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3D Sound Mapping Techniques and Applications

Introduction

This project was meant to serve as proof of concept that this type of data collection could be viable on a large scale but there would need to be a few key differences for data collection on an entire outdoor city area.

Data

To effectively map the sound levels in an urban landscape in 3 dimensions. It would be necessary either to deploy large scale microphone arrays or take measurements from many different locations. Due to the nature of sound, measurements can be drastically different depending on the location from which they were taken. For example, the amplitude of sound measured in the corner of two reflective surfaces would be roughly two times louder than the same sound measured in free space. Thus, it is important to collect data from many different locations to accurately measure the sound levels.

In large cities, like Washington DC, the noise level is very unstable. Between the hours of 8am and 9am noise levels were measured to be over twice as loud on average than between the hours of 3am and 4am due to increased air, vehicle, and pedestrian traffic. Noise levels can fluctuate drastically in a short period of time which means that one short recording is not satisfactory to estimate average noise levels in a city. Not only can levels fluctuate within a given day, but they also depend on the day of the week and time of year. For example, snow is an extremely effective sound absorbing material with absorption coefficients between .5 and .9, which means that snow absorbs at least half of the noise energy it encounters (King, et al. 2012). Thus, on snowy days in winter, noise pollution levels are noticeably lower. To be able to accurately estimate the noise levels in a city, data is needed around the clock, for each day of the week, and for a few different times of year.

For this project, a few methods of data collection were attempted before deciding on a final method. One important factor to consider was that certain digital microphones adjust their gain to limit distortion in recordings, but this also affects the data because our goal in data collection was to analyze loudness. To account for this, it was important to ensure that noise levels were never compromised to improve quality of the audio recorded. This did not pose an issue to the research since the majority of the data was measuring the sound pressure level instead of frequency.

In the end, a Blue Yeti microphone was used for the final data collection with samples taken every second. The root mean squared was then calculated on each second of audio data to determine the average sound pressure level of the entire waveform. After calculating the SPL, further data about the specific frequencies was disregarded, but could have easily been acquired for a more in-depth analysis of sound sources.

Knowing which places are loudest is very helpful because this can help city planners make decisions on zoning, making sure that the loudest areas aren't used residentially, and building, making sure that appropriate measures are taken to limit the travel of noise pollution from the exterior to the interior of buildings. Not only can we use the data to determine the areas in a city with the most noise, but we can also look at how building materials, building shape, vegetation and other factors affect and control the noise pollution in urban areas (Yang 2013).

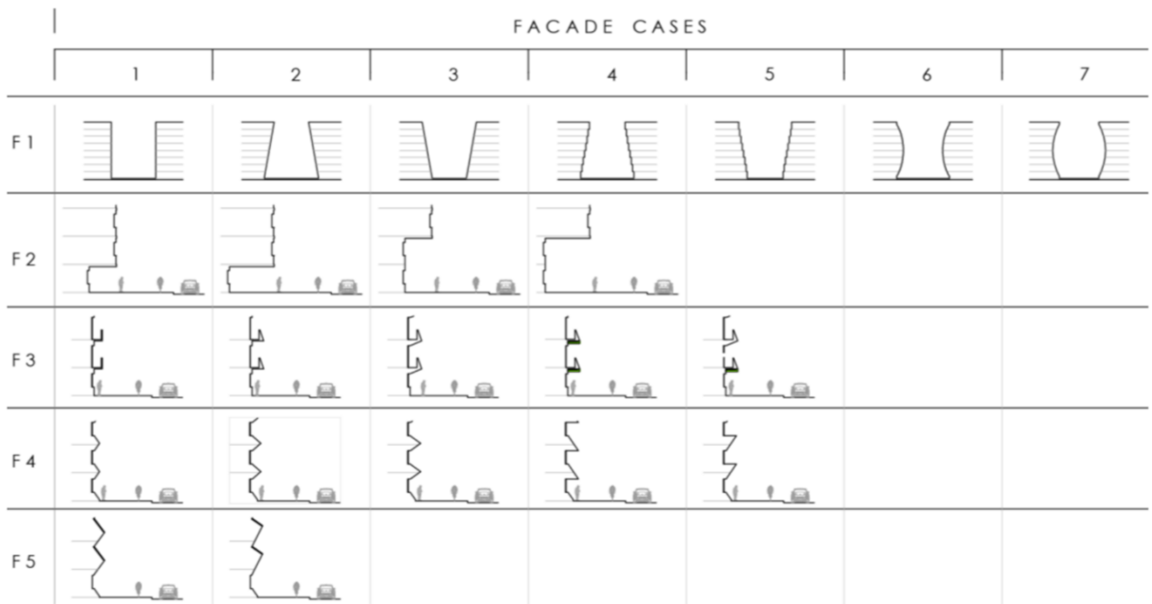
Frequency analysis to determine majority causes of noise

Another useful application of this is that the audio samples can be analyzed in the frequency domain to determine the most prevalent and loudest frequencies. With this information, we can identify possible major sources of the noise. For example, noise in the lower frequencies, 10Hz – 100Hz is often caused my large trucks, machinery/construction, and air traffic. Whereas noises in the 150Hz – 500Hz range is generally associated with vehicle traffic and highways. Determining the major noise pollutants would help city planners decide how to reduce noise pollution, whether that means limiting traffic of certain types of vehicles or choosing certain materials and methods of building to help absorb noise (Phelps 1973).

How Noise Can Be Reduced

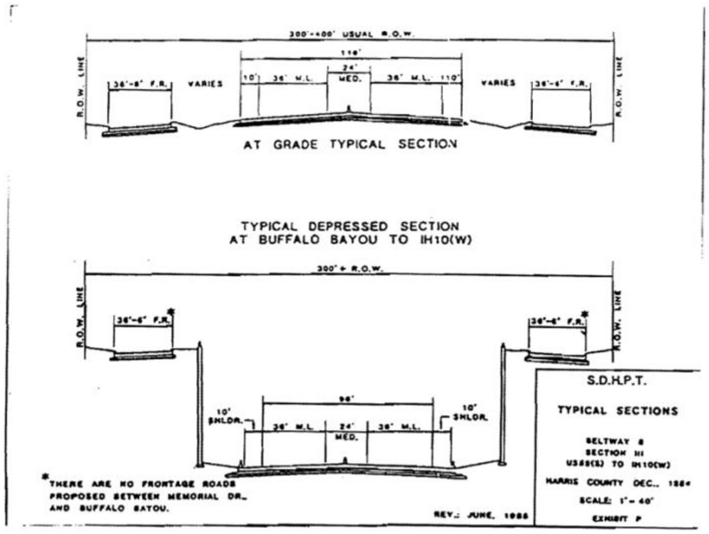
In this study, it was found that vegetation coverage, including ivy, trees, and smaller plants can effectively absorb all sounds between 100Hz and 5 kHz. Even green roof tops have been found to reduce noise levels by up to 10 dB in the “street canyon” or the ground level space between buildings. This provides a simple and cost-efficient method noise reduction with the other added benefits of greenery and nature in urban environments.

Experts have also studied the effect of the shape of building façade on noise reduction in the city.



They found that upwardly inclined façades were most effective at limiting noise exposure. These façades combined with noise absorbent furnishings on balconies and street level can highly reduce noise exposure for pedestrians and residents (Echevarria Sanchez, Van Renterghem and Botteldooren 2016).

Lastly, freeway and road design play an important role in the way urban noise is dispersed and scattered.



Sam Houston Tollway Section # 6, Houston

Here, it was found that depressed roadways can reduce noise levels by up to 10 dB (Zimmer and Buffington 1997). This means that the perceived loudness of the noise would be halved. Using this data, city planners can create efficient designs that take into account the excessive noise levels found in modern urban areas.

Why This Is Important

All of these findings are extremely important when looking at the effects of noise pollution on the health of those who it affects. Aside from the hearing damage and subsequent loss that is commonly associated to loud noises for an extended period of time, there are a host of other health implications also associated with noise pollution, including problems with heart health, mental health, risk of obesity, cognitive performance, etc.

One of the major effects of the high noise levels in urban environments is the risk of sleep disturbances. Not only can loud noises awaken the residents of a city, but repeated night-time awakenings can erode their quality of sleep which has very far reaching health impacts including all of those listed above (Passchiew-Vermeer and Passchier 2000).

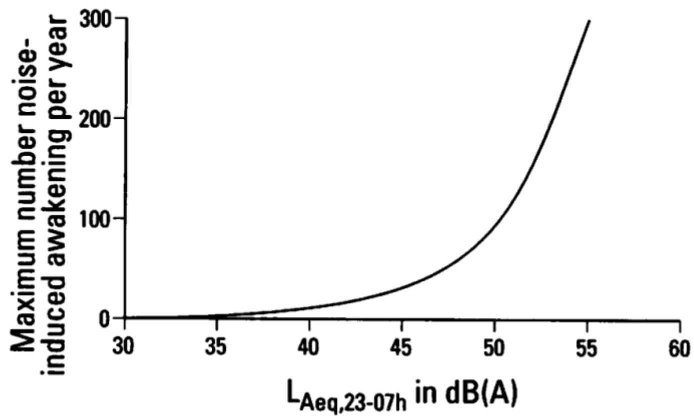


Figure 4. The maximum number of awakenings per year as a function of the outdoors night-time equivalent sound level (*8*).

This figure demonstrates the effect of high noise levels on sleep disturbances.

Further, those who are exposed to noise levels above 80 dB are at higher than average risk for hypertension and heart disease which directly correlates with risk for heart attack and stroke. In another study around the Munich Airport in Germany, it was found that those the noise level around the school was inversely correlated with reading comprehension, long-term memory, and sustained attention (Stansfeld and Matheson 2003).

Along with increased stress, risk of obesity, and a plethora of other negative health effects. Noise pollution clearly has fairly serious repercussions on those it affects. Using advanced methods of data collection, we can develop a new way to visualize data for city planners and others who can have a major impact on the amount of noise to which urban residents are exposed.

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