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Data set: BRIRs for position-dynamic binaural synthesis measured in two rooms

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Abstract

Binaural room impulse responses were measured with a KEMAR 45BA head-and-torso-simulator. For the first data set, it was placed at different positions located on a line with a length of 2 m in a 25 cm positional resolution and an azimuth resolution of 4°. Two source positions were considered in the setup, one in front of the line, one at the side. The same arrangement of source and receiver positions was realized in two different rooms, a quite dry listening laboratory and a quite reverberant seminar room. For the second data set, BRIRs and omni-directional RIRs were measured for a translation line with a length of 7.5 m through the given seminar room. The data sets are valuable for realizing, testing and studying dynamic binaural walk-through scenarios in the two different rooms.

1. Introduction

Today, devices for experiencing virtual and augmented reality are available to everyone and can be used even at home. The user can move within a certain area that is covered by motion capturing modules. For devices like head mounted displays the audio reproduction is usually realized over headphones with dynamic binaural synthesis.

To provide efficient audio rendering algorithms for position changes of the listener, researchers are currently investigating potential for simplification in psychoacoustical and data-driven studies. Various approaches for interpolation and extrapolation are considered. In this context data sets with binaural room impulse responses (BRIRs) measured at densely arranged positions for varying head rotation angles are of interest, e.g. to provide a reference scenario.

Within this publication, the measurement of such data sets for two different rooms is documented. The created data sets are provided for free download.

2. Data set 1 - 2 m line in two rooms

The same arrangement of loudspeakers and a line of 9 listening positions with a length of 2 m was realized in two rooms, a relatively dry listening laboratory and a quite reverberant seminar room. The direct sound is similar in both scenarios, but the amount of reverberant energy as well as the spatio-temporal structure of the early reflections differ with the room.

2.1. Room 1 - Listening laboratory

The first room is the listening laboratory of the university in Ilmenau. The room has a size of 8.4 m×7.6 m×2.8 m, a volume of V =179 m^3 and a reverberation time T_{60} =0.27 s (broad band). It complies recommendation ITU-R BS.1116-2.

A translation line with a length of 2 m was defined within the room as illustrated in Figure 2. A G.R.A.S. Kemar 45BA head-and-torso-simulator (HATS) with large ears was positioned on an electronic turntable Outline ET 250-3D for accurate rotation. Two loudspeakers Genelec 1030A were placed in the room, one in front of the translation line, the other a the side as illustrated in Figure 2.

Fig. 1: The measurement setup in the listening laboratory.

The translation line covers the distances of 1.25 m to 3.25 m to the center of the frontal loudspeaker and passes the second loudspeaker with a minimum distance of 1.25 cm (center head to center loudspeaker).

BRIRs were measured at nine positions with equal distances of 25 cm along the translation line. At each of the positions measurements were conducted with an azimuth resolution of 4° over the full 360° rotation of the HATS. Elevation changes were not considered. For the measurement a swept sine method with a logarithmic sweep ranging from 50 Hz to 20 kHz over a duration of 3 s was used.

2.1.1. Psychoacoustic evaluation and further experiments

In order to conduct a psychoacoustic evaluation, Neidhardt and Knoop [1] asked subjects to rate the plausibility of the position-dynamic binaural reproduction in a Yes/No paradigm without including a real version of the scene. With regard to their inner reference all participants rated the BRIR data set as plausible for the frontal loudspeaker reproducing male speech and a pop song.

In another study Neidhardt et al. [2] investigated the perceptual consequences of systematic simplifications of the BRIR data set in an interactive position-dynamic exploration scenario. The original data set was included as one of the test cases and was again rated as plausible by all participants.

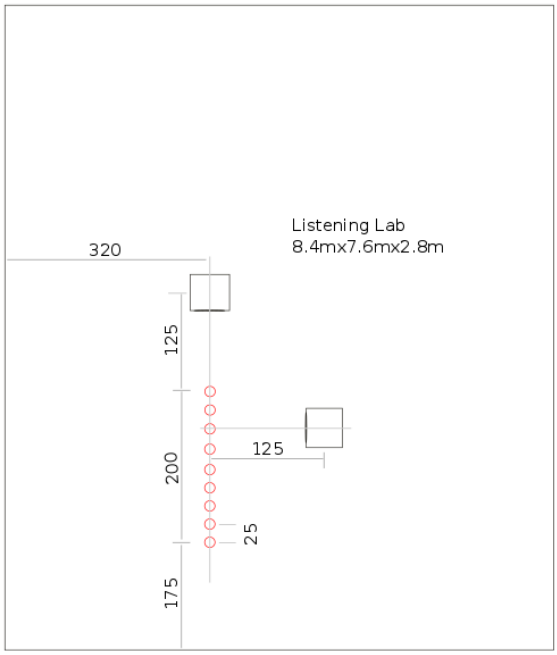

Fig. 2: Measurement positions of the Kemar 45BA and the two loudspeakers in the listening laboratory.

In both studies STAX SR-202 headphones with a non-individual headphone compensation filter with roll-off frequencies of 80 Hz and 20 kHz were used. The headphone filter was created from a measurement with STAX headphones positioned on the Kemar 45BA by the least squares approach according to the description by Schärer and Lindau [3].

Furthermore, in both studies pyBinSim [4] was used for the dynamic auralization. When switching between filters only a very short cross-fade in the time domain was applied. No interpolation or extrapolation was used.

2.2. Room 2 - Seminar room

The same arrangement of source and receiver positions was set up in a seminar room of the university. The room has a size of 9.9 m×4.7 m×3.1 m, a volume of V=144 m^3 and a reverberation time of T_{60} =0.99 s (broadband).

Again, the HATS was placed on the turntable at 9 positions along the translation line with the length of 2 m. The location of the translation line in the room is illustrated in Figure 3. A photo of the measurement setup shown in Figure 4. BRIRs were measured with an azimuth resolution of 4°.

2.2.1. Additional BRIRs: Same setup with headphones

In order to study the plausibility and authenticity as suggested in [5] and [6], BRIRs need to be measured for a scenario that can be directly compared to a real sound field. In such test subjects should not need to take the headphones off and put it on again. To create BRIRs for such a test paradigm, open headphones were placed on the HATS as shown in Figure 5.

In previous studies, extra-aural headphones were used. The

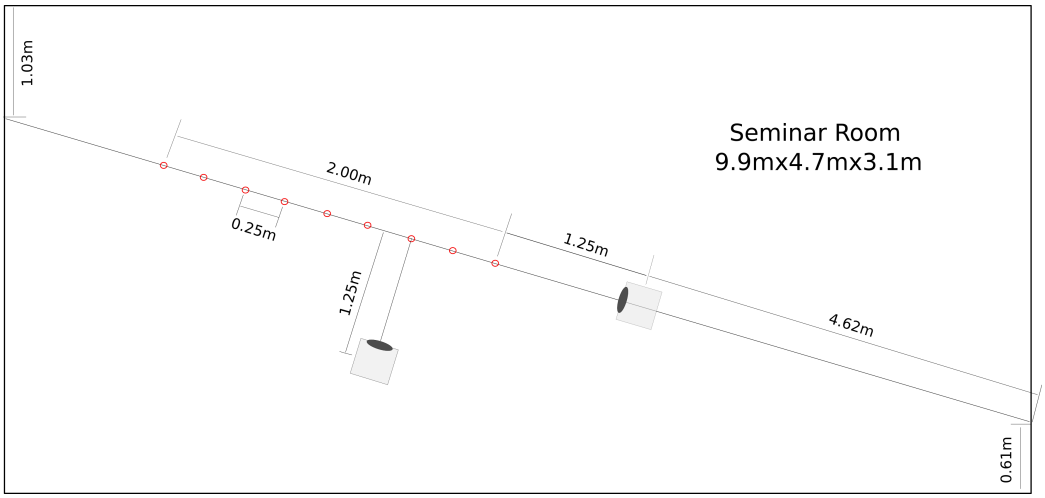

Fig. 3: Measurement positions of the Kemar 45BA and the loudspeakers Genelec 1030A in the seminar room.

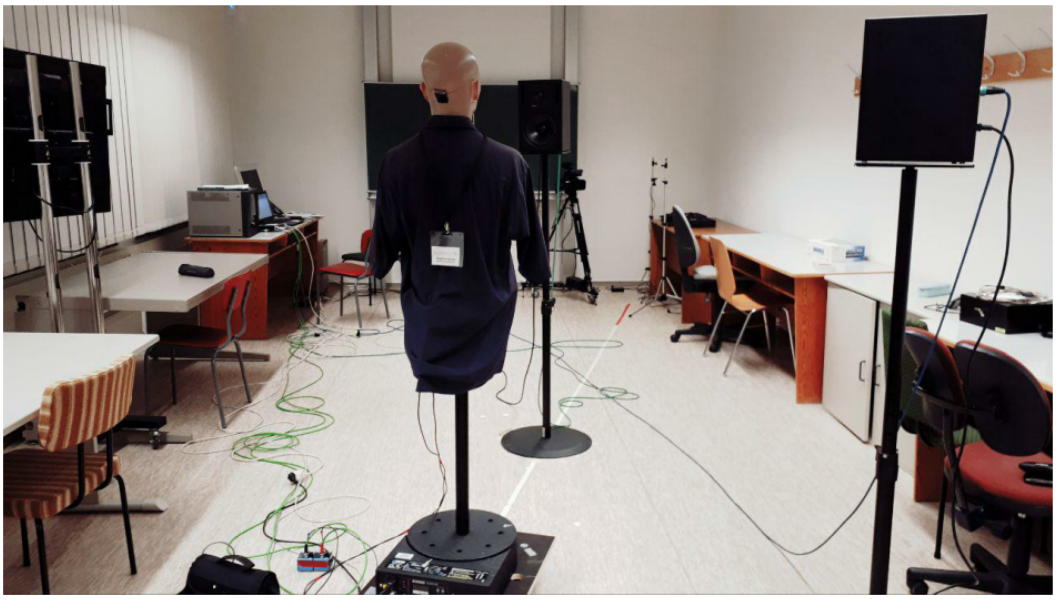

Fig. 4: Measurement setup in the seminar room.

data set presented in this study should enable the listener to move free and intuitively along the given line. The extra-aural headphone are quite heavy and instable on the head. Listeners usually carry out only slow careful movements while wearing those. As a consequence, we decided to use the open AKG K1000 headphones instead. They were placed on the dummy, which was moved only very carefully to make sure the headphones did not change their position on the head during the whole measurement.

Furthermore, the headphone transfer function (HpTF) was measured right away with the same positioning on the head. The headphone compensation filter created from this measurement is included in the data set.
For an authenticity study an azimuth resolution of 4° may not be enough. Therefore this additional BRIR set was measured with an azimuth resolution of 2°.

2.2.2. Psychoacoustic evaluation and further experiments

The BRIRs measured without the headphones on the HATS were used in a study similar to [2] with the goal to verify the observations in a more reverberant room. The results have not been published yet. Also in this study the measured data set was rated as plausible by the participants in a test paradigm that did not include a real version of the sound field. Continuity, externalization and the impression of walking towards a sound source were rated very well, too. The experiment included only the BRIRs for the frontal loudspeaker and the test was only conducted with dry male speech as a test signal. The results of [2] indicate that for noise the positional resolution is not adequate.

A psychoacoustic experiment [7] was conducted to evaluate plausibility in the Yes/No paradigm as suggested by Lindau and Weinzierl [5]. A detailed documentation of the experiment and the results, observations and discussion

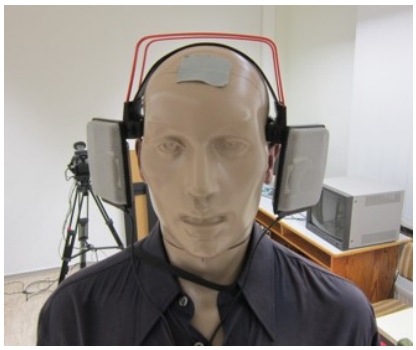

Fig. 5: Headphones AKG K1000 with a 45° opening angle were placed on the HATS in order to enable a direct comparison of the binaural reproduction with the real loudspeaker reproduction.

can be found in the corresponding paper [7]. Without an individualization, experts were able to identify the binaural auralization, though they found it challenging in several cases. Most of the untrained listeners did not find reliable cues for an identification.

3. Data set 2 - 7.5 m in seminar room

In order to investigate the position dependent change of BRIRs over a longer distance, a second BRIR data set was created in the same seminar room. A translation line with a length of 7.50 m was defined diagonal through the rooms. The line is an extension of the previous one, several listening positions are equivalent. However, the source positions were changed according to the illustration in figure 6. For this data set, the Kemar 45BA was placed at 16 positions along the line with a 50 cm spacing in between. The measurement positions cover a distance from 1 m to 8.50 m to the frontal loudspeaker. Again, for each of the positions and both loudspeakers BRIRs were measured with an azimuth resolution of 4° for the full 360° rotation.

3.1. Turning the loudspeakers by 180°

The directivity of a sound source influences the sound field and the acoustical reflection pattern in a room. To study this effect, the loudspeakers at both positions were turned by 180° around their center. Consequently, the loudspeaker membrane was moved to the other side. The whole series of measurements was repeated. The setup is shown in figure 7.

3.2. Omnidirectional RIRs

For a more detailed analysis, an omni-directional Microtech Gefell MK221 microphone capsule connected to a MV203 amplifier unit was placed subsequently at the center of each of dummy head positions. The same logarithmic sweep was used to measure the omni-directional room impulse responses at each of the positions.

4. Conclusion

This paper documents the creation of BRIR data sets for the realization of position-dynamic binaural synthesis. A comparable measurement setup was realized in two different rooms, a relatively dry listening laboratory and a quite reverberant seminar room. The created data sets are available as creative commons CC BY-SA 4.0 following the links provided in [8] and [9].

5. Acknowledgement

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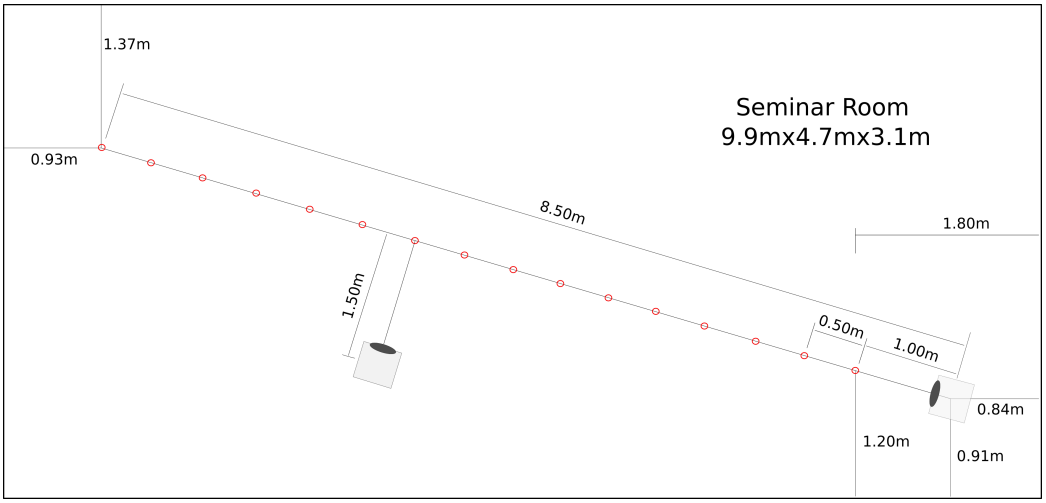

Fig. 6: Measurement positions of the Kemar 45BA and the loudspeakers Genelec 1030A for a translation line throughout the seminar room.

Fig. 7: Measurement setup in the seminar room with the loudspeakers turned by 180°.