Crowdsource noisemap

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***Abstract*—In this study the authors evaluate the usability of noise data measurement capabilities of an average smartphone and make a comparative study on available open source mobile applications potentially suitable to noise mapping. A reference dataset generated by professional equipment was also used but at a different date. The study confirmed that the mobile applications running on the smartphones tested are not capable for scientific measurement although tendencies suggest that calibration may lead to reasonably accurate noise level capture. The study also revealed that different mobile applications produce different outputs. This type of user generated noise measurements cannot substitute professional surveys but provide additional data for strategic noise mapping and monitoring. It can be involved in testing the effect of the action plans created by the settlements in order to reduce noise pollution and can be used for determining the most polluted areas.**

I. Introduction

Noise pollution is one of the main and growing environmental problem in urban areas. Noise affects everyday life, well-being and it can even cause severe psychological problems. There is a continuous exchange of substances, energy and information in urban settings and its surroundings but still there is not too much information available about the quality of environmental impacts.

According to the Environmental Noise Directive of the European Union 2002/49/EG (END) each agglomerations with a population more than 250 000 - pursuant to article 7 - should create a noise map. The directive regulates the process of the measurements and the kind of improvement that should be proposed by the local government in order to reduce the annoyance by noise pollution.

The Hungarian Government Decree 280/2004. (X.20) in 2004 obliged all settlements with a population more than 100 000 to create a noise map and a plan to reduce noise pollution exceeding the EU Directive.

All these maps should have been prepared by 2012 and there is an order to renew it from 2010 onwards every five years. However due to the lack of financial resources local authorities are unable to fund the renewal of these maps. In this case crowdsourcing may be a good solution to contribute the legislation. Through volunteered geographic information it can be tested how citizens can assess their environment, and can be compared to the measurements made by professionals. It may reveal how member of public see their city, and it can help in designing better managed cities.

The concept of using humans as sensor has a growing importance in the European Union. There are several applications in ecology, species survey, etc. There is a considerable interest in crowdsourced data also mentioned as volunteered geographic information [1] as the European Commission has funded projects to determine how much such data is suitable for risk management, monitoring deforestation. Due to increased availability of location-enabled digital data capture services on smart phones, these data acquisition will be critical in the future.

Another important aspect of smarter cities is how much citizens can be involved in assessing their surroundings. The crowdsourced data can be comparable with measurements by scientist and urban ecologist.

Also in the field of noise mapping several attempts were made to involve citizens through developing sensor network such as NoiseSpy [2]. Other attempts were focused on motivating users to participate like NoiseBattle and NoiseQuest [4]. Karolus Jacob in his thesis introduced an ”approach making use of machine learning techniques and collected noise measurements by a participatory sensing application to determine the noisiness factor of an area. By using the collected sound data in conjunction with further information on the vicinity such as nearby streets or buildings, they were able to create a machine learning model to predict the sound level with 80.9% accuracy.” [3]. A very similar approach to this is Ear-Phone [6].

None of the above mentioned research investigated the accuracy of the measurements therefore the goal of the recent study is to evaluate the usability of the data measurement capability of an average smartphone and make a comparative study on available open source mobile applications potentially suitable to noise mapping.

II. Method

The effect of noise on human varies via the spectrum of wavelength or frequency. It is a common practice to apply a frequency dependent weighting. The most common weighting used in noise measurement is A-Weighting. Like the human ear, this effectively cuts off the lower and higher frequencies that the average person cannot hear. A-weighted measurements are expressed as dBA or dB(A).

According to END in preparing the strategic noise maps the most important indicators are Lday, Levening, Lnight and Lden. The Lday, Levening, Lnight are the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all certain period, in which the day is 12 hours, the evening four hours and the night eight hours. (END) The day-evening-night level Lden in decibels (dB) is defined by the following formula:

According to the END, the acoustic indicators can be determined by computation or measurement methods. Usually computational methods are used with predefined

$$L_{den} = 10\lg\frac{1}{24}\left(12 * 10^{\frac{L_{day}}{10}} + 4 * 10^{\frac{L_{evening}+5}{10}} + 8 * 10^{\frac{L_{night}+10}{10}}\right)$$

models. The results can be processed in a GIS software where spatial interpolation is applied in order to create a continuous surface of sound levels. Five dBA ranges are used in the graphical representation.

In this study we investigated 2 basic phenomenon of noise level survey carried out by commercial smartphones to assess the possibility of crowdsourced noise measurement: (1) We compared the measurements of a professional equipment and a smartphone. (2) We compared the measurements of 2 different mobile applications running on the same model of smartphones.

A. *Comparing the professional equipment and smartphone*

The professional survey was carried out in 2012 in Székesfehérvár by a Brüel & Kjaer sound level meter type 2250 equipmet on 150 locations. As this equipment is not capable to record coordinates, the locations of the measurements were stored separately.

This equipment is capable to define [Alina Satmari, 2012]

- LAF – sound pressure level
- LAeq – average sound level
- LAFmax – higher time-weighted sound level
- LAFmin - lowest time-weighted sound level
- LCpeak - the maximum sound pressure value

and frequency weighting:

- LAS – Slow, A-weighted Sound Level
- LAF – Fast, A-weighted Sound Level
- LCS – Slow, C-weighted Sound Level
- LCF – Fast, C-weighted Sound Level

On each point 15 second long measurements were averaged.

We carried out the smartphone survey a year later by Sony Xperia P phones. As we had no access to the professional equipment, we repeated the survey when the conditions were the most smilar. The survey was repeated by university students on the same calendar day the following year and the measurements were carried out at the same period of the day. Both dates fall on a weekday so presumably the traffic conditions were the same and there was no change in the state of other objects responsible for noise emission.

In a professional survey several technical parameters are in control which cannot be expected from the public, however it is important that at least two minimum requirements are met during the measurements: (1) wind speed must be less than 5m/s and (2) it must not be raining. [284/2007.]

51 points were chosen to be used in the comparative study. These points were situated mainly in the inner part of the city, and near the railway lines.

For navigation to these points ArcGIS for Android was used as in Figure 1. ArcGIS for Android requires a continuous online connection as it synchronizes to the ArcGIS Online accounts where our maps are uploaded.

Figure 1 The process of the field measurements.

The noise level was measured by the software Sound Meter PRO. Four students took part in the survey.

The measurements were carried out at an average traffic, convenient wind speed and there was no rain. The students paid attention not to take a sample when cars were accelerating after traffic lights changed from red to green and 15 seconds of measurement were averaged on each point.

B. *Comparing different mobile applications*

The goal of the second survey was to compare the measurements of 2 mobile applications. There are several applications for Android equipments with different features. We chose (1) Sound Meter PRO by Mobile Essentials and (2) Noise meter by JINASYS. Both applications are popular among users and tested on different models of smartphones.

The applications use the built-in microphone and able to measure noise volume in decibels (db). It is important to note that built-in microphones are optimized to human voice (300-3400Hz, 40-60dB). Therefore these hardware have a limitation meaning the maximum values cannot exceed 80-100 dB. As both applications enable to calibrate the microphone, the quality of the measurements theoretically depend on the capability of the sensor only.

TABLE 1: COMPARISON OF NOISE LEVELLING SOFTWARE

Period	Time	Noise Meter (dB)			Sound Meter Pro (dB)			Deviation (dB)		
		LAmin	LAmax	LAeq	LAmin	LAmax	LAeq	LAmin	LAmax	LAeq
Lnight	6:00- 7:00	40,7	59,4	48,4	49	74	65	8,0	14,4	16,3
Lday	11:00- 12:00	46,3	58,6	51,1	58	73	67	12,1	14,4	15,6
	14:00- 15:00	45,6	56,7	50,3	58	73	65	12,0	16,2	15,2
	17:00- 18:00	46,0	56,9	50,7	57	75	66	10,7	17,7	15,8
Levening	21:00- 22:00	36,1	49,0	43,2	46	65	58	9,9	16,0	14,8

Sound Meter PRO enables to save the measurements in csv format, but not compatible with all type of smartphones.

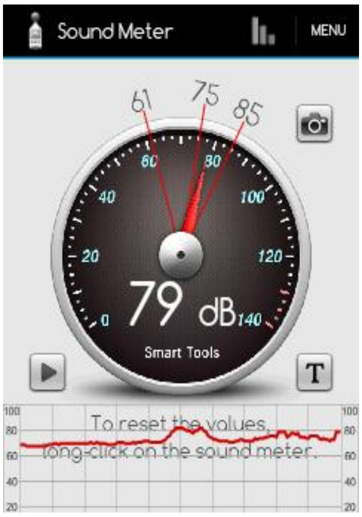

Figure 2 The control panel of Sound Meter during measurements.

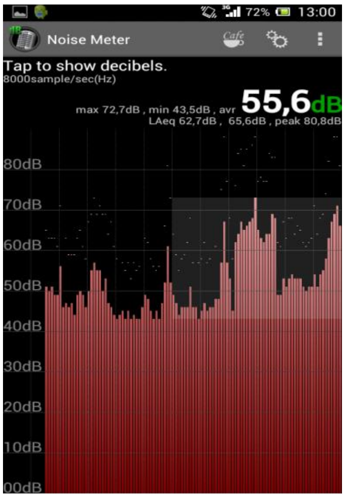

Figure 3 The control panel of Noise Meter during measurements.

Noise Meter is able to define LAeq, min, max and peak and LCpeak dB. The calibration function in this software is more complex than in Sound Meter Pro. The LOG file can be stored as txt.

The measurements were carried out by running the two software on different smartphones of the same model (Sony Xperia P) at the same time and location.

1 minute continuous measurement was averaged in every 10 minutes in all the 5 time intervals during the day (from morning to night 6-7, 11-12, 14-15, 17-18, 21-22 o'clock). Therefore peak hours and more quiet hours were also included. In each ten minutes one minute long measurement was taken.

The data was recorded at 7-8 m from the axis of the traffic line at the busiest intersection in Gyula, Southern Hungary. The aim of the study is to compare the 2 mobile applications so the traffic was not counted.

III. RESULTS

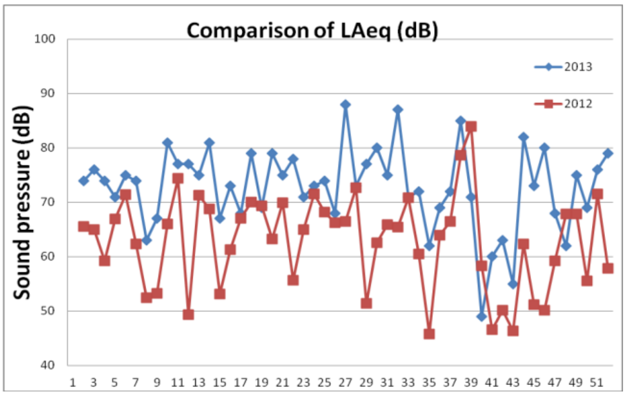

Figure 4. Comparison between professional and non-professional equipment.

Comparing the results of the scientific measurements and non-professional data, the latter produced higher values in dB (Figure 4). Since other circumstances were the same, it is most likely due to the lack of calibration. It seems to be feasible that acquiring calibration the values can approximately approach the scientifically correct values.

We created a noise map (Figure 5) based on the 2013 survey by IDW function in ArcGIS. This function interpolates data is based on the principle of spatial autocorrelation, which calculates degree of relationship-dependence between near and distant objects. The IDW function can be used when the distribution of points is dense enough to capture the extent of local surface variation needed for analysis. The source data was the LAeq value. According the EU directive the raster cell size of the generated map is 10*10 m and cubic convolution method was used as interpolation method as the regulation requires the usage of cubic polynomial function in creating noise maps.

Figure 5: The results of the noise measurements with the official noise map [7] in the bottom right corner.

Also we created the 3D model (Figure 6.) of the block house area with the different heights of the block houses. On the model there are measurements points and it can be seen behind the building the measured values are much lower.

In the second test comparing the deviation between the values measured by the 2 applications were approximately 10-15 dB (Table 1,).

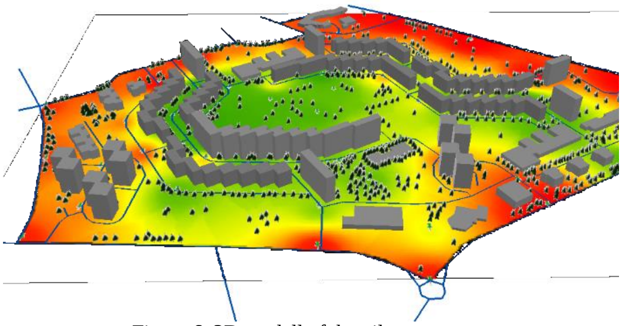

Figure 6. 3D modell of the pilot area

We supposed that the microphone of the smartphones have analogous technical properties. Three values could have been compared LAmin, LAmax, LAeq (Table 1).

Also it was possible to calculate the Lden values with both software:

$$L_{den\,[Noise\ meter]} = 10lg\frac{1}{24}\left|12 * 10^{\frac{50,7}{10}} + 4 * 10^{\frac{43,2+5}{10}} + 8 * 10^{\frac{48,4+10}{10}}\right|$$

$L_{den[Noise\ meter]}$ = 49,3 dB (A)

$$L_{den[Sound\ Meter\ PRO]} = 10lg\frac{1}{24}\left|12 * 10^{\frac{66,2}{10}} + 4 * 10^{\frac{58+5}{10}} + 8 * 10^{\frac{65+10}{10}}\right|$$

$L_{den[Sound\ Meter\ PRO]}$ = 65,1 dB (A)

The deviation of Lden is also approximately 16dB.

There are significant correlations between the professional equipment and the mobile phone measurements in case of LAFmax (p=0.0041) and LAeq (p= 0.0038) but the correlation is not significant in case of LAFmin (p= 0.349963942). The correlation coefficients of LAFmax (r= 0.39) and LAeq (r= 0.40) suggest that there are probable positive correlations between the professional and mobile equipment measurements.

Comparing the results of the professional and mobile phone measurements, the latter produced higher values of dB.

There are also significant correlations between the 2 different mobile application measurements in case of LAmin (p=8.3E-09) and LAeq (p= 0.0097) but not in case of LAmax (p= 0.075). The correlation coefficients of LAmin (r= 0.79) and LAeq (r= 0.43) suggest that there are probable positive correlations between the measurements of the 2 mobile applications. The deviation between the values were approximately 10-15 dB.

IV. CONCLUSION

There is a clear evidence that the mobile applications running on the smartphones tested in this study are not capable for scientific measurement. However tendencies suggest that calibration may lead to reasonably accurate noise level capture. A possible solution of calibration can be some predefined standard noise pressure level sounds generated by their computer.

Unlike the official noise map which is based on model calculations and can produce values on roads only, the map based on crowdsourced data can provide measured values at far more locations and more regularly.

The generated noise map reveals that the ten stories blocks of flats decrease the effect of noise pollution.

The study also revealed that different mobile applications produce different outputs. The characteristics of the sensors may differ but the microphones are the same model so we presume the contribution of this difference to the deviation is small. The difference in the mobile applications may contribute to the majority of the deviation. The mobile applications can retrieve a recorded sample from the microphone, the sound level values can be calculated from the sample only. Depending on the functions the applications calculates the noise levels from the same sound sample, the values may be different. There are many applications available but the second finding suggests that in a crowdsourced survey the same application have to be used by all surveyors.

In order to receive the same results it is beneficial to develop a customized application. It ensures that the function to calculate the noise levels is always the same and calibration can be enforced. Further advantages of a customised application are the enforcement of following the same protocol in order to be able to collect consequent data and take the characteristics of different equipments into consideration. The protocol must be planned by the authorities who would like to use these user generated data in order to creating strategic noise maps or to evaluate the effects of noise pollution. Gamification is also a strategy to be considered as it can involve more surveyors and increase the number of measurements.

These type of user generated noise measurements cannot substitute professional surveys but provide additional data for strategic noise mapping, monitoring, can be involved in testing the effect of the action plans created by the settlements in order to reduce noise pollutions and can be used for determining the most polluted areas. Furthermore, a strategic noise map must make an evaluation of the number of people exposed within the five dBA ranges.

Crowdsourcing can be a good option to involve citizens to measure noise exposure in their surroundings. This study suggests that standardising the protocol of the survey may lead to reliable measurements, however more investigations are required. We presumed that the characteristics of the sensors built in the same model of smartphones are the same but it needs to be checked. In a crowdsourced experiment members of the public volunteering to survey will use different brand and model of smartphones so further tests are necessary to compare the characteristics of the potentially different sensors.

Apart from the microphone the location of the measurements is also important. Even the EU regulation requires 10 m resolution, in urban settings a few meter difference may lead to significantly different noise values. Requiring accurate location of the smartphone, GPS management should also be implemented in the custom application.

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