A MULTISENSORY TOOL TO EVALUATE THE PERCEPTION DUE TO THE TRANSFORMATION OF NAPLES' WATERFRONT

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ABSTRACT

The traffic congestion of cities has led to Access Restriction Schemes (LTZ, LEZ, ZEZ, CCZ), based on air pollution criteria. Whilst waiting for noise pollution based ARS, the increasing presence of electric vehicles will cause significant changes on the soundscape. In order to predict people's reaction, not only quantitative air quality and noise reductions should be considered. The Immersive Virtual Reality represents a powerful tool that allows to model future scenarios and to offer a multisensorial experience. In this paper, the methodology for the implementation of possible scenarios of Naples' waterfront is presented, considering the arrival of electric vehicles in the existing Low Traffic Zone (LTZ).

1.INTRODUCTION

The strong urbanization in big cities and their traffic congestion has produced problems regarding air and acoustic pollution. In a recent European Environment Agency report, it is referred that at least 100 million of Europeans are daily exposed to road traffic noise levels that are detrimental to health. In European cities with populations of more than 250.000 inhabitants, more than 62% of the population is exposed to long-term average road traffic noise levels exceeding 55 dB L_{den} whereas, more than 42% of people in the same urban areas are exposed to long-term average road noise levels higher than 50 dB L_{night} [1]. The strategies adopted by European cities to mitigate these problems are different. Decreasing the number of vehicles circulating per person, improving public transport and limiting traffic in some areas. Access Restriction Schemes (ARSs) can be considered as one of the powerful policy instruments offering a significant potential for addressing the major challenges of urban sustainability [2]. They can be applied in different manner, e.g.: within the Low Emission Zones (LEZs) the access for pollutant vehicles is banned, in the Congestion Charging Zones (CCZs) a payment is due to have the right to drive and to pollute the environment, or in the Zero-Emission Zones (ZEZs) the access is allowed only to all-electric vehicles. However, a recent review have shown that a significant positive changing of the urban soundscape could be obtained only combining the electric propulsion system with silent tyres to a new concept of vehicles [3]. This is in line with the new concept of quiet zone (Q-zone) defined in the City Hush project where a new acoustic classification of the urban areas (from the quietest class, class A, to the noisiest class, class E) based on the exterior noise levels of vehicles was proposed [4]. The difference with the conventional ARSs is that, in these zones each vehicle has to guarantee acoustic requirements to be considered adequate for the access. Future urban scenarios will be more and more influenced by national and local policies.

Much has been written about the effectiveness of Immersive Virtual Reality (IVR) in reconstructing multi-sensory experiences, combining visual and auditory stimuli [5,6]. The good accuracy achieved in reproducing auditory and visual stimuli of the modern technologies based on auralization [7] and immersive virtual reality [8-10] may represent an effective tool to reconstruct urban scenarios, predict and assess possible changes due to the policies adopted.

In this paper the methodology for the implementation of this tool in the case study of a Naples' waterfront, is presented.

1. CASE STUDY: NAPLES' WATERFRONT

The case study is a stretch of the waterfront of Naples, consisting in a part of Partenope street. Today, up to the intersection with S. Lucia street, vehicle access is restricted to those operating with the hotels present at the street, whereas the remaining part is a limited traffic zone. The study area is flanked by the "Castel dell'Ovo", has a lenght of 420 m and a width of about 25 m. It is bordered to the east by “Fontana dei Giganti” and the curve on Nazario Sauro street, and to the west with the curve from the second part of Partenope street. On this part of the road there are some of the most important hotel in Naples (Fig.1).

Figure 1: A view of the study area.

The urban scene of this site has changed radically due to the restriction of the traffic. Today is configured as a space with a soundscape certainly more controlled, that does improve the quality of life of pedestrians and residents. For this reason, it turns out interesting to study this area, reproducing the past scenario, present and having the ability to control future scenarios.

The structure of the multi-sensory experience is organized in a flexible way through overlap of visual and auditory elements. In this way, once all the elements have been built up, it is possible to choose their presence as required in order to achieve the desired scenarios. In this study five scenarios were made by switching elements in a different way, hence obtaining the following urban configurations (Fig. 2).

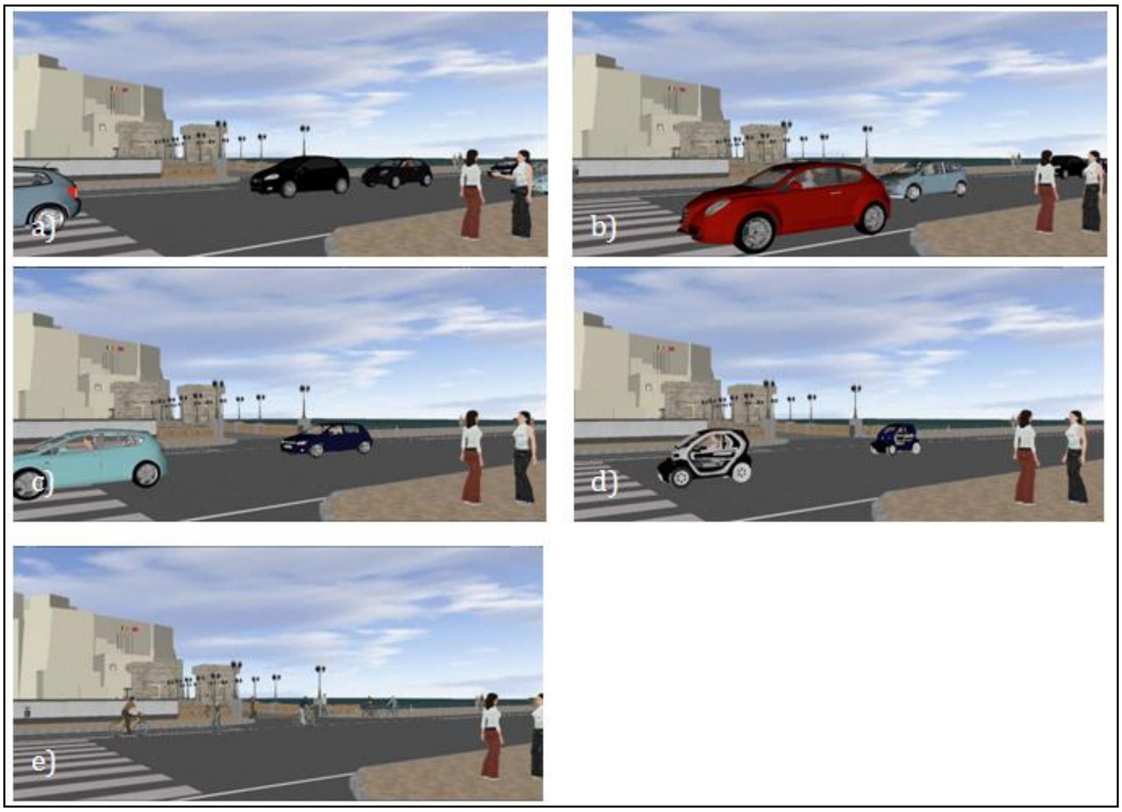

Figure 2: a) High density flow of enternal combustion engine (ICE); b) High density flow of conventional electric cars; c) Low density flow of conventional electric cars; d) Low density flow of compact electric cars (Renault Twizy); e) Pedestrian area.

3. METHODOLOGY

3.1 Graphical modelling

In recent years, tools such as Google Maps have become very important for the modeling of parts of the territory. It represents a real database of geometric, spatial and chromatic information of urban environments. Thanks to the correspondence with graphical modeling freeware such as Google Skethcup, it is possible to download parts of the city, including topography of the land and buildings. However, in some cities, these information cannot be found in a comprehensive manner. In these cases, the fastest and most effective method for modeling urban environments is divided into three parts: 3D modeling by GIS data, texture mapping and virtual reality (VR) enhancement.

For this study, a 3D reconstruction of a part of the waterfront of Naples has been built up using Google Sketchup software. Starting from the plans of the place, the elements present in this place were drawn: roads, sidewalks, volumes of the buildings and a 3D model of Castel dell'Ovo were added. The prepared 3D model was exported to 3d modelling and rendering software in order to refine the model and to add more realism to it.
At this stage it is necessary to collect more information from the real world to create reference materials. This reference information is basically photos, videos and, if necessary, representing sketches and dimensions of the important elements of the real environment. It is necessary to take a high number of photographs from different angles of vision. Subsequently, these scanned images are matched to the 3D model. This process, also called texture mapping, helps to produce a visual result that seems to have more wealth than what could be achieved with a limited number of polygons. To this aim, a photographic survey was carried out by using an SLR camera Nikon D 80 and an image editing software was used to correct and merge the photos, e.g. for the front of the building (Fig. 3).

Figure 3: Examples of texture applied to the front of the buildings.

The whole model was mapped with textures and other urban elements have been added to improve the graphics performance (Fig.4).

Figure 4: A comparison between a Google Earth photo (left) and the final 3D model (right).

To improve the visual stimulus another technique has been used several times, consisting in adding the information of the light on the materials. This technique is called Light Mapping and is done by Texture Baking process. However, this has not been done since it was not necessary in this phase. Animated elements were added in 3ds Max ambient, as avatars. In this phase, only animations that do not interact with the virtual visualization were added. The last step is to import the model into the IVR software Worldviz Vizard. Cars and other animated objects have been programmed directly into the environment created with this software, in order to link them with their corresponding auditory stimuli.

3.2 Audio modelling

Auralized signals can be managed directly from the IVR software. Through headphones, binaural reproduction allows to immerse the subject into a 3D sound environment easily. However, special care must be taken along the pre-processing stage, which varies depending on the acquisition method. In the next sections, two different methodologies are explained, as result of recording with an omnidirectional microphone, or with an ambisonics system.

For both of the cases, the environmental sound and the vehicles noise should be recorded separately, in manner that they can be managed independently in any configuration required. Hence, it is desirable to record the vehicles as clean as possible, so that background environmental noise do not add each other. Frequently, it may be advisable to record the vehicles in different and quieter locations. Nevertheless, especially when modelling narrow streets, it should be assessed to which extent the effect due to a different reflections pattern can be permitted from a perceptual point of view.

In addition, a precise model should consider level calibration of the audio stimuli. This can be done by measuring the resulting binaural signals in a dummy head, then adjusting the gain until accomplishing the levels measured in situ.

a) Omnidirectional microphone

Binaural signals can be obtained from omnidirectional recordings, if these are afterwards convolved with the corresponding head related transfer function (HRTF). With view to record a vehicle passing by (always at a specific speed in order to ease the post-processing), the microphone should be placed at the same distance in which the subject would be virtually positioned when recreating again the scene. In this way, propagation and ground effects are directly included. In order to recreate the binaural impression from this recording, when running the simulation each part of it should be associated with the corresponding HRTF. This must be chosen according to the relative angle between the subject's head orientation and the vehicle's position along its trajectory. Omnidirectional recording does not allow to record an environmental sound that can be reproducible in 3D. Alternatively, a simple solution consists in recording with a XY-stereo microphone set, even though this does not solve neither the issue of fully representing the real existing acoustic environment.

b) Ambisonics

The Ambisonics technique allows to record spatial sound in any direction, by means of a special 4-capsules microphone. With the adequate post-processing, it becomes possible to simulate afterwards virtual microphones pointing in any direction. Such capability permits a huge flexibility when it comes to 3D sound. Briefly explained, if willing to obtain binaural signals from an ambisonics recording, a method consists on simulating first a specific virtual loudspeakers configuration around the subject, where each loudspeaker feed corresponds to the contribution of a virtual microphone. With the proper processing (or dedicated plug-ins), it is possible e.g. to rotate or tilt the acoustic field. Once the desired effects are applied, binaural signals can be obtained by adding the contributions of each of the virtual loudspeakers, if convolving each with the HRTF corresponding to each relative angle with respect to the subject's head [11].

Therefore, with this method is possible to record a full 3D environmental noise. With respect to passing-by vehicles recordings, the same approach can be employed, by placing the microphone at the same distance the subject will be later virtually positioned in.

3.3. IVR interaction

Adequate IVR software allows to program every action and interaction within the virtual modelled world, including audio management. Therefore, the programmer can configure different scenarios, e.g. depending on different traffic flows or types of vehicles. In IVR, the subject is allowed to turn his or his head and look around. In such case, the script should be able to compute in real time the relative angle between his head and each of the noise sources, so that the correspondent HRTF is applied. An alternative offline consists in obtaining, prior to the simulation, every possible auralized binaural signal (e.g., if given a resolution of 10 degrees, the resulting 36 tracks). Finally, once all these have been triggered simultaneously, the code just needs to pick up and reproduce the track corresponding to the calculated angle between head and source.

About the hardware system of the virtual interaction there is a wide range of effect or/and sensor hardware offering different levels of immersion and usage for such studies. The visual interfaces are the most advanced effectors of VR systems; they are supposed to provide images to the human eye that is “indistinguishable from that experienced in reality in terms of quality, update rate, and extent”. Head mounted displays (HMD) and cave automatic virtual environment (projection on walls of a room-sized cube, a.k.a CAVE) systems are the most accurate and well-known interfaces. The VR navigation is obtained by a position tracker system (Precision Position Tracker-PPT X4) with 4 optical sensors to track 3DOF position of worn markers.

The audio reproduction system can be simply a headphone or audio system with speakers inside an anechoic chamber properly calibrated, in order to reproduce the same auditory conditions of the real scenario.

4. CONCLUSIONS

In a context strongly influenced by local and national traffic restriction policies (i.e. Access Restriction Schemes), the urban scenario of large cities is constantly evolving. The tool presented in this paper can be a good solution to predict and assess these changes, improving the environment and the quality of life of the population. Immersive Virtual Reality today is the most powerful method to reproduce the physical stimuli of the real world. In particular, the visual experience can be reproduced with a high level of accuracy: graphically by means of photorealistic images and baked textures on the 3D model, and spatially using stereoscopic visors, cave, powerwall and 3D projection systems. This allows to reach high level of immersion, that can be furthermore enhanced with the implementation of auralized environmental sounds. More complex scenarios can be built taking into account tactile and olfactive stimuli.

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