Open Database of Spatial Room Impulse Responses at Detmold University of Music

Database Documentation - v0.1 [1]

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[1] In its current status, this document is largely a preprint of our manuscript [1] from the 149th AES Convention.

Abstract

This manuscript presents an open source database of Spatial Room Impulse Responses (SRIR) captured at three different performance spaces of the Detmold University of Music. It includes one medium sized concert hall (Detmold Konzerthaus), one chamber music room (Brahmssaal) and one theater (Detmold Sommertheater).

The collection contains approximately 600 multichannel RIRs corresponding to several source and receiver configurations. For each room we include measurement positions on stage and at the audience area captured with both an artificial head and an open microphone array compatible with the Spatial Decomposition Method (SDM).

The Detmold Konzerthaus holds a large scale Wave Field Synthesis system, and SRIRs of an ensemble of focused sources on stage and conditions of increased reverberation are also included.

Introduction

Accurately capturing and reproducing room acoustics opens up research and creative possibilities in areas such as concert hall design, stage acoustics, mixed reality, musical performance research, immersive music production or auditory perception.

For instance, virtualizing concert hall acoustics allows for conducting perceptual and music performance research in laboratory conditions, simplifying the research logistics and isolating acoustics from other environmental factors. Or for example, binaural renders of studio mixing setups allow recording engineers to work on their mixes over headphones, reducing the need to work physically from the studio. Aside from that, the use of multichannel Room Impulse Responses (RIR) instead of monaural responses allow for the spatial analysis of sound fields.

In this paper we present an open database of Spatial Room Impulse Responses (SRIR) that can be used for acoustical analysis and auralization of three performance rooms from the Detmold University of Music. The database is hosted in a Zenodo repository under a CC BY 4.0 license[1].

[1]The database can be openly accessed at https://doi.org/10.5281/zenodo.4007388

Rooms

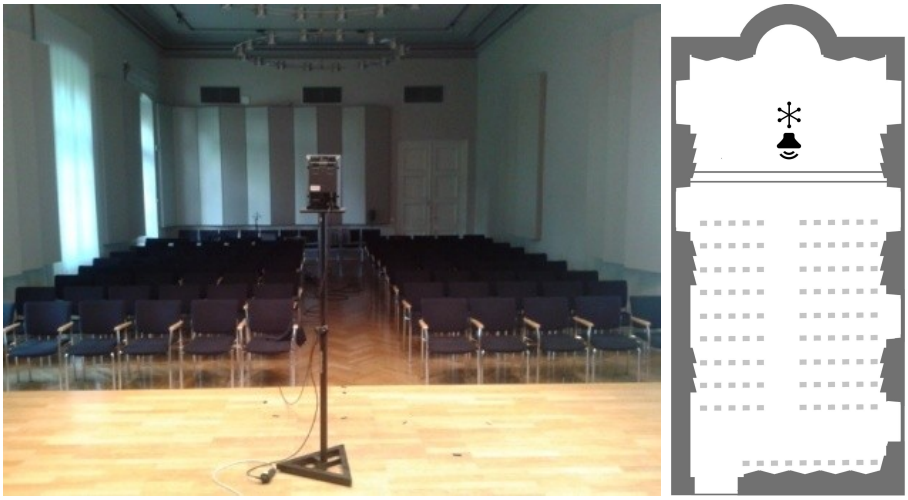
The SRIR database contains measurements in three performance spaces of the Detmold University of Music: Brahmssaal, Detmold Sommertheater and Detmold Konzerthaus. Overview pictures of each room and their floor plans are depicted in Fig. 3.1. The reader is referred to [2, 3] for a detailed acoustical analysis of the rooms.

The **Brahmssaal (BS)** is a small shoebox music chamber hall with approximately 120 removable seats and an approximate volume of 750m^3. The floor is laminated wood and the walls are painted concrete. The room is mostly used for solo performances, instrumental lessons and small ensembles. The audience floor is not inclined and the stage is slightly raised.

The **Detmold Sommertheater (DST)** is a small shoebox theater with lateral balconies. The room contains approximately 320 seats and the main floor is slightly inclined. The total volume of the room is approximately 2700^3. The stage is fitted with absorbing curtains and has a volume of approximately 650^3, including the volume of the fly tower. The room is mainly used for theater, opera, solo performances, small ensembles and amplified music.

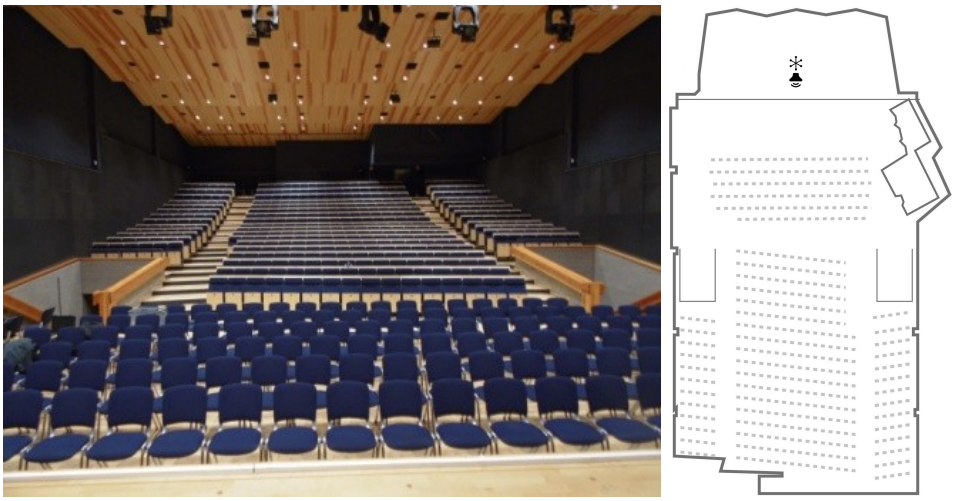
The **Detmold Konzerthaus (KH)** is the biggest performance room of the Detmold University of Music, with a volume of approximately 4600 m^3. It is a medium sized concert hall with a quasi rectangular floor plan, housing a pipe organ placed at one side of the room next to the stage. It contains approximately 600 seats arranged on a single floor, and is divided into two zones. A group of removable seats at the front allows rearrangements of the stage and for the accommodation of larger ensembles. The fixed seating area is arranged on an inclined plane.

The concert hall KH is equipped with a 3D loudspeaker array composed of a line of multiactuator panels (MAP) mounted on the wall and surrounding the perimeter of the concert hall, and a planar array of discrete loudspeakers mounted on the ceiling. The array is addressed using 328 channels and can be used to either increase the reverberation time of the room via a SIAP Acoustics processor [4], or to synthesize virtual sources via Wave Field Synthesis (WFS) [5]. The database that we release here includes SRIRs for increased room reverberation and focused sources generated with WFS.



a) Brahmssaal (BS)

b) Detmold Sommertheater (DST)



c) Detmold Konzerthaus (KH)

Figure 3.1: General view and floor plans of the measured rooms

Microphone Arrays

Three different microphone arrays are present in the database: an open microphone array, a binaural head and an omnidirectional figure of 8 array.

The **open array** is composed of 6 omnidirectional microphones – NTi M2010, arranged in 3 pairs aligned on an orthogonal axes. The spacing between each microphone pair is 10 cm and they are mounted on a 3D printed custom holder (see Fig. 4.1). The measurements produced by the array are compatible with the Spatial Decomposition Method [6, 7]. Although SDM analysis and auralization can be realized with unmatched microphone gains, we matched their responses at 1 kHz to enable other purposes and processing techniques.

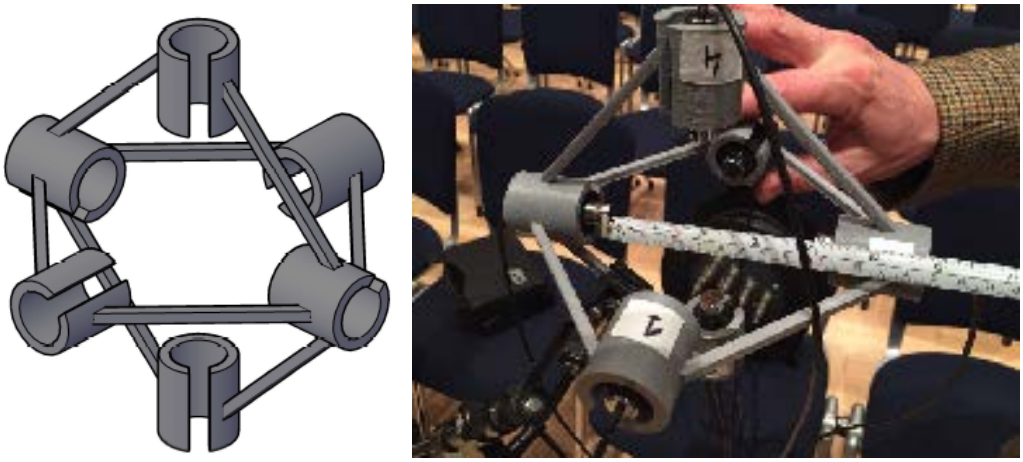


Figure 4.1: Open Microphone Array

For **binaural measurements** we used a Neumann KU100, and in some instances we mounted an **omnidirectional and a figure of 8 microphone** (OmniFig8, see 4.2). The microphone models are NTi M2010 and Schoeps CCM8, respectively. The OmniFig8 array allows for computing all parameters from the ISO 3382 standard, including the lateral energy parameters [8].

Figure 4.2: Binaural head with OmniFig8 array mounted on top (in KH).

Structure of the database

The measurements released in this database have been used in the context of various research projects on room acoustics, music performance and spatial audio reproduction. For clarity, we release the various datasets grouped into three subgroups.

5.1 Set A: Single Source Measurements (Open Array + Binaural)

The database contains measurements for all the rooms in which the room response of a single source (Neumann KH120) at the center of the stage was measured at various receiver locations. Measurements are done for the three rooms with the open microphone array. Additionally, for DST and BS there are binaural measurements as well for one single head orientation.

5.2 Audience area measurements

The measurements in the audience area were conducted in a variety of positions at seating height, both with a binaural head (one orientation) and with the open array, allowing their processing with SDM and reproduction over loudspeakers or binaural. Some of these measurements have been used in the Acoustics and Musical Instruments Sound Explorer (AMISE) [9], an educational tool that allows listeners the acoustic exploration of several instruments and various playing styles under different acoustic conditions[1].

5.2.1 Stage measurements

For the stage measurements, the source and microphone array are arranged such that they resemble a trumpet player performing on stage. The locations of the source and microphone array coincide with those of the trumpet bell and the ears of the musician [10]. These have been used extensively to investigate the influence of room acoustics on live music performance [2, 11, 12] and stage acoustic preferences [2, 13] of solo trumpet players. Additionally, for the rooms KH and BS there are stage measurements with a music stand in various positions (see Fig. 5.1). More details on the acoustic effect of the music stand on stage can be found in [14].

5.2.2 Artificial Reverberation in KH

By making use of the MAP array, a distributed microphone array and a SIAP Processor, the reverberation time of the KH can be artificially extended to up to approximately 5 seconds at mid frequencies. All measured positions and music stand configurations of the KH have also been measured in 7 different reverberation conditions (C1 to C7), including the natural acoustics of the hall. The frequency dependent reverberation of each condition is displayed in Fig 5.2. The reported reverberation times have been computed using measurements acquired at the middle of the removable seating area.

[1] The tool is available at
`https://amise.netzwerk-musikhochschulen.de/`

Figure 5.1: Exemplary stage measurement configuration of Set A: single source (Neumann KH120), open array and music stand (in BS).

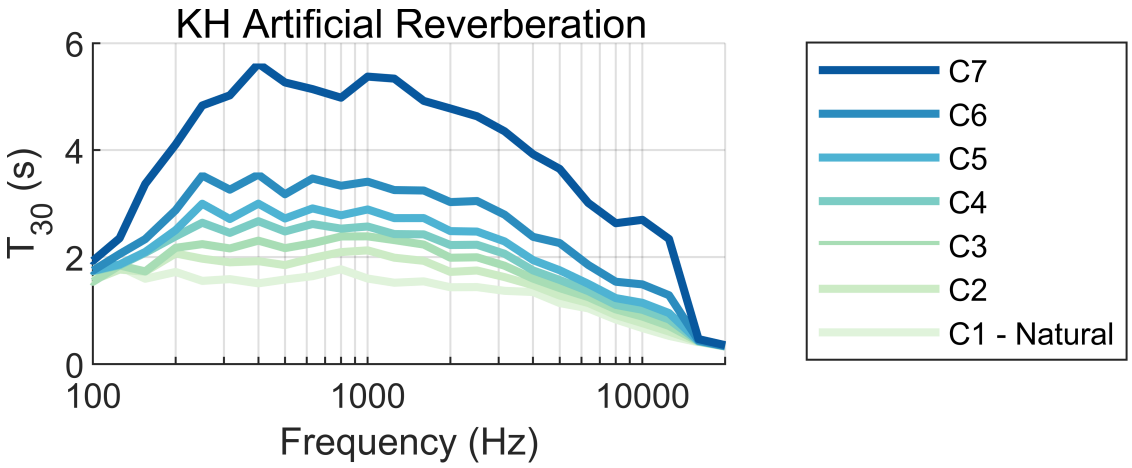


Figure 5.2: Measured reverb conditions in KH.

Figure 5.3: Loudspeaker orchestra (8 sources) on stage at KH. The MAP array used for WFS and artificial reverberation can be seen mounted on the wall.

5.3 Set B: Loudspeaker and WFS Orchestra in KH (Open Array)

The use of a loudspeaker orchestra has recently enabled a vast body of research in concert hall perception using auralization in the last decade [15]. Following the same principle, we arranged a smaller version composed of 8 sources on stage. We implemented two versions: a loudspeaker orchestra (see Fig. 5.3), and a focused sources orchestra realized with the WFS system installed in the KH.

This measurement set contains SRIRs measured with the open array at 3 locations in the audience area for each of the 8 sources in each configuration. Details on the measurement procedure, synthesis of the focused sources, and acoustical analysis can be found in [16].

5.4 Set C: Loudspeaker orchestra in KH - dense grid (Binaural + OmniFig8)

In order to investigate the spatial dependency of standard and binaural room acoustical parameters in KH, we conducted measurements with a binaural head (one head orientation) and the OmniFig8 microphone array at 33 locations. This data was also used to conduct perceptual studies on room acoustical preferences using static binaural auralizations. Further details on these measurements can be found in [3, 17].

Conclusion

In this manuscript we presented an open database of SRIRs acquired at three different performance spaces of the Detmold University of Music. The measurements contain unusual configurations, such as a single music stand on stage, artificial reverberation in a concert hall, or a WFS and loudspeaker orchestra on stage. See Tab. 7.1 for a summary of the released data. Most of the data has been used in the past in a variety of projects for auralization and analysis of concert hall acoustics. With this release we aim at encouraging the use of the measurements for any suitable application such as music production, mixed reality experiences, or further research on spatial audio, room acoustics or musical performance, among others.

Appendix A: Database summary

Dataset	Source	Receiver	Extra Reverb	Stand	Source Pos.	Rec. Pos.	KH	DST	BS	
A	KH120	Open Array	No	No	1	Multiple	2	6	6	[10, 13, 2, 9]
A	KH120	Open Array	Yes (5)	No	1	2	10	0	0	[9]
A	KH120	Open Array	Yes (6)	Yes	1	1	6	0	0	[14]
A	KH120	Binaural Head	No	No	1	Multiple	0	6	5	
B	LS Orchestra	Open Array	No	No	8	3	24	0	0	[16]
B	WFS Orchestra	Open Array	No	No	8	3	24	0	0	[16]
C	LS Orchestra	Binaural Head	No	No	8	33	264	0	0	[3, 17]
C	LS Orchestra	Fig.8 + Omni	No	No	8	33	264	0	0	[3, 17]

Table 7.1: Summary of the included measurement configurations.

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