Soundwalking in virtual ambiances: applying game engine technologies in soundscape studies

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Abstract The aim of this paper is to identify new methods and instruments that can be employed for the description of the sound environment in virtual ambiances.

The intention is to investigate the role of the sensory perceptions for defining the liveability of the open urban spaces as opposed of the "oculo-centrist" approach, thus recalibrating the attention of urban planning to a multi-sensory perception approach of the open spaces in the city that can be considered fundamental components for the physical and psychological wellbeing of citizens. The research focuses on the role of soundscape in the urban environment, without forgetting the need to consider the constantly overlap and influences of the other sensory stimuli.

The tools presented were focused in particular for the reproduction, in a virtual environment, of the soundwalk methodology. This methodology of analysis was developed in the early 70ies and it can be considered as the preferred tool employed to investigate the auditory urban environment. Up to now soundwalking has been adapted and modified by various researchers, nevertheless its application in virtual environment is was not so widely investigated. However, the possibility to re-listen a soundwalk, enriched with the visual components of the urban ambiances, into a virtual environment, provides useful tools for the actors involved in the design of the urban environment.

In fact, the need to describe the soundscapes, and therefore to identify efficient tools for this purpose, does not only regard the intent to provide a preliminary analysis of the urban ambiances and their recording, but above all the aim is to design urban spaces in which the sensory description is not considered as a consequence of an "ocular-centric" approach, but carefully evaluated in order to design quiet areas, distributed into the urban fabric, and defined by the EU directive 2002/49, necessary for the physical and psychological wellbeing of the city users. It is clear the importance that time and dynamic elements have for providing an effective outcome in order to describe the sensory urban form, and in these terms it is evident the inadequacy of the existing tools used for the representation of the urban environment.

The attention of this research is focused on two different tools: Google Earth™ and Unity3D™ that are used to develop different products and compared to highlight their limits and potentialities.

Thanks to both the possibility to change the visual elements of the virtual environment, which permit to obtain several ambiances to be compared together, and the opportunity to conduct an interactive survey among the users of the simulation, the game engine technology can be worthwhile in order to provide an effective support to the research and design practices of new 'quiet areas', according to their quantitative and qualitative forms.

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Introduction

The urban environment, considered in its complexity defined by a multitude of elements influencing each other, is a heterogeneous system characterized by a superimposition of multi-sensory *-scapes* that are naturally intertwined (Pallasmaa, 2005). From their careful reading it is possible to identify *hidden* spatial and temporal structures: the senses of hearing, touch and smell (in addition to the others perceptive apparatus that we use to interact with the environment) can highlight places invisible to the eyes and characterized by blurred boundaries changing over time.

However the design of new urban open spaces was often addressed with oculo-centrist approaches, thus restricting the others sensory spheres as pollutants that must be reduced, for example confining in specific places the activities responsible for unwanted odors or noises (Zardini, 2005). The current regulations take this position focusing their attention on the quantitative aspects of the sensory spheres, providing precise thresholds that have to be respected. The aim of these norms is to prevent hazardous situations for city-users, but tackling this problem just employing a quantitative approach is not enough to ensure a high level of well-being for these. Moreover, a quantitative approach does not adequately permit to describe the sensory spheres through a perceptive point of view and, most importantly, it does not show negative or positive effects of the various sensory stimuli (Kihlman et al, 2001).

The gap between quantitative and qualitative approach is evident in the study of the acoustic environment: the auditory stimuli, in urban practices, are mostly considered in terms of pollutants as noise. Its qualitative aspects are taken into account mainly in architectural and urban projects that are based on the sound as their primary function (theaters, cinemas, concert halls, auditoriums, etc.). Moreover, the open spaces are often treated as a source of disturbance to confined spaces rather than places where the sound components should be properly designed and considered in order to ensure an adequate level of physiological and psychological comfort for the city-users.

Soundscape

The idea that noise has to be considered more than a numerical index of pollutant, and the focus on the qualitative aspects of the sound components, can be found in the first researches about the sound environment started during the late '60s and the early '70s (Schafer, 1977). Schafer, and his research group, defined the terms of acoustic ecology and soundscape (compared to the term of landscape) which refers to "our sonic environment, [or] the ever-present array of noises with which we all live". He argues that the soundscape, in urban and rural environments, should be considered as element that deserves to be valorized, preserved when it is good and even enriched.

The research group identified methods of classification for the sound components forming a new vocabulary to describe the sound environment. Schafer proposed a subdivision of the sound in keynote sound, sound signal and sound mark, which make a connection between the five elements paths, edges, districts, nodes and landmarks described by Kevin Lynch in his book 'The Image of the City' (1960). Schafer gave also a definition for lo-fi and hi-fi soundscape: the first one refers to a sonic environment where the sound events are hard to extricate (like our cities); the second one is the environment where all the sound events are clearly understandable, and this is the result we want to achieve for the quiet areas.

Others research groups began to work on these aspects from the suggestions given by the World Soundscape Project of Schafer and various classification methods have been developed and provided. In particular, among the research groups to be mentioned for our studies the CRESSON laboratory, established in 1979 by Jean Francoise Augoyard, began to work on the qualitative aspects of the sound environment related to the urban practices in its broad sense. CRESSON defined the tool of the sound effect: according to Auguyard, the sound effect is placed at an intermediate level between the sound object, too detailed and disconnected from its source, and the soundscape, that is too general and too broad to provide an accurate description

(Augoyard & Torgue, 2003). The sound effect allows to describe the relation between the sound event, the built environment and the perception of the user in the urban space. The sound effects are both a classification methods and an actual tool for urban design practices as argued by the authors.

Soundwalk

Which tools and methodologies can we use to investigate the auditory experiences in the urban environment? An intimate survey approach is required to tackle this perceptual topic. We have to immerse ourselves into the urban environment (Porteous, 1990; Secchi, 1995) and an effective and straightforward method to analyze the multi-sensory form of the urban environment is to walk in it. By walking we are constantly immersed in a multisensory experience, and focusing on a specific sensory sphere allows the users to discover the hidden palimpsest of the urban environment. In soundscape studies the act of walking has been used since the ‘60ies as the privileged survey tool taking the name of ‘soundwalk’:

"A soundwalk is any excursion whose main purpose is listening to the environment. It is exposing our ears to every sound around us no matter where we are. We may be at home, we may be walking across a downtown street, through a park, along the beach; we may be sitting in a doctor’s office, in a hotel lobby, in a bank; we may be shopping in a supermarket, a department store, or a Chinese grocery store; we may be standing at the airport, the train station, the bus-stop. Wherever we go we will give our ears priority" (Westerkamp, 1974).

In short, a soundwalk is a walk through the urban environment, that can be performed alone or in group, where the focus is on the auditory stimuli rather than the visual stimuli. This basic activity was interpreted and adapted by various research groups with the aim to individuate sound components, sound sources and sound effects, both in a qualitative and quantitative way, localized and recorded along the paths followed.

Visualizing the sounds

While the techniques of survey and classification of the sound components, as showed above, were extensively developed, the representation of these discontinuous and fragmentary elements, and in particular their qualitative aspects, has been less investigated. The auditory stimuli, both for noise and sound, have been described mainly using cartographic representations. The majority of the noise maps developed are using graphical conventions (points, lines, areas) and heat maps to represent the sound level pressure of the environment; the auditory stimuli are simplified and showed as a numerical index and translated into a visually outcome. These data are gathered using onsite surveys or employing advanced simulation software.

For the description of the qualitative aspects of the sound components the ‘soundmaps’ have been employed. A soundmap is a form of representation that permits to localize and connect the sound components to a specific place. It is possible to found first examples of these representation media in the early ‘70s from the researches of Michael Southworth (1969) and of the World Soundscape Project (Schafer 1977b). The earlier soundmaps, as the noise maps presented, employed graphical conventions and notations, then, with the improvement of informatics technologies, and in particular from 2005 when Google provided the Application Programming Interface (API) for Google Maps™, and the growing concept of web 2.0, these maps were enriched with sound fragments recorded by the users, with the mash-up technologies and geo-localization of multimedia objects on digital maps.

It is possible to highlight some limits in these cartographic representations for describing the sound environment:

- maps are 2-D and generally static, while the sound components are influenced by the surface materials composition and the tridimensional shape of the urban fabric and moreover, they are time dependent;

- these products provide mainly a mono-sensory representation, without taking into account, in the majority, the other sensory stimuli and physical components that interact with the sound environment;
- the use of technical jargon, as graphical notations and conventions, employed in order to visually translate the auditory stimuli, are often difficult to comprehend for non-experts and can generate misunderstanding;
- few soundmaps were developed to be used as an urban design tool; the majority of the maps examined are disorganized archives of sounds where the methodologies used for their recording is seldom explained.

The aim of this research is to overcome these limits by proposing new instruments, which employ virtual models, in order to extend the communication capability of the cartographic representation.

3-D models as simulation background

In the last decades, the use of 3-D models in the urban studies has taken a step further: 3-D models have been employed not only as a method of representation for the existing or designed urban open spaces, but as an effective background for simulations and instruments of advanced analysis. They permit to show, in a better way for non-experts users, the outcomes of new design proposals and to describe elements that can be just partially represented on a 2-D support (Crooks et al, 2010; Ceconello & Spallazzo, 2008; Evans et al, 2005). The questions are: can 3-D models of cities be used also for investigating the sensory forms of the urban environment? How should these products be shown to the actors involved? And finally, how can the tools of the soundwalk be integrated and used in a virtual model, and what kinds of outcomes can we expect?

Two different products were tested, Google Earth™ and Unity3D™. Google Earth™ is a software provided by Google that allows the users to interactively visualize the satellite images of the globe surface with a high level of details. During the last years the product has been enriched with others resources like the 3-D models of several cities, various information layers, multimedia objects etc. But Google Earth™ is not just a passive tool: for instance, it allows the users to draw points, lines and areas on the maps, to insert 3-D models realized with other software, in order to enrich the base model provided, and to embed GPS tracks and GIS data. The software has another useful tool that permits to create virtual tours along a predetermined path. The software is mainly used and focused on the visual representation and just few works have highlighted its potentiality in presenting dynamics and acoustical elements.

The other software considered is the game engine Unity3D™. A game engine is a software system designed for the creation and development of video games, characterized by various components (Andreoli et al, 2005). This software permits to create highly interactive products where the users are not just a spectator but they can interact directly on the provided simulation. In the last few years, a sort of pitch invasion of these technologies had been noticed, and this type of software is increasingly applied also in other fields not closely related to a playful attitude, such as Serious Game, thanks also to the quality that they reached and the ease of use (Bishop, 2011). There are few examples of the employment of this type of software in urban studies while most of the examples found refer to the architectural scale.

Methodology

The two products presented above were employed for reproducing various visually and acoustically walks, recorded near to the Politecnico di Milano, along Via Edoardo Bonardi and surrounding areas (Fig. 1). The street separates the engineering school from the architecture school. The segment of street covered by the walk is 250 meters long, and has a tram line in the center, flanked by two rows of trees, then two lanes for each direction of travel and the two sidewalks. The university buildings have different heights and facade materials, and the urban fabric does not make up a continuous street canyon.

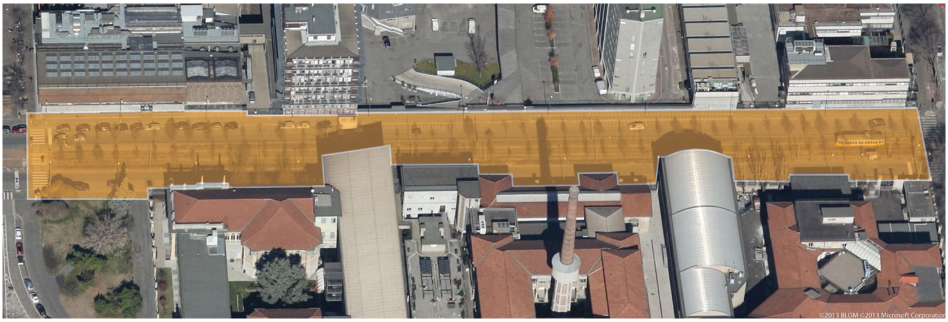

Fig. 1 The street Via Edoardo Bonardi and the surroundings used in the simulation

The first step is the collection of the base data for the creation of the 3-D model needed for the construction of the simulation. The model was built considering the three key elements that define the urban ambiances: the built environment (terrain, buildings, vegetation and urban furniture), the dynamic components (trams and vehicles) and the physical signals (sound events, shadows).

Google Earth™ already provides an inbuilt 3-D model of Milan, however this model has a low level of detail for being efficiently used at the neighborhood scale: it has low resolution terrain height-map, the satellite images lack the necessary accuracy for a street view simulation, and the 3-D models of the buildings are simply extruded without any details aside the photorealistic textures applied on the facades. Moreover, the model lacks the urban furniture details such as the fences, the street lighting and the rows of trees, as well as dynamic components, which are necessary in order to recognize the virtual environment as a realistic one. For this reason, using a 3-D modeling software, a more detailed digital model has been implemented, in particular by adding the elements missed employing the cartographic materials provided by the city of Milan, the data collected from the surveys realized onsite (drawings and photos) and readymade models of the urban furniture (Fig. 2). The level of detail that a virtual environment has to reach cannot be easily determined, and it will depend on the purpose of the simulation. Moreover, if our aim is to focus on the auditory environment, the visual representation can be less detailed and more evocative. For sure this topic needs further investigation.

Once the digital model has been created, various soundwalks were performed in different periods of the day. All the sound events were recorded using a Roland™ R-05 digital audio recorder with the inbuilt stereo microphones. There are two methods that can be employed to insert the sound elements in the software proposed: the first one is to record the actual soundwalk, the second one is to record the various sound sources and the sound events present along the road under investigation including the surroundings. With the first method it is possible to precisely collect all the nuances of the sound environment but the final products will be less interactive; the second one will be less accurate but it will improve the interactivity of the final products.

A virtual tour was created using the inbuilt tool in Google Earth™ and the length of the path was drawn according to the soundwalk performed. The tour created allows the users to visualize the virtual environment, in order to enrich these virtual walks, with the sound components; it was necessary to export the tour in the Keyhole Markup Language (KML) file format and then modifying part of it using a text editor by adding the necessary information for playing the sounds (the location of the file, its delay during the tour). The product obtained allows to reproduce a soundwalk in a virtual environment enriched with the visual components with the possibility to show annotations superimposed on the virtual model.

Fig. 2 From the left: comparison between the real environment, the low resolution 3-D model provided by Google Earth and the 3-D model enriched by the author

With the game engine it is possible to produce more complex products that the one created with Google Earth™. Unity3D™ allows the users to freely interact with the virtual environment although in this case it is necessary to spatialize the individual sound sources for the reproduction of the correct sound environment. In addition to this, the software is highly customizable through various programming languages and permits to add effective interactive solutions as questionnaires or informative boxes. The 3-D model previously prepared was used in the software, and the dynamic components of the road traffic, the tram, and the pedestrian flow using some simple behavior rules were included (Fig. 3). The position of the sun was set according to the solstices and equinoxes for three different hours of the day in order to obtain the effect of shadowing produced by the buildings. The sounds were connected to the sources present in the virtual model; some of these sources are in movement like the tram and the cars, others are static as the air conditioning systems. Finally, the design of a custom user interface was implemented. Beside the virtual interactive environment, that interface includes also others products, like the technical maps of the area and various 360-degree panoramas of the surroundings.

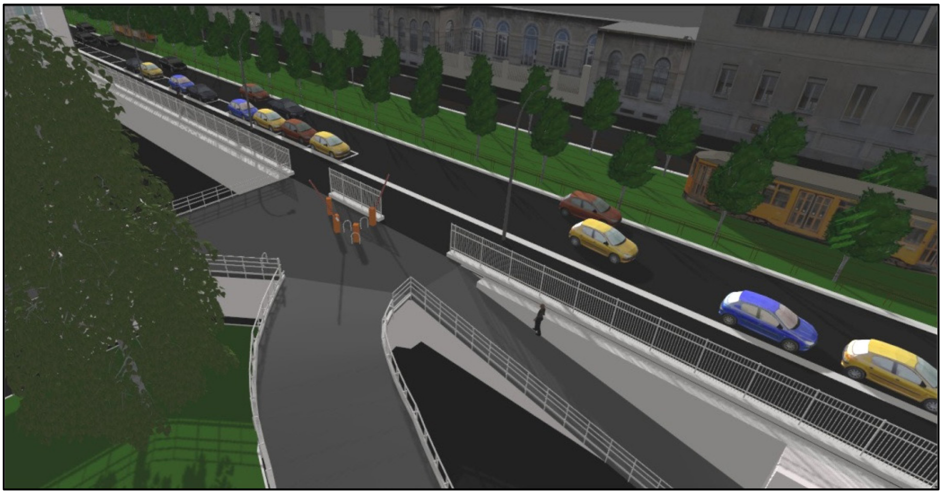

Fig. 3 The 3-D model of Via Bonardi and surroundings, imported into the game engine environment

The following table (Tab. 1) summarizes benefits and limits of the technologies employed in this work.

Google Earth	
Pro	Con
- readymade models of several cities provided by Google that can be enriched by GIS layer data and 3-D models produced by the users; - interactively and user friendly interfaces; - customizable using XML based file format; - it can be used inside a browser with a plug-in;	- models and textures are low resolution for the neighborhood scale; - private spaces are not modeled, thus it can be used mainly for public spaces; - the 3-D models cannot be too detailed (in terms of number of polygons); - the sound components are not easy to control and manage;
Unity3D	
Pro	Con
- the user interfaces and the virtual environment are customizable with various programming languages; - interactive components and dynamic objects can be easily inserted; - high quality graphic, and advanced sound engine; - it can be deployed on different platforms;	- time-spending for the creation of the base data or for developing advanced tools; - informatics knowledge is needed also for the development of simple products; - the sound engine does not consider the materials and the shape of the spaces;

Tab. 1 Comparison of the two products chosen

Conclusion and future works

The research has shown the importance to consider the auditory sensory sphere for the design of the urban ambiances, highlighting the lack of effective tools to describe, represent and communicate this sensory field. The importance to consider the 3-D virtual models as a background for further simulations, and not only as a media for visual communication, can found a fruitful application for the research in sensory studies despite it still remains underestimated. In this field, with the recent software technologies, often not directly developed for the urban practices, it became possible to extend the communication capability of the traditional representation methods for the description of these perceptive sphere.

The proposed instruments, and in particular the game engine technology, can provide an effective support to the research and design of new quiet areas, thanks to the possibility to build existing or expecting scenarios that can be presented, with the same conditions, to several users. However, different aspects need to be further investigated. In fact, a first barrier concerns the construction of the 3-D model: it is necessary to find an effective methodology for rapid reconstruction of the urban environment in a detailed way; an aspect that using the traditional modeling techniques needs a great amount of time.

The second limit regards the reconstruction of the soundscape in a correct physical and psychological way that at now, with the existing technologies, is not an easy task to handle. Nevertheless, these aspects are crucial to enrich the decision making process, in order to establish an effective dialogue with non-expert users, and to provide an advanced design tool for architects and urban planners. Recently, the field of game studies has shown a growing interest on the auditory experience for the entertainment purpose, and more precise and advanced tools are going to be developed. In any case the products provided can be successfully employed to communicate the nuance of the visual and auditory sphere and further investigations will provide more efficient products for the research on the sensoryscapes.

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