Unfolding the Soundmaps. Suggestions for Representing and Sharing The Sensory Form of Urban Spaces Through Virtual Environments and Web-Mapping Technologies

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Abstract

The European Noise Directive introduced the necessity to identify, protect and enrich places characterized by a substantial sound quality with the aim to reduce the harmful effects of noise pollution by providing quiet areas for the wellbeing of the city dwellers. However the condition of quietness requested cannot be addressed by applying just a noise control strategy as well as it is not only focused on the sound quality of the urban environment, but a multi-sensory approach for their design is needed. Moreover the representation tools commonly used in the urban design practices seem to be inadequate for dealing with this topic. The ongoing research aims to propose new instruments, based on the usage of interactive virtual environments, for the description and analysis of these complex environments in order to overcome the quantitative approaches currently used, as well as prevent a mono-sensory description of these sensitive places.

Keywords: soundmaps; web-mapping; game engine; virtual environments; quiet areas; urban design

1. Quiet areas as an opportunity for applying a multisensory approach

It is a decade since the European Noise Directive 2002/49/EC (END 2002) was issued and, albeit with significant delays, which still persist (COM 321, 2011), the member States have adopted the recommendations contained in the European text in their legislative frameworks. The aim of the directive is:

> [...] to define a common approach intended to avoid, prevent or reduce on a prioritized basis the harmful effects, including annoyance, due to exposure to environmental noise [...] emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery. (END 2002)

Moreover an important aspect underlined by the END is the necessity to identify, protect and enrich quiet areas characterized by a substantial sound quality in order to provide places useful to deals with the growing problem of environmental noise that, together with air pollution, constitutes one of the major threat to physical and psychological health of the city users (WHO 2011; EEA 2010; Kihlman et al. 2001; Berglund and Lindvall 1995).

The quiet areas need to be conceived as places in which the sound quality deserve to be carefully treated for the wellbeing of their users and not only as collectors of noise sources that have effect on the surrounding's indoor environments. Furthermore the definition of quiet areas located in an agglomeration needs to comprise, besides the urban parks or the areas close to sensitive receptors (such as schools and hospitals), the small and medium sized open spaces spread in the urban fabric (square, garden, pocket-park etc.) that can form an effective and easily accessible restorative network (Figure 1).

Figure 1. Which characteristics and requirements should have the quite areas? Small and medium sized urban open spaces, adequately designed, can form an easily accessible restorative network.

2. The limits of the noise control strategies

The European directive did not provide guidelines or methods to identify or protect these places but, by proposing two quantitative and average indicators, it suggests a reductive noise control approach (END 2002: art. 2). European projects (Quadmap[1], Qside[2], Hush[3], Harmonica[4], Silence[5], CityHush[6], Hosanna[7]) and national researches (Grimwood 2011; Licitra et al., 2011; Payne, Davies and Adams, 2009; Faburel and Gourlot 2008; Symonds, 2003), were

1. http://www.quadmap.eu
2. http://www.qside.eu
3. http://www.hush-project.eu
4. http://www.harmonica-project.eu
5. http://www.cityhush.eu
6. http://www.cityhush.eu
7. http://www.greener-cities.eu

conducted in the years after the issue of the END with the aim to propose new indicators and methodology for dealing with this lack. They pointing out that, although necessary, an approach based exclusively on noise control is insufficient to identify the quiet areas in the urban fabric since the harmful effects of noise pollution are not related exclusively to the overcoming of specific sound level threshold (Lercher, Schulte-Fortkamp 2003): the frequency range covered by the sound sources, as well as their temporality, in terms of duration and repetition, are attributes equally important to consider. Moreover the proposed indicators describe a average sound pressure level over a long period of time, and for this reason they do not allow us to distinguish the presence of impulsive sounds, that are characterized by high sound pressure levels and short duration, as well as they do not allow us to identify intermittent or periodic sounds. Through these indicators it is not possible to identify specific tonal components, in which prevails a certain range of frequencies, and in particular are not adequate to estimate the annoyance provided by the sound sources that cover the low frequencies of the audible spectrum (EEA 2014; Berglund, Lindvall 1995). However even considering the physical attributes of the sound, we would provide just a partial description of the acoustic environment. In fact the sound components are tightly linked with time, daily and seasonal changes, and characterized by the space in which they are emitted: the morphology of the urban fabric; the materials and finishes of buildings and public spaces; the urban furniture and vegetation; the components of the local climate; as well as the various human activities, contribute to form unique soundscapes in the city (Venot and Sémidor 2006; Jeon, Jang and Kim 2013). In addition to these elements, the perception of the users is another important parameter to consider and evaluate, since any sound event can be identified as pleasant or annoying regardless its physical characteristics but considering the value that the listener assigns to it. For these reason the influences of the others sensory cues need to be carefully taken into account (Booi and Van den Berg 2012; Axelsson 2011; Kang 2007; Amphoux 2003; Augoyard and Torgue 1995). It is clear at this point that the identification and design of these sensitive environments should abstain from an approach limited solely to a noise control strategy or focused on the physical aspects of the sound, and at the same time it should avoid an exclusive attention on the auditory sphere (EEA 2014; Gehl and Svarre 2013; Pheasant et al. 2010; Gidlof-Gunnarsson and Ohrstrom 2007; Kang 2007; Zardini 2005; Martellotti 2004; Southworth 1969). A broader sensory approach is needed for the identification and design of these places, both in quantitative and qualitative terms. In order to achieve this goal tools and methodology able to support the urban design process for the representation of the sensitive places have to be developed.

3. Representing the sensory form of the city beyond the cartographic media

Nowadays the cartographic media are widely used both for the qualitative and quantitative representation of the sound environment. They permit to link the acoustic components with the space in which they are emitted. While the Noisemaps[8] (Figure 2), used for "presenting geographical distribution of noise exposure, either in terms of measured or calculated levels" (Kang 2007) in a specific period of time and using defined indicators, are developed and employed for urban planning purposes, the qualitative representation of the sound environment obtained using the Soundmap (Figure 3), is rarely used in the urban studies.

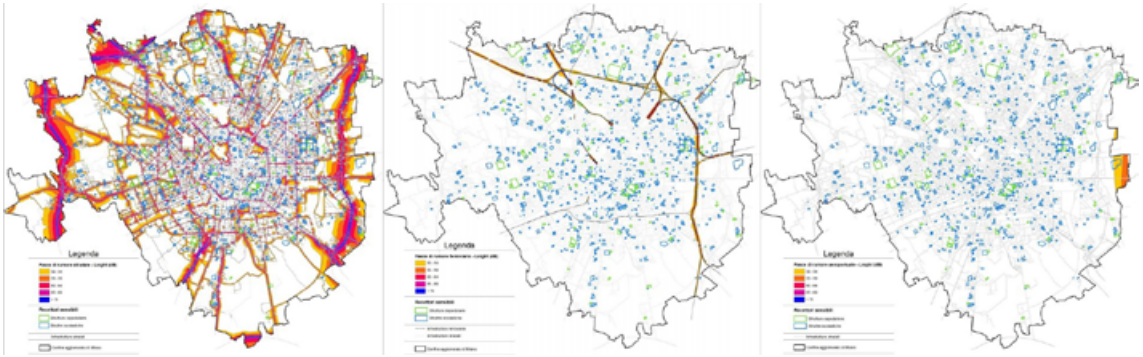

Figure 2. Strategic Noise Map of Milan. Representation of the LN data for the major roads, railways and airports. The sensitive receptors (mainly schools and hospitals) as represented as well (AMAT 2013).

The soundmap is a form of locative media that links a place with its sonic representation. These products were mainly developed during the '60, (Radicchi 2012). The World Soundscape Project, a research group established at the Simon Fraser University of Vancouver, developed a series of these soundmaps using various graphical techniques for representing visually the qualitative aspects of the sound (Schafer 1977b). However as Schafer claimed in his research work:

8. The noise data are represented through various graphical techniques such as points, contour lines and areas, and using a color scale. The European directive has required to use two annual average indicators for the noisemaps: a noise indicator for annoyance during the day period (Lden) and a noise indicator for sleep disturbance (Ln) focusing in particular on the noise emitted by the major transport infrastructures (END 2002). The noise data can be determined either by computation or by measurement. In the first case the reliability of the computation depends by the algorithm used, the accuracy of the urban model employed and the sound sources data (i.e. number of vehicles passing on a specific road).

> Such diagrams are hints only, but perhaps this is all one should expect of sound visualization – a few hints which the ear can then follow up in its own way. [...] The temptation of bad habits is no doubt still implicit in them, and it is for this reason that I conclude this chapter with a warning that no silent projection of a soundscape can ever be adequate. The first rule must always be: if you can't hear it, be suspicious. (Schafer 1977: 132)

Thanks to the improvement of informatics and the growing of web services, in the first half of the 2000s these maps were enriched with the possibility to insert, on digital map support, various multimedia objects such as images, videos and of course sounds, correctly geo-localized. These products allow us to directly hear a sound fragment, rather than being interpreted by a visual translation. In the last decade a multitude of soundmaps have been developed.

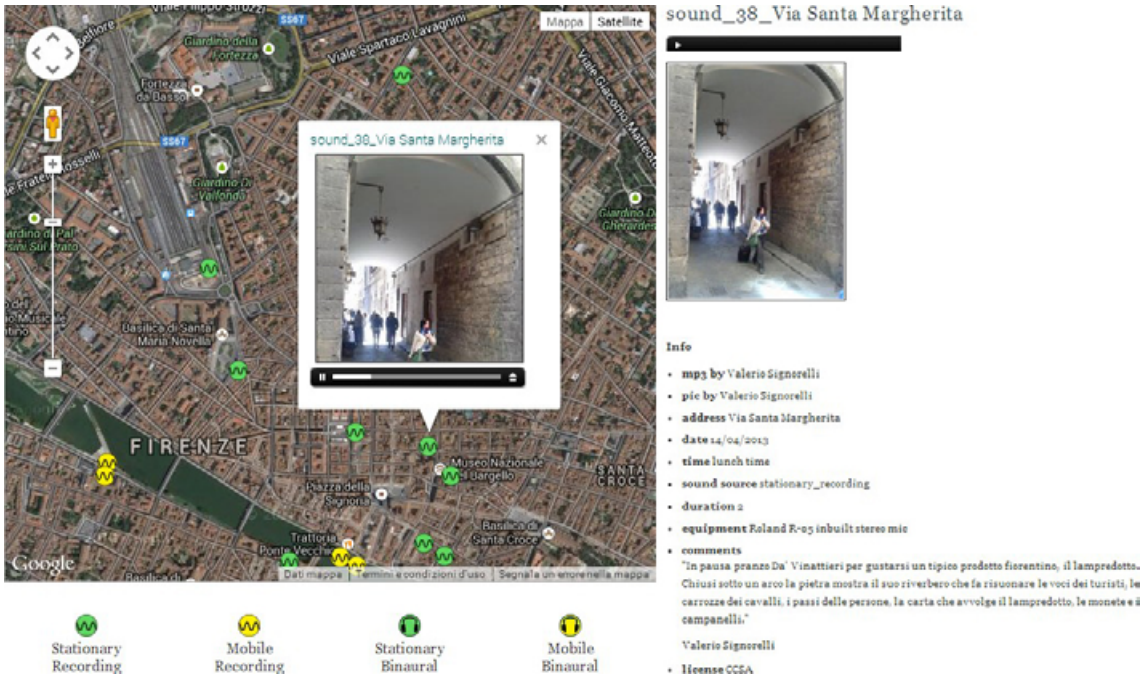

Figure 3. An example of Soundmap, FirenzeSoundmap, recently published in the OpenData of the municipality of Florence Italy http://www.firenzesoundmap.org/ (Radicchi 2012).

How can we employ the soundmap as a useful tool in the urban design practices for describing the soundscape identity of the quiet areas, bearing in mind the necessity of considering a multi-sensory approach? And moreover can we take advantage of the existing soundmaps or do we need to enrich them? As described above, in order to deal with the identification and the design of the small and medium sized urban open spaces a more de-

tailed approach is needed and bearing in mind our aims we can recognize some limits in the cartographic solutions employed: the soundmap provides a mono-sensory description of the urban environment focused on the auditory stimuli, while a more comprehensive descriptions for the identification of the quiet areas is needed. The cartographic media is limited to a planar representation necessarily simplified for being intelligible. Finally the majority of the soundmaps consulted are conceived as a 'static archive' of recordings, a freeze-frame that aims to collect the memory of the current soundscape disconnected from the others elements of the urban environment, while the purpose of our research is to propose a multi-sensory descriptions of these places involving also their temporal connotations. To summarize the project (Figure 4) will be developed over three phases:

- developing a interactive digital map system focused on the representation of the quiet areas in which the auditory data are intertwined with the others sensory and physical parameters and analysis needed for describing the urban open spaces;
- developing a three-dimensional interactive virtual environment of the sensitive places enriched with sound components using a Game Engine software. Various three-dimensional models are added in the environment in order to present different scenarios. Real time shadow and dynamic object are added as well;
- publishing the final product using different platforms (such as immersive virtual reality devices), and test of the tool in order to better understand the interaction between different sensory spheres in the urban environment. A series of questionnaires will be developed directly in the virtual environment;

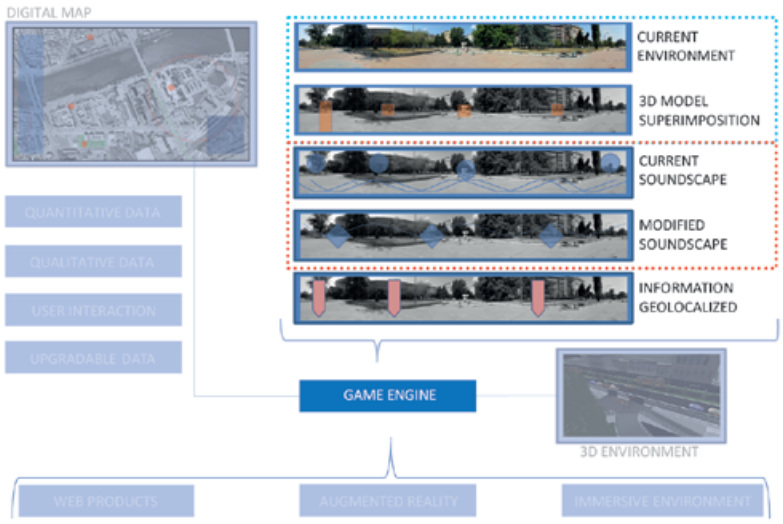

Figure 4. Scheme of the different phases of the project proposed.

In this paper the second phase will be presented.

4. Unfolding the maps through the virtual environments

In the last decades, the virtual environments in the urban studies have taken a step further by being used not only for visually representing existing or designed urban open spaces, but as an effective basis to realize and display various environmental analysis and simulations that can be partially represented by a planar support (Crooks et al., 2010; Ceconello and Spallazzo, 2008; Batty 2007; Evans et al, 2005). The effectiveness of virtual and interactive environments in urban design practices, especially in public participation processes, have been investigated as well (Griffon et al. 2011; Salter et.al 2009; Bishop and Lange 2005). However we should taken into account that modeling complex urban models might require a large amount of time if the necessary data are not readily available, and this obstacle is evident when the aim is to model small and medium urban spaces where presence of details is crucial for the purpose of the project presented (the materials and finishes of buildings and public spaces; the urban furniture and vegetation). For this reason, the use of the 360° spherical images has been investigated for rapidly reproducing the existing urban environment. A spherical image is a visual medium that can be obtained by the composition of multiple images, realized following precise methods and digitally processed using specific software (known as photo stitching software), in order to obtain a single image characterized by an enlarged field of view (Figure 5). The image obtained can be applied as a texture map on the inner surface of a three-dimensional primitive (usually a sphere or a cube) and then can be displayed interactively giving to the user the impression of being surrounded by an urban environment. The use of the panoramic images for developing virtual environments can be found since the '90s when the limited computational capabilities of the computer systems were not able to manage large three-dimensional urban model (Hudson-Smith 2003). The improvement of digital photography and computer technology, has made possible to easily produces these images using cheap cameras and open source software maintaining high resolution outcomes. Moreover recently various devices were specifically created to accelerate the process of acquisition and composition of these panoramic images. For the prototype presented was used a high resolution panoramic image, realized using a method developed at the Laboratorio di Simulazione Urbana 'Fausto Curti' of the Politecnico di Milano (Piga et al. 2013)

Figure 5. The final result of a high resolution panoramic image after being processed by a photo stitching software (Source: Laboratorio di Simulazione Urbana 'Fausto Curti').

The second step of the project is to collect the data of the sound environment. Before recording the various sound sources located in the area and in its surroundings, several soundwalk were performed in different days of the week in order to identify the different sound events that characterize the chosen area. In addition to the sound recordings of the soundwalks, and the sound recordings captured in the same position in which the panoramic image was taken, some sound sources were recorded individually paying attention to avoid sound overlapping. Every sound recordings has been described in detail (time of the recording, climate data, devices used etc.). Finally, various three-dimensional models have been created for enriching the virtual environment with dynamic objects, as well as the proposed urban furniture and the surrounding buildings.

Once the base data have been collected, a game engine system has been chosen in order to link these heterogeneous materials. A game engine is a software system characterized by various components called engines which are used to handle the visual representation render engine, the sound reproduction with the possibility to spatialize the various sound sources, audio engine, and a series of framework useful for managing the animations and the artificial intelligence, as well as a physics engine. The game engine allows us to create highly interactive environments where the user is not just a spectator but he/she can interact directly with the provided simulation (Andreoli et al. 2005). These software were originally developed for the creation of videogames, but in the last decades these technologies have been used also in fields not closely related to a playful attitude (Bishop, 2011; Signorelli 2013). The software employed in this research is the game engine Unity3D™. Due to its flexibility the final product can be easily customized using various programming languages that permit also to interface the game engine to external software (Unity 2014). Shown below a briefly

description of the steps used for developing of the prototype: Using a 3d modeling software the panoramic images were projected on the six faces of a cube. By employing this method the six images obtained can be easily modified in a photo editing software (Figure 6).

Figure 6. The panoramic image re-projected on a cube and divided in six images.

In fact, in order to have the possibility to insert 3D models behind the elements contained in the photo (e.g. a row of trees) the images need to be adequately elaborated and a transparent alpha channel needs to be created. At the end of the process the images are used as textures for different cubes placed one inside the other (Figure 7). This procedure is carried out directly in the game engine environment. A map of the area is used as a reference for placing, at the correct distance, the cubes generated in the 3d modeling software.

Figure 7. The images are applied on the six faces of the cube. In the center is placed the camera.

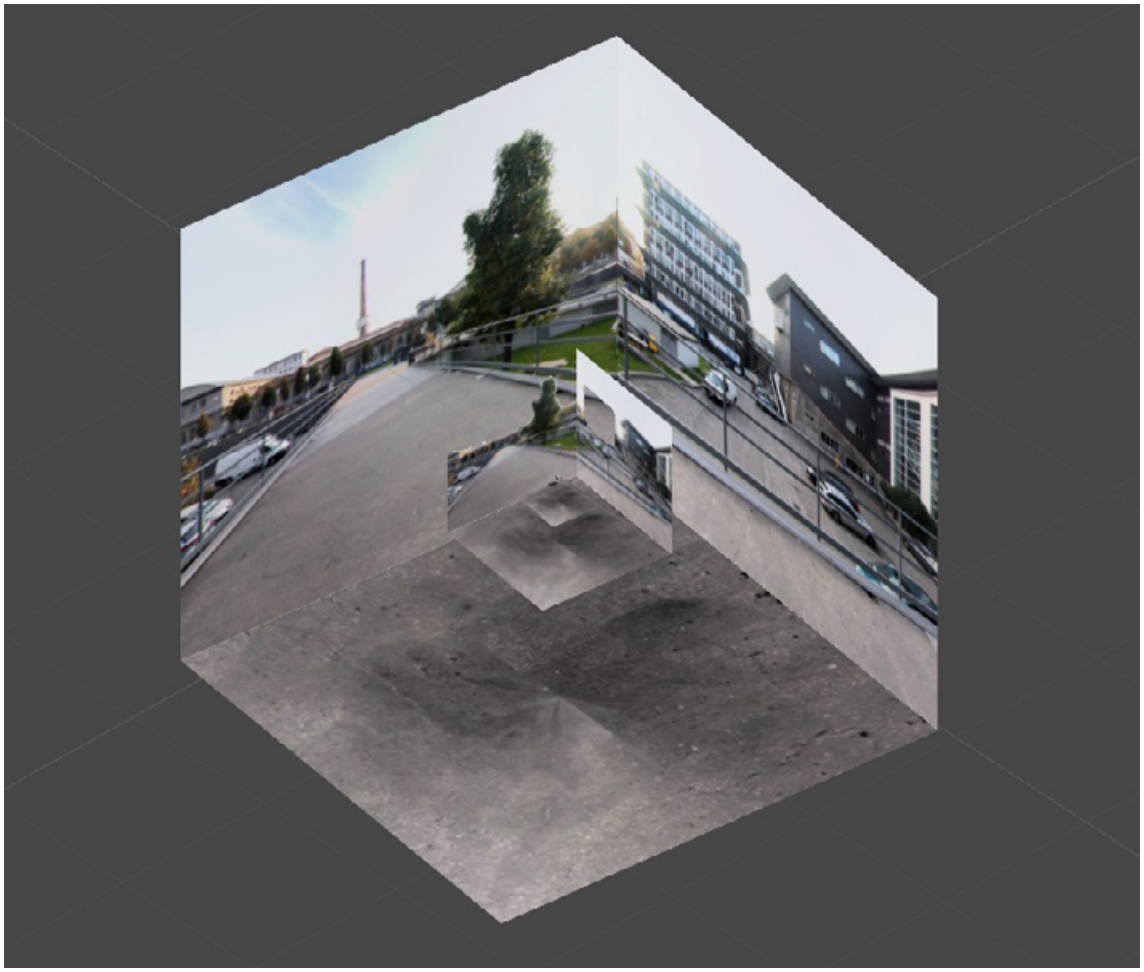

Figure 8. The three cubes in the game engine's environment. The alpha channels of the inners cubes are visible.

Afterwards a camera is placed in the center of the cubes and a script for allowing the interactive movement is attached to it (Figure 7–8). Also the sound elements collected are inserted in the virtual environment and placed using the previous map as reference. In this first prototype, fixed and moving sound sources were added. The sound environment was integrated using the internal sound engine of the software that do not allows us to apply advanced audio filter useful for providing an efficient spatialization. Thus far just a distance attenuation effect, a doppler effect and a pan effect are used together with a simple reverberation. However a more effective sound reproduction will be investigated. Finally the virtual environment is enriched with the three-dimensional models created, both static and dynamics.

Figure 9. Screenshot of the tool, the shadows and the animations of the people are realized in real-time by the game engine. The user can interrogate and interact with the virtual objects.

5. Conclusion

The ongoing research aims to highlight the importance and needs, for the urban design practices, of new methods and tools for the representation of the quiet areas in the urban environment by avoiding strategies based on a merely quantification of the sensory components, as well as approaches focused on a mono-sensory description. The use of new technologies, not necessarily developed for the urban practices, have been investigated and in particular the use of a virtual environment, conceived as a background for heterogeneous simulations, and not only as a medium for visual communication, has been proposed in order to extend the communication capability of the cartographic media currently employed. We believe that the game engine technologies can be conceived as an hub able to link and represent the sensory data with others environmental analysis useful for providing a better description of the complexity that belongs to the quiet areas spread in the urban fabric. As presented in the article, various aspects need to be analyzed in this ongoing research, among these one of the most important regards the correct simulation of the soundscape environment and its reproduction. Thus far the sound engine included in the game engine employed present several limitations that do not permits to reproduce complex virtual soundscape scenarios (compared to the use of the render engine that permits to obtain high quality outcomes). In order to increase the involvement of the user other solutions will be investigated in order

to overcome these limits. Consequently the integration between the cartographic medium and the virtual environment proposed will be studied, paying attention on the possibility to optimize the products for being accessible on a web-service; finally the virtual environment proposed in the article will be tested with users employing different output devices (from the monitor to the virtual reality device) in order to evaluate its effectiveness.

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