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Environmental Noise Mapping with Smartphone Applications: A participatory noise map of West Hartford, CT.

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ABSTRACT

This paper reports on the second phase of an on-going study concerning the use of smartphone applications to measure environmental noise at the University of Hartford. This phase involved the development of two strategic noise maps of West Hartford town center: i) a standard noise map developed using traditional mapping techniques and ii) a participatory noise map utilizing smartphone-based measurement data (a citizen-science approach to noise mapping). The objective of the study was to assess the feasibility of developing a noise map using a citizen science based approach. Results suggest that smartphone applications can be used to collect environmental noise data and these data may be used in the development of a participatory noise map.

1 INTRODUCTION

The development of smartphone technology and its impact on environmental noise studies has only recently begun to receive some attention in the academic literature^{1,2}. This technology has the potential to completely redefine approaches to environmental noise studies, and a number of projects assessing the potential for smartphone technology are currently ongoing at the University of Hartford. This paper reports on the second phase of a project concerning the use of smartphone applications to measure environmental noise at the University of Hartford.

1.1 Previous Work

Using test facilities at the University of Hartford's Acoustics Lab, Murphy and King recently completed experimental tests to assess the capability of noise monitoring applications to be utilized as an alternative low cost solution to traditional noise monitoring (i.e. the use of a calibrated sound level meter)³. The methodology consisted of testing 100 smartphones in a reverberation room. Broadband white noise was utilized to test the ability of smartphones to measure noise at background, 50, 70 and 90 dB(A) and these measurements were compared with true noise levels acquired via a calibrated sound level meter. Tests were conducted on phones

using both the Android and iOS platforms. For each smartphone, tests were completed separately for leading noise monitoring apps culminating in 1472 tests. These tests identified best performing apps and indicated that it may be possible to harness the capability of smart phones for environmental noise assessments.

1.2 Objective of current study

While several studies have demonstrated the possibility and limitations of smartphone noise apps for measuring environmental noise, none of them have assessed specifically how smartphone apps could be integrated into the current strategic noise mapping process. The objective of this study is to develop the initial work of Murphy and King and field test the application of smart phones for an environmental noise assessment. This involves the development of a noise map using smartphone data which is then compared to a noise map developed using traditional methodologies.

2 THE ANATOMY OF A NOISE MAP

Calculation methods for noise mapping generally consist of two parts: a method to calculate the level of noise at the source (the source model) and a method to describe how noise will propagate away from the source (the propagation model)⁴. Most methods used in practice are either empirical or semi-empirical and contain many simplifying assumptions including a very basic definition of the source characteristic⁵. These models are generally based on empirical observations (measurements) and, therefore, are only accurate for source and receiver conditions which are similar to those associated with the original dataset⁵. The accuracy of a noise map is always limited by the accuracy of the input data.

Most noise prediction methods, irrespective of whether they are dealing with road, rail, air or industrial sources, implement some form of the following basic equation:

$$L_p = E - A_{tot} + C$$

where L_p is the sound pressure level at the receiver, E represents the emission of the source, which is a representation of the sound power level of the source. A_{tot} represents the total amount of sound attenuation occurring between the source and receiver and C represents a collection of different correction factors which may include reflections from façade, road surface types etc.

Traditionally, all noise maps are based on prediction. The source emission is predicted from variables describing traffic volume, composition, speed, etc. while the attenuation depends on the position of roads, buildings, topography, etc. Usually datasets, collected from a variety of sources, are collated in a GIS model and the overall noise levels are calculated through noise prediction software implementing a national calculation method.

In 2009 King and Rice reported that separating the source and propagation models in noise mapping would allow users much more flexibility in developing a noise map⁶. In fact, most of the error in a noise map is due to an inaccurate (or incomplete) source model. So, by separating the source and propagation model, users can develop a custom (more accurate) source model and combine it with a well-accepted (and validated) propagation model to develop a refined noise map.

3 TEST PROCEDURE

The study area for the current piece of research is a one square kilometer area in the center of West Hartford, CT. The town is located on the northern suburbs of the city of Hartford. It encompasses 22.2 square miles and has a population of 62,000.

3.1 Development of Standard Noise Map

The standard noise map for West Hartford town center was developed within Esri's Arc-Geographical Information System (ArcGIS) mapping platform. The city of West Hartford supplied shapefiles for all roads and buildings. Once the development of the model was completed in ArcGIS it was exported to Predictor V9.112. Shapefiles contained spatial data but no attributes such as traffic counts, speeds, and building heights. Required attributes to develop the noise model were gathered (via short term traffic counts and site observations) and manually input. A standard building height of 8m was assumed throughout the model. The estimated average daily traffic data (ADT) was assigned to each road along with speeds estimated from the posted speed limits obtained from the Connecticut Department of Transportation. Throughout the development of the model assumptions based on the Good Practice Guide for Noise Mapping were implemented. All predictions were made according to the French national computational method, XPS 31-133.

3.2 Development of Participatory Noise Map

The participatory noise map does not utilise any input data for the noise calculation model. As mentioned previously, noise calculation models typically have a source model and separate propagation model. This is incorporated into Predictor by allowing the user to manually input estimates of the sound power per meter for each road segment in the model. In this case these values were reverse-engineered from the smartphone measurements on the roadside edge.

3.2.1 A note on Measurement Methodology

Five minute measurements were taken by 20 volunteers with smartphones at 93 locations throughout the test area. Measurements were undertaken on September 26th 2015 between 10am and 2pm. All of the testing devices were iPhones with no reported significant damages; all phones had the SPLnFFT app installed. Volunteers were required to remove any phone covers and set their phone to 'airplane mode' in order to eliminate cellular activity. They were also briefed on a standard measurement technique to ensure consistency in testing i.e. volunteers were instructed where to hold phones, the approximate distance with respect to the road edge and what would warrant a measurement to be repeated. The height, orientation and position of phone with respect to the volunteer's body were all consistent with the methodology tested by Murphy and King.

Using this approach L_p is thus measured directly and a value for E is estimated for each test location. Participants were instructed to hold the phone a fixed distance from the road surface edge at a fixed height. All phones were positioned 2.5m from the road edge with no reflecting surfaces, other than the ground, in the vicinity of the measurement. By designing our measurement procedure with a view to holding A_{tot} and C as fixed as possible, a consistent conversion from L_p to E is applied. Our approach replaces the traditional source model, which is

predicted from input data from road traffic and associated data, by manually inputting sound power data estimated from smartphone measurements.

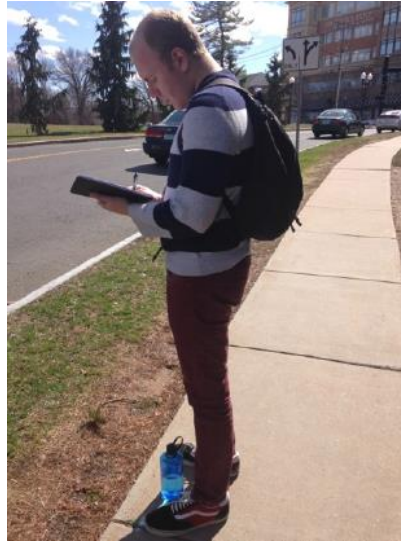


Figure 1: A volunteer logging a test result in West Hartford center

4 RESULTS

Figures 2 and 3 display the noise maps developed from both methodologies.

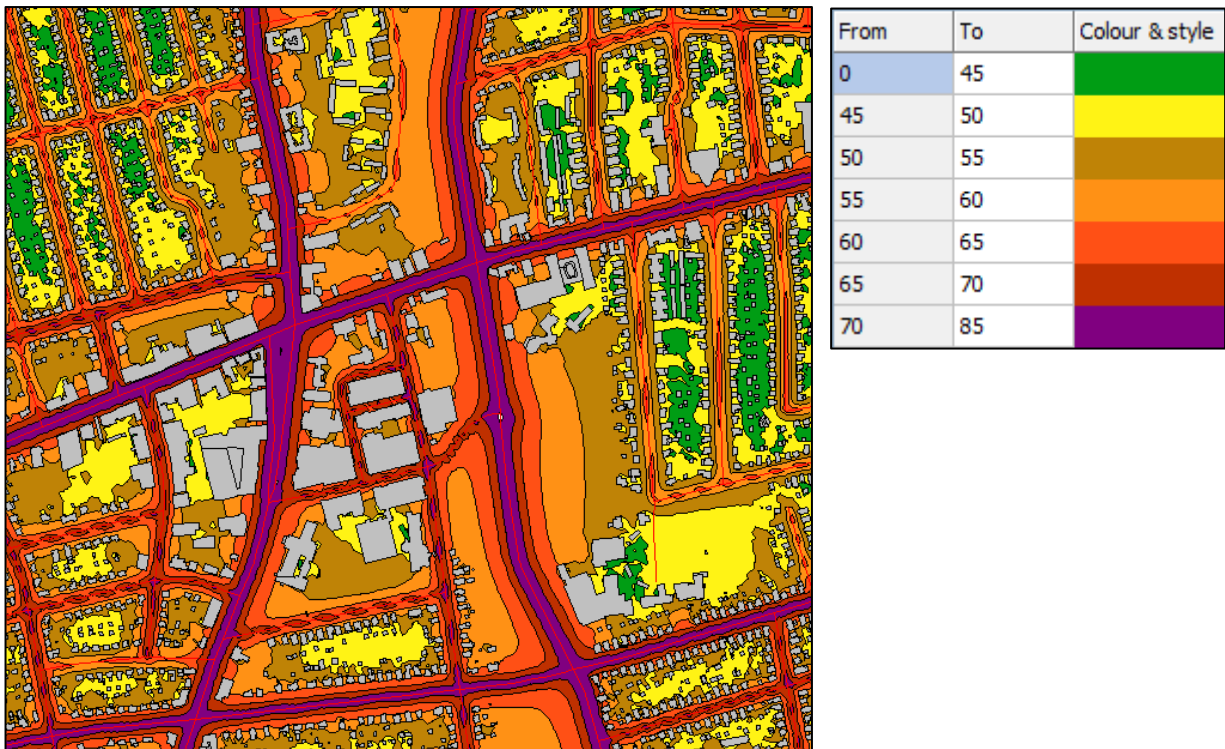


Figure 2: Noise Map of West Hartford center based on traffic count data (the 'traditional' approach)

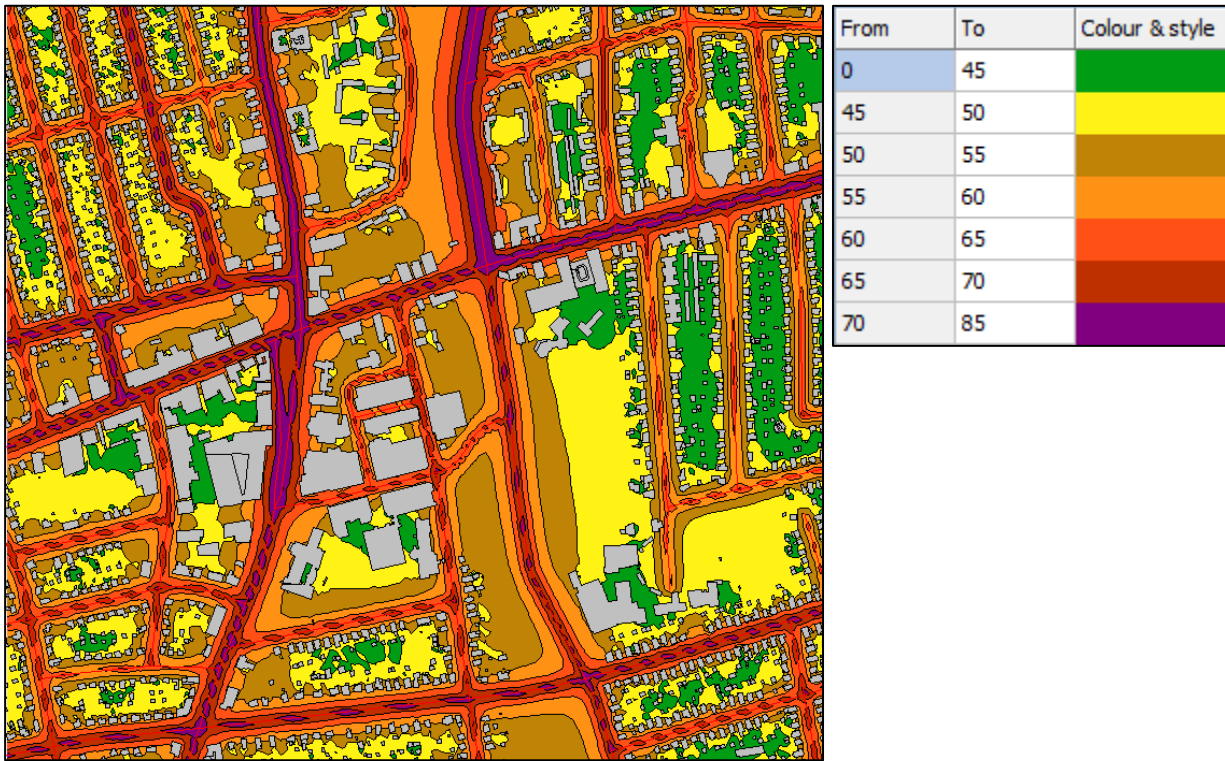


Figure 3: Noise Map of West Hartford center based on smart phone data (the 'participatory' approach).

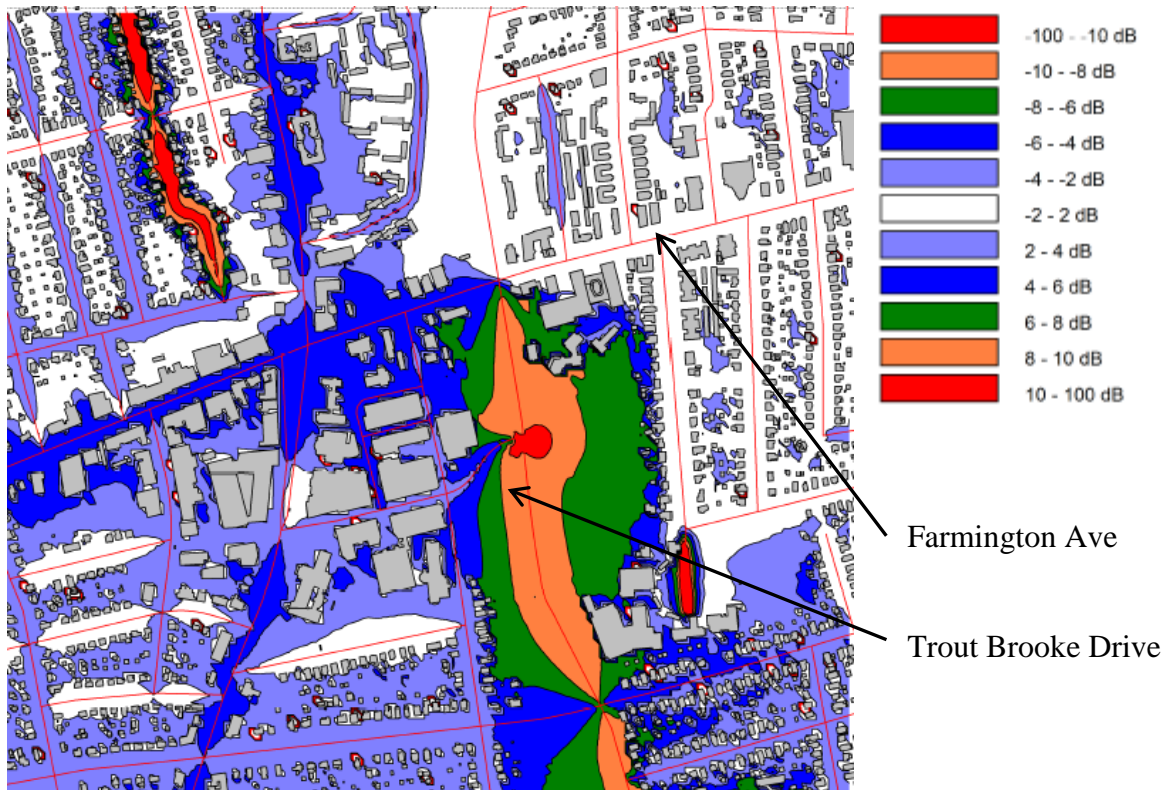


Figure 4: Difference Map – Traditional vs. Participatory Noise Map

In order to highlight the differences between the strategic noise maps with integrated smartphone data and that using the traditional approach, a noise difference map was (Figure 4). The difference map may be displayed if an identical grid is used in the initial development of the two maps. Each receiver point from a baseline noise map is compared to its corresponding point in the second noise map and the calculated sound pressure level difference is determined for each point. After each difference is determined the difference contours are interpolated using linear triangulation.

It can be seen that the greatest differentials are close to the busiest routeways such as Trout Brook Drive south of Farmington Avenue. However, it can also be seen that in overall terms there is a ± 4 dB(A) differential at most locations using the two approaches. While this is significant in decibel terms given the logarithmic nature of how sound is measured, it is nevertheless encouraging that the differential is in the main close to the acceptable degree of error of ± 2 dB(A). Moreover, it suggests that if noise apps are refined further in the future, there is real potential for the measurements associated with such apps to be integrated into the strategic noise mapping process.

5 CONCLUSION

This study shows the potential for a citizen science based approach to noise mapping. Results from the participatory noise map are (for the most part) comparable to the noise map developed using traditional methodologies. While there is indeed a significant degree of error associated with data acquired via smart phones, it is unlikely to be any greater than that typically associated with the input data in computation models that rely heavily on traffic data. Data such as traffic flow, composition and speed information are often, in practice, either estimated or assumed for input into noise model and therefore is also subject to considerable inaccuracy. The approach presented here is of considerable practical importance because it removes the need for any input data for the source model.

While we use the traditional noise map as a benchmark in this study, we do not consider the accuracy of it to be absolute. In fact, it is quite possible the noise map based on smart phone measurements may be more representative of the actual acoustic environment.

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