SPHÉRACOUSTICA: MEASURING USER'S IMMERSIVE ACOUSTIC PERCEPTION ON AUDIO DISPLAYS

Hector Szabo, Bessam Abdulrazak, Philippe Mabilleau, Mauricio Chiazzaro
Laboratoire DOMUS, Université de Sherbrooke, Québec, Canada

ABSTRACT

Sound positioning in virtual immersive acoustic environments is a demanding task for people with visual impairments. The goal of our research is to create a model of user audio perception, to enhance game experience for persons with visual impairments. We present the immersive audio game engine developed to gather user performance localizing 3D sound virtual position and the experimental setup.

I. INTRODUCTION

Sound localization in a virtual immersive acoustic environment contributes to enhance user's experience assisting the navigation and recognition of virtual environments by persons with visual impairments. Sound probes help the user, by giving orientation clues in the absence of other usual sensing guides, such as: sun heat, wind or odors.

Immersive acoustic environment design faces the challenge of sound probe selection. In an immersive environment without visual display these probes represent scene, characters and special effects.

Existing immersive acoustic environments describe the scene to the user orienting her or him with different approaches. "Terraformers" game uses a virtual "talking devices" (PDA, Sound Compass, Sonar, GPS) to give clues and guides [1]. "Demor" game uses sound beacons (non-speech) and music to orient and provide game context to a user [2]. "Audio Quake" uses "earcons" (non-speech sound beacons) to help navigation and localization tasks while using effects as reverb to signal closed spaces dimensions or air-movement sound to signal open spaces [3]. We opted to use non-talking acoustic beacons integrated to the scene (i.e. a water droplet, a cricket). This approach could be less artificial and may be used in immersive simulators or games. The selection of "good" acoustic beacons is essential to ensure user understanding of the proposed virtual world [4].

Audio probe selection is not intuitive: sound probes are rendered simulating distance, azimuth, elevation and effects like Doppler or reverberation. These simulated audio positions may be more difficult to perceive than natural sounds. Rendered sound perception could produce unexpected recognition difficulties. [4][5] We have found initial evidence of these difficulties while creating immersive audio games and measuring user performance in those games. [4][7]

The objective of our research is to produce guidelines to orientate acoustic designers in the selection of appropriate sound probes.

We created a tool (SphérAcoustica) to collect user performance information identifying the virtual location of different sound renderings. User perceives the tool as an acoustic immersive game, which could be a dancing game or even an "aim and shoot" activity. The engine represents the immersive world without graphical interface allowing persons with and without visual challenges to share game activities on an equitable base. The game plays acoustic beacons of different lengths and frequency ranges around the user at different virtual azimuths, elevations and distances. The engine controls game interactions and records experimental variables of interest: user response time, pointing time, targeting precision and the pointing path. The tool takes a picture and tracking information of the user to record her or his alignment with the speaker array.

II. PREVIOUS WORK

We have participated in the creation of acoustic games in the academic context. In

those games, the user was challenged to find his way out from a labyrinth and seek “collectible objects” without visual display, based on virtually placed “3D” sounds used as user orientation guides [7] [8]. The development process aroused usability issues on selected sound beacons and audio effects, because some of the audio probes were harder to localize than expected. Those tests were done at advanced game development stages hence impacting on game production time and costs.[9]

We had measured the user perceptions of audio effects, using “Acoustic Dance Dance Revolution” (ADDR), an inclusive 2D audio game without visual interface. This tool automatically gathers user performance. [10]

Early observations with ADDR [10][11]

ADDR was originally proposed as a fitness tool for visually impaired persons. We found the possibility to include the automatic gathering of user performance as an indicator of sound probe usability as acoustic beacons. The tool captures the user response time to do a “dance step” oriented towards beacon virtual position. At the same time, the engine takes a picture to record user orientation at the “stepping” moment and the tile selected by the user.

Users performed better with higher pitched sounds. Total hits per user spread over larger ranges at any condition (blindfolded, open eye, basic dancing score, or advanced dancing score) using lower frequency beacons.

Users felt that their acoustic perception was better when blindfolded; nonetheless, they performed worse against expectations and personal sensations. We found that the absence of tactile references induced some users to rotate, degrading their accuracy. [11]

III. SPHÉRACOUSTICA PROJECT

Objectives

The goal of our research is to produce guidelines for acoustic designers in order to help them in the selection of appropriate sound probes for users with and without visual challenges.

Experimental design

The experimental design is an evolution of our previous work with ADDR. The game proposes to the user different sound probes. The user moves an “acoustic sight" pointing to virtually placed sounds using two game controls. The game has no visual interface.

Sound probes are our independent variable. Our variables of interest are user initial response time, user pointing time, user precision, and the pointing path. The tool takes a picture and head tracking information when user clicks on the target, recording her or his alignment with the speaker set.

These measurements are used as an objective indirect evaluation of user capability to identify different audio beacon positions. [12]

We use three wide band sounds in low, medium and high pitched ranges. Each sound probe is presented in a short and long version (one and ten seconds, respectively). Sound probes are rendered at 26 different virtual positions around the user (azimuths of 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, and elevations of 0°, 45°, 90°, -45°, and -90°). Virtual sound distance is the same for all events. Each combination of sound probe, length and position is proposed thrice to the user. This requires four game sessions, played the same day with rest periods between games. Users without visual challenges play two game sessions blindfolded.

Users perform a game learning activity with a special training game with spoken guides. In this training game the users learn the interface, game characters, game rules and how to use game controls. We do not take into account user performance captured while learning.

Four users performed SphérAcoustica proof of concept tests, and we plan to do the experiment with 40 users. Half of them should have visual challenges from moderate visual impairment to blindness, according to WHO categorization. [13] However, we will not be considering blindness level categorization, although we will register visual illness evolution in the anonymous user record.

Experimental setup

We use a controlled listening room at the GRPA Laboratory of Sherbrooke University. This laboratory is an audio controlled environment equipped with a set of flat response speakers and a multichannel amplification system. Audio probes are rendered with an external low cost generic USB 7.1 audio card via optical interfaces. A standard PC located outside the listening room runs the game. A USB cable connects the Webcam to the PC, and a Bluetooth USB card connects game controls and infrared cameras to the PC.

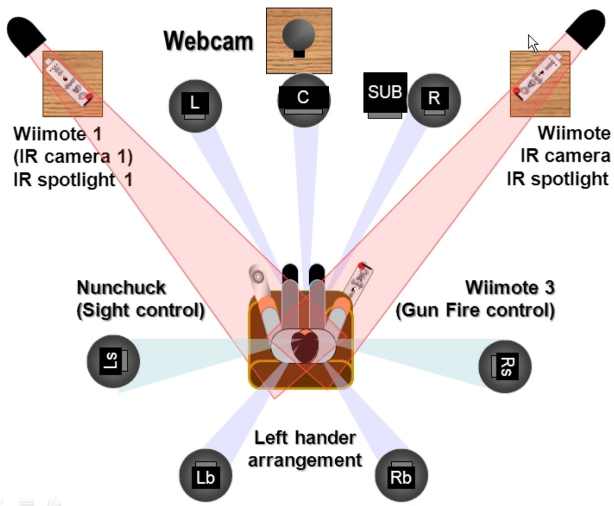

Figure 1: SphérAcoustica lab arrangement

User plays the game seated at the laboratory acoustical hot spot with a set of Nintendo controllers one on each hand, which allow "pointing" and "triggering" activities. We expect a reduction on misalignment problems aroused on previous experiments with this static position. Two extra Nintendo Wiimotes and a Webcam point towards the user, to record her or his position and torso tracking information at "triggering" event. To support this tracking feature, the user has three IR reflective stickers on head and shoulders and is illuminated with two IR reflectors. Tracking information and user image allows the automation of user misalignment detection, reducing the analysis effort on post-game image treatment.

To support "pointing", the game renders an "acoustic sight" at selected position. This rendering uses the same algorithms used to virtual position the targets. This approach neutralizes displacements on location perception, as far as sight and target are both interpreted with the same technological and physiological means.

User game perception

"Park Témiscouata" game stages an ecological activity: user must tag some animal species with a "marking gun" using game controllers. It is perceived as a first person shooter game (FPS). [14]

The gameplay presents three animals to be marked: moose (Alces Alces, low pitched sound), snowy owl (Bubo Scandiacus, high pitched sound) and great horned owl (Bubo Virginianus, medium pitched sound). We use real call sounds edited to adapt frequency range to the experiment needs. The action is done at night, thus, user must point using an acoustic sight using her or his virtual sound perception. User pointing is done by displacing a "sonar-like" audio effect serving as an "acoustic sight".

The user has a Nintendo "Nunchuk" control and "Wiimote" control. Pointing is done with the "Nunchuk" control and triggering is done using the Wiimote trigger.

Game presents sound probes on a pseudo random sequence. In this sequence, we displace next rendered sound 135° in azimuth and 45° in elevation from the previous sound probe. This is done at right or left, up or down on an irregular basis. This homogenous angular distance will require the same pointing effort in all cases, allowing the comparison of different pointing and triggering events.

Game engine technological aspects

"SphérAcoustica" is a Java application running on Linux platforms. It uses OpenAL primitives to render monophonic sounds on a virtual spherical world. This acoustic rendering virtually locates sound probes at desired azimuth, elevation and distance. Immersive game engine supports azimuths and elevation with a precision of 1 degree and virtual distance fading. In our testing game, we opted to use azimuth and elevation positions spaced 45 degrees from each other to allow users a more successful game experience.

Game engine interacts with Nintendo Wiimotes and Nintendo Nunchuk using a Java porting of WiiUse C library (WiiUseJ), allowing the engine to react to the user gameplay with Nunchuk, Wiimote joystick and buttons and to use IR cameras to do user tracking. The engine computes relative positions of sight and target when the user "triggers". All session data gatherings are automatically done while the user is playing.

IV. EARLY TESTS STAGES

At this stage four users had tested one short script (20 events) in a residential environment with a 5.1 speaker array. They found the acoustic pointing activity challenging but feasible after two game sessions. Sounds were adequate and pointing quality was more stable in lateral positions, for all frequencies. Since we were using a 5.1 speaker array, we did not test elevation and deflection perception.

V. CONCLUSIONS

The use of directional sound probes, earcons or acoustic clues is used to create a comprehensible virtual world for users with visual challenges. A model allowing a clearer selection of probe characteristics will enhance user experience. Early results show that playable games can be done with SphérAcoustica, allowing automated gathering of performance information. This information will help us to define this model and to compare the user performance for persons with and without visual challenges.

ACKNOWLEDGEMENTS

This work is supported by the resources and collaboration of GRPA laboratory (Groupe the Recherche sur la Parole et l'Audio) of Sherbrooke University.

REFERENCES

[1] T. Westin, "Game accessibility case study: Terraformers – a real-time 3D graphic game", *Proc. 5th Intl Conf. Disability, Virtual Reality & Assoc. Tech.,* Oxford, UK, 2004

[2] E. Velleman, E. van Tol, S. Huiberts and H. Verwey, "3D Shooting Games, Multimodal Games, Sound Games and More Working Examples of the Future of Games for the Blind", *Lecture notes in computer science, Volume 3118/2004, 624*, Linz, 2004.

[3] M. Atkinson, S. GucuKoglu, C. Machin, A. Lawrence, "Making the Mainstream Accessible: Redefining the Game", Proceedings of the 2006 ACM SIGGRAPH symposium on Videogames, Boston, MA, USA, 2006.

[4] F. Alonso, J. Fuertes, L. Martínez, H. Szabo; "Análisis de Percepción en Entornos Acústicos Envolventes con Asistencia Háptica para Ciegos"; *AST 2005*, Rosario, Argentina, 2005.

[5] A. Gonot, N. Chateau, M. Emerit, "Usability of 3D sound for navigation in a constrained virtual environment," *120th AES Convention,* Paris, France, 2006.

[6] K. Doerr, H. Rademacher, S. Huesgen, W. Kubbat, "Evaluation of a low-cost 3D sound system for immersive virtual reality training systems," *IEEE Transactions on Visualization and Computer Graphics*, *Vol. 13, No. 2,* March / April 2007

[7] S. Franco, A. Segovia, "Audio game, escape de la Fortaleza de Santa Teresa," *Ort University,* Montevideo, Uruguay, 2004.

[8] M. Babuglia, N. Fernández, P. Pereira, G. Cuiñas, M. Lazar, "Audiojuegos. SHADE. simple haptic acoustic development engine," *Ort University,* Montevideo, Uruguay, 2005

[9] F. Alonso, J. L. Fuertes, L. Martínez, H. Szabo, "Design guidelines for audio – haptic immersive applications for people with visual disabilities," *Lecture Notes in Computer Science, Volume 4061*, Linz, 2006.

[10] D. Cohen, V. Machado, "Percepción de sonidos direccionales en un entorno virtual 5.1," *ORT University,* Montevideo, Uruguay, 2007.

[11] H. Szabo, P. Mabilleau, B. Abdulrazak, "Acoustic dance dance revolution: an automated test tool for 3D sound perception evaluation", *AES 35th International Conference,* London, UK, 2009.

[12] S. Bech, N. Zacharov, "Perceptual audio evaluation," *John Wiley & Sons,*NY, USA, *pp. 30-36*, 2006.

[13] WHO, *"International Classification of Diseases, ICD-10",* Chapter VII, section H54, as published in http://apps.who.int/classifications/apps/icd/icd10online/, 2011

[14] K. Hullet and J. Whitehead, "Design patterns in FPS levels," *FDG'10 Proceedings of the Fifth International Conference on the Foundations of the Digital Games,* ACM, NY, 2010