Modifying the Virtual Acoustical Room Size in an (CAVE) Echoic Environment

Ercan Altinsoy, Thilo Gürtler, Sebastian Merchel

Dresden University of Technology, Chair of Communication Acoustics, Germany,

Email: ercan.altinsoy@tu-dresden.de

Abstract

Auralization of the environments (virtual or real) is based on the modelling or measurement of the room impulse response. Impulse response of a room contains information about the room size and room dimensions [1]. The late reverberation part of the impulse response characterizes mainly the room size. Therefore it is possible to modify the room size with shortening or reshaping the impulse response. At the same time in various virtual environment applications, it is possible to observe that the handling with long impulse responses in real time can be computationally intensive. In such cases, the shortening the room impulse can be beneficial. However the shortening of the room impulse is not a straight forward process, because of the artefacts. In this study, an investigation was conducted in a WFS-based virtual environment which allows simulating various room reflections. The results show that even abrupt shortening of the room impulse responses does not cause audible artefacts, if additional room reflections are generated using artificial delays. This approach might be promising for particularly CAVE applications.

1. Introduction

In this study, an investigation was conducted in a WFS-based virtual environment which allows simulating various room reflections. This system consists of 464 loudspeakers and 4 subwoofers [2]. Each individual loudspeaker is driven by wave field synthesis signals generated from the incoming audio signals and spatial parameters assigned to each sound source. The thresholds for the various parts of the room impulse response were measured. In the first experiment, the measurement criteria was the room impulse response length. The measurement criteria of the second experiment was the sound pressure level of the different parts of the room impulse response. Therefore the room impulse responses of three different places, such as a concert hall (Semper Oper), a church (Hofkirche Dresden), and an office were used. Multimodal interaction plays an important role on the room perception [3, 4]. However this investigation was limited with only auditory experiments.

2. Impulse response measurements

In the first step of this study, the room impulse responses of Semper Oper, Hofkirche Dresden, and an office room were measured. The auralization of the environments should be realized using a WFS-based virtual environment. Therefore, a virtual array with a sphere-configuration was defined for the room impulse response measurements and a prototype spherical array measurement system was developed for our lab by Fraunhofer Institute, TU Ilmenau and TU Delft. A microphone mounted on a robotic arm moves along a Lebedev distribution of discrete positions on a spherical surface [5, 6].

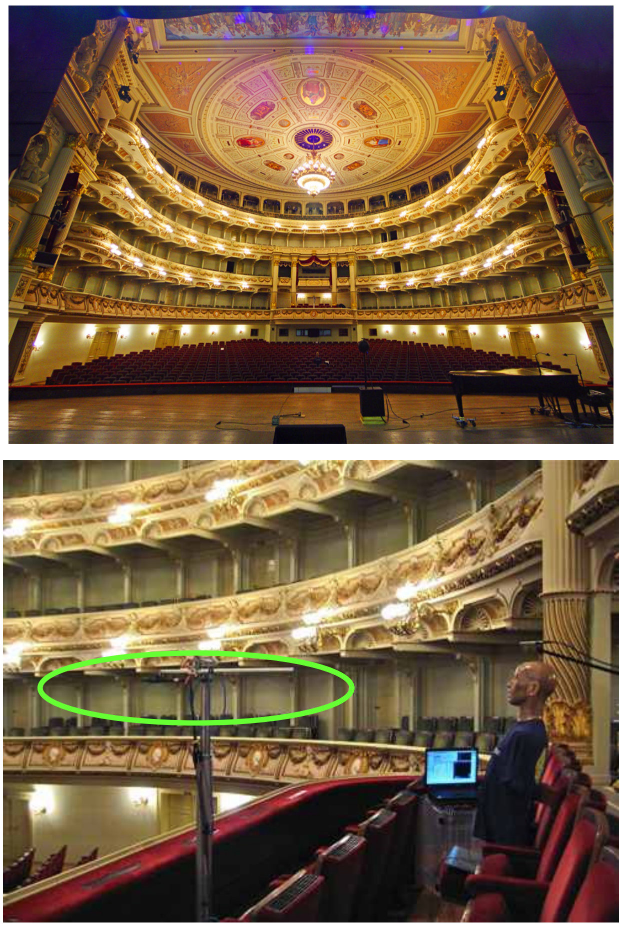

Fig. 1: Room impulse response measurements in Semper Oper. The robotic arm with the microphone (green marked) and an artificial head were used for the recordings.

3. Threshold measurements

In the first experiment, the duration of the room impulse response was varied. The aim of the experiment was to measure the just noticeable differences (JND) for the room impulse response duration. The Alternative Forced Choice (AFC) method (1-up-2-down) was used for the threshold measurements. Twenty subjects, twelve men and eight women aged between twenty and twenty-five years (mean age: 22 years), participated in the experiment. All of these subjects have no acoustic know-how. Anechoic room recordings of speech and music (guitar, pop song, classical music) signals which have 6 sec. duration, were chosen as stimuli. The sound pressure level of the stimuli was about 80 dB(A). The results of the JND investigation was shown in Figure 2.

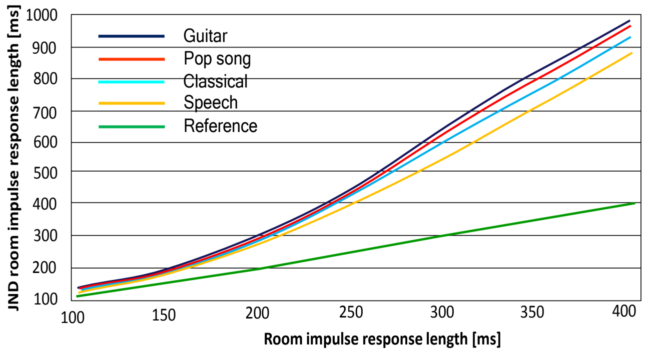

Fig. 2: The just noticeable difference measurement results for the room impulse response length. The JNDs were shown for different stimuli with different colours.

The results show that the participants are not very sensitive to the room impulse response length variations. Possibly expert listeners may have smaller thresholds than non-experts. Speech signal obtained the shortest JND results. During this investigation, if early and late reflections (The number of the reflections was 8 for each) were delayed randomly, even abrupt shortening of the room impulse responses does not cause audible artefacts. This is a promising aspect for CAVE type environments. Because of the existing natural reflections of the walls. These type of reflections can be consciously used to evoke different room impressions.

In the second experiment, the relationship between the sound pressure level of different parts of the room impulse response and the room size impression was investigated. The sound pressure level of the early and late reverberation parts of the above mentioned three room impulse response were increased and decreased. Eighteen subjects, twelve men and six women aged between twenty and fifty-five years (mean age: 30 years), participated in the experiment. Speech and music signals were used for the experiment. The subjects are asked to sort the room, which they heard, into one of seven categories (Chamber, living room, classroom, theatre, concert hall, church, cathedral). A Matlab graphical user interface was used for the experiment. The mean values and standard deviations for the late reverberation part are shown in Figure 3. 0 dB indicates the original sound pressure level.

The results show that it is possible to generate an impression of a cathedral or a chamber only decreasing the level of late reverberation part of the room impulse response. For a classroom or living room impression, a decrease of original sound pressure level about 15 dB is necessary.

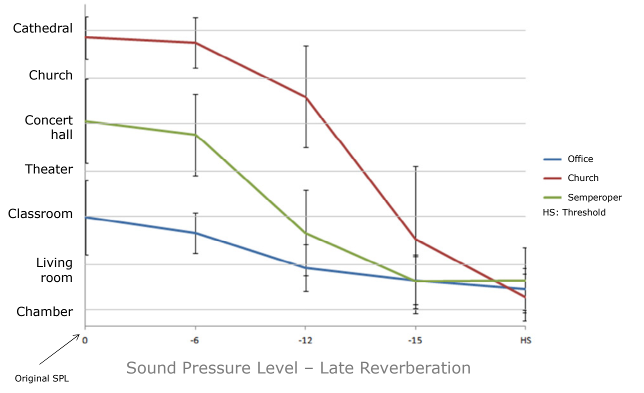

Fig. 3: The relationship between the sound pressure level of the late reverberation part and the room classification.

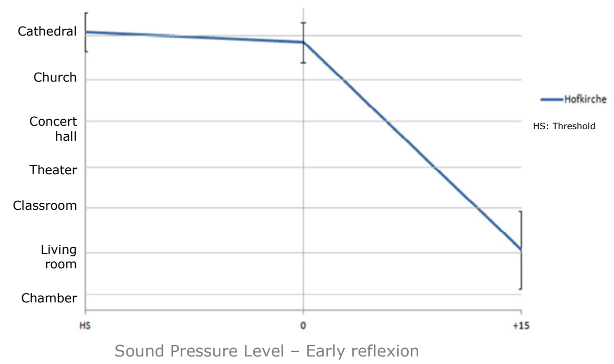

Fig. 4: The relationship between the sound pressure level of the early reflection part and the room classification.

4. Literatur

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