Virtual Reality and Sonic Perception

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ABSTRACT

In simulating a sonic environment for understanding of human perception, we cannot stress more on the importance of how the sonic environment is created as close to reality as possible. Nevertheless, we consider the ability to assimilate actual human movement while listening or perceiving is of equal importance as the sonic environment is spatial, temporal, dynamic, and complex. The paper introduces some of the latest VR technologies and presents how such technologies possibly enhance immersive experience and perception of future sonic environment.

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1. INTRODUCTION

Humans are exposed to all kinds of sounds throughout their lives. Sounds can be good or bad, depending on the perceptions of receivers. In cities, most people are exposed to the sounds emitted from anthrophonic sources such as vehicles, construction equipment, mechanical systems in buildings, household appliances, amplified music, trade activities, etc. Nevertheless, people can also experience sounds from biophonic sources such as birds, dogs, cats, monkeys, insects, etc. in parks and suburban areas of cities. Besides, there are geophony sounds such as rain, wind, thunder, sea wave, waterfall, etc. (1, 2) Positive sonic environments can help maintain human psychological and physiological well-being (3-5) while negative sonic environments induce stress, create anxiety, and adversely affect human health (6-8). Because of that, many governments have enacted noise control ordinances or noise regulations in the past decades (9-11). The governments set different 'acceptable' noise levels for different places at different periods of time. Unfortunately, in-situ noise measurements indicated that the measured noise levels actually exceed the 'acceptable' noise levels at most of the time (11). But how bad the situations are has yet to be properly assessed. It is because sonic environments are spatial, temporary, dynamic, and complex. A single point energy-average noise measurement over a period of time (say one hour) i.e. $L_{\text{eq-1 hr}}$ is very unlikely to truly reflect the influence due to the complexity of sounds on human perceptions. As the advent of auralization, visualization, and other sensory technologies, it is now possible to immerse people in a virtual space and let them explore and experience the change of sonic environment dynamically.

2. VIRTUAL REALITY

2.1 Definition and the Use of Virtual Reality

The term, virtual reality or "la réalité virtuelle" in French, was used by Antonin Artaud who described the illusory effect of objects and characters in theatres (12). Jaron Lanier later popularized virtual reality by founding VPL Research which designed and produced virtual reality goggles, data

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gloves, 3D audio system, and virtual reality software system (13). Virtual reality is generally defined as a computer-simulated environment in which an individual can look, move around, and experience other sensory stimuli in that environment (14, 15).

Virtual reality has been applied in different manufacturing settings ranging from machining, assembly, inspection, to other complex processing simulation (16-18). Virtual reality has also been applied in education (19, 20) and medical training (21, 22). As virtual reality can produce telepresence and allow an individual to experience an environment without actually visiting the place, it has also been used in the areas of rehabilitation, therapy, and psychotherapy (23-25). Annerstedt et al. (25) studied physiological stress recovery with sounds of nature in a virtual reality forest. The results of their study demonstrated that stress recovery was facilitated by the addition of sounds of nature in a virtual green environment.

2.2 Virtual Reality Technologies

According to Mujber, Szecsi, and Hashmi (17), virtual reality technologies shall enable an individual to mentally 'go' through a display into a three-dimensional space in which its realism depends on how human stimuli are triggered. Virtual reality systems can be broadly categorized into non-immersive systems, semi-immersive systems, and fully immersive systems (17). Table 1 shows the characteristics of these systems.

Table 1. Characteristics of virtual reality systems

	Non-immersive	Semi-immersive	Fully immersive
Input devices	Keyboards, mice, joysticks, or trackballs	Joystick, space balls, or data gloves	Data gloves, voice commands, or motion commands,
Output devices	High-resolution monitor	Large ultra-high resolution monitor, large screen projector system, or multiple-monitor system	Large ultra-high resolution monitors, or head mounted displays.
Display resolution	High	Ultra-high and large	Ultra-high
Audio quality	Mono-sound	Stereo or surround sound	3D audio
Other sensory stimuli	No	No	Yes
Sense of immersion	Low	Medium-high	High
Interactivity	Low	Medium	High

Adapted from Mujber, Szecsi, and Hashmi (17)

3. SONIC PERCEPTION

3.1 Sonic Perception

Perception is the collection, filtering, organization, identification, and interpretation of sensory information in order to understand, articulate, and represent the environment (26). Human perception involves two processes. One of them is to convert sensory input from low-level information to higher-level abstract information such as extracting shapes or features for later processing. Another one is cognitive recognition in which the processed information is connected with a person's experiences, concepts, and expectations i.e. her/his knowledge as well as a person's selective mechanisms i.e. her/his attention that influence perception (27). Hence, 'perceiving is selecting' and the perceptive action of hearing depends on a person's intention and selection (28). As perception as a spatial action is influenced by sensorial stimulations and cognitive representations, sonic perception depends on the acoustic features of sounds, other non-acoustic features of the environment, and the person's characteristics (28).

3.2 Effect of Sound on Human in a Virtual Environment

As mentioned earlier, Annerstedt et al. (25) reported that the existence of natural sounds positively influenced physiological stress recovery in a virtual green environment. Brinkman, Hoekstra and van Egmond (29) studied the effect of 3D audio and other audio techniques on virtual reality experience. Using the sound clip of a flying wasp, Brinkman, Hoekstra and van Egmond reported that people were able to differentiate between mono, stereo, surround, and 3D audio files of the flying wasp. Brinkman, Hoekstra and van Egmond found that the format of sound file had significant effects on people's spatial perception, presence, and self-reported anxiety. The results of their study also indicated that adding sounds had a significant effect on people's experience in a visual virtual space. Nevertheless, there was no significant difference between people's experience in a virtual environment using stereo sound and that in a virtual environment using 3D sound (29).

Recently, Aletta, Kang, Fuda, and Astolfi (30) investigated the effect of different footpath materials used in urban parks on soundscape quality and walking quality perception. Using a large screen projector system and a 2.4m x 0.6 m walking platform in an anechoic chamber, Aletta et al. (30) reported that different walked-on materials for footpaths in urban parks influenced participants' soundscape perception and haptic comfort. Aletta et al. (30) found that among four studied materials, namely grass, wood, gravel, and stone, grass was found to be the most appreciated materials and gravel was found to be the most unwanted footpath materials, for both haptic and auditory sensations.

4. VIRTUAL REALITY AND SONIC PERCEPTION

4.1 Virtual Reality App

Chung, To, and Schulte-Fortkamp (31) presented a virtual soundwalk application software i.e. app that would enable users to auralize different background and foreground sounds and link those sounds to a three-dimension, virtual, photorealistic environment. On one hand, the app allows soundscape designers to virtually create, place and move objects in a 3D scene, assign sonic characteristics and attributes to each object, and facilitate free navigation to obtain an immersive experience so as to iteratively revise or fine tune the soundscape design. On the other, the app allows crowd-sourcing of comments and feedback from stakeholders expressing how they feel and rate.

The architecture of the app comprises three major elements, namely, the 3D scene, the sonic and the interaction. The 3D scene was designed to be adaptive to prevailing rendering engines so as to allow flexibility in future expansion. Visual animation and audio-realistic of objects were included into the app to make the scene look more lively and easy to interact, implementing with careful consideration in camera position, lighting and shading, use of materials and texture as well as visual effects. The sonic computation was referenced to basic principles of acoustics, from sound source, propagation, to screening etc. and realized using techniques such as 3D spatial sonic, real-time mixer and signal flow control on sound sources, etc. The interaction system was designed to provide an intuitive first-person experience to navigate around the virtual world using the meshing technology as well as run-time determination of moving and colliding, height and line of sight, and pace of navigation, etc.

4.2 Designing Soundscapes

The app allows users to experience a wide range of sonic environments when they walk along different paths i.e. following different walking trails. Town planners, architects, and designers can change settings in the virtual environment so as to create different sonic environments in each of the possible locations. Sound-generating features such as waterfalls, fountains, trees in which birds may sing upon the tops, playgrounds, meeting places, etc. can be added as so as to alter sonic environment. In so doing, a desired future sonic environment can be specified while environmental noise problems can be identified and avoided during the planning stage. The acoustic features of each sound including its magnitude, directionality, attenuation rate, temporal change, etc. have to be close to reality as possible.

4.3 Augmented and Mixed Reality

To further enhance the immersive experience and perception of future sonic environment, visual reality is considered to be as important as sonic perception. One of the logical next steps is to adopt augmented reality (AR) technology. Instead of having a purely computer-generated scene, AR technology allows 3D virtual objects to be overlaid, either static or dynamically, onto the real world providing an even more realistic perception. Combining VR and AR gives the mixed reality where there are planned developments in the scene which are non-existent in the present physical world.

5. CONCLUSIONS

This paper gives an overview on how important it is to provide a realistic visual and sonic scene for better sound planning of any cityscape. A review has also been given on some of the latest VR technologies, indicating that the adoption of which in computer software application is useful enhancing immersive experience and perception of future sonic environment. The authors further consider the use of augmented and mixed reality technologies to be one of the very next moves, in particular for situations where future developments have to be included in the scene.

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