IoT-powered Smart Environmental Adaptive Horn for Dynamic Noise Control and Enhanced Road Safety in Urban Areas

Varshini. P. A
UG Student
Department of Artificial Intelligence and Data Science
Arunachala College of Engineering for Women, Nagercoil, Tamil Nadu, India

Abstract — Noise pollution has been a major concern for us these days, which causes various issues like headaches, increased stress levels, sleeplessness at night, hearing impairments etc. The people living in urban areas are more prone to it and almost all of us could have been exposed to noise pollution, especially when we are travelling. One of the major contributors of noise pollution is the fixed volumes of the vehicles that we use for travelling. These fixed volumes have high range of sound which causes irritation to the public when they are travelling in congested and traffic prone areas. This paper presents an IoT-powered Smart Environmental Adaptive Horn, which adjusts the sound output based on the surrounding environmental noise levels like in sensitive areas the sound will be low and in others it will be adjusted based on certain criteria like the closeness of the nearby vehicle in such a way that it is not a disturbance to the public. This system uses "IoT based sensors" and "GPS" to analyze the surrounding noise levels and detect the kind of environment in which the vehicle is moving and modulates the horn volume based on the collected data. This approach offers a sustainable solution to noise pollution while enhancing road safety and public health. Its adaptability shows its potential to transform and control the urban noise pollution especially during travel.

Keywords: Pollution, Hearing Impairments, Adaptive, Iot, Contributor, Sensitive Areas, Exposed, Criteria, Approach, Analyze

I. INTRODUCTION

There has been a gradual increase in noise pollution throughout the decades in urban areas. While horns play an important role in road safety its fixed volume causes various other issues. Sometimes these are also not used Wisely by the drivers which causes problems like irritation. These unregulated volumes especially lead to disturbance in sensitive areas like schools, hospitals and residential areas. Even though it is useful sometimes, its unwanted high level fixed noise is unnecessary in quiet zones.

The existing systems like manual dual tone horns often fail to adapt to the changing environment, which causes noise pollution. This system helps in filling the gap by proposing an adaptive horn which automatically adapts and changes the volume of the horn in real time.

This paper presents an IoT-powered Smart Environmental Adaptive Horn for Dynamic Noise Control which various sensors like ultrasonic and GPS to gather information about the surrounding noise levels and the environment in which the vehicle is moving and based on the information collected the Pulse width modulation controller is used to adjust the volume of the horn as per the requirement of the environment. This system continuously analyzes the surrounding noise levels and automatically changes the volume and frequency of the horn thereby minimizing the unnecessary noise levels in quiet zones but maintains safety by increased volume in high noisy areas.

The goal of this research is to present an innovative and sustainable solution to noise pollution, especially in congested and traffic prone urban areas and also enhancing road safety and public health.

II. LITERATURE REVIEW

Noise pollution is a growing concern in urban areas where the traffic density is high. According to Nidhi gaur et al. (2024), In urban areas, more than half of the total environmental noise pollution is produced solely by traffic noise. This research highlighted that the unnecessary usage of horns and loudspeakers, either for spiritual or political purposes constitute noise pollution and harm human health and social activities. Adaptive systems for controlling noise pollution have been introduced in the field of machinery by Bharadwaj et al. (2019) but however it remains underdeveloped in India. And most of the innovations mainly focus on controlling noise pollution in construction or machinery related areas rather than in vehicle noise pollution (Verma et al., 2018).

Rao et al. (2020) developed an IoT-based noise monitoring system that detects the environmental conditions and provides alert when the noise levels exceed the threshold. Rajeshwari et al. (2019) proposed an AI-based vehicle-to-vehicle communication system to enhance safety and reduce congestion in urban areas.

Even though these proposals show some of the ways in using sensors and ai algorithms to detect and alert when the noise level exceeds a certain threshold these are not completely automated which clearly shows the need of a smart adaptive horn which automatically adjusts the volume based on the environmental conditions.

III. METHODOLOGY

The smart environmental adaptive horn system was developed using a combination of hardware and software components. It involves three main processes collection of information regarding the noise from the surrounding environment, processing the information collected, modulating the volume based on the collected data.

1) Microcontroller Unit (ESP32): This acts as the brain of the system, responsible for reading sensor inputs, processing data, and controlling the horn's output. ESP32 was chosen for its built-in Wi-Fi and Bluetooth capabilities, low power consumption, and sufficient processing power for edge AI tasks.
2) Sound Sensor (KY-038 or MAX4466): This sensor continuously monitors the ambient sound levels in decibels (dB). It outputs analog values representing

environmental noise, which are then digitized and analyzed by ESP32.

3) Environmental Threshold Analysis: The microcontroller classifies noise levels into three categories—low, medium, and high—based on predefined thresholds. A lightweight machine learning algorithm running on the ESP32 helps in fine-tuning the decision-making process by learning noise patterns from different urban environments.
4) Adaptive Sound Output: Depending on the noise classification, the horn's intensity and frequency are adjusted accordingly:
   - In low-noise zones (e.g., residential areas), the horn produces a softer tone using a piezo buzzer with lower frequency. The prescribed threshold level to detect low noise zone is <60dB.
   - In moderate-noise areas (e.g., regular roads), it produces a standard tone. The prescribed threshold level to detect moderate noise zone is in between 60dB-80dB.
   - In high-noise environments (e.g., marketplaces), the horn amplifies the sound for maximum audibility. The prescribed threshold level to detect high noise zone is >80dB.
5) Speaker and Amplifier Module: A compact speaker module paired with an amplifier is used to generate the horn sound. The frequency and volume are modulated via Pulse Width Modulation (PWM) signals from the ESP32.
6) Power Supply: The system is powered by a rechargeable lithium-ion battery with a voltage regulator module to ensure stable operation of the components.
7) Programming and Software: The system software for the ESP32 was developed using the Arduino IDE. Python was used for training the noise classification model, which was later converted into a lightweight C-based implementation suitable for microcontrollers.
8) Testing and Calibration: The system was calibrated by recording noise levels in various urban environments to determine accurate thresholds. Performance was validated through real-time testing across different city zones.

IV. Results and Discussion

The IoT-powered smart environmental adaptive horn prototype was evaluated tested in three distinct urban environments: quiet areas (e.g., hospitals), moderate noise areas (e.g., regular city streets), and high noise areas (e.g., Busy roads). The testing was aimed at measuring the adaptability of the volume produced by the horn on various types of environments.

In residential zones, where the ambient noise level was typically below 60 dB the volume of the horn generated automatically was low as required. The system reduced the horn's volume by approximately 60% and modified the frequency to produce a low volume sound. This approach effectively minimized noise disturbance to nearby homes, schools, and hospitals. The horn's sound was still audible to drivers in these low-noise environments, ensuring that road safety was maintained without contributing to unnecessary noise pollution.

On urban streets, where noise levels were in between between 60–80 dB due to traffic and other environmental factors, the system produced a horn sound with normal volume and a regular frequency. This setting ensured that the horn was both audible to surrounding vehicles and its users while avoiding an excessive volume that would add to the overall noise pollution. The horn's volume was adjusted according to the real-time environmental noise data provided by the sound sensor, ensuring that it was adjusted for the surrounding conditions.

In high-noise environments, such as marketplaces or densely populated areas with noise levels exceeding 80 dB, the system increased the volume of the horn and used a higher frequency to ensure audibility above the surrounding noise. The horn sound was effectively increased to maintain its function as a safety warning device. The system's ability to adjust its output in real-time was crucial in preventing accidents and ensuring that the horn remained an effective tool in ensuring road safety without adding unnecessary noise pollution.

V. Conclusion

In this paper I have presented an innovative IoT based smart adaptive horn which adjusts the volume and frequency of the horn based on the real time data collected from the environment thereby reducing the noise pollution. The prototype, built with cost-effective components and a budget under INR 3500, successfully demonstrated the system's ability to adapt to various urban environments. Traditional vehicles horn which has a fixed volume often contribute to the noise pollution in urban areas. This innovation helps in overcoming this problem by proposing a horn that automatically adjusts its volume by analyzing the environmental conditions using various sensors.

References

[1] Bhatia, M., & Kapoor, S. (2021). Urban Transportation and Noise Pollution Management. Chennai: Global Environmental Press.
[2] Sharma, A. (2018). Environmental Noise and its Control. New Delhi: Indian Institute of Environmental Science.
[3] Gaur, N. (2024). Advancements in Environmental Noise Control Technologies. New Delhi: GreenTech Publications.
[4] Agarwal, S. (2020). Sensor Networks and Environmental Monitoring. Bengaluru: Academic Press.

