Huerta, Schade, Granell (Eds): Connecting a Digital Europe through Location and Place. Proceedings of the AGILE'2014 International Conference on Geographic Information Science, Castellón, June, 3-6, 2014. ISBN: 978-90-816960-4-3

A comparative study on VGI and professional noise data

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Abstract

The ubiquitous nature of mobile devices and its growing presence in urban areas, turn them up into low cost environmental monitoring platforms. In this field, several authors made different efforts to provide alternatives to Sensor Networks, to assess noise pollution in cities using crowdsourcing techniques. In this sense, citizens might potentially produce large spatio-temporal datasets using their mobile devices to measure noise levels. There are few attempts of assessing the quality of the mobile noise samples on a real scenario and compare them to commercial data to evaluate if they are reliable enough. This contribution reviews the existing applications to collect or assess the quality of noise samples when they are used as sound level meters. Moreover, it presents the results of our experiment: the volunteer noise dataset generated in a 'mapping party' on our campus is compared to professional data. Results show that VGI data might be sufficient for multiple daily situations.

Keywords: Citizen Science, VGI, noise pollution, environmental monitoring, crowdsourcing, Smart Cities.

1 Introduction

According to United Nations report, the demographic growth over the next decades will be concentrated on cities and, by 2050, it is estimated that 70% of world people will be living in urban areas [18]. To improve economic and social conditions in urban environments, technicians and urban planners develop infrastructures that connect everyday living to the natural and informational resources to help making cities more sustainable [9, 17].

As population increases, cities become bigger and noisier and excessive noise levels have a direct impact on nature and environment: some species might be altering their behaviour to adapt to the increasing noise around us [4, 16, 1].

An effective way of monitoring our environment is through crowdsourcing [8]. With the application of this technique, we enable citizens to produce geographic information at a very low cost. Using VGI, we are capable of potentially extracting enough data from a city, with citizens' collaboration. However, due to the novelty of VGI approaches and its volunteer and collaborative nature, it is difficult to state if the quality of volunteer data is good enough for data analysis. To our knowledge, there are no approaches that compare commercial and volunteer noise data acquired through smartphones in a real scenario. Therefore, the work presented in this paper will try to provide a general overview of the potential of volunteer mobile noise monitoring.

Section 2 contains the related work, where we review several approaches considering noise monitoring and noise quality. In Section 3 we describe our data collections and the process carried out for the spatial analysis to obtain noise maps from our volunteer data. Section 4 presents the limitations and issues found in this project, whereas Section 5 outlines possible future lines of work. Finally, Section 6 summarizes the findings of our work.

2 Related work

Monitoring our environment is a crucial task to know how human activities affect our planet. In [5] Goodchild proposes a new way of acquiring environmental data and presents the concept of "citizens-as-sensors", also known in literature as crowdsourcing. There are several approaches to monitor noise pollution in urban environments applying crowdsourcing techniques. NoiseSpy [10] is a web platform that allows the measurement and real-time visualization of noise samples that the community of users uploads to a central server. NoiseTube [11] allows the creation of noise maps by sharing public measurements. This application provides to each user their personal exposure to noise pollution. NoiseBattle [6, 7] is a gamified application for noise sampling that tackles the problem of motivation and engagement of users for environmental monitoring.

However, these applications are focused on the noise collection, information visualization or user engagement and motivation, but do not consider directly the goodness of noise data mobile devices can acquire on a real scenario. In [13] it is possible to find the demonstration on how a mobile device after a calibration process can produce highly accurate measurements, when compared to a professional device. Similarly, [12] suggest that it is possible to obtain with mobile devices data with a precision and quality just few decibels different from professional devices.

In [3, 15] it is possible to find a discussion about how good might be the quality of noise samples collected with mobile phones. The article describes an experiment where three mobile devices and a sound level meter are exposed in few tests to different sources of noise.

3 Producing noise maps

This section explains the process followed to obtain noise maps to compare VGI and professional datasets. First, we describe both data collections, then we explain the process carried out during the analysis part and finally we present our results separately: on one hand all volunteer data involved in the project and, on the other, in particular for two concrete types of mobile devices.

3.1 Data collection description

As stated before, two different noise data sets were used: one collected by volunteers and the other one obtained with professional means.

Crowdsourced data. Volunteer dataset was obtained helding a 'mapping party' on University Jaume I Campus with members of GEOTEC Group. Data were collected in the central part of campus, comprising three faculties, the access gate and the central garden. In total, the study area is 585 meters long and 487 meters wide, giving an area of 0'285 km^2. Within this area, participants were encouraged to take measurements in 30 predefined locations.

The software used to collect noise samples is described in [6, 7]. An extra layer with the 30 points of the grid was added to help the user taking the measurement in the recommended locations. The experiment was repeated on the same places as the professional company did in order to generate maps that were possible to compare. Weather conditions on that day, screening effect and other possible ground effects were not considered. In the mapping party, a total of 12 users participated in the noise collection. This activity was carried out on Friday 25th October 2013, between 9am and 11am. The devices used on this experiment are shown in Table 1.

Table 1: Devices used to map noise and number of observations taken

Device model	Num. of devices	Num. of samples taken
LG Nexus 4	4	282
HTC One	1	35
HTC Wildfire S	1	67
Samsung Galaxy S4	1	31
Samsung Galaxy S3	1	112
Samsung Galaxy S2	1	1*
Samsung Galaxy Ace 2	1	29
Sony Xperia S	1	21
Celkon A27	1	3*

As seen, there was a reasonable variety of mobile devices. In total, 581 noise samples were taken during the mapping party. Two of the users (marked with an asterisk) had problems with their devices and could not get enough data during the established time. The study area used in this experiment may be considered a small-sized real scenario, where there are multiple devices providing a different number of observations, such as in a real scenario.

Professional data. Every four years, a private company carries out a noise pollution study [14] in Campus following ISO 1996 standard for acoustic reports. In 2012, this study was done for the third time, using the same methodology: Noise measurements are collected during the daytime, when most of human activities occur, and span several days. Campus was monitored following a grid pattern to assure uniform data distribution. In each node, the sound level meter was exposed to noise pollution for 5 minutes. This professional way of data collection considers noise weakening conditions, such as screening effect, sampling height, wind speed or distance to buildings and prevents the noise acquisition of those unwanted conditions.

3.2 Analysis and results

In general, the process of analysis is carried out as follows: Represent the point features on ArcMap 10.2, create an interpolation surface with the Spatial Analyst extension and then subtract the VGI data surface to the professional data surface. For each point, the mean noise and the standard mean error was obtained and those results are presented in a chart. Considering that four participants had the same mobile device, results will be presented in a double way: together for all measurements taken and then for two specific models.

For all noise maps, we chose a color ramp from green to red. Although in general it is useful to detect noisier areas, it is important to consider this when comparing images, because the legend will be slightly different.

General noise map. Using ArcMap 10.2, collected data were represented as a point feature layer. In order to see if there is a spatial relation among the values represented by each point feature, an interpolation surface using Kriging was created. Then, the same operation was repeated with data collected by professional means, so we obtained two basic different maps and compare them. Finally, both raster layers were subtracted using Raster Calculator, to obtain another map showing the difference in measurements of both layers.

Figure 1 depicts the first attempt of creating the campus Noise Map. It is representing the total bulk of data, without any filter correcting possible outliers. As seen, there is a clear similarity between two maps, detecting low noise levels (~50dB) in the central garden and surroundings, moderate noise levels (55dB to 60dB) around the faculties and high noise levels near the road used as main access to campus (>60dB). As seen, most of the samples collected with crowdsourcing present a certain clustering near the nodes of the professional grid.

Figure 2 presents the difference between professional and volunteer raster layers seen in Figure 1. Pink areas highlight places where VGI noise layer measured higher values in decibels while green areas represent the opposite phenomenon.

Finally, areas in yellow areas represent areas where the measurements taken with both methods are very similar. As seen, differences are visually remarkable, but examining the map legend, they are ranging from -5.2dB to 5.6dB, results in line with the ones obtained in [12].

Figure 1: General overview of professional (top) and VGI data (bottom)

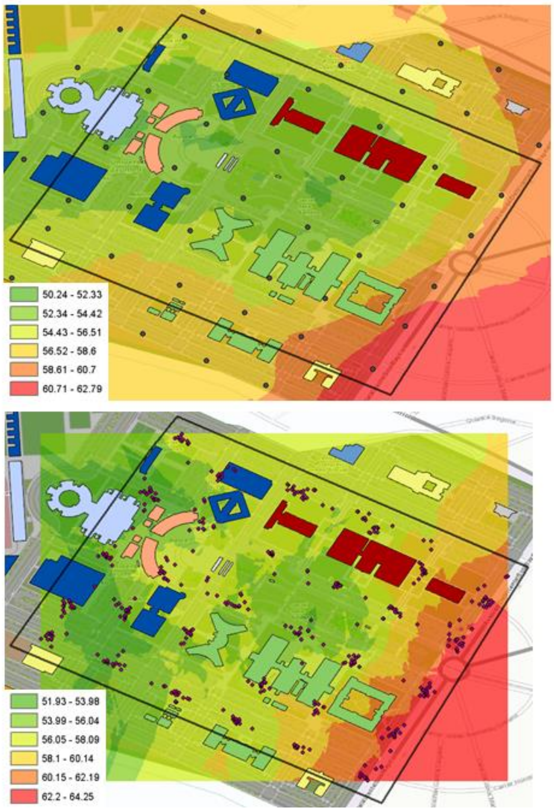
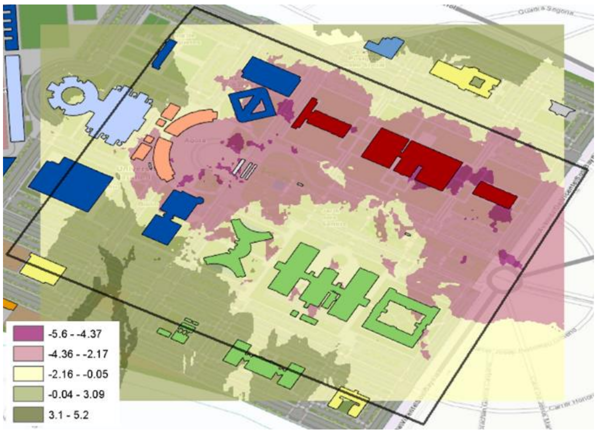
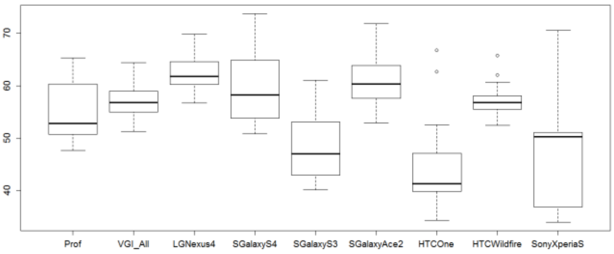


Figure 2: Difference in decibels between professional and raster layers



To conclude this section, a chart (Figure 3) summarizing all data collected in this experiment is presented. First column represents the range of professional noise measurements and the second one is a summary of the subsequent columns. Column "VGI_All" was created by obtaining the mean of the volunteer observations around each node of the grid. It is possible to see that each column in itself is not very similar to the "Prof" one. However, when all individual data are summarized using the mean of all observations per grid node, it seems that results are much more similar to the professional dataset.

Figure 3: Chart showing the summary of professional and volunteer observations collected.



Noise maps for particular mobile devices. In this section new noise maps are created for two particular models: LG Nexus 4 and Samsung Galaxy S4. We chose the first model because four of the devices participating in the experiment were made by this manufacturer and provided one third of the samples. Regarding the second model, we chose it due to its (at present) high-end hardware capabilities. To create these noise maps we carried out a similar process as described in the previous section.

Figure 4: Campus noise map and difference from professional data for LG Nexus 4

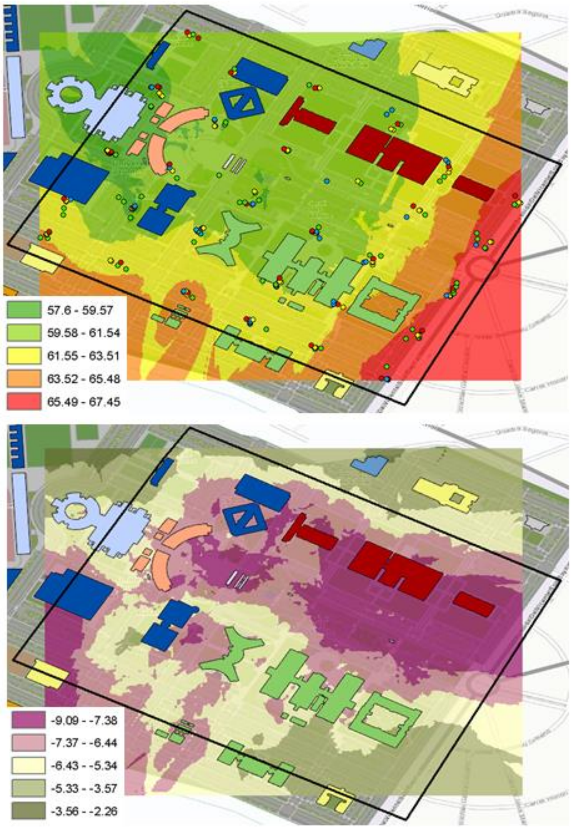
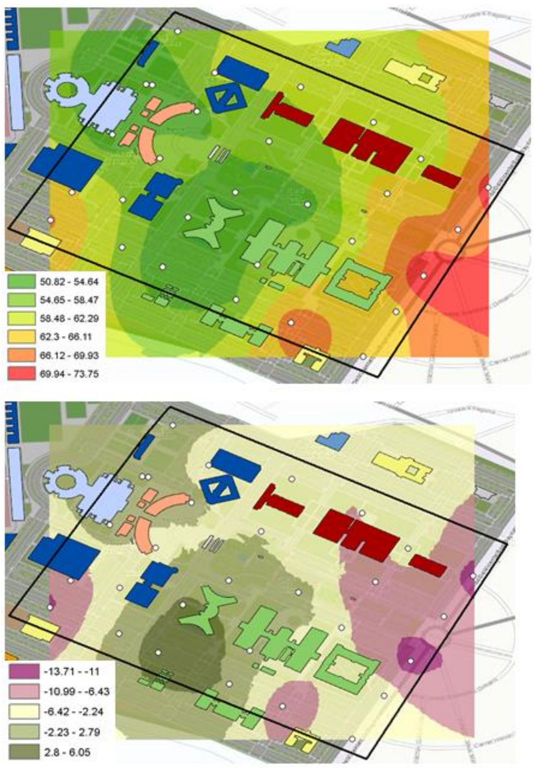


Figure 4(a) presents the general noise map for LG Nexus 4. There are four colored dots in the map showing where each of the four users took a measurement. In general, the map roughly presents an appearance similar to the one obtained with professional data and it is highlighting the same pattern: the campus is quiet in its central part and noise is increasing as long as we get closer to the main roads and accesses. However, when studying the legend, we can see that in this case, the minimum and maximum boundaries are shifted about 5dB higher than the professional samples. Figure 4(b) depicts the difference between both datasets. As seen, there is a large area in dark pink indicating that LG Nexus 4 mobile devices measured between ~7dB-9dB more than the professional dataset. Similarly, Figure 5(a) presents the general noise map for Samsung Galaxy S4. Resulting map is quite different to Figure 1(a) and the device is collecting a wide range of decibels. In this case, the difference layer depicted in Figure 5(b) shows this device is measuring higher mismatches nearby the main access road (from ~6dB to 14dB).

Figure 5: Campus noise map and difference from professional data for Samsung Galaxy 4



Summarizing, it seems that noise maps created for a particular mobile device do no present very accurate results when compared to the professional noise map with the current number of samples. However when all of them are combined into a single one, the output layer presents a reasonable similarity with the professional one.

4 Limitations

The experiment performed in this paper show comparing volunteer data taken with a single device to professional samples does not provide accurate results. However, acceptable noise maps are obtained with the combination of observations provided by a heterogeneous set of devices. Moreover the costs of the required platform (basically maintaining an Internet server) are low with respect to professional tests and the availability of mapping is total. With our proposed system, anyone can take a noise sample in anyplace without time restrictions.

Noise is highly volatile, so, in principle, each sample taken in a determined timestamp might be valid. Several authors [13, 3, 15] point out that it is recommended to take noise samples lasting several minutes to minimize the effect of sudden noises sources. In this experiment, the sampling time lasted several seconds and probably is not enough to provide highly accurate results. Similarly, no sources of attenuation were considered, such as, geometric spreading of noise, physical barriers and we did not use any noise propagation model.

5 Future work

This experiment was carried out using just Android devices in order to obtain a first assessment of noise capture with non-professional means. It would be interesting to repeat this experiment using other devices, such as the ones based on IOS and Windows Phone. Moreover, we also consider using open hardware platforms, such as Arduino or Raspberry Pi, with specific sound level sensors to build a low-cost noise monitoring station.

6 Conclusions

This paper describes a way of comparing volunteer and professional noise data. The professional data was provided by a private company, whereas we generated the volunteer data by means of Android-based devices. Using ArcGIS Spatial Analyst, we created two noise maps from the point features representing noise with a Kriging function. Our results show that individual measures do not seem very reliable, but acceptable results appear when we combine the maps obtained with the different devices used in the experiments.

In general, considering the noise ranges acquired with the professional sound level meter (50dB to 63dB) and the volunteer ones (52dB to 65dB), we consider that noise monitoring through mobile devices is showing very promising results.

We are conscious that this is a preliminary analysis to give a general overview of the potential of VGI data to measure noise pollution. We are not stating that official noise maps and acoustic studies are not needed anymore. However, VGI data might be sufficient for multiple daily situations, like measuring the noise levels on a leisure area (children playground, city center) or for early detection of city noise issues, such as heavy traffic on a residential street. Crowdsourcing noise pollution is a low cost approach that might be suitable for those communities with a lack of noise sensor networks.

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