Noise Tube: Measuring and mapping noise pollution with mobile phones

Praveen Kumar[1] Urvi Pritam[2] Rajneesh Yadav[3] Dr. Govind Pandey[4]

[1,2]M.Tech in Environmental Engineering [3]M.Tech in Hill Area Development Engineering [4]Associate Professor

[1,2,3,4]Department of Civil Engineering

[1,2,3,4]Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh

Abstract— In this report a new approach for the assessment of noise pollution is investigated involving the general public. The goal of this idea is to turn GPS-equipped mobile phones into noise sensors that enable citizens to measure their personal exposure to noise in their everyday environment. The goal is to investigate how participative and people-centric data collection can be used to create a low-cost, open platform to measure, annotate and localize noise pollution, as it is perceived by the citizens themselves.Thus each user can contribute by sharing their geo-localized measurements and further personal annotation to produce a collective noise map. This report also highlights the advantages of using GPS equipped mobile phones monitoring noise pollution over the process of conventional noise monitoring.

Key words: GPS, conventional noise monitoring, mobile phones monitoring

I. Introduction

Noise is derived from the Latin word "nau-sea" implying 'unwanted sound' or 'sound that is loud, unpleasant or unexpected'. The noise originates from human activities, especially the urbanization and the development of transport and industry. Though, the urban population is much more affected by such pollution, however, small town/villages along side roads or industries are also victim of this problem. Noise is becoming an increasingly omnipresent, yet unnoticed form of pollution even in developed countries.

In India, the problem of noise pollution is wide spread. Several studies report that noise level in metropolitan cities exceeds specifiedstandard limits. It is responsible for rising incidence of deafness among the inhabitants (Bhargawa, 2001). A study by Singh and Mahajan (1990) conducted in Delhi and Calcutta, found that the noise level is 95dB as against the ambient limit of 45dB. Even at the "calm" places, it does not fall below 60dB. Murli and Murthy (1983) also found that traffic noise in Vishakhapatanam exceeds 90dB even in morning hours that acts as a source of nuisance.

The movement against noise pollution is weak in India. Most of the people do not consider it a pollutant, and take it as a part of routine life. Of late, it has been recognized as a pollutant (Negi et al., 1999). In India, the Noise Pollution (Regulation and Control) Rules, 2000 have been framed under the Environment (Protection) Act, 1986. These are a set of guidelines for regulation and control of noise. The ambient levels of noise for different areas/zones specified in the rules are indicated in chart 1.

Area Code	Category of Area/Zone	Limits in dB*	
		Day Time	Night Time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

Chart 1: Ambient noise standards

**The limit in dB denotes the time-weighted average of the level of sound in decibels on scale A which is relatable to human hearing.*

Source: Environment (Protection) Act, 1986 as amended in 2002

Unless and until, measures are taken to control the level of noise, the ongoing urbanization and industrialization may complicate the problem so much that it becomes incurable.

There are several methods that can be utilized for controlling the level of noise. First of all, the design and technology of machines/equipment could be altered resulting in low noise emission. Secondly, noise barriers may help us control noise. A third method is to protect receptors of sound by a shield e.g. building may be insulated against noise. Similarly, body and window planes may be made sound proof. Apart from technology, we may undertake various steps to modify or regulate the behavior of users of machines and equipment. Though a legal framework could be enforced to regulate users of vehicles/equipment, but it requires huge resources and good governance. The public education appears to be a good option because it is a social problem. Sheer ignorance about the adverse effects of noise pollution appear to be a key factor in laying inadequate stress on controlling or reducing its levels. To make India a world-class destination for tourism, industry, and a place for healthy living, the development and implementation of a comprehensive noise control program is a dire need of hour.

This report presents the Noise Tube project, which follows a novel approach to noise pollution monitoring involving the general public. The goal is to investigate how participative and people-centric data collection can be used to create a low-cost, open platform to measure, annotate and localize noise pollution, as the citizens themselves perceive it. In continuation of earlier research, we want to apply the potential of community memories [5, 6] and citizen science [4] to noise monitoring.

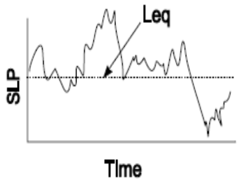
II. Assessment Of Environmental Noise

A. *Noise level measurement*

Noise level or loudness is generally measured as the equivalent continuous sound level or L_{eq}. Measured in decibel (dB), L_{eq}captures the sound pressure level of a constant noise source over the time interval T that has the same acoustic energy as the actual varying sound level pressure over the same interval. Furthermore the human ear perceives the loudness differently depending on the frequency of the sound. Standard “weighted scale” frequency functions have been developed to reflect human perception, notably the A-weighting scale, written dB (A) is commonly used.

$$L_{eq} = 10\log\frac{1}{T}\int_0^T \frac{p^2}{p_0^2}dt$$

p = sound level pressure (SLP) recorded
p_0 = minimal audible SLP



B. *Traditional measuring approach*

Nowadays noise assessments in urban areas are usually carried out by officials who collect data at a sparse set of locations, e.g. close to roads, rail- ways, airports and industrial estates, by setting up sound level meters during a short period of time. Propagation models are then used to generate noise maps by extrapolating local measurements to wider areas. This practice has a number of limitations:

1) Spatio-temporal data granularity

Computational models often produce results with an unknown error margin, which may lead to incorrect conclusions regarding caused uncomforted [3]. As stated by the EU practice guide [2] real data with high granularity in both time and space is required. However, data collection at sparse locations hardly scales to meet such requirements. Furthermore, strategic noise mapping only allows detecting general noise conditions. How can we monitor unusual local or short-term noise pollution?

2) Indoor noise assessment

current noise mapping only covers environmental noise, i.e. outdoors noise. However, most people spend a significant portion of their time indoors.

Fig. 1. Official noise map of Paris generated using a propagation model and measurements made at a limited number of locations and times. Quiet areas are coloured in green while noisy places are in purple. Gray areas represent places for which no information is available (e.g. in buildings).

III. NOISE TUBE PLATFORM

The current prototype of the Noise Tube platform consists of an application, which the participants must install on their mobile phone to turn it into a noise sensor device. The mobile sensing application runs on GPS-equipped mobile phones. This application collects local information from different sensors (noise, GPS coordinates, time, user input) and sends it to the Noise Tube server, where the data is centralized and processed.

A. *Measuring loudness in real time*

The mobile application contains a real-time signal-processing algorithm, which measures the loudness level of the microphone recording the environmental sound (at 22500 Hz, 16 bits) over 1 second at a chosen interval. An A-weighting filter is then applied to the recorded sound and the equivalent sound level (Leq)2, measured in dB(A), is computed.

The calculated loudness is displayed (see Fig. 2) in real time using a graph and as a value in dB(A). To add meaning to this value it is associated with a colour that represents the health risk of the current exposure level: < 70: green (no risk); > 70 and < 80: yellow (be careful); > 80: red (risky).

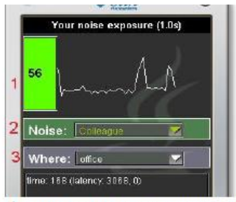


Fig.1 – The Mobile sensing application. Including 3 components: (1) The visualization of the loudness measured and a color representing the danger (2) The noise tagging (3) The tagging of the location (for indoor location for instance)

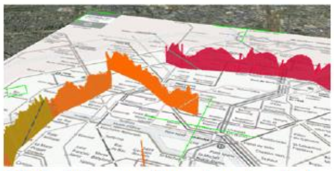


Fig.2 - Noise map of two subway lines (indoor location) reconstructed thanks to the geo-tagging feature in the mobile sensing application

B. *Tagging*

In addition to measured loudness, public noise maps often only provide very limited information regarding the source or context of noise. This sort of semantic information is vital to make such maps meaningful for both citizens and decision makers.

Environmental tagging: In order to better support this, users can directly annotate sound in specifying the source of a noise (e.g.: cars, aircraft, neighbours) and give an annoyance rating or any additional contextual information in the form of free words (tags).

Geo-tagging: Because indoor positioning is virtually impossible with GPS (see 5.2), we let users precise their location using a map or a list of favorite places (e.g. “home”, “office”). Afterwards this information can then be matched with actual coordinates. For example, by specifying sub- way stations a path followed in the subway can be reconstructed after- wards (see fig. 3).

C. *Visualizing noise maps*

Once the measured data is sent the server, any user can see his own contributions or exposures by going to the NoiseTube website and visualize them on a map using Google Earth. A collective noise map is also publicly available. This map is constructed by aggregating all the shared measurements. Each map can show a layer of tags entered by participants to add context and meaning to the loudness data. A real time monitoring of the loudness readings of all participants is also available.

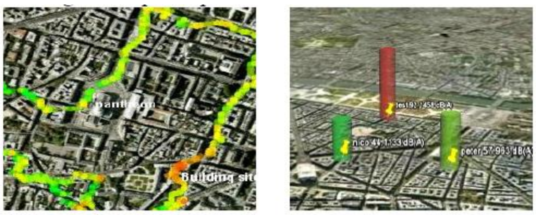


Fig. 3 – Visualisation with Google Earth. On the left, the collective noise map generated by all the measures. On the right, a real time visualization of the collective noise exposure.

D. *Web API to access public data*

Currently, the raw measures are generally not directly accessible for public or scientists, limiting their exploitations by third-parties. The EC directive [1] requires only a web user interface to improve the accessibility of noise maps for the public. To avoid creating an inaccessible information silo we want to go further than that. Therefore, the Noise Tube platform exposes a simple web API for publishing or accessing data. Using this API scientists or developers can use individual or collective noise exposure data to create web mash-ups or analyses data for scientific purposes.

E. Implementation

The current version of the mobile application was written in Java and is aimed primarily at smart phones running the Symbian/S60 operating sys- tem. The program was mainly tested on a Nokia N95 8GB smart phone. Although untested, many other phone brands3 and models are supported as well, as long as the device supports the Java J2ME platform, with multi- media and localization extensions4. A GPS receiver (built-in or an external unit that is connected via Bluetooth) is needed to localize measures. A version for the Apple iPhone is also planned. The server side is implemented using Ruby on Rails, MySQL, Google Maps and Google Earth.

IV. Data Credibility

The credibility of measurements is fundamental issue of low-cost sensing.

A. Mobile phone as Sound Level Meter

Without proper calibration, sensor devices produce data that may not be representative or can even be misleading. Experimentation has been conducted to measure the precision of the loudness computed with a mobile phone compared to a sound level meter5. We generated a pink noise at different levels of decibels (every 5 dB, from 30 to 105) and measured the results of our algorithm on the Nokia N95 8GB.

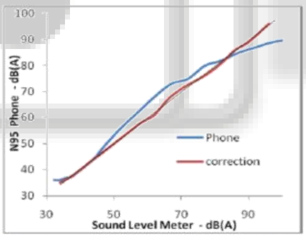


Fig. 5. Blue line: results of the distortion of the N95 phone's microphone compared to a sound level meter in the computation of the loudness (L_{eq}). Red line: results after applying post-processing.

The blue curve on figure 5 shows the response of the microphone com- pared to a sound level meter. According to this result this phone can be used as a sound level meter in the interval [35, 100 dB] due to the curvesobjectivity. After applying the inverse function as a post-processing corrector we obtained results with a final precision of ± 4 dB (red line).

V. Discussion And Future Work

Democratization of technologies such as Noise Tube will bring new applications and new questions for the participatory sensing paradigm.

A. Roles of citizens

How to sustain a human network at a larger scale and for a longer time than a local and short-term experimentation or campaign? How to design a network mixing humans and machines to monitor environmental re- sources? As far as we know, these questions have not been tackled yet by the current research on participatory sensing due to the small amount of participants and so the lack of complex structures. No explicit network topology has been used for the experimentation except the basic „stars" topology. But further investigation could take advantage of social relation-ships, shared interests or reputation (expert/scientist) among the participants as a solution for problems as data and analysis credibility by using them not only as sensors but also as filters or regulators.

B. User feedback and awareness

The user experience, especially with the mobile phone application, is crucial to motivate users to contribute. Even though the current version allows users to visualize noise exposure in real-time, we would like to improve the feedback by giving interesting insights coming from the collective experience, e.g. a map to highlight unusual pollution measured by other participants, in order to support local decision-making. Furthermore, we are planning to develop more features related to the social translucence to sustain motivation, accountability and participation.

VI. Conclusion

In this report aNoise Tube is presented, a project aimed at developing a participative noise pollution monitoring network to enable citizens as well as governmental bodies and non-governmental organizations to gain awareness of and insight into the problem of urban noise pollution and its social implications. Here it is discussed aapproach and the supporting rationale as well as a prototype implementation. While this project is still in an earlystage it should be planned to open up a first public experiment soon to evaluate user experiences and participation, as well as the credibility of the generated noise maps compared to traditional ones.

References

[1] European Commission (2002), Directive 2002/49/EC Assessment and managementof environmental noise.

[2] European Commission Working Group: Assessment of Exposure to Noise (WG- AEN) (2006). Good practice guide for strategic noise mapping and the production of data on noise exposure, Version 2.

[3] Hepworth P. (2006). Accuracy implications of computerized noise predictions for environmental noise mapping.International congress on Noise Control Engineering (Inter-Noise 2006).

[4] Paulos, E. et al. (2008). Citizen Science: Enabling Participatory Urbanism. Hand- book of Research on Urban Informatics: The Practice and Promise of the Real- Time City, Marcus Foth (Ed.), pp. 414-436, Idea Group.

[5] Steels, L. and Tiselli E. (2008). Social Tagging in Community Memories.Proceedings of the AAAI Spring Symposium on Social Information Processing, AAAI.

[6] Steels, L. and Tiselli E. (2008). Interfaces for Community Memories. Proceedings of the ACM International User Interface Conference IUI-2008, Workshop on Intelligent User Interfaces for Developing Regions, pp. 23-28, ACM.

