

## USING SMARTPHONES AS PERSONAL MONITORING TOOLS FOR THE ACOUSTIC ENVIRONMENT

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### ABSTRACT

The proliferation and ubiquity of mobile devices in current era opens a window of opportunity to new ways of interaction between people and environment. In addition to its processing power, this generation of mobile devices is equipped with a set of sensors able to collect information regarding different layers of our activity and environment. Our research explores the opportunities offered by such devices to work as personal monitoring tools of the acoustic environment and applies the monitoring outcomes in the social networking domain, as a strategy to raise awareness for the sonic phenomenon among non-experts.

### RESUMO

A atual proliferação e ubiquidade dos dispositivos móveis abre uma janela de oportunidade para a exploração de novos modos de interação entre as pessoas e o meio ambiente. Paralelamente à elevada capacidade de processamento, as novas gerações de dispositivos móveis estão equipadas com um conjunto de sensores capazes de recolher informação sobre diferentes dimensões da atividade humana e contexto envolvente. Este artigo apresenta um sistema que utiliza este tipo de dispositivos como ferramenta de monitorização pessoal e contínua do ambiente acústico, aplicando os resultados da análise ao domínio das redes sociais em linha, como estratégia de sensibilização para o fenómeno sonoro.

### INTRODUCTION

Humans and most known species in the animal kingdom have some kind of sensors that allow them to acknowledge the surrounding world. The set of sensors present in each specie is called the sensory system, which acts as a multi-modal analysis system, providing complementary and redounding information to the brain. Sound is among the different physical phenomena that can be sensed by the human sensorial system, being one of the most crucial for its survival and socialization. It provides not only a vehicle for gaining awareness about the environment but also a powerful human-to-human communication channel and one of the most essential forms of artistic expression.

In this research project we have focused on the properties of environmental sound, more specifically under the umbrella of soundscapes. The soundscape concept was first coined by Murray Schafer to describe the sound of a particular location in a particular time, analogously to what happens in the visual realm with the term landscape [1].

Schafer was the main promoter of a new scientific subject called Acoustic Ecology, which debates the relation between sound and environment. Drawing from his background in music composition, Murray Schafer assumes the global soundscape as a musical piece, where all humans are regarded as musicians and potential composers. He aspires to a positive balance between human-produced soundscapes and the natural soundscapes of earth [1]. This balance is, by necessity, anthropocentric as it regards man as the disturbance and victim at the same time, and demands from individuals an increase on their level of awareness of the acoustic environment at any given time, that is to say, their sonological competence [2].

The actual soundscape of modern urban areas is most of the times exhibiting high density and great intensity, shrinking the acoustic horizon to few meters around each subject. That is to say, sounds no longer have the ability to be heard far away from its source, since the sonic background of the city masks and circumscribe them to their immediate surroundings. When that happens, sound loses its potential of traveling and carrying meaning across the community and people gradually lose the ability to listen. A paradigmatic fact is the increasingly habit of using headphones to listen to music or other type of audio content. Such practice confines the social experience of listening to an individualized experience. People no longer listen to their environment; they prefer a lonely sonic experience that, actually, creates an acoustic bubble, separating them from the sonic environment. One of the reasons people do that is because sounds of the city are no longer meaningful as they are harmful and unpleasant. The city traffic noise and the subway noise are just some of the examples of sounds that contribute to create an unpleasant soundscape in urban areas, which results in a conflict between the individuals and the acoustic environment.

The research presented here has the underlying goal of promoting sound awareness among people, to make the average people realize that sound is underrated in our actual society, due to the fact of the overload of the urban soundscape. By raising awareness and promoting sonological competence, people will also be more exigent regarding their sonic environment, compelling stakeholders to change their attitude towards the acoustic design of urban areas.

In order to reach that goal, we developed a system based on mobile computing, context sensing and social media, applying some of the properties of sound to the social media (SM) domain.

We chose SM as a way to demonstrate our goal for two main reasons: 1) SM it is nowadays widely used among people around the world and; 2) it is based on sharing users personal information, most of the times regarding their current context and activity (where they are, with whom they are, what they are doing, how they feel, etc.). As we mention before, sound is good providing information about places and activities, therefore we are able to use this information for enhancing the online social networking experience.

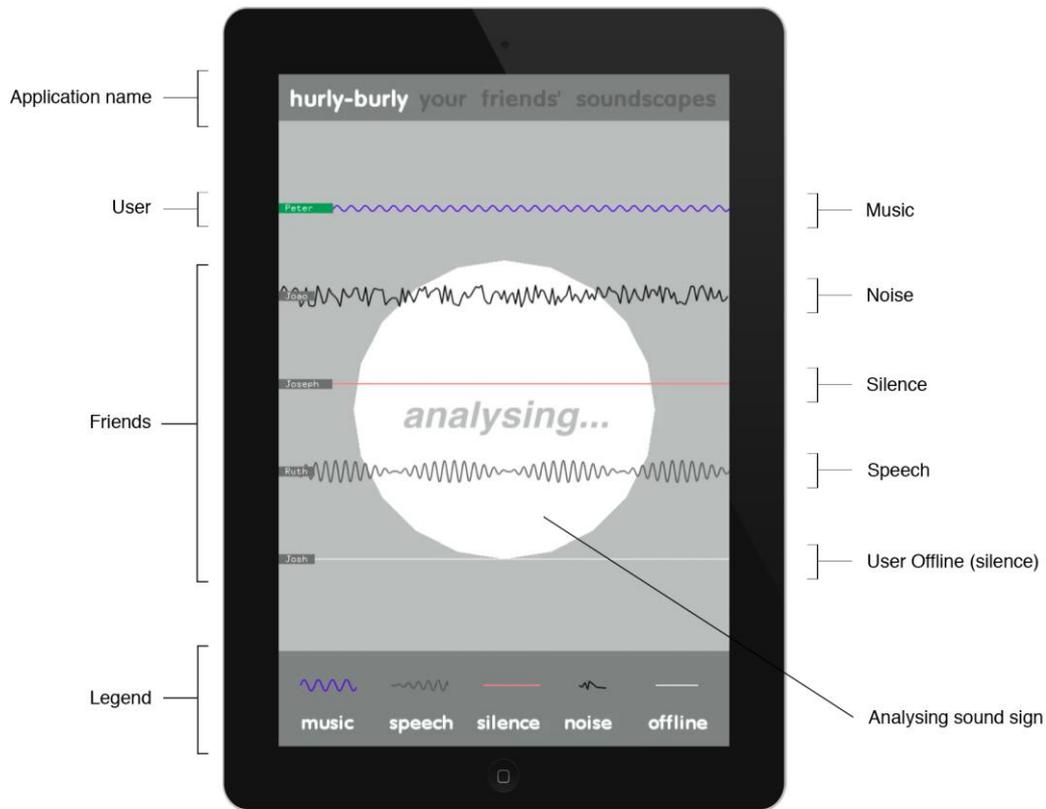


Figure 1 - Hurly-Burly GUI

## HURLY-BURLY SYSTEM

In this point we briefly describe the system functioning and implementation. A more detailed characterization can be found in [3] and [4].

The system is comprised of a mobile application running on iOS devices, a web application and a database running on a webserver. The mobile application is the main part of the system, since it is the most exposed to the user. It is based on the online social networking paradigm, where several users are linked and share several bits of data among them. The application has a module of soundscape sensing that continually analysis the stream of sound reaching the device's microphone (with intervals of 1 minute). The analysis produces a generic output based on the sound environment, classifying it in one of three categories, according to its source: speech, music and environmental sounds (when several indistinct/unconstraint sounds converge). Furthermore, the sound intensity is also analyzed, along with the devices movement, varying between "moving" and "still". The application sends this information (sound classification, sound intensity and movement) to the database, which, in turn, broadcast it to the "friends" network of the user. Each user is able to monitor in real-time his/her friends' soundscape description (not the sound), along with the movement (Figure 1).

At the same time, the user is keeping a record of his/her data that can be later accessed through the web application on a web browser. The application was written in C++, using OpenFrameworks for the main programming block and PureData for the sound classification algorithm (wrapped inside C++ using PdLib).

The web application presents an interactive graph where users can browse through their soundscape history; each sample is represented through a point that displays different colors according to the type of sound analyzed, and a vertical value depending on the sound intensity (Figure 2). The graph affords scrolling and zooming on the temporal axis (horizontal). The web application was programmed in HTML, PHP and a JavaScript library used for the graph plotting (Google Chart).

The database server is responsible for keeping a record of all the users, their connections (links) and all the collected data. It is a fundamental part of the system but invisible for the user. It is programmed using MySQL with a PHP web interface.

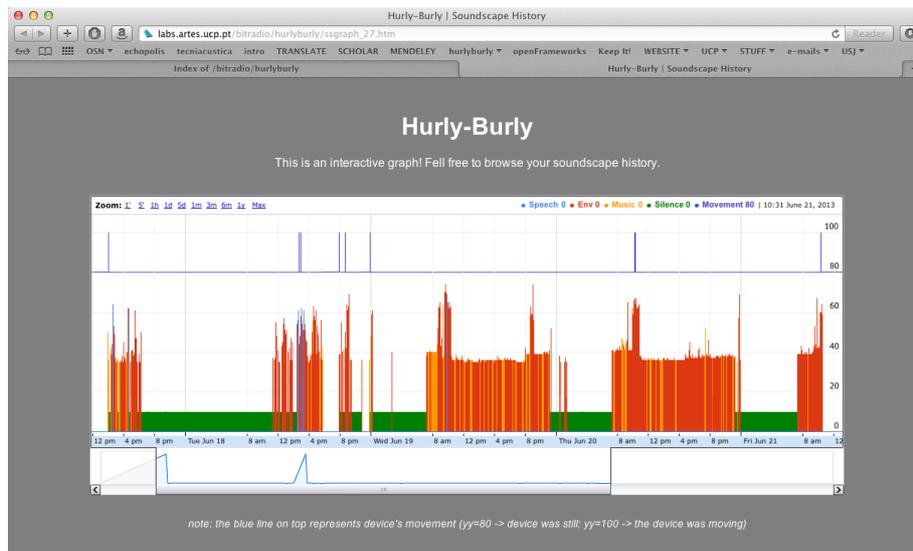


Figure 2 - Soundscape history graph

The overall performance of the system was good. Only the classification algorithm presented some faults, occasionally misclassifying steady environmental sounds (e.g. air conditioning systems) as music.

## RESEARCH METHODOLOGY

The choice of a research method always depends on the phenomenon being studied and the scientific field in which it is pursued. More traditional sciences – like physics or astronomy – have long established their methods, while younger and emergent sciences – like HCI or network science – are still consolidating their fundamental procedures. Our research project lies in a multidisciplinary field that aggregates different areas of knowledge such as – but not limited to – HCI, Acoustics, Sociology and Psychology. Therefore, the designated methodology should comply with the best practices observed in each of these sciences, merging and adapting to the project's demands.

Our methodological approach was based on the development of a mobile application, which users utilized in their daily activity. This application was our main research tool, providing us with quantitative data from user logs; and setting the context for surveying the users, after those having used the application (granting us with qualitative data). The methodology suffers a great conceptual influence from *cultural probes*<sup>1</sup> design methodology, developed by [5], which tackles

<sup>1</sup> Cultural Probe is the name given by the authors to a set of crafted materials (not typical research materials such as questionnaires, but postcards, maps, stickers, disposable photographic cameras and sketch books), which are distributed among groups of participants in the experiment, in order to document

the problems from an “artist-designer” tradition rather than purely “engineering-based” approaches. As in Cultural Probes methodology, we are also not searching for a solution to a precise problem, but instead giving people the opportunity to experience their environment and technology in novel ways and assess their feedback, in the hope of getting valuable inputs for future models and theories, that may then be materialized into everyday objects or practices. Furthermore, we highlight and relate to the importance given to the “*tone and aesthetics of the probe materials*” (which in our case is the mobile application, project’s website and questionnaires) in order to reduce the distance between general public and the vernacular scientific world.

## EXPERIMENTAL PROCEDURE

The first step was the selection of a sample of subjects to participate in the experiment. In order to ensure external validity, i.e. the ability to reach generalizable results, the sample had to be statistically representative of the population to whom the study concerns. The requisites for people to be selected as subjects of the sample were:

- Familiar with mobile online social network (MOSNs)
- Owner of an iOS device, supporting iOS <4.3
- Belonging to a highly clustered group
- Voluntary participants
- Willing to share private data with friends
- Willing to test unknown and experimental software on their devices

Taking into account these constraints, three tests groups were formed, counting a total of 23 subjects, which ran the application and filled in the survey. These groups were defined according their offline proximity, usually rooted in a common occupation (school class, work, common project). Some users were present in more than one group. We, as research coordinators, were part of all networks but did not fill in a questionnaire.

Generally speaking, subjects can be described as *young adults, both male and female, engaged in social networking, belonging to the middle class and having some relation to the media world*. One third of the subjects live in Asia and the rest in Europe; one subject was living in Canada during the experiment. The groups are not representative of the whole worldwide population but they significantly represent the user profile mention above.

Group 1 – Communication and Media Students / USJ - This was the first group to test the application. The group was formed by 9 students from Communication and Media Licentiate in University of Saint Joseph, Macau. They are aged between 19 and 23, 3 male and 6 female subjects, all students and most working part-time.

Group 2 – Staff from Sound and Image dep. / UCP - Teachers and researchers on the Sound and Image Department and CITAR – Research Center for Science and Technology of the Arts, in the Portuguese Catholic University, in Porto, formed this group with 10 members. It is aged between 27 and 42, and has a gender distribution of 6 males and 4 females subjects.

Group 3 – Hurly-Burly Team - This group was composed of people that worked on the conceptualization and graphic interface of the application. It is a group specialized in interaction design, therefore expert in the field of HCI but not necessarily in the sound domain. This was the smallest group of the whole experience, with four members only, aged from 24 to 32, one male and 3 female. They were all regular users of online social networks.

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and register their ideas about a place or a phenomenon. The probes are later returned to the researchers to be analysed.

The tests occurred separately in each group and followed the order mentioned above. The time frame for running the test in each group was approximately three days. During this period, users were asked to run the application as long as possible, including during the night. An indicative period of 24 hours of use was set as suitable.

After running the test, a questionnaire was delivered to the subjects, in order to assess their experience using the application and collect information about the users and their relation with the topic of mobile sound, online social networking, self-disclosure and privacy. The questionnaire was produced in the digital format, created and distributed by e-mail using Google Drive (Form document).

Accompanying the survey was a link for a webpage containing the interactive graph, displaying the history plot of users' sonic and movement activity. The link was only sent to the users showing a significant amount of data and was necessary for answering one question of the survey.

## RESULT ANALYSIS

The sample is comprised of 48% male respondents against 52% female. While there is a balance in the overall sample, the group comparison shows that USJ and HB groups have a higher rate of female participants than UCP.

Regarding the age of the participants, the groups are also distinct, in particular USJ and UCP. The former is comprised of undergraduate students with an average age of 20 years old. The latter is comprised of teachers and researchers, showing an average age of 34. There is a gap of fourteen years between these two groups. HB group is situated approximately in this gap, presenting an average age of 27 years old.

The nationality of the subjects is very diverse due to the fact that the experience took place in two different continents. Moreover, universities tend to be a place of international confluence. Also in this variable the groups differ: HB and UCP tend to be mainly constituted by Portuguese people, while the USJ group is mainly comprised of Asian nationalities.

Regarding Social Media use, Facebook was, by far, the most popular SM service among participants of every group, with 70% of the share. When enquired about the regularity in which they use SM, users demonstrate a high commitment with this kind of services, regardless of the test group they belong to, with 78% saying that they use this service everyday. The reasons why people use SM tend naturally to the "social" dimension of these services, based on the exchange of text messages, audio, *likes*, voice chats, etc. However, this focus is not completely homogeneous through all test groups. For example, the younger group of USJ clearly prioritizes *leisure* as the second reason for using SM, while the older groups are more focused on the selective information they can collect via this service.

Focusing on the social dimension of SM, we asked participants what they were looking for: meeting new people or mirroring their offline social network. In general, the answers were unanimous: participants use OSNs mainly as an extension in the virtual domain of their offline social network (85%). When asked about the content they like to share and receive on SM, answers tend to be homogeneous among the groups, electing *photos* as the most popular media (24%), followed by text (20%) and *likes* (19%).

Regarding the devices used to access SM, users do prefer laptop computers to mobile devices (48%). However, if considering tablets as mobile devices, the statistics tend to even.

The iPhone was the main device used among participants, 65% against 17% for the iPad and 18% for the iPod. During the experiment, 48% of the users carried the devices always with them.

and 52% did it most of the time. Regarding the connection of the device to the Internet, 78% of the users had the device always or almost always connected, while 18% were connected half the day and 4% only occasionally connected to the Internet.

From a scale of 1 to 4, where 1 is “understood completely” and 4 is “I did not understand at all”, 52% of the enquiries evaluated their general understanding of the application goals (question 4.1). as “1” (excellent) and 39% as “2”. Only 9% replied “3” and no one reported total ignorance about the application goals. Regarding the easiness of working with the application, in a scale of 1 to 4, the results were also positive, with 61% of users evaluating as “1”, 17% as “2” and 22% as “3”.

Concerning the application performance, the majority of the users evaluated it as “working well” (48%) or “working with minor problems” (34%), while 9% reported “major problems” and 9% did not produce any evaluation. However, separating the evaluation results by the users of different devices, the results show that iPhones users reported significantly more problems than other users. When questioned about the first reason that would take them to quit the application, 72% of the users replied “low battery” issues, 21% evoked “privacy issues” and 7% mention “all the reasons” as valid to quit the application (this question was posed only to the group UCP and HB). When enquired about the GUI, in particular the representation of the sound, 69% of the users replied that they like the representation and understand the match, 15% understood but did not like, 8% did not understand and 8% was not sure (this question was posed only to the group UCP and HB). Participants were inquired about their knowledge about the soundscape concept, 70% said they knew the concept, 26% *more or less* and only 4% ignored the concept. The second question related to the topic of soundscapes addressed directly the potential of soundscapes as an enhancer of social interrelations (question 4.5). From all the respondents, 4% denied this possibility and 26% were very skeptical about it, however 26% recognize some potential and 44% are sure about it.

Regarding the issue of privacy in the context of SM, we asked participants to imagine a new version of Hurly-Burly application where the actual soundscape (the sound recording) is shared within the network. The results show that 17% of the users would never use an application like that and 39% would use it in very controlled situations only. 31% said that they would use it with caution and merely 13% evaluated this feature as very appropriate and useful.

When correlating these results with those obtained in the previous question, one observes a direct relation between the willingness to share sound and the acknowledgment of HB as an ONS enhancer (correlation = 0,6; Figure 3).

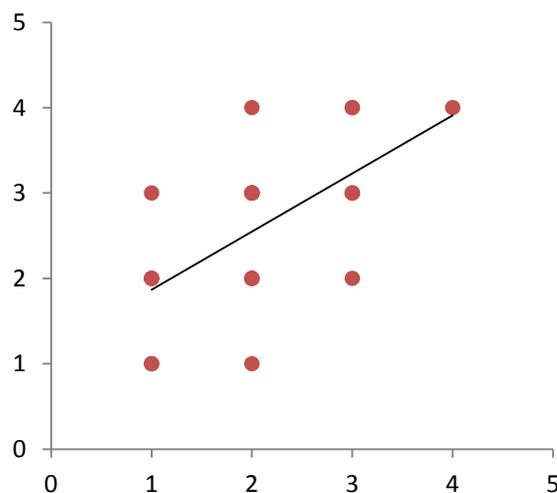


Figure 3 - Correlation between sharing sound and HB

One of the questions addressed the use of HB-like applications as tools for active participation of citizens in noise control activities, namely by monitoring noise pollution levels. In this matter, 61% of users agree that such applications are useful for this end, 30% believe in that possibility but are not sure and only 9% are skeptical but do not deny it.

Also in this topic, when we characterize the respondents according to their knowledge about the term soundscape, becomes obvious that those who know the meaning of the word are more inclined to accept HB-like applications as monitoring tools at the service of noise mitigation actions.

Finally, we enquired participants about the plotting of their soundscape history, which they accessed through the web application. The results show that 46% of the users recognized the match between the plot and their activity during the test, although some periods did not match. 46% affirmed that they were able to recognize some parts but not in general and 8% did not find any match (only HB and UCP groups answered this question).

## DISCUSSION

In our sample, younger groups of students tend to use social media applications as a way of entertainment more than the adult users, which are more inclined towards a utilitarian usage. The groups from UCP and HB elected information as the second use for SM, after socialization, while USJ group (the younger group) chose entertainment. These results show that our sample is, partially, in tandem with the findings of (Dunne, Lawlor, & Rowley, 2010) and (Cheung et al., 2011); however, extensive studies are lacking in academia regarding the age distribution of users intentionality in SM and OSN. In any case, one may say that the technology behind both uses – entertainment and information - is very similar and is based on powerful syndicalization algorithms, which perform a gate keeping task, tailored to the users' interaction and identification profiles.

When users are asked about the things they most like to share/receive in SM, contextual cues are among the least considered. Our study shows that only 8% of the sharing options contemplate information about the context of the user. The two options are people accompanying the user (4%) and geo-localization (4%). One may argue that text messages and photos - two highly regarded options – are mostly about context, but not necessarily. This fact raises the discussion about the relevance of soundscape analysis in SM, since not many users are prone to share contextual cues. Nonetheless, one of the reasons that refrain people of sharing more contextual cues is privacy. A system based on soundscape analysis may overcome these constraints by providing contextual cues without sharing sensitive information. The answers to the questionnaire also demonstrated that our sample accompanies the overall tendency observed in SM, of moving into the mobile world (State of the Media: The Social Media Report, 2012). The dominant device for accessing content in SM is still the laptop (48%), but mobile devices are becoming more prominent. When combining desktop and laptops computers in one category the score reaches 52%, against 48% of both mobile and tablet devices combined. This fact opens wider perspectives for integrating ubiquitous computing features in SM, which is also supported by the increase of computing power in every new generation of mobile devices.

From the direct analysis of the results, we noticed that people have the habit of carrying their mobile devices on a daily basis. Comparing the overall values against the type of device, we found that iPhone users are more likely to bring their devices always with them (67%), while the majority of iPad and iPod use them most of the time but not always (88%). Although this is not a novelty per se, it shows that mobile devices are suitable for real-time and long-term monitoring, at least from the perspective of proximity and intimacy with the user. Moreover, 78% of the participants said they had access to an Internet connection during most of the experience

period, which highlights the “always connected” status of contemporary users. This phenomenon was cross-cultural and cross-ages.

Regarding the reasons that would take people to shut down the application, battery issues is the first with 72 %. In fact, all users of smartphones and other mobile computing devices struggle against battery consumption. This is a major impediment for long-term background running applications, being one of the reasons why manufactures like Apple present high restrictions to this kind of applications. The second reason elected by users concerns “privacy issues” (21%), showing that privacy is also an important element to have in mind when designing monitoring applications, however, we are leaded to conclude that the result is not extreme since no audio is shared. This conclusion is supported with answers to question.

Regarding the relevance of soundscapes for OSN, although 70% of the participants provided a positive vote, we found that the results were highly dependent on the application’s performance and user’s knowledge about the concept of soundscape. Participants who evaluated negatively the application performance (“the application worked with major problems”) also evaluated negatively the potential of soundscapes as social networking enhancer. In the other hand, participants who evaluated the application positively also have evaluated positively the potential of using soundscapes in the OSN domain (above 70%). This fact ratifies our methodology: providing a working prototype of a sound-based social network is a convenient way for people to understand the potential of soundscapes in the social domain.

Moreover, when comparing the evaluation of soundscapes as social enhancers with the users knowledge of the term soundscape, results confirm that those who have a prior knowledge of the term show a higher tendency to recognize the potential of soundscapes as a social network enhancer. When people are more conscious about the sound phenomenon (soundscapes in particular) they acknowledge more effectively its underlying potential. This conclusion is the driving force of this research: creating awareness for the soundscape phenomenon in order to unveil its full potential and attain a balanced soundscape in contemporary world.

Regarding the hot topic of privacy, the results gathered by the questionnaire tend to be conservative. When enquired about a version of the application where the audio is shared, 56% say that they would never use it or would do it only in very controlled situations. Only 13% of the participants show no objections to sharing audio in SM. Comparing these results against those, where only 21% of the participants would shutdown the application for privacy issues, we conclude that sharing audio is a big step towards privacy disruption. There is a kind of “uncanny valley” where too real representation may refrain people to interact with technology.

From all the participants, those more willing to share sound are, in general, the ones who tend to acknowledge the potential of HB in OSN. This suggests that people showing a propensity for this type of applications are more open to share the actual soundscapes, revealing fewer privacy concerns.

## CONCLUSIONS

This paper describes a mobile computing system based on the use of soundscapes as a social network enhancer. From the results, we conclude that sound can play an important role in new SM media applications if used with caution. To much self-discloser will refrain people of using this application and so we conclude that our design approach (of not sharing audio) is pertinent. Actual mobile devices are able to accomplish monitoring tasks but battery is not optimized for such intense use. In addition, mobile phones show worst performance than music players and tables. In order to run conveniently this kind of application, fabricants should take this in consideration and improve audio multitasking in mobile phones. Both faults lead people to quit the application, compromising its goal. The soundscape plot (when holding significant amount of data) provides a very interesting sonic profile, which matches the users activity and allows comparison of the overall intensity people are exposed on a daily basis. Finally, it is interesting

to recognize that people more conscious about the soundscape theories are also who acknowledge its higher potential, suggesting that a pedagogical approach will contribute to have more exigent citizens regarding their sonic environment.

#### ACKNOWLEDGEMENTS

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