Implementation

An algorithm that samples sensor data over 100ms, computes RMS and compares to to threshold is used.

The code: from
machine import
Pin, ADC, I2C
import time from
ssd1306 import
SSD1306_I2C
# ----------- PINS -----------
MIC_PIN = 26# A0 -> GP26
SDA_PIN = 4
SCL_PIN = 5

```
# ----------- SETUP ----------
mic = ADC(Pin(MIC_PIN))
# OLED setup i2c = I2C(0,
scl=Pin(SCL_PIN),
sda=Pin(SDA_PIN)) oled =
SSD1306_I2C(128, 64, i2c)
# ----------
SENSITIVITY ---------#
Change this to adjust
sensitivity from code
THRESHOLD = 3000# LOWER = more sensitive
def display(text1, text2=""):
    oled.fill
    (0)
    oled.tex
    t(text1,
    0, 10)
    oled.tex
    t(text2,
    0, 30)
    oled.sh
    ow()
display("Sound Sensor", "Adjusting...")
# ---------- MAIN LOOP ---------while
True: value = mic.read_u16()     # Get
loudness value (0 - 65535)
    # Show current value on OLED
    display("Value: " + str(value), "TH: "
    + str(THRESHOLD))
    # Test if
    above
    threshol
    d if
    value >
    THRES
    HOLD:
        display("GETTING NOISY!!!", "Value: " +
        str(value)) time.sleep(2)      # pause to see the
        message
    time.sleep(0.5)
```

VII. Advantages

- Provide high spatial accuracy, allowing precise identification of noise sources in small areas.
- Support IOT integration, making them compatible with smart city infrastructure.

- Improve public awareness by sharing real-time noise data with communities.
- Can generate noise maps for better policy-making and regulation.
- Support remote monitoring, allowing authorities to observe conditions without being physically present.
- Help in early detection of noise pollution, enabling timely corrective actions.

VIII. Limitations and Future Work

- Battery-powered version with solar charging: This would enable long-term outdoor deployment without dependence on wired power.
- Mobile app integration:A dedicated app could provide notifications, heatmaps, historical data insights, and personalized noise-exposure summaries.
- AI-powered noise prediction models: Predictive algorithms could forecast when noise levels are likely to rise based on historical patterns.

VI. Conclusion and Future Scope

The development of a hyperlocal noise detector presents a significant advancement in modern environmental monitoring systems. This research demonstrates that low-cost acoustic sensors, when integrated with microcontroller-based processing and IoT communication, can effectively capture and analyze noise levels with high spatial precision. The proposed system successfully overcomes the limitations of traditional noise monitoring methods by providing real-time, fine-grained data that reflects true on-ground variations within small urban and residential zones.

The results confirm that hyperlocal noise detection enables accurate mapping of noise hotspots, supports early identification of abnormal sound events, and offers actionable insights for urban planners, policymakers, and community stakeholders. By combining digital signal processing techniques with cloud-based analytics, the system provides a scalable and reliable solution for continuous environmental monitoring.

Overall, this research highlights the potential of hyperlocal noise detection technology to contribute significantly to smartcity development, improved noise management strategies, and healthier living environments. Future enhancements may include advanced machine-learning-based sound classification, larger sensor networks, and the integration of predictive analytics to further elevate the system's accuracy and impact.

This project demonstrates that affordable electronics and IoT can be effectively used to create a Hyperlocal Noise Pollution Monitoring System. The prototype provides real-time feedback on environmental noise and encourages awareness at the community level. With further improvements, such systems could form a low-cost sensor network for cities, helping authorities manage and control noise pollution more efficiently.

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