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A methodology and a tool for interchangeable reproduction of sound samples in listening tests through different sound reproduction systems

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ABSTRACT

A common practice in the execution of listening tests is to choose the sound reproduction system based primarily on its availability, with little regard for its potential influence on the results of such tests. To examine the magnitude of this influence, a methodology is proposed and a tool is developed for presenting sound samples through different sound reproduction systems. The tool is equipped with a user interface that enables easy and seamless change of the sound reproduction system, as perceived by the listener. The design of the tool eliminates the need for any kind of intervention that would interrupt the listening session, such as on-the-fly system reconfiguration or calibration. The goal is to achieve interchangeability between binaural reproduction using headphones and 3D Ambisonics reproduction using a multichannel loudspeaker system as a typical spatial audio reproduction system. However, the extension to two-dimensional amplitude panning systems such as stereo or 5.1 surround is considered as well. The software design of the tool is based on Cycling '74 Max programing language. The tool is to be used in listening tests focused on the subjective evaluation of overall acoustic comfort, in relation to the quality of sound insulation in closed spaces and their room-acoustical properties.

Keywords: Ambisonics, 3D Sound, Listening tests, Headphones, Speaker calibration, Max/MSP

1. INTRODUCTION

Previous studies have shown that there is not a significant difference between the usage of headphones and 3D audio reproduction systems while conducting listening tests (1,2). Nonetheless, the research questions investigated in those studies have been broadly stated and have not regarded the listening tests conducted in the research of acoustic comfort, which includes the subjective evaluation of sound insulation. This article presents a foundation of a broader research with the goal to show the differences between the current norms in building acoustics and the human perception, e.g. in the single number values evaluation of impact noise and air borne sound transmission index, or differences in perception of sound insulation. Since the preparation of the entire listening test requires a more detailed analysis of the problem (3), the organization and execution of the complete experiment will not be covered at this time. Therefore, only the technical aspects of the experiment are presented in this article.

The idea is to take a slightly new approach to the listening test methodology, which tackles the question about the optimal choice of the sound reproduction system that best suits the listening test. To answer that question better insight is needed considering the advantages and disadvantages of using a 3D audio reproduction system compared to much simpler and less expensive headphones setups for listening tests and what situations would be appropriate to use one or the other.

This experimental setup is primarily meant to be used in two similar listening rooms with the Ambisonics systems: the one located in AuraLAB at the University of Zagreb (figures 3, 4 and 5), and the one in TGM – Fachbereich für Akustik und Bauphysik in Vienna (figure 1). The technical details and measurements of the AuraLAB are shown in (4).

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Figure 1 – Ambisonics listening room in TGM Fachbereich für Akustik und Bauphysik in Vienna

2. METHOD

The system and its calibration procedure are created to allow the participant, once seated inside the listening room with the headphones on his head, to participate in the listening test in its entirety without the need for the removal of headphones. This allows the comparison of the individual's perception of the differences between those systems. The principal block diagram of the system can be seen in the figure 2.

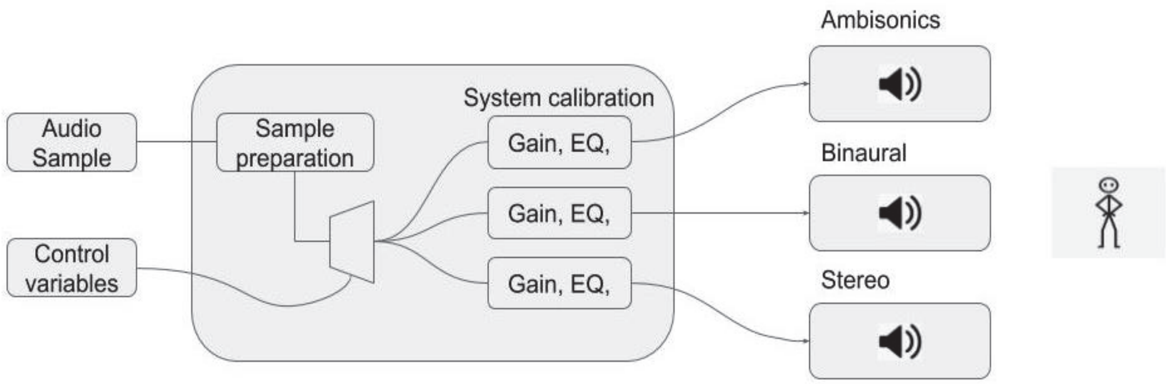

Figure 2 – Principal block diagram of the system

The inputs to the system are individual mono audio samples and control variables which allow the choice of the reproduction system and the directivity of the listening source. An audio sample gets its directivity properties inside the system and is passed through filters to assure that the system produces the equivalent stimuli on all the sound reproduction systems.

Perceived spatial localization properties can be improved by the rotation of the head (5), which would be disadvantageous for the situations when the stimuli are presented through headphones compared to the Ambisonics system where the sound field does not depend on the position of the head of the listener. To ensure the head of the participant is fixed during the listening test, the listener will be instructed to place his or her chin on a chinrest.

Considering the platform and the programing language, there are several different existing ones used for conducting standardized listening tests today, which is nicely summarized by Jillings et. al. (6). For this system, the Cycling '74 Max programing language is used due to the capabilities for a simple creation of a suitable user interface, the possibility of using third party VST plug-ins, and real time processing that will be useful for a planned inclusion of extra features to the system.

The sample preparation and Ambisonics decoding is done using IEM Ambisonics VST plug-in suite (https://plugins.iem.at/). For binaural directivity IEM BinauralDecoder uses HRTFs recorded with the Neumann KU 100 dummy head.

The level and frequency calibration of the system is made using a FabFilter Q2 EQ plug-in and its frequency match functionality, which uses up to 24 band EQ filters to match the spectrum of two signals. The use of FabFilter Q2 EQ plugin has been sufficient so far, but alternative non-commercial options are being considered, and a custom frequency matching Max patch is being developed which will allow a much better control for the majority of the calibration process.

Although the main tool is made in Max, the usage of third party VST plugins allow the system to be adoptable to any DAW, such as Reaper or Cubase.

3. SETUP AND CALIBRATION

This experimental setup assumes a single participant in the listening test at a given time. Adjustments for a higher number of participants might be possible but would require major changes to the entire calibration procedure and will not be regarded at this time. The system calibration is a process that requires several steps and its goal is to prepare filtering so the sound samples would represent the equivalent stimuli on each system on which they are reproduced.

The first step is the calibration of the individual speakers of the Ambisonics system using a measurement microphone (figure 3). A pink noise signal is played over each speaker individually and the overall level and frequency spectrum of the input signal, recorded with the microphone, is compared to the output that is being fed to the speakers. These signals are then matched so their difference is reduced to a minimum. The matching is repeated for each of the 16 speakers. This provides a flat room correction curve in the sweet spot of the room and serves as a reference in the subsequent steps of the calibration.

Figure 3 – Calibration of the system with a measurement microphone

A calibration procedure continues with the placement of the dummy head on the chair in the listening position (figure 4), simulating the situation in which the participant will be in during the listening test. The position of the dummy head's ears should be at the same height as the middle row of the speakers in the Ambisonics system. The dummy head used for this calibration process is Bruel & Kjaer head and torso simulator type 4128. A pink noise is then played over the Ambisonics system and then recorded with the dummy head. This recording is to be used as a reference signal for the rest of the calibration.

The next step of the calibration is the placement of headphones on the dummy head (figure 5). A pink noise signal is then played back via the Ambisonics system and compared to the previously recorded signal without the headphones on. A frequency correction curve is then generated to compensate for the filtering introduced with the placement of the headphones. Since the variability of headphone placement should be taken into account (7,8), the procedure is repeated several times with the repositioning of the headphones to create a suitable average for the filter.

The last step in the calibration process generates a correction curve for the playback over headphones to nullify the coloration that is introduced by the headphone's own frequency characteristic.

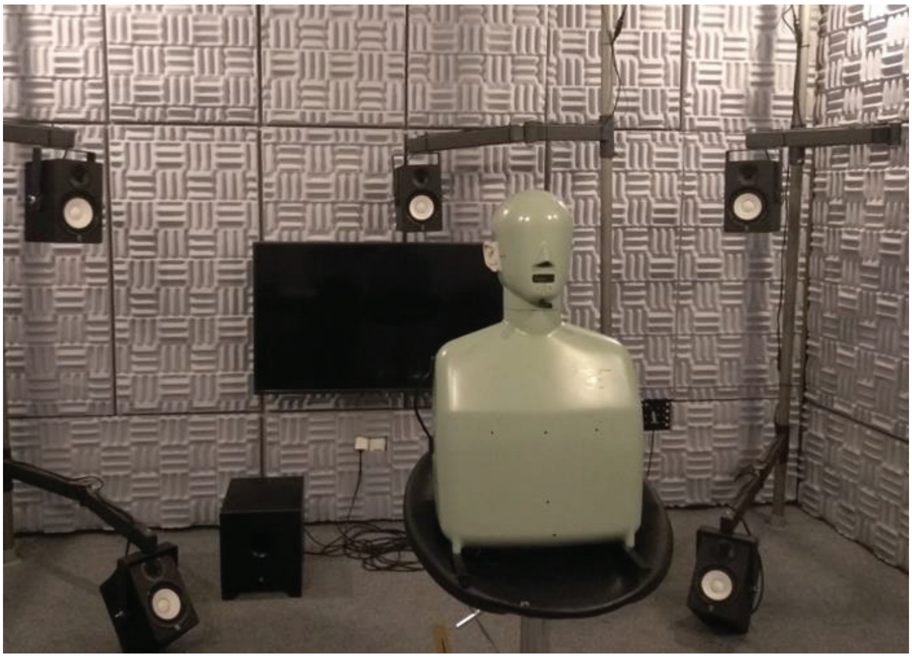

Figure 4 – Calibration step using the dummy head

Figure 5 – Calibration of the system with the headphones on the dummy head

4. DISCUSSION AND FURTHER WORK

Although this system is still in its early stage of development, it will be continuously improved through further use and implementation of individual listening tests. The addition of a real time head tracking function to this system is something that will be added in the future to remove the need for a fixation of the head position during the listening test with a chinrest. The development of the Ambisonics codec and panning algorithms is also being considered to improve the control of their parameters with which a higher level of reliability could be achieved. Also, a possibility to merge this system to the existing universal listening test interfaces, e.g. Hulti-gen (9), could provide a useful contribution to the development of such interfaces.

This system is to be used in several listening tests that are currently in preparation. Such listening tests include: a conduct of the listening tests already carried out on one of the reproduction systems and looking at the possible differences while using an additional system; a test of the perception of the localization from different systems; testing the measured sound insulation parameters of building elements with different materials and their impact on people, both in situations when people sleep or rest and during work or study scenarios that require a higher level of concentration.

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