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A LOW COST PLATFORM FOR NOISE MAPPING USING SMART PHONES

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Although there are many apps available in the market for the recording and assessment of noise levels using smartphones, the main issue is the accuracy of such devices if they are to be used for assessment of noise levels or archiving of soundscape. The built in microphones of smartphones are commercial entities with diversified performance characteristics. We also found out during the course of research that some smartphone manufacturers artificially impose a software control on the maximum noise level that could be recorded by the smartphones. In this respect, we have developed a methodology to calibrate a typical smartphone with a finer frequency resolution to obtain good accuracy for typical noise measurement and sampling of soundscape. For example, a typical Samsung S7 with proper calibration with a type 1 sound level meter could achieve an accuracy of ±1.5 dB for typical environmental noise measurement. Examples for the use of the low cost platform that has been developed for the development of Word Noise Map will be presented for noise mapping of several cities in the world such as Lisbon and Madrid.

Keywords: Noise mapping, smartphones, environmental noise, sound level meters

1. Introduction

The soundscape is typically constructed or measured using automated or semi-automated digital recording systems. Digital acoustic recorders store the timing and intensity (or power) of the sounds detected by microphones, and signal processing is used to reconstruct the frequency distribution of the signal intensity over time. Sound can be measured using standalone microphone systems with wireless transmission and remote controlled features. In a city, the sound recording equipment can be mounted on vehicles to cover a wider area. An idea is the use of a noise map (DEFRA, Noise mapping England) to monitor the environmental noise and this approach has been reported in a number of countries such as the United Kingdom (http://tinyurl.com/) and Germany [1]. A noise map is like a weather map for noise and it shows areas which are relatively louder or quieter. An example of such a noise map was reported in US on a typical day in summer. The link is

http://news.sciencemag.org/environment/2015/02/new-map-shows-americas-quietest-places

The map was expensive to produce and the results were collated based on 1.5 million hours of acoustical monitoring from places as remote as Dinosaur National Monument in Utah and as urban as New York City. It would be difficult to cover a large area in a natural park as the shear presence of a vehicle or drone would affect the surrounding soundscape. Besides the use of typical sound level meters, the proposed research will explore the use of in-house developed apps for noise mapping using smart phones which will capture both the WAV files as well as the GPS locations on the move. Besides indicating the noise levels on the map, the associated soundscape (in terms of wav files) could also be played back when one re-trace the paths of the city.

The soundscape is also spatial and temporal in nature. The spatial measurement is typically done by positioning sound recording equipment at different locations but the individual sound source cannot be located. An alternative feasible approach is the use of smart phones for noise monitoring, in technical context, known as community sensing, mass sensing or ubiquitous sensing. The key idea is the use of ordinary people to participate in the collection of noise data making of smart phones equipped with microphones and Global Positioning System (GPS) receivers. Due to the ubiquity and universal usage of smart phones, the proposed approach can offer a large spatial–temporal sensing coverage at a small cost. The annual survey done by IDA in 2012 found that about 65% of the residents used a smartphone and the highest smartphone usage was among residents aged 25 to 34 years old (95%). The survey by Deloitte's Global Technology, Media and Telecommunications (TMT) published on 11 Feb 2015 revealed that Singapore was ranked highest globally for smartphone penetration, with nine out of 10 respondents having access to a smartphone. Soundscape recording and collection based on smartphones is therefore an attractive approach for the acquisition and establishment of Singapore soundscape as intangible cultural heritage before they are gone due to redevelopment of the city.

Such a method has been reported by Rana et al. [2] coined as Ear-Phone: A context-aware noise mapping using smart phones. The calibration of smart phones was done using a method based on calibration tone using Audacity software. The accuracy for calibration based on this method is yet to be confirmed. D'Hondt et al. [3] reported a citizen science experiment for noise mapping in a 1 km2 area in the city of Antwerp using NoiseTube, a participatory sensing framework for monitoring ambient noise. The calibration was done for 11 different handsets of the same model to study how hardware differs for the same model of a smartphone. The idea of NoiseTube was reported earlier by Maisonneuve et al. [4]. This was deemed to be a new approach for the assessment of noise pollution involving the general public. The main 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. Thus each user can contribute by sharing their geo-localized measurements and further personal annotation to produce a collective noise map. Schweizer et al. [5] reported an application based on Android phones for generating real time noise maps. This approach has therefore gaining momentum but the main issue is the accuracy, meaning a method for calibrating the smartphones and also how the locations for the measurements can be automatically captured. Kardous and Shaw [6] studied the accuracy of smartphone sound measurement applications (apps) and whether they could be appropriately employed for occupational noise measurements. They evaluated more than 130 iOS apps but only 10 apps met the selection criteria. Only 4 out of 62 Android apps were tested. The results showed two apps with mean differences of 0.07 dB (unweighted) and 0.52 dB (A-weighted) from the reference values. The study suggests that certain apps may be appropriate for use in occupational noise measurements. Based on these recent reports and studies, we can conclude that certain models of smartphones with suitably designed apps could be made into a low-cost platform for the sound measurement.

2. Methodology

2.1 Refinement and upgrading of the existing apps

We have developed a sound level meter app known as Noise Explorer for Android-based smart phones. Noise Explorer measures sound pressure level using the built-in microphones available in smart phones and displays to the user instantaneous, minimum, and maximum SPL in dBA as well as equivalent continuous SPL in dBA since the recording was started. The users can also choose to show either a live frequency spectrum or Google map showing the current location of the smart phone (Figure 1). The app automatically records noise levels and location to a XML file on the phone itself at a user specified frequency (default is 15 seconds, but can be adjusted for 5 and 10 sec). The user can optionally choose to record the audio as uncompressed WAV files. Even though uncompressed WAV files occupy more space we chose the format so that we can perform spectral and even psycho-acoustic analysis on the recordings. For most smart phone on-device storage is not an issue these days. Moreover, users can delete recorded WAV file or moved to external storage device or micro SD cards once they have uploaded them to the server (or even without uploading). The app also allows user to specify the calibration factor and response type (slow, fast or impulse).

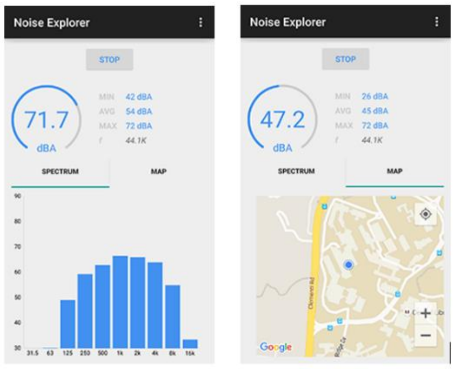

Figure 1: Noise Explorer interface

2.2 Calibrating of Smart Phones

A microphone with linear response should be calibrated for each octave or one-third octave band giving one calibration factor for each band (total of 11 or 33 factors). A microphone with non-linear response should be calibrated for each octave or one-third octave band at various noise levels (for example between 30 and 100 dB in steps of 5) giving a list of calibration factors for each band. Calibrating a non-linear microphone obviously will require much more work and calibration accuracy will be dependent on non-linearity and step size selected for noise levels.

Android supports a number of logical input sources for recording audio suitable for various scenarios. Typically, OEM's such as Samsung will perform signal processing on the input source to satisfy various regulatory requirements as well as internal acoustic requirements set by OEM themselves. For example, we have found that for Samsung S4 and S7 smart phones using the MIC source, noise level would saturate beyond about 76 dbA. However, In Focus M210 did not saturate for higher noise levels (Figure 2). To develop an accurate sound level meter app it is necessary to disable any signal processing before computing noise levels. Android offers VOICE_RECOGNITION input source which requires OEM's to disable any effects/pre-processing. In addition, VOICE_RECOGNITION must have a flat frequency response (± 3dB) from 100Hz to 4kHz. These requirements make VOICE_RECOGNITION an ideal source for using any acoustic data capture and analysis and we use it in our app. We have not found any reference to this in any paper so far and most of the popular sound level meter apps in Google Play Store seem to be using MIC source instead of VOICE_RECOGNITION source.

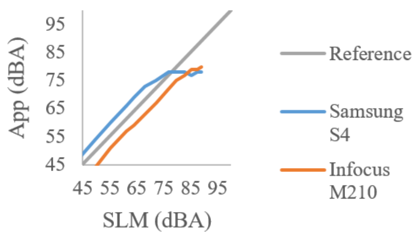

Figure 2: MIC source saturates noise levels in Samsung S4 but not in In Focus M210

In our testing with Android-based phones we have found that microphone response for VOICE_RECOGNITION source was mostly linear (Figure 3) between 55 to 85 dBA for all phones that we had tested (Samsung S3, S4, S7 and In Focus M210). Figure 4 illustrates that the response of Samsung S4 microphone for various pure tones from 63 Hz to 16 kHz is linear. Even though the response of each frequency is linear, the response is not same for all frequencies. Therefore, we decided on the following calibration process:

- Generate a set of pure tones at a number of different levels.
- Compute calibration factor for each frequency as the average difference the between the noise level computed by smart phones and a type I sound level meter (B&K Model 2235) for the noise levels.

At first we attempted to calibrate using only octave band frequencies, however, the results we obtained were not accurate with error of more than 3db. We decided to increase the frequency resolution to a finer level and discovered a large dip in calibration factor around 7 kHz which might be the source of inaccuracy. With the increased frequency resolution, we were able to obtain good accuracy of ±1.5 dB for environmental noise.

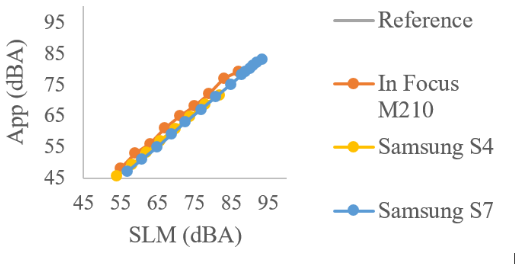

Figure 3: Response of various smart phone microphones

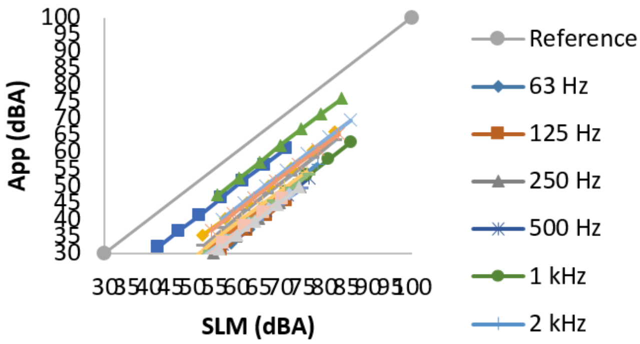

Figure 4: Response of Samsung S4 microphone for various pure tones

2.3 Archiving and presentation of data

The data will be initially stored on the smartphones and then upload to a dedicated server. We will also develop the feature of automatic uploading of the data with the consent of the user during the course of the research. The data can be presented for different time of the day or different weeks of the month. They can also be presented in terms of average values for a particular day or particular month. For the data presentation, besides presenting the basic noise levels on a map and also the soundscape at specific locations, we will also include the feature of rendering of the soundscape when a path on the map is retraced. This part of the work will be carried out by a research fellow. The current version of the apps only have the accuracy of 2 dB. We are improving the accuracy of the apps to be within 1 dB which will be close to a typical class 1 sound level meter with an accuracy of 1 dB.

3. Sample Noise Maps

The previous version of apps with an accuracy of 2 dB for S7 has been used during the recent trip to Lisbon, a historical city of Europe. The apps captures both the noise level, the WAV files as well as the GPS locations on the move. From the example on the noise mapping of the Lisbon city (Figures 5 and 6), the red spots indicate noise level above 80 dBA. It occurred along narrow streets with trams passing by. The green spots indicate noise level below 60 dBA. It occurs at the Sao Jorge Castle on top of the hill without any surrounding vehicular traffics. It also captured the noise level on a ferry across the strait. For Madrid shown in Figure 7. The noise level is generally higher. The apps also captured the noise on a train from legane to Madrid city main strain station for the elevated track.

Figure 5: Noise map of Lisbon, Portugal

Figure 6: Noise map of Lisbon city around São Jorge Castle, Portugal

Figure 7: Noise map of Madrid, Spain

4. Conclusion

In this paper, we presented a method for accurately calibrating smartphone microphone against a reference type 1 microphone. The NoiseExplorer app which uses the calibration method is able to report accurate sound pressure levels to the user. The app also records the location of the smartphone which is to generate noise maps and compare difference places. Examples for the use of the low cost platform that has been developed for the development of Word Noise Map. Samples for noise mapping of several cities in the world such as Lisbon and Madrid have been presented.

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REFERENCES

1 Santini S, et al., First experiences using wireless sensor networks for noise pollution monitoring, in: Proceedings of the REALWSN'08: Workshop on Real-World Wireless Sensor Networks, Glasgow, Scotland, 61–65, (2008).

2 Rana R, Chou CT, Bulusu N, Kanhere S, Hu W. *Ear-Phone: A context-aware noise mapping using smart phones, Pervasive and Mobile Computing* **17**, 1–22, (2015).

3 D'Hondta E, Stevens M, Jacobs A. Participatory noise mapping works! An evaluation of participatory sensing as an alternative to standard techniques for environmental monitoring, *Pervasive and Mobile Computing*, **9(5),** 681–694, (2013).

4 Maisonneuve N, Stevens M, Niessen ME, Steels L. NoiseTube: Measuring and mapping noise pollution with mobile phones, Proceedings of the 4th International ICSC Symposium, Thessaloniki, Greece, May 28-29, Published by Springer Berlin Heidelberg, pp. 215-228, (2009).

5 Schweizer I, Probst F, Bärtl R, Mühlhäuser M, Schulz A. Noisemap - real-time participatory noise maps. In Second International Workshop on Sensing Applications on Mobile Phones (2011).

6 Kardous CA, Shaw PB. Evaluation of smartphone sound measurement applications. *J. Acoust. Soc. Am.* **135 (4)**, EL 186-192, (2014).