Noise Battle: A Gamified application for Environmental Noise Monitoring in Urban Areas

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Abstract

Urban environments are places where changes occur at a quick pace. Collecting observations related to environmental factors, such as noise pollution, is crucial to monitor trends and changes in a city that can decrease citizens' welfare. However, monitoring noise in cities through classical approaches has a high cost for local and regional governments. In recent years, mass-market mobile devices such as smartphones have started to incorporate several sensors, enabling countless measuring capabilities and becoming low-cost portable measuring devices. In our case, we use the microphone to collect environmental noise measurements. In this paper we present a novel approach to collect environmental noise data by developing a crowdsourced gamified mobile application. Our purpose is to encourage users to collect noise measurements with their personal smartphones so that other stakeholders can use these measurements in their analysis and decision making processes. This research presents a prototype to monitor environmental noise based on gamification techniques and outlines some possible analysis to obtain noise maps in cities.

1 Introduction

According to the United Nations reports [1], in 2008 more than half of the world's population was living in cities and it is expected that this number will increase by 70% by 2050. This fact influences the growth of activities in industrial parks and urban areas that affect environmental conditions, increasing noise pollution. A sustained exposition to environmental noise can raise health problems as some authors [2, 3] point out. These potential issues can range from mild sleep disturbances to hear impairment or even mental instability. Daily city activity cannot stop, therefore, in this context, it seems important that cities have near-real time data available about noise pollution in order to prevent major public health issues.

Noise pollution is a phenomenon produced in the entire city area, all day long and with different intensities. Thus, in order to accurately measure the noise occurring, as many samples as possible should be collected. Classical approaches to acquire noise samples have some drawbacks: they have a very high cost for municipalities and the spatial and temporal resolution might be very low, ignoring most parts of the city.

Our research considers a cheap and different way of data collection, based on volunteer citizenship participation, also known as crowdsourcing. When using crowdsourcing, the massive and sustained participation of the general public over time is crucial, in order to obtain a large noise data repository for a city and to do further research and analysis. However, noise data collection is not a motivating task at first sight, so users might need additional motivation to do so.

In this paper we are presenting an application, currently being developed, by applying new concepts for environmental noise monitoring through Gamification techniques. The idea is to encourage citizens to collect noise samples through their smartphone's microphone while they play a game. This novel approach of collecting noise data provides a mechanism to motivate users to get samples by converting a tiring and repetitive task into an engaging and fun one. From the users' point of view, they will be playing a game while contributing transparently with a noise repository whose data can be later used for scientific purposes.

The rest of the article is structured as follows: In Section 2 we discuss the background of this work. Section 3 describes how we applied gamification concepts to this project In Section 4 we briefly describe the general architecture of this project and describe the application prototype, and finally, in Section 5 we present the conclusions and future work ideas.

2 Background & Related Work

Monitoring our environment is an important task to control our planet's status and how human activities affect it. For our research we want to monitor noise levels in urban environments using volunteer information provided by citizens. This approach, involving citizens' participation is also known as crowdsourcing.

Related to this concept of extracting information from the crowd, we can find in [4] a good description of the "human-as-sensors" concept. The author states that humanity as a collective has a huge amount of information and, if we provide the crowd with digital devices, we can obtain a massive data collection of every measurable parameter. These data repositories could then be used in different analysis and services. In [5], a Participatory Public GIS (PPGIS) is described as the resulting system of providing GIS capabilities and tools to the general public. There are many examples of crowd-sourced PPGIS: In [6] a system where Canela (Brazil) citizens can upload comments about health, education or cultural heritage city issues is described. The work presented in [7] describes how to use the power of the crowd to identify potential problems in Africa through Ushahidi collaborative tools. Meteoclimatic[1] is a volunteer weather station network that provides free meteorological information in Spain. Finally, in the field of crowdsourced games, we can find Kort[2], a gamified mobile application used to correct and improve Open Street Map data.

According to the classification found in [8], in the field of environmental noise monitoring, there are three different approaches to control noise levels in cities: *simulation maps* and data collection through *sensor networks*. The first method consist of applying physical noise propagation laws by considering well-known noise sources to get noise affection maps, while the second method is based on acquiring data using a distributed network of sensor devices. Finally, there is another method they outline, based on the direct participation of citizens by providing VGI, known as a *grassroots campaign*.

This volunteer information has gained a lot of attention in research in the last few years; with the appropriate treatment crowdsourced information can complement official data source channels [9] and therefore, assist in environmental monitoring and help detect events in near-real time.

3 Gamification Concepts

Gamification has been successfully applied to many domains, such as education or personal training [10], but in environmental modeling it is something still not very exploited. Therefore, our contribution can be considered a novel approach to environmental noise monitoring based on *grassroots campaigns*.

One of the main issues we deal with is how to motivate citizens to provide and share information. According to [11] users are willing to provide information voluntarily, but due to the repetitive nature of noise monitoring, we may face problems in the data supply considering that, by default, people do not feel motivated to take noise measurements.

Users need incentives to do repetitive tasks sustained over time. We thought that designing a gamified application to measure environmental noise could help to bring a scientific problem closer to non-specialists users

In [12] the author discusses how we can motivate the general public to participate highlighting how important it is to attract and encourage standard users to contribute by obtaining a decent data collection.

According to [13], to perform a good gamification process we have to motivate and engage the user with a gamified application. For this purpose, we have to consider 4 key concepts: status, access, power and stuff. *Status* recommends splitting the game progress in stages or levels so users can compare their achievements with other users. *Access* allows users to unlock new features depending on their contribution to the game Transferring *power* to some users by letting them do actions that are not allowed to be done by all users is important to foster competition. Finally, *stuff* recommends providing a set of rewards or gifts as an incentive to keep playing.

Regarding the target user analysis, we used the classification found in [14], where the author divides users in four different types, namely: *killers*, *achievers*, *socializers* & *explorers*.

4 Noise Battle game

This section describes in detail how we developed Noise Battle prototype, considering first the application of gamification concepts and then the logical components. Finally, after collecting a small set of noise samples with the application, we present some preliminary results that outline what type of analysis can be done with crowdsourced noise data.

4.1 Prototype

Noise Battle is a gamified application developed for the Android platform. The final goal of this game is conquering the city by taking noise measurements at certain locations on a regular basis. The city map where the game takes place is split into cells of a grid, so the user can conquer the cells by taking more and better measurements (i.e. higher quality, more recent, or at a remarkable time of the day, etc.) than other users in the area.

In Section 3 we mentioned that we had to focus mainly on two things to perform a good gamification process: the type of players and four key concepts. In our application we have identified that the main user role is an *achiever*, someone that enjoys playing and keeps advancing in the game. So based on these decisions we have designed our game, disseminating rewards and highlighting that it is a competition that simulates a virtual war.

Then we grounded the four key concepts as follows: In the case of *status*, the gamified application shows user progress based on the number of noise observations: as users collect information, they get more points that will increase their score and level. The *Access* concept is grounded by owning more city areas, as collecting noise observations is the key to progress and to access different rewards. *Power* is given to users by providing them with the capability of sending noises (or sounds) to the enemies in the battle. This kind of actions foster competition among users, so they feel more motivated to keep progressing in the game and gain power over other users. Finally, the *stuff* concept has been represented by creating a set of rewards and allowing the possibility of customizing the avatar.

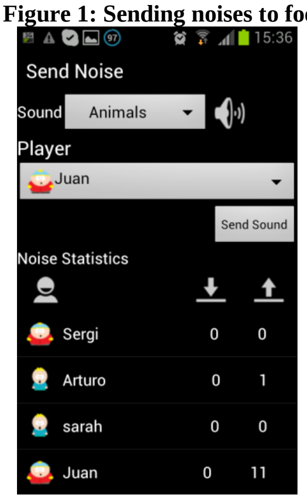
During the game, users are rewarded by measuring the proximity of one of the rewards placed in the area or by conquering the cells. The rewards can be taken only if the user has previously conquered the cell, and therefore there is restricted access to them. The parameters measured are later evaluated by the game server, which applies different criteria for determining if the cell has been conquered. The criteria include different aspects: the quality of the measurement, how

[1] http://www.meteoclimatic.com/

[2] http://wiki.openstreetmap.org/wiki/KortGame

recent the previous measurement on the cell is or if the cell was not previously conquered.

Figure 1: Sending noises to foes.



Rewards might include the possibility of sending noises or sounds to the foes (Figure 1). The sounds sent to the rivals are used to show the power obtained by its sender and thus to encourage the players to regain power by gathering new data. The rivals have the option of re-conquering previously conquered cells by performing better quality measurements (based on NoiseDroid[3] quality assessment) or more recent measurements. These mechanisms should encourage the players to provide better quality measurements or updated noise data, as we consider how old the measurement is, a quality feature. Regarding the rewards, we have considered awarding measurements dispersion and data quality in order to assure a regular number of observations taken in the entire city area. Moreover, we also took into account placing rewards (or having a higher density of them) in zones where there is more interest about noise pollution conditions. For example, it could be more important to have data from the city center than from somewhere in the surroundings.

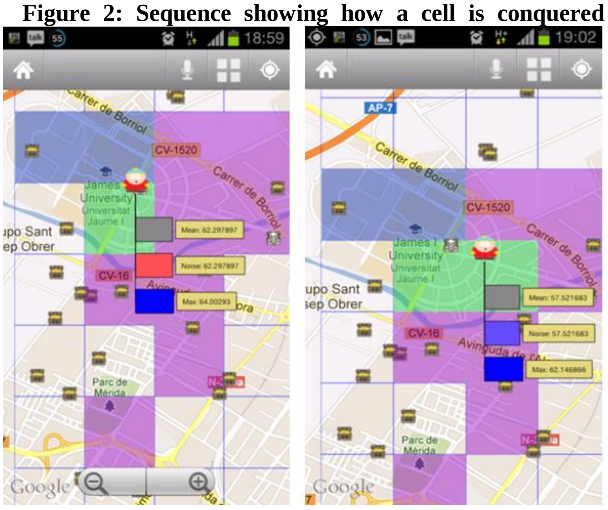
In Figure 2 we can see a sample of the battle field at an advanced stage of the game. In this scenario there are three players, each of them represented with a colour. The sequence (left, then right) shows how a cell changes from violet to green; meaning that the green player has now conquered and now owns the cell.

4.2 Architecture

For this project, we followed a multi-layer (Figure 3) architecture that could be implemented and extended by other applications with a similar purpose.

The *mobile application layer* represents the front-end the user interacts with to capture and submit noise measurements. It contains the user interface to take noise samples, encode and send them to the game server layer. When the server receives a new noise sample, the game status is recalculated and sent back to the mobile application. Then, in the mobile application, the new status is decoded and depicted through the use of different elements in the map.

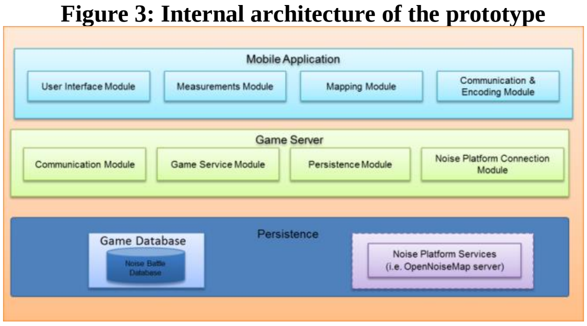
Figure 2: Sequence showing how a cell is conquered



The *game server layer* implements the logic of the game and makes the status of the game available to the client applications. This layer interacts with the game database to store the relevant information such as noise data collected by users, game status, actions performed by users during the game, rewards and data about the interaction between users.

This layer is in charge of contributing to the enlargement of external noise data platforms by submitting users' collected data to a noise data repository (i.e. Open Noise Map Platform[4]). Reusing an existing noise platform favours not only collaboration and data availability but also provides access to analysis tools built for such platforms.

Figure 3: Internal architecture of the prototype

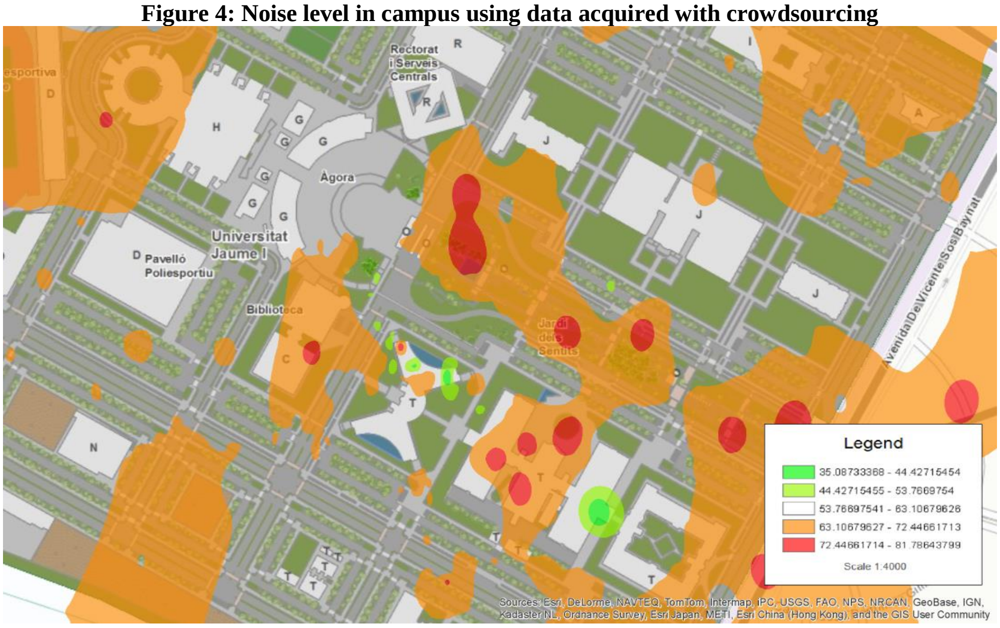


Finally, the *persistence layer* involves the necessary components to store the data related with the measurements taken by the users, the game definition (game's city location and grid) and its state (rewards, score, etc.).

3 Some of the components used in Noise Battle come from NoiseDroid open source application. Found in: https://play.google.com/store/apps/details?id=de.noisedroid

4 https://wiki.52north.org/bin/view/SensorWeb/OpenNoiseMap

Figure 4: Noise level in campus using data acquired with crowdsourcing



4.3 Preliminary results

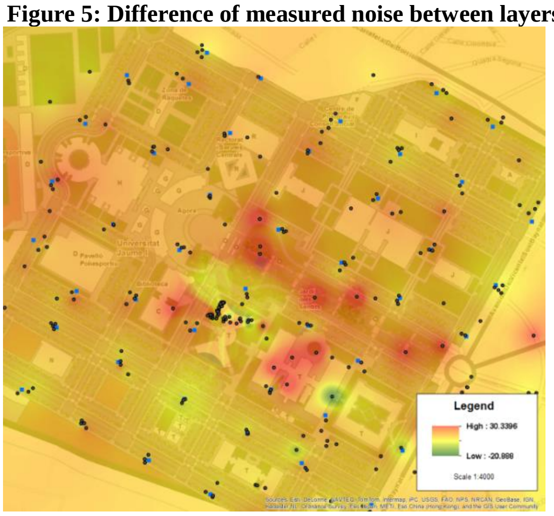
The ultimate goal of these types of *grassroots campaigns* is to have a good collection of data available to obtain noise maps in cities, help municipalities to identify potential issues.

We tested Noise Battle and obtained a small set of data we used to prepare preliminary noise maps. Figure 4 shows a University Jaume I noise map that was prepared using ESRI ArcGIS[5] software. To create this map we used an *Inverse Distance Weight* function to convert our point features, representing individual noise measurements in a continuous surface. To make easier understanding the map, we made transparent the generated surface for medium-range noise level (50dB to 60dB), so noisy areas are highlighted. Noise samples cover most of the campus area. With just a few engaged users, the spatial and temporal resolution is high enough to observe a certain pattern: although the general noise level is moderate (ranging from 35dB in light green areas until 80dB in red areas), it is higher in the surroundings of the IT & Engineering School, the central garden and university campus main gate.

It is important to note that these data have been acquired in different dates, so we are representing the total bulk of data, not the snapshot for a particular moment.

After this first analysis, we wanted to determine the accuracy goodness of our volunteer data. For that purpose, we compared our dataset with another one obtained by a private company through professional means. To do this, we converted their point dataset into a raster dataset and then, subtracted both raster layers using the *Raster Calculator*. Figure 5 represents the difference between the values of two layers: the yellow color indicates that there is little difference between both layers while red/green indicates where one layer presents a higher/lower value than the other. As seen, the predominating color is mainly yellow/light-orange, so we can conclude that the data we collected through crowdsourcing has a reasonable quality.

Figure 5: Difference of measured noise between layers



However, it is important to note that data coming from the private company form a grid, while data taken with Noise Battle do not follow any pattern. Therefore, in the places where there are a lot of differences and where a private company's measuring spot is not near, we cannot compare both layers, neither invalidating Noise Battle data.

Both maps illustrate the potential of crowdsourced environmental noise monitoring, and the data collected that other stakeholders or decision-makers might consider for their analysis. The deployment of the game in broader areas and a more sophisticated analysis (using noise propagation laws, considering barriers and obstacles), would enable detecting spatio-temporal noise patterns in this and other city environments.

[5] http://www.esri.com/software/arcgis

5 Conclusions

We presented an approach to gamify environmental noise monitoring in cities using crowdsourcing. This process intends to engage users to do a repetitive task through time, to help collect data at a low cost.
As seen, collected noise data can be used with a GIS application to create quick noise maps of the area of interest and to obtain promising and interesting results for crowdsourced noise monitoring. Also, this data might be included in more complex analysis and services.
In the future, we should improve some parts of the game in order to include more natural divisions than a grid and implement a noise measurement expiration policy, to encourage users to take up-to-date measurements. We should also consider the implementation of mechanisms for filtering and correcting volunteer data and increase the general quality of the data acquired.

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