Developing an online Virtual Reality application for e-participation in urban sound planning

Like Jiang[1], Luigi Maffei[1], Massimiliano Masullo[1]

[1] Department of Architecture and Industrial Design, Second University of Naples
{jianglike@yahoo.com, luigi.maffei@unina2.it, massimiliano.masullo@unina2.it)

Abstract
Effective involvement of the public in local governance and decision-making via e-participation is one of the key characteristics of smart cities. Use of Virtual Reality (VR) for multisensory environmental evaluation is one of the innovations in planning process to support the involvement of local population in shaping their living environment. It allows the locals to experience the proposed developments in a realistic virtual environment powered with multisensory output. The power of VR in public participation is further enhanced by its application online. However, current online VR applications in e-participation is mostly restricted as visualisation tools, evaluation of the virtual sound environment is hardly supported. This study is to develop an online VR application for e-participation in urban sound planning, following the concepts of gamification, easy accessibility, and real-time auralisation. Based on a case site, audio-visual scenarios of urban developments, including different traffic control actions and street designs, are built in game engine, and will be published online in the form of a WebGL game. The application will then be tested in trial e-participation in urban sound planning, to discuss the advantages and limitations of such applications, as well as possible solutions to improve.

Keywords: urban sound planning, e-participation, virtual reality, auralisation, visualisation.

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1 Introduction

E-participation is public participation supported by information and communication technologies. Effective involvement of the public in local governance and decision-making via e-participation is a key enabler of smart governance in smart cities [1].

One of the innovation in e-participation initiatives in urban planning is the use of online Virtual Reality (VR) to support the involvement of local population in shaping their living environment. VR has been intensively investigated and employed as a technology to present proposed urban development in intuitive and interactive ways. It allows policy makers and local communities, as well as urban planners themselves, to experience and to better understand the changes in the concerned environment before the development takes place, and thus to enable information sharing and consensus building throughout the planning process [2,3]. With the rapid development in information and communication technologies in recent years, the power of VR in public participation is further enhanced by its application online. The online approach has advantages in making VR participation accessible to much wider communities without restrictions of time and place, and encouraging expression of opinions by providing a non-confrontational atmosphere [4]. Online VR has opened up new forms of communication, interaction and collaboration for e-participation in urban planning.

However, nearly all the current online VR applications for e-participation in urban planning are developed as visualisation tools to involve the public in decisions solely on the visual environment [5,6,7,8]. Sound environment is of vital importance to a liveable and sustainable urban environment. Action plans are required in European cities to address noise issues and to reserve quiet areas [9]. Recently, strategies are being extended from pure noise control to design of the sound environment, with interventions being made from the beginning of the planning process [10]. Sound planning has become an important part of urban planning and should also be covered in e-participation initiatives.

On the other hand, the potentiality of VR, applied off-line, to depict sound environment along with visual environment for public participation in urban projects, has be widely studied [11,12,13,14]. VR has shown its advantages in scenario control and ecological validity for multisensory evaluation of urban environment.

Several factors might have contributed to the hindered development of online VR applications for e-participation in urban sound planning. Firstly, the computational load of rendering spatialised audio content for complex environments can be prohibitively high [15,16], and this issue can be more intractable in the case of online applications. Secondly, sufficient control over individual end users' audio hardware and playback settings can be hard to achieve. Last but not least, emphasis placed on sound environment in urban planning and effort made to promote public participation in this area are still relatively low.

Therefore, the aim of this study is to develop an online VR application for evaluation of urban sound environment. The application will then be tested in trial e-participation in urban sound planning, to discuss advantages and limitations of such applications, as well as possible solutions to improve.

2 Design concepts

The design of the application in this study followed three concepts: gamification, easy accessibility, and real-time auralisation.

2.1 Gamification

Gamification is the use of game elements in interactive systems in non-gaming contexts [17]. It has become increasingly popular as a tool for academics, practitioners and business professionals to improve user motivation and engagement in non-gaming tasks [18]. The particular benefit of gamification for public participation in urban planning is that it simulates real-life tasks which allows immediate and intuitive behavioural and emotional responses of the participants to the presented urban development [19].

2.2 Easy accessibility

Easy accessibility is essential for high rate of participation and low bias in representation. In the case of online VR for e-participation in urban planning, there is a challenge in balancing the complexity of the virtual environment and the accessibility for participation, since high complexity in virtual environment may require high specifications that are not common for home devices, which can lead to discouraged and biased participation. This challenge is particularly highlighted when presentation of virtual audio environment is of no less concern due to the high computational load of auralisation. For the application in this study, this challenge was tackled by focusing on a relatively small case site and simplifying the content and mechanics of the virtual environment as much as possible within acceptable quality limits.

The application was also designed to be web-based. The web-based solution would further constrain the complexity of the virtual environment due to the limits in browsers' memory space, however, it can promote accessibility since it is easier to spread and more convenient to use.

Headphones, instead of dedicated or built-in speakers, were proposed to be used by the participants as audio devices to playback the audio content. For one reason, with the use of headphones it is easier to control how the spatialised sound will be played by each individual participant, for the other, headphones are widely available and commonly used at home or work [20].

2.3 Real-time auralisation

In many virtual soundscape studies audio contents were reproduced using edited recordings [21,22,23,24,25] or based on off-line convolution of recordings [26,27,28]. While they are cost-effective ways to achieve perceptually valid auralisation, the associated disadvantages are low interactivity which limits user movement, and constrained design of sound events which can result into stereotyped sound scenarios that are not typical in real life especially in complex and vibrant urban context.

Recent developments in auralization techniques have made it possible to achieve real-time rendering of spatialised sound for virtual environments, particularly, the auralisation of road traffic noise [16,29,30,31]. However, real-time auralisation is still by far not as advanced as real-time visualization. For the application in this study, we aimed to achieve real-time auralisation in computationally cheap approaches, to allow an interactive and less-stereotyped while affordable virtual sound environment for the general public to experience online.

3 Methods

3.1 Case site and scenario design

Piazza Vittoria in Naples, Italy was chosen as the case site (Figure. 1). The square is about 70 m × 150 m in size. it connects Villa Comunale, the historic town and the waterfront of Naples, which makes it a popular place for locals and tourists in the area; while receives and directs traffic from the port and several main roads, which makes it an important node of the city road network. The square provides a sound environment that has a need and a potential to be improved.

Figure 1 – The case site: Piazza Vittoria in Naples (reproduced based on Google Maps capture).

Four scenarios were designed and are described in Table 1. For traffic conditions, the traffic flows are shown in Figure 2. In total, 2820 vehicles pass Piazza Vittoria per hour in the No-restrictions scenario; 2490 vehicles pass Piazza Vittoria per hour in the ZTL scenario. Due to blocked entrance of Via Partenope, traffic moving towards it is reduced and diverted to Via Giorgio Arcoleo in the ZTL scenario. For streetscapes, the existing streetscape and the shared-street design on the east segment of Piazza Vittoria are illustrated in Figure 3. The shared-street design unifies pavements of sidewalk and carriageway to blur the boundaries between them, and adds street furniture and plants that discourage vehicular traffic. The idea was to create a more pedestrian-friendly yet still efficient street space [32,33]. Sound environment was not changed by the shared-street design. This visual scenario was included in this study because research had shown that visual settings can affect the perceived quality of sound environment [34,35,36].

Table 1 – The four virtual scenarios designed in this study.

Scenario	Traffic condition	Streetscape
Scenario A	No restrictions	Existing streetscape
Scenario B	Zona a traffico limitato (ZTL) on Via Partenope	Existing streetscape
Scenario C	No restrictions	Shared-street design on the east segment of Piazza Vittoria
Scenario D	Zona a traffico limitato (ZTL) on Via Partenope	Shared-street design on the east segment of Piazza Vittoria

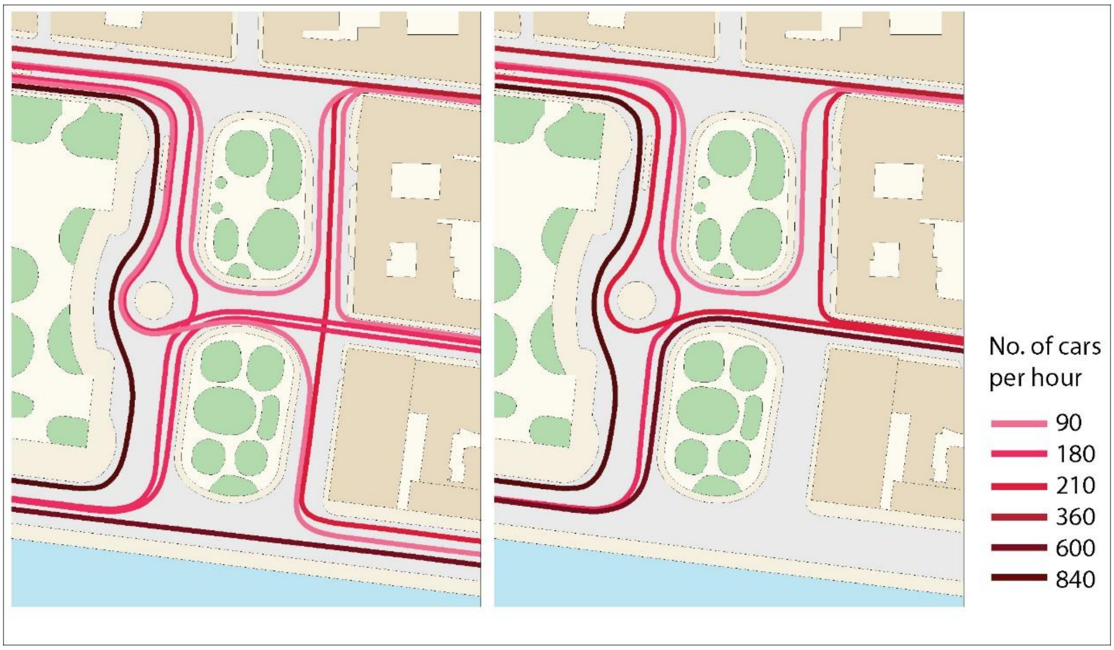

Figure 2 – Traffic flows in the two traffic conditions.

Figure 3 – The existing streetscape (left) and the shared-street design (right) on the east segment of Piazza Vittoria.

3.2 Visualisation and auralisation

The virtual environment of Piazza Vittoria was built in Unity (https://unity3d.com/), including buildings, roads, street furniture, vegetation, pedestrians and vehicles. Photos of building facades taken on site were edited and textured on modelled building objects to visualise buildings with less details yet high realism. Pedestrians and vehicles were animated on constrained paths. The speeds of vehicles varied depending on road conditions, from 20 km/h to 50 km/h and reduced at turnings. Speeds on the shared design street were 5 km/h lower than those in the existing scenario on the same paths.

Sound elements added to the virtual environment included vehicle sound, bird sound, water sound and human voice. Vehicle sound consisted of sounds emitted from individual vehicles animated in the virtual environment and sounds of traffic noise in the background. Sounds emitted from individual vehicles were simulated using the model developed within LISTEN project (https://www.tii.se/projects/listen) as source noises and attached to corresponding vehicles. The volumes and spectral characteristics of the sounds changed according to the speeds. The received sound of the vehicles was rendered in real time by Unity’s sound engine, applying attenuation, spatialisation and Doppler effect according to the relative positions and movements of the participant and the vehicles. Reverberation, which would be less influential in open space, was not considered to reduce computational load. Sounds of traffic noise in the background were auralised using edited recordings attached to traffic roads outside the visualised virtual environment with long-box-shaped attenuation and spatialised by Unity’s sound engine. Bird sound, water sound and human voice were also edited recordings and attached to relevant objects, e.g. bird sound to trees, human voice to shops, crowds and in the background, and water sound to fountains. Attenuation and spatialisation were applied.

3.3 Participation tasks

The application will be launched in the form of a WebGL game, which can be accessed via a URL link and played in 32 or 64 bit web browsers.

Upon the start, participants are shown an introduction page in which a short description of the application is given and participants’ demographic and audio device information requested. Screen resolutions are automatically acquired and graphic performance of the devices will be captured in terms of frame rate during the virtual environment session. The next step is to calibrate their audio devices. This will be achieved by playing a recording of face-to-face dialogue and asking participants to tune the audio volume played back by their headphones to what they felt approximate to real life situations. When they are ready, they click a button on the screen to start the virtual scenarios.

To keep the participation session in a reasonable length and avoid tediousness of repetitive tasks, each participant will only experience one virtual scenario, randomly selected from the four. Upon starting the scenario, the participant is located at the northwest corner of Piazza Vittoria in first person view. Instruction of player control is given, followed by the assignment of the first task.

The first task is to find Cafe SONORUS which is located at the southeast corner of Piazza Vittoria. This is to get the participant familiar with the virtual environment. When the participant find Cafe SONORUS, he/she is asked to evaluate the soundscape of the piazza by rating *eventful-uneventful; chaotic-calm; exciting-monotonous and unpleasant-pleasant* on 7-point scales [37]. The interface is shown in Figure 4.

The second task is to find the place where the participant thought the quietest in the piazza and the third task is to find the noisiest. After these, the participant is asked to imagine that he/she is waiting for a friend, and the fourth task is to choose a place where he/she would feel most comfortable to stay while waiting. When the participant arrives the place, he/she is asked to answer what make him/her feel comfortable there, by making multi-choice from a list of elements in three categories: *visual environment (trees, vehicles, fountains, buildings, others); sound environment (traffic sound, bird sound, water sound, human sound, others); facilities/human activities (benches, shops, people, other)*. The fifth task is the same as the fourth, only that the participant is asked to choose a place where he/she would feel most uncomfortable to stay, and choose elements that make he/she feel uncomfortable.

At the end of the participation session, participants are asked to rate the qualities of the visualisation and auralisation of the virtual environment, and leave comments that they have, followed by a word of thanks

All the participants' data, including their information, ratings, chosen locations and comments will be logged and maintained in a SQL database.

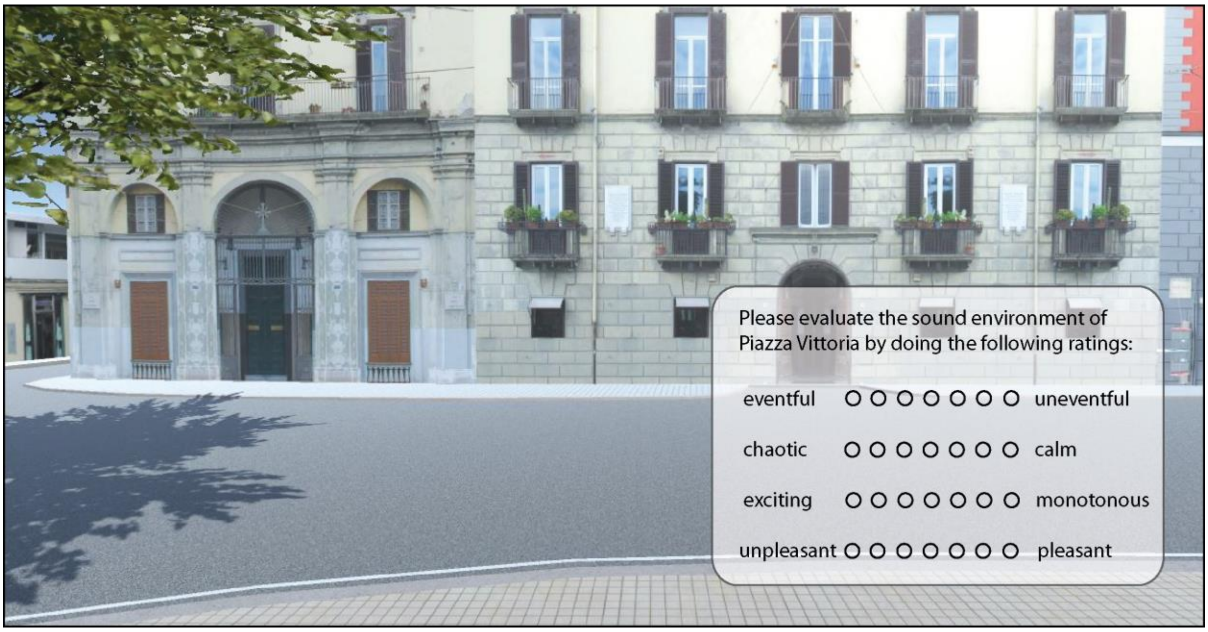

Figure 4 –The interface for evaluating the sound environment of Piazza Vittoria.

3.4 The trial e-participation

The application will come in English and Italian versions, and be distributed via online social media to local people in Naples as well as peoples in other places over the world, for a trial of using web-based VR for e-participation in urban sound planning. The responses of participants in the four scenarios will be compared with noise maps, which are typically used to evaluate noise impact and mitigation measures in classical approaches.

4 Conclusions

Online VR has immense potential for enhancing e-participation in urban sound planning. The application developed in this study is a demonstration of how such applications can be built, following the concepts of gamification, easy accessibility, and real-time auralisation. The trial e-participation using this application will reveal the advantages of such applications, as well as limitations and challenges that currently exist.

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