Urban Noise Detection and Management for a Smart City using IOT Enabled Model

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Abstract:
Noise is an environmental effect which can cause annoyance and can significantly affect health. With ever increasing population densities of cities, the noise levels are increasing and a balance needs to be achieved between legitimate commercial activities and controlling potential adverse noise effects to reasonable levels. Smart cities should be planned in accordance with urban noise detection and management guidelines to achieve better level of control over noise. In this context, a framework for Urban noise management is developed based on the IOT concepts. Crowd sourcing approaches, where a human is thought of as a sensor (with embedded sensors in his/her mobile phones) are used in this work to dynamically map and analyze the urban noise levels in different zones.

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Introduction

About 72.2% of Indian population lives in some 638,000 villages and the rest 27.8% in about 5,480 towns and urban agglomerations. In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001 and 53 in 2011[1]. Due to this growing density, noise has gradually and steadily increased and is considered among the most pervasive and frustrating sources of everyday annoyance. Noise is considered as an environmental pollutant because of the danger it poses to health such as Cardiovascular and Metabolic disease and also its impact on our well-being and quality of life [2].

Noise management is an important component in the smart cities vision, is supported by new sensors that are capable of detecting and processing various parameters related to noise. The Internet of Things (IOT) enables the connectivity, accessibility and tasking of the sensors to enable the citizens to access real time information on the noise levels. This will help them in planning various activities of their day in a much smarter way. Since noise has a spatial component, GIS can provide an appropriate and attractive platform for mapping and analyzing it and ultimately help for its management[3]. It is possible to obtain an accurate picture of the acoustic situation and Noise Risk zones (NRZ), with the help of advanced interpolation techniques in GIS based on finite number of sample points recorded using microphone of cellphones as a sensor. Integrating crowd sourcing techniques, it is possible to develop an efficient noise mapping system that can show the dynamically changing noise environment in a city.

Background

According to the Ministry of Environment, Forest & Climate Change, mechanical energy released by any source in a medium creates vibrations of molecules. The molecules start vibrating in the oscillatory mode and the energy travels through the medium in form of vibrations. If the oscillations in the medium are in the range of 20 Hz to 20 KHz it is audible by human ears and categories as sound [4].

2.1 Ambient Noise

Ambient noise is often referred to as environmental noise. It is the noise that one hears in day to day life and does not include workplace noise. Various sources of noise are: industries, road traffic, rail traffic, air traffic, construction sites and public works, indoor sources (air conditioners, air coolers, radio, television and other home appliances) etc.

2.2 Air Quality Standards

The Central Pollution Control Board constituted a Committee on Noise Pollution Control, recommended noise standards for ambient air and for automobiles, construction equipments and domestic appliances, which were later notified in Environment (Protection) Rules,1986 as given below:

<table>
<thead>
<tr>
<th>Code</th>
<th>Category of Area / Zone</th>
<th>Limits in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day Time (6.00 am to 10.00 pm)</td>
<td>Night Time (10.00 pm to 6.00 am)</td>
</tr>
<tr>
<td>A</td>
<td>Industrial area</td>
<td>75</td>
</tr>
<tr>
<td>B</td>
<td>Commercial area</td>
<td>65</td>
</tr>
<tr>
<td>C</td>
<td>Residential area</td>
<td>55</td>
</tr>
<tr>
<td>D</td>
<td>Silence Zone</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1 Ambient air quality standards in respect of noise
Silence zone is referred as areas under 100 meters around such premises as hospitals, educational institutions and courts. These zones are to be declared by the Competent Authority. Use of vehicular horns, bursting of crackers and loudspeakers shall be banned in these zones.

Most monitoring stations where high levels of noise were recorded were next to busy and congested roads where vehicles were the biggest contributors with constant honking aggravating the problem. The ambient noise levels in residential and commercial areas indicate average day time noise levels in the metros to be higher than the national standard of 55dB for the residential and 65dB for the commercial area. As the data is available on real-time, the governments can devise traffic plans for actual time intervention.

Methodology

There is availability of existing sensor network in metro cities laid by competent authorities such as Union Ministry of Environment and Forest, but it has limited coverage. Crowd sourcing makes the sensor network much more wider, flexible and economical. As there is active participation of people due to crowdsourcing, it becomes easy to monitor high fluctuations in the noise level during festivities and also makes it easier for people to avoid visiting areas contributing very high noise levels.

Figure 1: Flowchart of Noise Detection and Mapping
Noise Detection
Instead of laying a network of sensors at prominent locations to collect the noise data, mobile phone’s microphone is used as a sensor. An android application (Noisetrack) is developed to collect the noise data using mobile phone’s microphone. This app can be used as a two-way communication tool i.e. it can collect the noise data and also can be used to show the noise data analysis at user’s end. By adopting this technique, more number of samples can be collected while reducing overall expenses significantly. The sensor collects the noise data in terms of sound pressure Level (SPL) in Pascal which is then converted into decibel scale (dB) by using formula,

\[
SPL = 20 \log_{10} \left( \frac{P}{P_{\text{ref}}} \right) \text{ dB}
\]

Where,
- \(P\) = Sound pressure we are measuring
- \(P_{\text{ref}}\) = Sound pressure humans can hear (2.0×10\(^{-5}\) Pa)

The noise level measured by the App is uploaded to the server (ESRI server) using HTTP post request. The noise level gets stored on the server along with coordinates of sampling site, date and time of sampling. For multiple sampling at a same point at a same instance average value of the noise data will be considered during data analysis. This averaging helps in getting rid of ambiguity created due to local disturbances near the sensor. The data stored on the server is then used for spatial analysis of noise levels which then used for mapping of the noise levels.

GIS Noise Mapping
The objective of this work is to develop a mobile application to continuously monitor the noise in various zones of the city, and provide real time analytics to the user. In order to achieve this, the following approach is adopted:

- **Step 1:** Mapping of GPS collected data along with noise levels, taking the average noise level values.
- **Step 2:** Designing a Spatial feature layer on a server (ESRI server).
- **Step 3:** Spatial modeling and application of advanced interpolation techniques in GIS to obtain an accurate picture of the acoustic situation based on a limited number of sample points.

GPS Data Mapping
The data collected was mapped into the GIS and displayed on the base map of IIT Bombay on ESRI server.
Spatial Database Development
To support recorded noise level with geographical information a spatial database has to be created. For database, Feature layer was created on ESRI server. Each point contains the following attribute data:

a- Geographical coordinates (Latitude and Longitude)
b- Date and time of collection
c- Average noise level

Spatial Interpolation via IDW
Inverse Difference Weighted (IDW) estimates the output grid cell values by averaging the values of nearby sample points using linear weighted combination. The weight is a function of inverse of distance of sample points, closer the points more weight it is given.
Results

As shown in the following figure, red dots show the noise levels exceeding the limits. IIT Bombay falls into silent zone and hence the noise levels exceeding the range 40-50 dB are shown in red dots and ones which are less than 50 dB are shown in green dots. Traffic congestion points near the gates and student’s activity areas are generally noisy during the day, in the context of the area under observation, and depend on the sources of noise emissions.

![Figure 4. Map showing noise levels at sensed locations](image)

Conclusion

Millions of people already carry smartphones with rich sensing capabilities. Our work is to develop free and open source mobile application in Android environment, used to sense noise levels and provide useful feedback to users. Noisetrack is able to provide noise levels in dB on real-time as well as daily and monthly basis. Smartphone sound app can serve to empower and educate workers and decision makers for better environment. The dataset created by Noisetrack can be used to determine mean noise levels at different locations, which then can be used for traffic routing by comparing it with real time data. In future, using Geocoding techniques automatic zone identification can be carried out which will be helpful in deciding the noise level threshold for that area. The ubiquity of smartphones and availability of sensors can create research opportunities and also noise management in urban planning, i.e. a step toward smart city.
References

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