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# Realistic Real Time Simulation of Room Acoustics using Virtual Reality with Auralization

## *Development and Initial Testing*

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*This paper describes the development and initial testing of a Virtual Reality with Auralization system. To facilitate a realistic auralization, sound sources were recorded in an anechoic room and inserted into a test scenario. The scenario was presented to test persons in order to evaluate the realism of the system, and provide feed-back ahead of further development.*

**Keywords:** *Virtual Reality, Auralization, System Development*

## INTRODUCTION

Evaluation of the acoustic quality of a room is in most cases based on exact and precise calculations of specific positions in a room. Realistic real time simulation of room acoustics in Virtual Reality (VR), also known as auralization, is another usable tool for evaluation, allowing comparison of multiple design options set against each other.

VR with real time auralization can act as a supplement to detailed acoustic calculations made by acoustic engineers. This method provides the ability to listen to how an acoustic design solution sounds (Kleiner, Mendel; Dalenbäck, Bengt-Inge; Svensson, 1993; Savioja and Svensson, 2015), and base design decisions on experiencing the acoustic perception of a room, in addition to the quantitative results from calculations.

In this paper we use the definition of Auralization formulated by (Schröder, 2011) as: Analogous to visualization... the generation of aural stimuli that correspond to the current sound propagation throughout the simulated scene".

VR in the building industry has previously primarily focused on the visual aspects of the tool, allowing immersion and interactivity, better perceptual experiences and communication leading to better decision making (Niu and Leicht, 2016; Roupé, Johansson and Tallgren, 2016).

Even though VR is used for many types analysis and evaluation of the indoor environment on design projects, the building industry nevertheless rarely include auralization to evaluate the acoustic qualities of rooms or buildings (Vorländer, 2008; Pelzer et al., 2014). The acoustic indoor environment is however just as important for the user experience of a room or building, as the thermal, atmospheric and visual indoor environment.

VR can act as a mean for communication between users and designers (Sørensen and Svidt, 2017) and additionally function in the same way as real life mock-ups, however without the same special and financial expenses involved (Zou, Li and Cao, 2017).

The acoustic design is especially influential in open office environments as unwanted sounds, often described as noise, is suggested to cause interruption, irritation and lowered performance for people perceiving it (Roelofsen, 2008; Seddigh et al., 2015). Sound disturbance is however not necessarily based on a particular sound or the magnitude of a sound, but how the sound is perceived (Roelofsen, 2008). Accordingly, some sounds might appear more annoying in real time than what calculations of the acoustic design might indicate. Realistic auralization in room acoustics is challenging, as a result of the sensitive perception of sound people have (Vorländer et al., 2015).

We designed a VR with Auralization system allowing realistic perception of sound, focusing not only on the acoustic calculations, but also on the realism of the auralization, to facilitate a better foundation for decision making with respect to the acoustic design, allowing for a realistic perception of sound within the virtual environment.

Informal user experience tests using scenarios inserted into the system with real time auralization were performed. The scenario was supplied with realistic sounds from typical one family housing units and educational buildings, allowing testing of the system's realism. Testing additionally allowed us to attain new information about the system and its capabilities ahead of further system development.

## METHODOLOGY

To test the VR with Auralization system, anechoic-recorded sounds were inserted into a 94 m2 lecture room test scenario in VR. Sound sources were placed in the scenario using the Epiito Software and AM3D auralization software, based on the Unity Game Engine.

The VR setup for testing included the Oculus Rift CV1 head mounted display (HMD) for the visual part and Seenheiser PC 363 D headphones for playing the sounds during the real time auralization.

The VR with auralization was then examined by multiple persons, with the intention of evaluating the realism of the recorded sounds, the placement of the sound sources, and the realism of the perception possible in the system.

The acoustic quality of the test scenario was based on manual adjustment of the sound levels of the sources. The reverberation was adjusted by a choice of absorption coefficients based on the actual materials in the room and knowledge of the reverberation time.

### *Empiric data collection*

Empiric data were collected based on the contextual design methodology as described by (Beyer and Holtzblatt, 1997) using contextual inquiry, to both ask questions to the test persons, and observe the test persons during their interactions with the system.

### *Recording setup and entities*

Even though sound is perceived differently from person to person, the sounds used for auralization in evaluation of room acoustics, the quality of recordings need a known calibrated recording chain without influence of reverberation from surroundings.

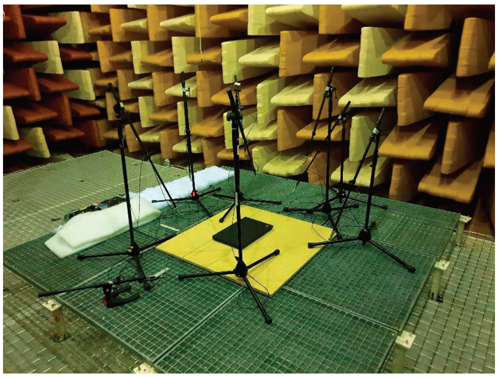

Figure 1
Recording of sound from a laptop in an anechoic room. A square wooden board was placed under the laptop to ensure realism of the recording.

As part of this study, sounds were recorded in an anechoic room at the Department of Electronic Systems at Aalborg University. The anechoic room has sound absorbing wedges assuring a reflection free environment down to approximately 65Hz.

8 G.R.A.S. 40AZ microphones with preamplifier type 26CC were placed around the entity being recorded. In this paper, an entity refers to the thing or process being recorded. The sound was recorded through an RME Micstasy sound card (44.1 kHz 24 bit) using a multi-track recording software on a PC.

Microphones were placed with a distance of 500 mm from the entity being recorded, placed in a sporadic grid constellation as shown in figure 1.

The entities being recorded were selected based on analysis of common household appliances and electronic equipment in typical one family housing units and educational buildings. The scope was thusly limited, to ensure usability of the auralization with VR, in new design and renovation of typical family houses and educational buildings.

### *System testing*

The system was tested using informal experience tests, involving both software and method developers and end users of the VR with Auralization system.

Test persons were instructed to walk around in the scenario and listen to the sounds of the various sound sources placed in the room, as shown i figure 2. The test persons were also instructed to consider the sound transition of the multiple sound sources placed in the scenario.

The sounds played in the scenario were:

- Speech.
- Sound from electronic equipment.
- Sound from construction work through an open window.
- Sound from neighbouring room through an open door.

All sound sources were placed in a fixed position on a specific surface in the scenario.

The testing of the scenario was conducted in the exact room the scenario was based on, at Aalborg University. To make the scenario as realistic as possible it was furnished in the same way as the real room. This was done to allow the test persons to easily compare the experience of the VR scenario to the real room.

## FINDINGS

- The overall reactions by the test persons were that the perception of sound through the VR with Auralization system was realistic, and gave a keen understanding of the acoustic qualities of the scenario.
- The ability to interact with the virtual environment allowing the test persons to relocate furniture in the scenario, was a distraction for some of the test persons, who seemed to occasionally focus more on the capabilities of virtual reality than the auralization.
- As some of the test persons were not accustomed to the use of VR, the controlling of the avatar made some of the test persons give up moving around in the scenario, which limited their feedback with respect to the realism of the sound sources.
- The sound source of a neighbouring room, was placed on the open door. When passing through the door all sounds were muted, which was commented by a couple of test persons, as a limitation to the realism of the system.
- As the sound sources in the scenario had a fixed placement, some of the test persons experienced a lowered realism of the sounds movement in the room, as the sound perception was only altered in volume when moving around, and not how the sound was reflected from surfaces.

## DISCUSSION

As the use of Virtual Reality (VR) has seen increased use in recent years for various types of design and construction evaluation, including acoustic evaluation, using auralization to the wide portfolio of VR-uses therefore seems logical. Even though full real

Figure 2
Test persons navigating around the test scenario.

life representation of the visual aspects in VR is not a necessity (Pitt et al., 2005), this is not the case when it comes to acoustic design evaluation using VR with auralization.

To be effective as a decision tool for acoustic design, a high degree of realism is imminent. This means the perception made possible by the system must sound realistically.

Virtual Reality is often used as an interactive design platform (Svidt and Sørensen, 2012; Petrova et al., 2017; Rasmussen, Gade and Jensen, 2017) with communication during use occurring either in real life, by people speaking to each other, or through a headset using internet technology to connect with people also using VR in another location.

When using VR with Auralization, with communication in either real life or through communication technology, it can be difficult to control the sound levels.

The sound levels however needs to be controllable in a way that ensures that communication and interaction with other system users sound realistic. This means that sound arising from communication by users, must be played and controlled, without affecting the sounds played in VR. This issue was not addressed in the user experience test. A solution addressing the problem would however optimize usage and realism of the system, when more than one person needs to communication whilst using the system.

The ability to listen to solutions allows designers to make informed design decisions, but also communicate design choices to clients and design project participants in a more tangible manner than looking at drawings, 3D models, graphs or calculations.

## LIMITATIONS OF THE STUDY

- The absorption coefficients of the system were adjusted according to actual materials in the room as well as the measured reverberation time, however, the auralization software only allowed for specification of one overall absorption coefficient per surface. So frequency dependencies of the reverberation time in the real room would not necessarily be recreated in VR.
- Only stakeholders of the system development were involved in testing, allowing an obvious bias in evaluating the system as more realistic and usable than people without a bias might have.
- Only one test scenario was used, limiting the range of generalizability of the study.
- In the current study, no quantitative methods were used to document the informal user experience test, all conclusion are therefore based on qualitative evaluations.

## CONCLUSION

This paper investigated the possibilities of realistic sound recordings and the use of such in Virtual Reality (VR) with auralization, supplementing acoustic calculations with the ability to listen to design options in a realistic real life manner, before a room or building is constructed.

Informal user experience tests of the sounds made it possible to evaluate the use and realism of the system. It additionally made it possible to see how VR with auralization can potentially supplement the acoustic design evaluation used in the design industry.

Promising results were captured during the tests, through contextual inquiry, as all test persons rated the system as realistic. Improvements however needs to be made to the VR with Auralization system with respect to placement and movement of sound sources and transition of sound between rooms or scenarios.

## FUTURE WORK

To ensure a reliable perceptual experience for users of the Virtual Reality (VR) with auralization system, further research must be done in respect to placement of sound sources in VR.

To make the system available on a larger scale, calibration of listening devices is necessary to ensure accurate playing of the recorded sounds in both headphones and through speakers, in order for the perceptual experiences to be realistic. Such calibration device must therefore be developed as part of future development of the system.

Unbiased tests of the system is needed in order to evaluate the system, its use, and its usability with respect to the design industry in general.


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