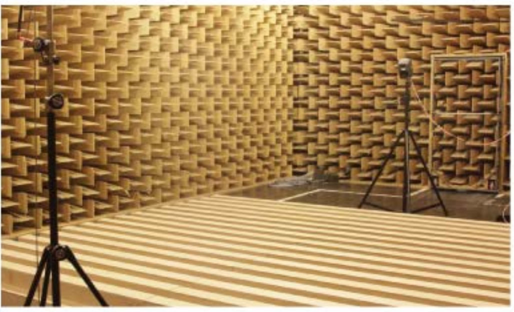
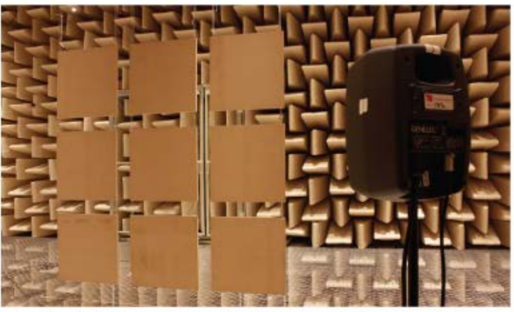
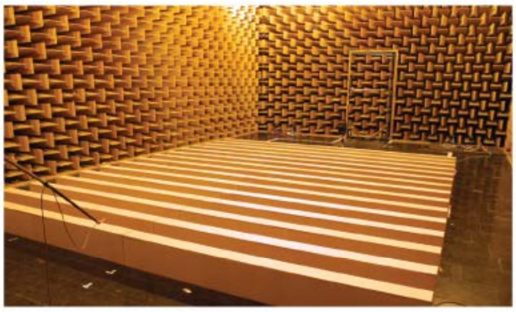
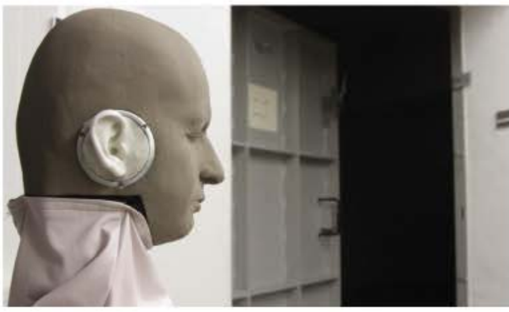


GRAS

ground truth for **r**oom **a**coustical **s**imulation

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Ground truth for Room Acoustical Simulation (GRAS)

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Documentation of the database

Lukas Aspöck, Michael Vorländer
RWTH Aachen, Institute of Technical Acoustics,
Kopernikusstrae 5, D-52074 Aachen, Germany
{las; mvo}@akustik.rwth-aachen.de

Fabian Brinkmann, David Ackermann, Stefan Weinzierl
TU Berlin, Audio Communication Group,
Einsteinufer 17c, D-10587 Berlin, Germany
{fabian.brinkmann; david.ackermann; stefan.weinzierl}@tu-berlin.de

Contact: rr@ak.tu-berlin.de

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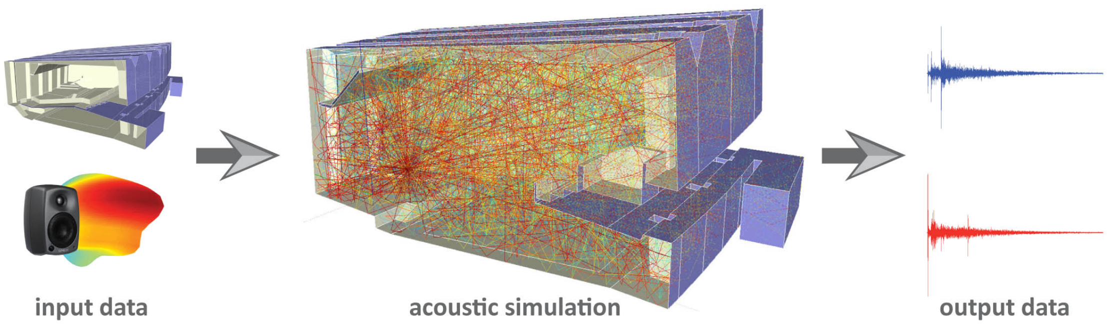


1 General Information

The Ground truth for Room Acoustical Simulation (GRAS) database contains eleven acoustical scenes that are intended for the evaluation of room acoustical simulation software. This comprises simple scenes (no. 1-7) that isolate certain acoustic phenomena, as well as complex environments (no. 8-11) of different shape and size. Each scene consists of (a) a scene description giving the room geometry, and the positions of the acoustic sources and receivers, (b) the corresponding source and receiver characteristics, (c) the description of the acoustic materials by means of absorption and scattering coefficients, and (d) the measured single channel and binaural impulse responses.

The database is separated into multiple zip-files, in case only a certain part of the database is needed. The zip files can be extracted to the original folder structure in the following way: Under UNIX based operating systems, the terminal command `unzip \*.zip` can be used after changing the working directory to the folder that contains the zip files. Under Windows operating system, the default unzipping tool can be used. In this case it has to be confirmed that the content of each zip file is merged into already existing folders.

The data are organized in the folders `1 Scene descriptions`, `2 Source and receiver descriptions`, `3 Surface descriptions`, and `4 Additional data` that are explained in the section 2 Documentation. The eleven scenes are introduced one by one in the corresponding sections (e.g. Scene 8: Coupled rooms (laboratory & reverberation chamber)), which also list all input data that are required for the acoustic simulation of the scenes. An overview of the scenes that are included in the database is given in Table 2.

2 Documentation

The database structure is outlined in the following. More information on the concept of the GRAS database and the data acquisition can be found in an accompanying research paper.

2.1 Scene descriptions

The scene geometries can be found in the folder `1 Scene descriptions` and are provided as SketchUp[1] models. All files are named according to the scheme `sceneNo_IRtype`, e.g. `scene10_RIR` defines the geometry of the medium room for simulating single-channel room impulse responses, whereas `scene10_BRIR` defines the same room with source and receiver positions for simulating two-channel binaural room impulse responses. In some cases, a scene is divided into sub-scenes, which is noted by `sceneNo_IRtype_subScene`,

[1] *SketchUp Make* is free for educational purposes and can be downloaded here

e.g. `scene1_RIR_Diffusor`. In addition to the SketchUp files, one screenshot of each scene configuration is provided as a png file.

Each SketchUp file contains the 3D model of the room, as well as the positions and orientations of the sources and receivers. The surfaces of the 3D models have textures assigned to them that specify their material. For example the texture `mat_RockFonSonarG` links to a material whose surface properties can be found in the corresponding folder (cf. Section Surface properties). To view the texture of a surface in SketchUp, use the *Sample Point* option of the *Paint Bucket Tool*. If the object belongs to a group or a component, it is necessary to first go in the *edit mode* of the group by double clicking the object before being able to show the material. The degree of detail in the scene geometry is thought to be sufficiently accurate for acoustic simulations, but may be reduced to foster the needs of a specific simulation software.

Source and receiver positions are marked with 3D icons and corresponding text labels. The label position refers to the acoustic centers of the source and receiver. They are named `LSno_type` for the sources (loudspeakers), and `MPno_type` for the receivers (microphones). For example `LS1_Genelec8020c` gives the position of the first loudspeaker that was a Genelec 8020c active 2-way monitor in this case. The directivity files are named correspondingly and will be described in the next section. The relevant information about position and orientation is always given in the label – the positions of the objects in the SketchUp file might show slight deviations. Positions are always specified with respect to the global coordinate system of the scene where φ [°] gives the orientation in the horizontal plane (orientation in the x/y plane, $\varphi = 0$ pointing in positive x-direction, $\varphi = 90$ pointing in positive y-direction), and ϑ [°] specifies the elevation ($\vartheta = 90$ pointing in positive z-direction, $\vartheta = -90$ pointing in negative z-direction).

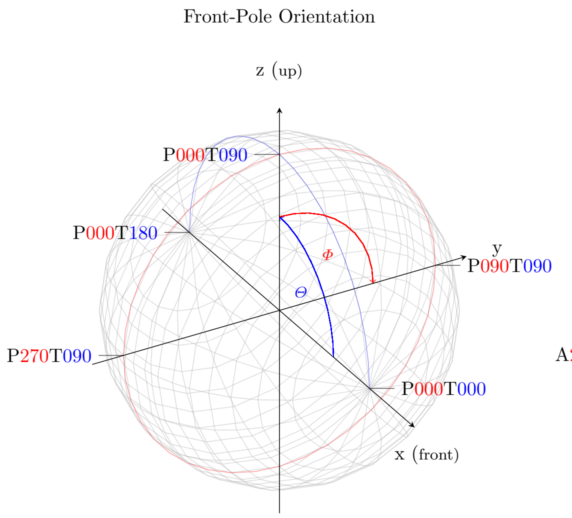
2.2 Source and receiver descriptions

Three different sources and three receiver types were used for creating the GRAS database: A 3-way dodecahedron loudspeaker and a Genelec 8020c 2-way near-field monitor were used for measuring single channel impulse responses, and QSC K8 2-way PA monitors were used for measuring binaural impulse responses. A G.R.A.S. AF40 1/2" free field measurement microphone was used for the acquisition of single channel impulse responses in the free-field environments, while a 1/2" B&K 4134 diffuse-field measurement microphone was used in reverberant scenarios. The FABIAN head and torso simulator was used for measuring binaural impulse responses.

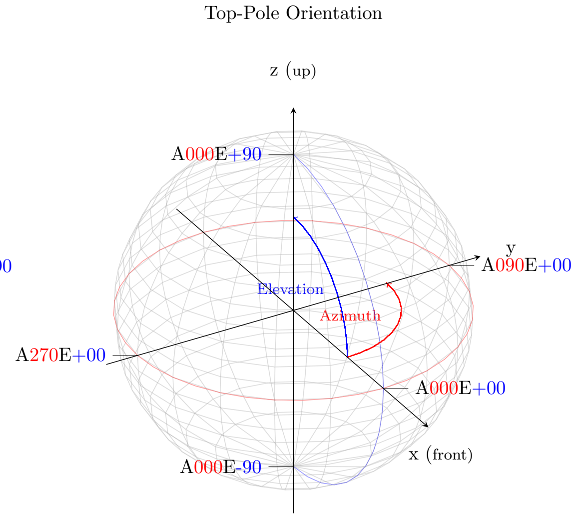
Directivities by means of impulse responses and/or third octave spectra are stored in comma-separated value (CSV) and/or MATLAB files inside the folder `2 Directivities`. They are provided on a Gauss-like spherical sampling grid with an angular resolution of 1° along azimuth, and elevation, with a total of 64,442 sampling points. Each line in the CSV-files holds the data for one sampling point of the grid as specified in Figure 1 (c, d). The structure of the provided MAT-files is shown in Figure 1 (e, f). Note that different coordinate conventions are used for loudspeaker directivities (Figure 1a), and head-related impulse responses (HRIRs) (Figure 1b). Moreover, the coordinate convention of the directivity files is independent from the absolute coordinate system of the scene geometries given in the SketchUp files. The directivities of the dodecahedron loudspeaker, and the two measurement microphones were assumed to be omnidirectional.

Source directivities (Genelc 8020c & QSC-K8 loudspeaker)

The source directivities are stored in the front-pole coordinate system. In these cases, Φ [°] gives the orientation in the frontal plane (y/z plane, $\Phi = 0$ pointing in positive z-direction, $\Phi = 90$ pointing in positive y-direction), and Θ [°] gives the orientation in



(a) Front pole coordinate convention.



(b) Top pole coordinate convention.

```
P000T000,3.1549356,-5.1039181,5.2946804,-6.3453707,3.2898423,-5.1400114,4.2449563,...
P000T001,2.4440977,-6.2950617,5.7606979,-5.0275684,2.8864353,-5.4994686,3.8488389,...
⋮
P359T179,-1.2831306,-0.8082714,-1.9258609,-2.0064113,-2.4464460,-2.4244988,-2.1148782,...
P000T180,-1.2037028,-0.7688371,-1.6461457,-1.5970641,-2.1745634,-1.9213576,-2.3674620,...
```

(c) Impulse response data format (front pole convention).

```
f in Hz, 20, 25, ..., 20000,
P000T000,-73.9423324 + 41.6702700i,-78.6705701 + 315.0149088i,...,2028.4094010 + 2827.0861137i,
P000T001,-74.4630423 + 41.5323030i,-79.9799539 + 314.4980953i,...,-303.6213314 + 3420.0222030i,
⋮
P359T179,-21.5571372 + 37.5295540i,35.9925572 + 299.1564067i,...,78.3276506 - 63.5002594i,
P000T180,-22.5353947 + 37.6447504i,34.7547710 + 299.3479605i,...,-8.3261083 - 99.2947006i,
```

(d) 3rd octave spectrum data format (front pole convention).

```
Genelec8020_1x1_64442_IR_front_pole.mat
├── IR <4096x64442>
├── Phi <1x64442>
└── Theta <1x64442>

Genelec8020_1x1_64442_MPS_front_pole.mat
├── MPS <31x64442>
├── Phi <1x64442>
├── Theta <1x64442>
└── Frequency <31x1>
```

(e) Loudspeaker directivity data format MAT-file.

```
HATO_0_1x1_64442_HRIRs_top_pole.mat
├── HRIR_L <256x64442>
├── HRIR_L <256x64442>
├── azimuth <1x64442>
└── elevation <1x64442>
```

(f) HATO directivity data format MAT-file.

Figure 1: Coordinate conventions and data format.

the median plane (x/z plane, $\Theta = 0$ pointing in positive x-direction, $\Theta = 90$ pointing in positive z-direction). Loudspeaker directivities are provided as 4096 sample impulse response (IR) at a sampling rate of 44.1 kHz, and third-octave band magnitude/phase spectra (MPS) from 20 Hz to 20 kHz:

- `LoudspeakerName_1x1_64442_IR_front_pole.csv`
- `LoudspeakerName_1x1_64442_MPS_front_pole.csv`

Please note that the on-axis frequency and impulse responses are included in the first row of the csv and mat files. The directivities were not normalized to frontal sound incidence, and the on-axis frequency responses must be included in the simulation, i.e., the directivities should be used as they are without further normalization.

Source description (ITA dodecahedral omnidirectional loudspeaker)

The directivity of the custom dodecahedral loudspeaker that was used in scenes 8-11 could not be measured due to mechanical restrictions. Instead, the diffuse field sound power spectrum is provided in third octave frequencies together with technical drawings of the three-way speaker, and a written documentation.

Receiver directivities (FABIAN Head-related impulse responses – HRIRs)

The HRIRs are provided in the top pole coordinate system. In this case, the azimuth φ [°] gives the orientation in the horizontal plane (x/y plane, $Azimuth = 0$ pointing in positive x-direction, $Azimuth = 90$ pointing in positive y-direction), and the elevation ϑ [°] gives the orientation in the median plane (x/z plane, $Elevation = 0$ pointing in positive x-direction, $Elevation = 90$ pointing in positive z-direction). The HRIRs are provided as 256 sample impulse responses. Separate datasets are provided for 45 different head-above-torso orientations (HATOs) between ±44° with a resolution of 2°, whereby a HATO of 10° denotes a head rotation of ten degree to the left, and a HATO of -10° denotes a head rotation of ten degree to the right. The corresponding file sis named:

- `HATO_10_1x1_64442_top_pole.csv  (.mat)`
- `HATO_-10_1x1_64442_top_pole.csv  (.mat)`

Different HATOs are necessary, to reflect the head orientation of the FABIAN head and torso simulator during the BRIR measurements. HRIRs were measured for HATOs between ±50° in steps of 10° and taken from the FABIAN database [1, 2]. They were interpolated as described in Brinkmann et al. [3] using functions from AKtools for Matlab [4]:

```
AKhrirInterpolation(az, el, HATO, 'measured_sh').
```

3-D surface mesh representation of FABIAN's head and torso are provided for wave based BRIR simulations. They are available for the neutral HATO, and in two resolutions, that provide valid results up to 6 kHz and 22 kHz. The corresponding files are named:

- `FABIAN_6k_HATO0.stl`
  with average edge lengths of 2 mm, 10 mm, and 10 mm for the pinnae, head, and torso can be used for simulation up to 6 kHz
- `FABIAN_22k_HATO0.stl`
  with average edge lengths of 2 mm, 2 mm, and 10 mm for the pinnae, head, and torso can be used for simulation up to 22 kHz

Meshes for HATOS between ±50° with a resolution of 10° are contained in the FABIAN database [2]. To obtain HATOs with a higher resolution, the cylindrical neck in the meshes can be cut and rotated above the z-axis.

2.3 Surface descriptions

Because of the large number of acoustic materials that were involved in the creation of the GRAS database, and a lack of established in-situ methods to determine the acoustical impedance across the full acoustical frequency range, characteristics of the walls and surfaces of the scenarios are only provided as absorption and scattering coefficients in third octave band values for the frequency range from 20 Hz to 20 kHz. They can be found in the folder `3 Surfaces`. An overview of the 35 materials is given in the file `AllMaterials.pdf`. Each material's characteristic is defined in a CSV file (see folder `_csv`), a short documentation in a corresponding text file (see folder `_descr`), a figure showing the absorption and scattering values (see folder `_plots`), and an image of the corresponding surface (see folder `_img`). While the materials that were used in the simple scenarios (scenes 1-7) have their individual documentation, only one documentation file for all materials inside the complex rooms (scenes 8-11) is given, and named correspondingly. The scene descriptions, provided in the *.skp files, indicate which material should be used for the surfaces of the scene (cf. Sec. 2.1 Scene descriptions).

Different acquisition techniques were applied to determine absorption coefficients of the materials. For the simple scenarios (1-5), the absorption was either determined by impedance tube measurements [5, 6] for a frequency range from 100 Hz up to 7 kHz or by applying a transfer function method, valid from 100 Hz up to 15 kHz, to the measured results of the scene. For the rooms, the absorption values were estimated based on in-situ measurements using a PU-probe [7], and a modified microflown procedure regarding the measurement setup and post-processing. This method provides results between 200 Hz and 10 kHz. The results were averaged over multiple measurements and several post processing methods were applied. The final data was manually adjusted by referencing to similar materials in absorption databases. For very low and high frequencies, missing data was estimated and extrapolated to cover the range from 20 Hz to 20 kHz for all materials used in the Round Robin. Scattering coefficients were estimated according to structural dimensions of the materials.

We are aware that some of the applied measurement techniques contain a high level of measurement uncertainties and do not necessarily represent the real acoustical characteristics of the materials. However, the absorption and scattering coefficients were prepared with the goal to provide a set of input data containing plausible values for the boundary conditions.

2.4 Impulse responses

The measured singe channel and binaural impulse responses are contained in the folders `1 Scenes/*/RIRs` and `1 Scenes/*/BRIRs`, respectively. They are provided as SOFA files according to AES69-2015 standard [8] and wav-files (sampling rate 44.1 kHz). The SOFA files contain all IRs of one scene and hold additional meta data, while the wav files only contain a single IR but might be easier to read across different operating systems. In case of the binaural impulse responses, the first channel of the wav-file corresponds to the left ears impulse response.

The files are named following the scheme `sceneNo_type_addInfo.type`. For example `scene1_RIRs_Rigid.sofa` holds all IRs for the `Rigid` sub-scene of scene 1, whereas `scene1_RIR_Rigid_LS1_MP3.wav` holds the IR for a specific loudspeaker-microphone combination of the same scene. For scenes 8 to 11, impulse responses were measured for 4 different orientations of the Genelec 8020c speaker. This is denoted by `LSorientation` label and is detailed in the corresponding scene descriptions in sections Scene 8 - Scene 11.

Calibration and Processing

Singe-channel impulse responses: To establish an absolute sound pressure level for the measured single-channel room impulse responses, the signal input chain was calibrated with a microphone calibrator, and the output chain was calibrated to a free field sound pressure of 80 dB at 1 kHz, and a distance of 2 m in front of the loudspeaker (i.e. $\Phi = \Theta = 0°$ in Figure 1a). As a consequence, the unit of the single-channel impulse responses is Pascal.
Binaural impulse responses: FABIAN is equipped with DPA 4060 microphones at the blocked ear channels. Their on axis free-field frequency response was removed from all BRIRs. Because the BRIRs are intended for auralization, they were normalized to 1 (0 dB) between 300 Hz and 1 kHz. For each scene, the scalar gain factor was obtained from the loudspeaker closest to FABIAN and a HATO of 0° with AKtools for Matlab [9]:

```
[ , ,gain] = AKnormalize(brir_l_r, 'abs', 'mean', 'mean', 1, [300 1000]);
```

Afterwards, the gain was applied to all BRIRs of the corresponding scene. Consequently, the binaural impulse responses are without unit. The smallest common time of flight – i.e., the leading zeros – was removed from the BRIRs to reduce the system latency during auralization. This was done separately for each scene, and it was made sure that differences in time of flight between loudspeaker positions and different HATOs remained as they were.

SOFA files

The SOFA files can, for instance, be read with the Matlab/Octave API. Inside the SOFA files, the impulse responses are stored in the field `Data.IR`. The dimensions of this field differ among scenes and IR types (single channel, or binaural) and are listed in Table 1. For an unambiguous assignment of the loudspeaker-microphone combinations to the entries in `Data.IR`, additional meta data entries were created (c.f. Table 1, meta data). The EmitterID and ReceiverID list the loudspeaker and microphone number according to Sec. 2.1 Scene descriptions. In scene 5, for example, the impulse response of loudspeaker 4 and microphone 2 are stored in the 8th column, i.e., `Data.IR(8,:,:)`. In case of the scenes 1-8, the ListenerView (which equals the HATO) is relative to the source, i.e. a ListenerView of 0 means that FABIAN is directly facing the source. In the case of scenes 9-11, the listener view is relative to loudspeaker 7 (the center speaker), i.e. a ListenerView of 0 means that FABIAN is facing loudspeaker 7, while loudspeaker 3 is to it's left, and loudspeaker 6 to it's right.

2.5 Additional data

For your convenience, two kinds of additional data are provided. Room acoustical parameters in third octaves were calculated using the ITAtoolbox [10] and saved as comma-separated values. A Matlab script for loading the impulse responses and calculating the parameters is also available. This is intended for a physical comparison of measured and simulated impulse responses. Moreover, a short excerpt of an anechoic string quartet recording and binaural auralizations of scenes 9-11 are included in the database. These files are intended for a perceptual comparison of measured and simulated impulse responses.

#	Type	Data.IR	Dimensions	Meta data
1-7	RIR	$\mathrm{M} \times \mathrm{R} \times \mathrm{N}$	M: Number of IRs R: 1 N: IR duration [samples]	M: EmitterID, ReceiverID R: - N: -
8-11	RIR	$\mathrm{M} \times \mathrm{R} \times \mathrm{E} \times \mathrm{N}$	M: Measurements for each R, E R: Microphone pos. E: Loudspeaker pos. N: IR duration [samples]	M: MeasurementView R: ReceiverID E: EmitterID N: -
1-11	BRIR	$\mathrm{M} \times \mathrm{R} \times \mathrm{E} \times \mathrm{N}$	M: Number of HATOs R: 2 (left, and right ear) E: Loudspeaker pos. N: IR duration [samples]	M: ListenerView R: ReceiverID E: EmitterID N: -

Table 1: Data format of impulse responses inside the SOFA files. The *Meta data* column, lists which field in the SOFA files hold additional information on the order of the impulse responses.

3 Scene overview

A list of the scenes that are included in the GRAS database is given in Table 2. Although a detailed description of the data acquisition is out of the scope of this documentation and is left to the accompanying research paper, a brief description is given for your convenience.

All single channel (room) impulse responses (RIRs) were measured with the ITA-Toolbox [10] for Matlab, while the binaural (room) impulse responses (BRIRs) were measured with the FABIAN head and torso simulator measurement system for Matlab [11]. In case of the RIRs, the measurement chain was fully calibrated for measureing with absolute sound pressure level. Swept sine sweeps and deconvolution by means of spectral division [12] were applied to obtain all impulse responses. A list of the equipment used for the acoustic measurements is given in Table 3. The following hardware was used:

RIRs Scenes 1, 5, 6, 7 -	Hardware A, D, F, H, J
RIRs Scenes 2, 3, 4 -	Hardware A, D, F, H, K
RIRs Scenes 8, 9, 10, 11 -	Hardware A, C, E, F, H, L
BRIRs Scenes 1, 3, 5, 8 -	Hardware A, G, I, J
BRIRs Scenes 9, 10, 11 -	Hardware B, G, I, J

Cross line lasers (Bosch Quigo), and a laser distance meter (Bosch DLE 50 Professional) were used for the alignment of objects, sources, and receivers within a scene, and a VariSphear Microphone array system was used for scanning the room geometries of scenes 8-11. The measurements that took place in Aachen were conducted by Lukas Aspöck, Fabian Brinkmann, Thomas Mainz, and Hannes Helmolz. Measurements in Berlin were conducted by Fabian Brinkmann, David Ackermann, Lukas Aspöck, Rob Opdam, and Hannes Helmholz.

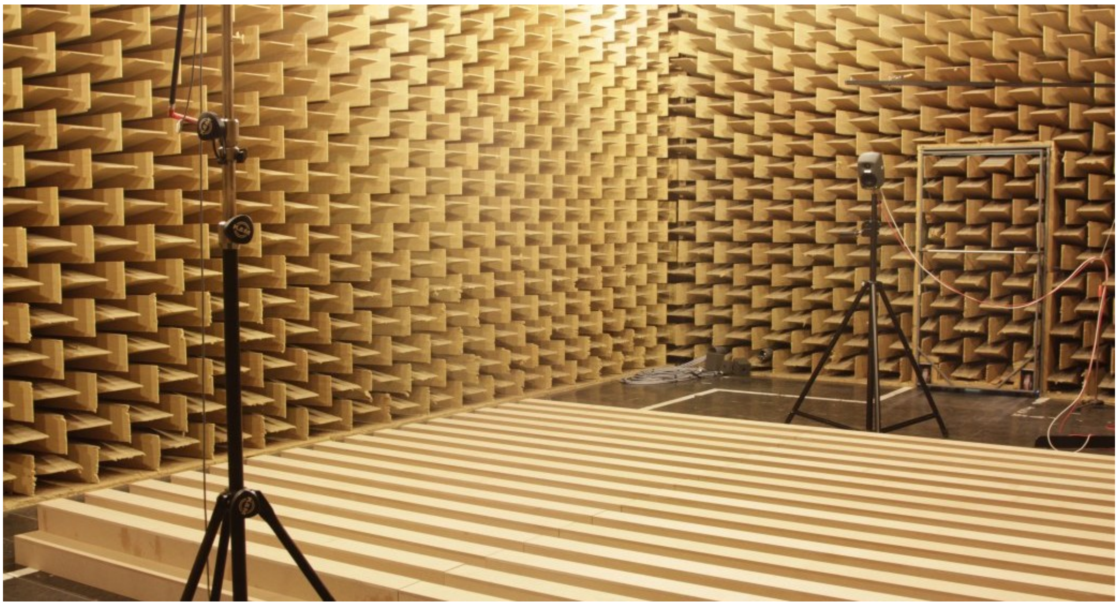
#	Name	Date	Location	RIR	BRIR
1	simple reflection (infinite plate)	24.-25. Nov. 2015	RWTH Aachen	3/3	1/1
2	simple reflection and diffraction (finite plate)	9.-10. Dec. 2015	TU Berlin	6/5	-
3	multiple reflection (parallel finite plates)	8. Dec. 2015	TU Berlin	1/1	1/1
4	single reflection (reflector array)	10. Dec. 2015	TU Berlin	6/6	-
5	diffraction (infinite wedge)	26. Nov. 2015	RWTH Aachen	4/4	1/1
6	diffraction (finite body)	16. Dec. 2016	RWTH Aachen	3/3	-
7	multiple diffraction (seat dip effect)	19.-20. Dec. 2016	RWTH Aachen	2/4	-
8	coupled rooms (laboratory & reverberation chamber)	26. Nov. 2015	RWTH Aachen	2/2	2/2
9	small room (seminar room)	23. Nov. 2015	RWTH Aachen	2/5	5/1
10	medium room (chamber music hall)	3.-4. Dec. 2015	Konzerthaus, Berlin	3/5	5/1
11	large room (auditorium)	2. Dec. 2015	TU Berlin	2/5	5/1

Table 2: Over view of the GRAS scenes. Columns *RIR* and *BRIR* give the number of source/receiver positions for each scene.

#	Type	Manufacturer	Model
A	Loudspeaker	Genelec	8020c (2-way active studio monitor)
B	Loudspeaker	QSC	K8 (2-way active PA speaker)
C	Loudspeaker	RWTH Aachen	3-way dodecahedron loudspeaker, with FourAudio HD2 loudspeaker management system
D	Microphone	G.R.A.S.	40AF 1/2” free-field capsule
E	Microphone	Bruel & Kjær	Type 4134 1/2” diffuse-field capsule
F	Microphone	Bruel & Kjær	Type 2669-B 1/2” microphone preamplifier
G	Microphone	TU Berlin	FABIAN head and torso simulator, with DPA 4060 microphones
H	Preamplifier	Bruel & Kjær	Type 2692-A-0I1 Nexus charge amplifier
I	Preamplifier	Lake People	C360 2-channel microphone preamp
J	Audio interface	RME	Multiface II with HDSP cardbus
K	Audio Interface	RME	Fireface UC
L	Audio Interfaces	RME	Digiface (HDSP cardbus) with OctaMic preamp

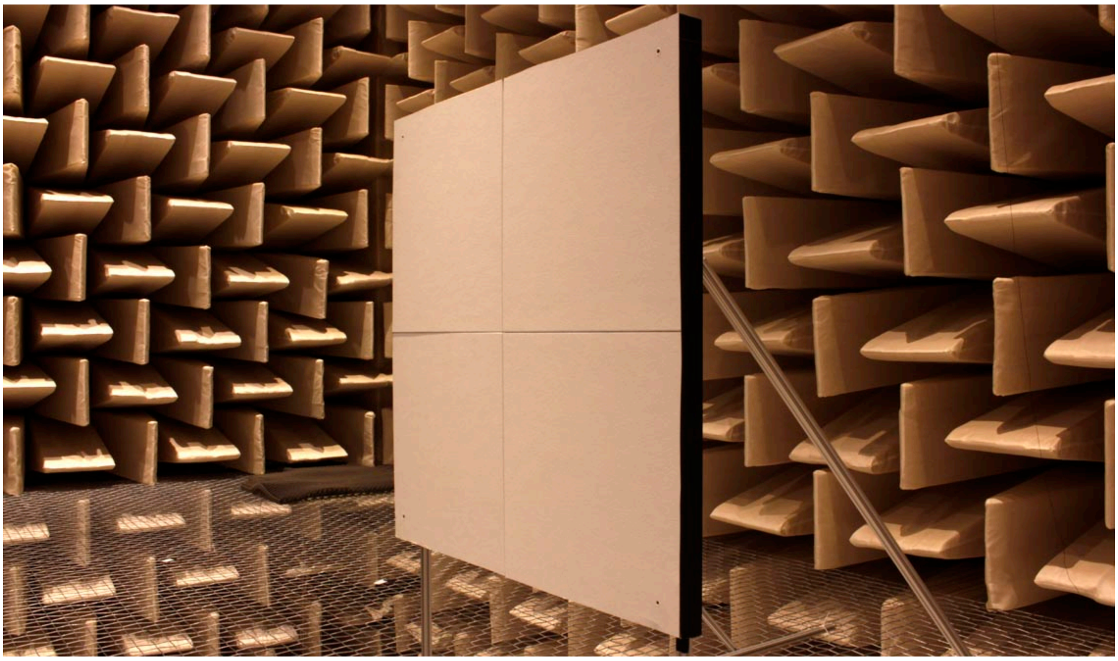
Table 3: Hardware used for acquisition of the GRAS database.

Scene 1: Simple reflection (infinite plate)



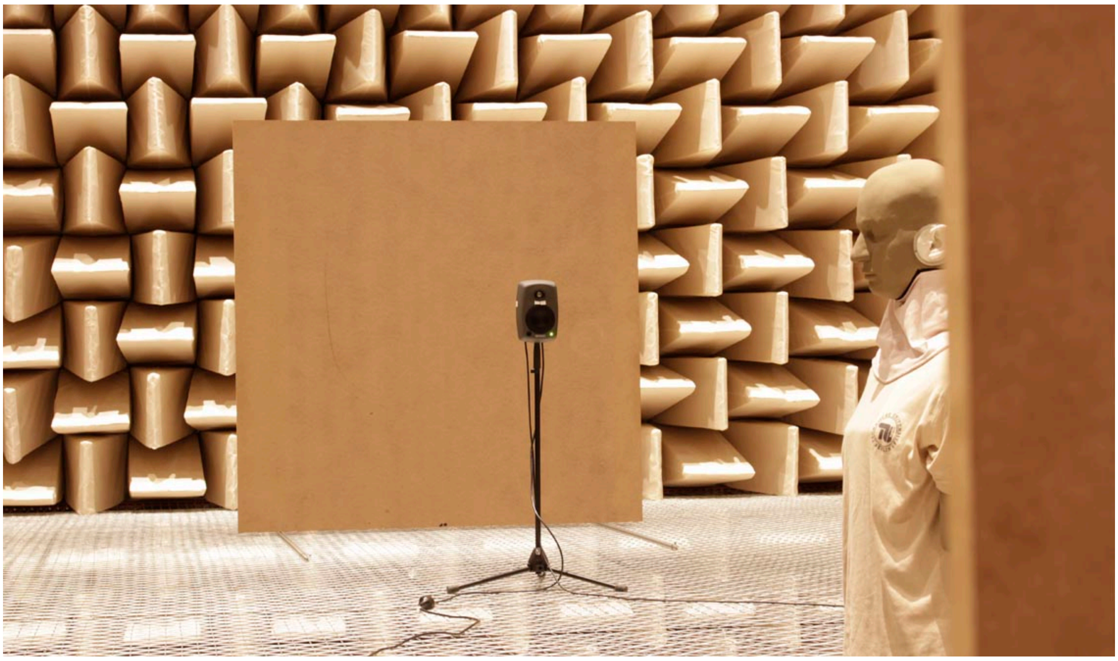
Short description:	Simple reflection on three different (infinite) surfaces: Hard floor of hemi anechoic chamber, RockFon absorber and medium density fiberboard (MDF) diffusor. Monaural impulse responses for three loudspeaker positions and angles (30 °,45 °, 60 °) and three microphone positions. Binaural impulse responses for one loudspeaker position and one receiver position.
Room:	hemi anechoic chamber RWTH Aachen ($V = 296$ m^3, $f_{\mathbf{low}} = 100$ Hz)
Temperature:	20.3 °C
Humidity:	41.5 %
Sampling rate:	44100 Hz
Scene geometry:	scene1_RIR_Floor.skp scene1_RIR_Absorber.skp scene1_RIR_Diffusor.skp scene1_BRIR_Floor.skp scene1_BRIR_Absorber.skp scene1_BRIR_Diffusor.skp
Output IRs:	29 RIRs; 3 BRIR sets (11,025 samples duration)
Comment(s):	For a more detailed description of the reflecting objects, see *.skp files in the folder *AdditionalSceneDescription*.

Scene 2: Simple reflection and diffraction (finite plate)



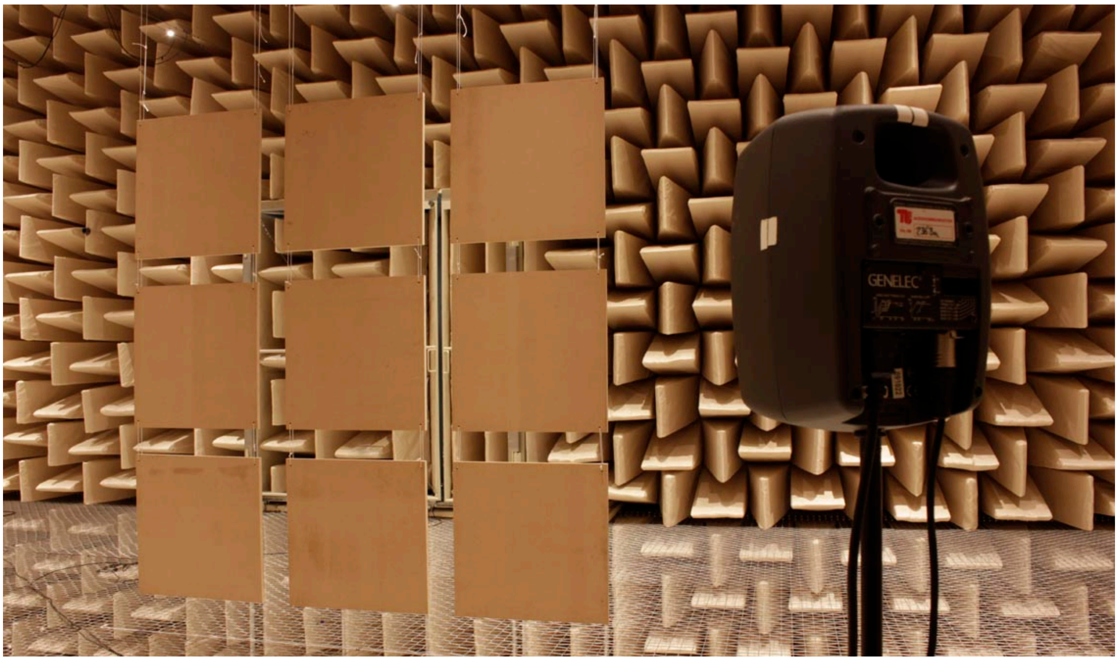
Short description:	Simple reflection and diffraction on, and around finite square boards with edge length of 1 m, and 2 m, rigid and absorbing surface, and multiple angles of sound incidence (30°, 45°, 60°). Plates were of medium density fiberboard (MDF) with a thickness of 25 mm. As absorbing material, Rockfon SONAR-G with a thickness of 20 mm was glued to the plate.
Room:	fully anechoic chamber TU Berlin ($V = 1070$ m^3, $f_{\mathbf{low}} = 63$ Hz)
Temperature:	17.6 °C
Humidity:	47 %
Sampling rate:	44100 Hz
Scene geometry:	scene2_RIR_1mPlate_Rigid.skp
	scene2_RIR_1mPlate_Absorbing.skp
	scene2_RIR_2mPlate_Rigid.skp
	scene2_RIR_2mPlate_Absorbing.skp
Output IRs:	18 RIRs; 0 BRIRs (6,000 samples duration)
Comment(s):	Due to logistical reasons diffraction was not measured for the 2 m plate with the absorbing surface. Sound transmission can be approximated based on density of the reflector plate, provided in the material description file *mat_MDF25mmA_plane*. The supporting structure, that holds the reflector, was included in the scene geometry for completeness, but might be removed for acoustical simulation.

Scene 3: Multiple reflection (finite plate)



Short description:	Multiple reflections between two finite square boards with edge length of 2 m, and rigid surfaces. Plates were of medium density fiberboard (MDF) with a thickness of 25 mm.
Room:	fully anechoic chamber TU Berlin ($V = 1070$ m^3, $f_{\mathbf{low}} = 63$ Hz)
Temperature:	17.3 °C
Humidity:	49.5 %
Sampling rate:	44100 Hz
Scene geometry:	scene3_RIR.skp
	scene3_BRIR.skp
Output IRs:	1 RIRs; 1 BRIR set (50,000 samples duration)
Comment(s):	Sound transmission can be approximated based on density of the reflector plate, provided in the material description file *mat_MDF25mmA_plane*. The supporting structure, that holds the reflector, was included in the scene geometry for completeness, but might be removed for acoustical simulation.

Scene 4: Simple reflection (reflector array)



Short description:	Simple reflection on a reflector array with rigid surfaces, and for multiple angles of sound incidence (30°, 45°, 60°). The loudspeaker was positioned to aim at the center of the array (on-center), and between two plates (off-center). Plates were of medium density fiberboard (MDF) with an edge length of 68 cm, and a thickness of 25 mm.
Room:	fully anechoic chamber TU Berlin ($V = 1070$ m^3, $f_{\mathbf{low}} = 63$ Hz)
Temperature:	17.6 °C
Humidity:	45.5 %
Sampling rate:	44100 Hz
Scene geometry:	scene4_onCenter.skp
	scene4_offCenter.skp
	scene4_sketch.pdf
Output IRs:	18 RIRs; 0 BRIRs (8,000 samples duration)
Comment(s):	The SketchUp files show the actual geometry of the reflector array. The intended geometry of a perfectly even spaced array could not be met, however, deviations are below 1 cm in most of the cases (cf. scene4_sketch.pdf). The reflector array was hung from the ceiling with cords. Sound transmission can be approximated based on density of the reflector plates, provided in the material description file *mat_MDF25mmA_plane*.

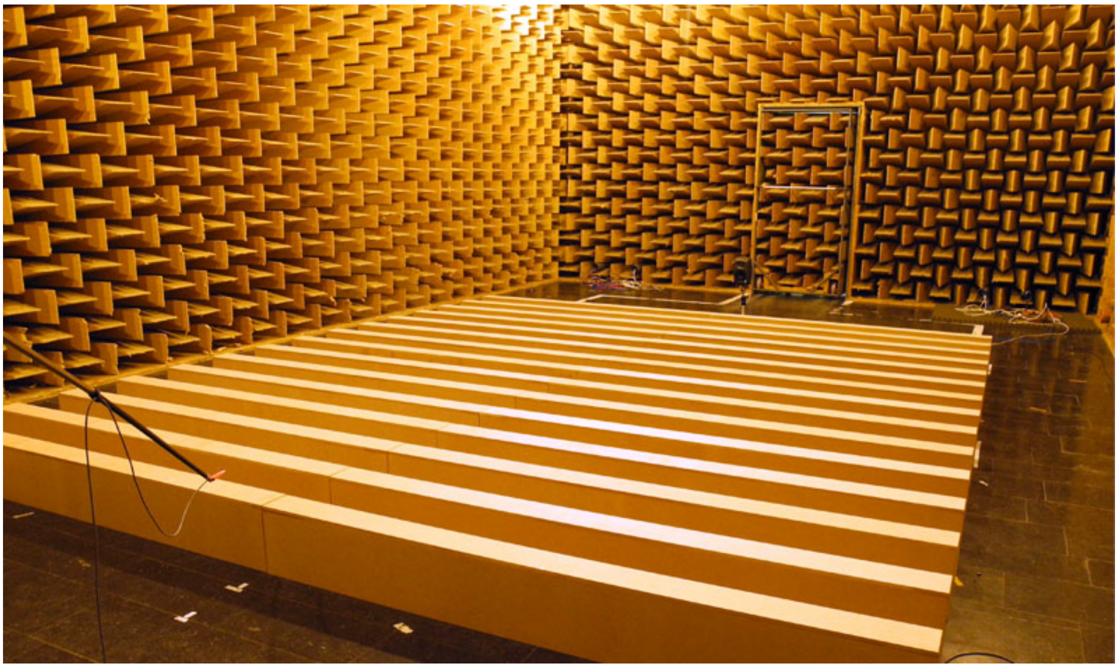
Scene 5: Simple diffraction (infinite edge)

Short description:	Simple diffraction at a partition (25mm MDF) with a height of 2.07 m. Monaural impulse responses for four loudspeaker and four microphone positions (different heights). Binaural impulse responses for one loudspeaker position and one receiver position.
Room:	hemi anechoic chamber RWTH Aachen ($V = 296$ m^3, $f_{\mathbf{low}} = 100$ Hz)
Temperature:	20.3 °C
Humidity:	40.3 %
Sampling rate:	44100 Hz
Scene geometry:	scene5_RIR.skp scene5_BRIR.skp
Output IRs:	16 RIRs; 1 BRIR set (11,025 samples duration)
Comment(s):	Sound transmission can be approximated based on the density of the partition, provided in the material description file *mat_MDF25mmB_plane*.

Scene 6: Diffraction (finite body)

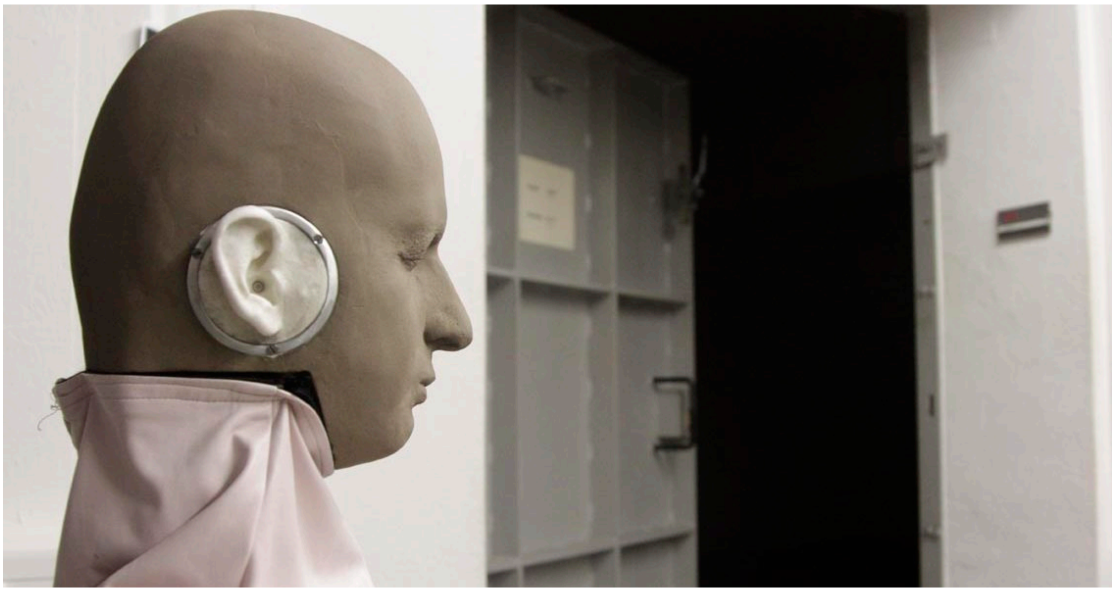
Short description:	Diffraction around a cubic body made of 18 hollow wooden blocks (25mm MDF) with a total height and depth of 0.72 m and a width of 4.14 m. Monaural impulse responses for three loudspeaker and three microphone positions (different heights).
Room:	hemi anechoic chamber RWTH Aachen (V = 296 m^3, $f_{\mathbf{low}}$ = 100 Hz)
Temperature:	19.9 °C
Humidity:	40.1 %
Sampling rate:	44100 Hz
Scene geometry:	scene6_RIR.skp
Output IRs:	9 RIRs, 0 BRIRs (11,025 samples duration)
Comment(s):	Sound transmission can be approximated based on the density of the wood, provided in the material description file *mat_MDF25mmB_plane*. Note that the body is set up by separated components, check the scene description file for details.

Scene 7: Multiple diffraction (seat dip effect)



Short description:	Seat dip like diffraction around 15 cubic blocks with a height of 0.27 m, depth of 0.12 m, and a length of 4.1 m (25mm MDF). Monaural impulse responses for two loudspeaker and four microphone positions (different heights).
Room:	hemi anechoic chamber RWTH Aachen ($V = 296$ m^3, $f_{\mathbf{low}} = 100$ Hz)
Temperature:	19.2 °C
Humidity:	40.3 %
Sampling rate:	44100 Hz
Scene geometry:	scene7_RIR.skp
Output IRs:	8 RIRs, = BRIRs (11,025 samples duration)
Comment(s):	Sound transmission can be approximated based on the density of the wood, provided in the material description file *mat_MDF25mmB_plane*.

Scene 8: Coupled rooms (laboratory & reverberation chamber)



Short description:	A simple case of coupled rooms where a reverberant chamber is coupled to a laboratory room with a lower reverberation time. The scene was measured for two different opening angles of the door (DoorAngle1=4.1°, DoorAngle3=30.4°) for the door between the rooms.
Temperature:	18.2 °C
Humidity:	47.6 %
Sampling rate:	44100 Hz
Scene geometry:	scene8_RIR_DoorAngle1.skp scene8_RIR_DoorAngle3.skp scene8_BRIR_01_DoorAngle3.skp scene8_BRIR_02_DoorAngle3.skp scene8_TW1.skp (geometry only) scene8_TW3.skp (geometry only)
Output IRs:	40 RIRs; 2 BRIR sets (198,450 samples duration – 4.5 s) RIRs for the Genelec 8020c were measured for 4 orientations with the following labels and x/y/z orientation vectors according to the scene's global coordinate system: 01: $[-0.6552 \quad 0.7555 \quad 0]$ 02: $[-0.7555 \quad -0.6552 \quad 0]$ 03: $[0.6552 \quad -0.7555 \quad 0]$ 04: $[0.7555 \quad 0.6552 \quad 0]$
WARNING:	The level of the RIRs was manually corrected by 6 dB to meet the expected direct sound level.

Scene 9: Small room (seminar room)

Short description: The seminar room at Aachen University was chosen for the small room because its relatively simple and easy to describe geometry, but challenging low frequency behaviour.

Temperature: 19.5 °C

Humidity: 41.7 %

Sampling rate: 44100 Hz

Scene geometry: scene9_RIR.skp

scene9_BRIR.skp

scene9.skp (geometry only)

Output IRs: 49 RIRs; 5 BRIR sets (154,350 samples duration – 3.5 s)

RIRs for the Genelec 8020c were measured for 4 orientations with the following labels and x/y/z orientation vectors according to the scene's global coordinate system:

`positiveX`: $[1 \quad 0 \quad 0]$

`positiveY`: $[0 \quad 1 \quad 0]$

`negativeX`: $[-1 \quad 0 \quad 0]$

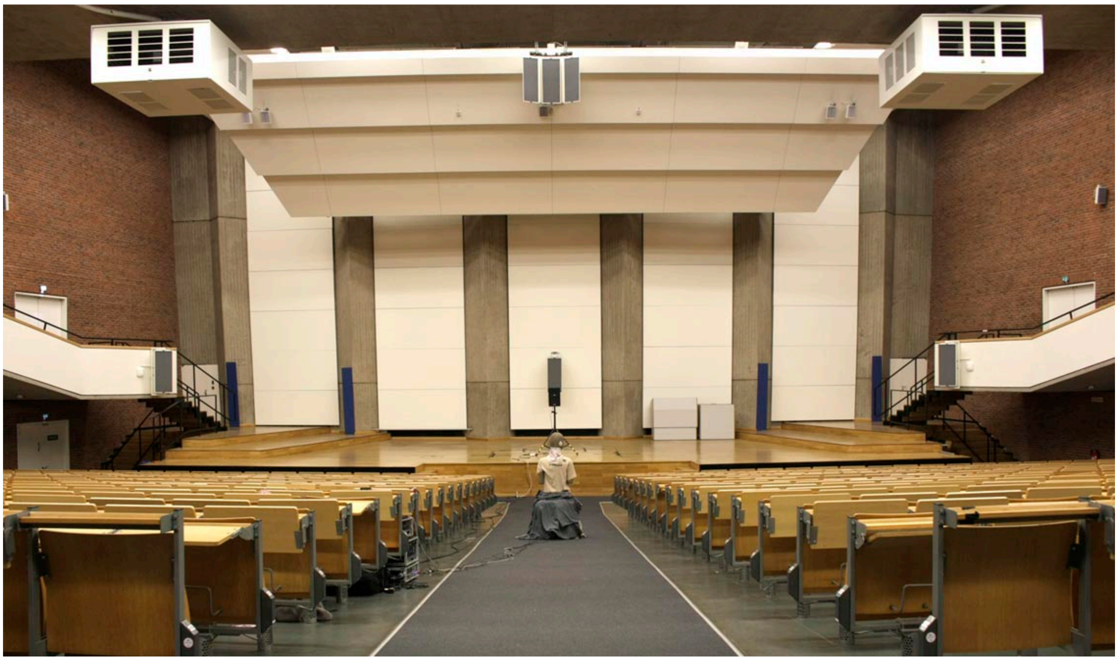
`negativeY`: $[0 \quad -1 \quad 0]$

WARNING: The level of the RIRs was manually corrected by 6 dB to meet the expected direct sound level. The RIR of the Genelec 8020c speaker for LS1 (orientation positive Y) MP5 is missing.

Scene 10: Medium room (chamber music hall)

Short description:	The small hall of the Konzerthaus Berlin was chosen for the medium room because of its relevance for chamber music and its relatively simple and easy to describe geometry.
Temperature:	22.4 °C
Humidity:	40.9 %
Sampling rate:	44100 Hz
Scene geometry:	scene10_RIR.skp scene10_BRIR.skp scene10.skp (geometry only)
Output IRs:	70 RIRs; 5 BRIR sets (154,350 samples duration – 3.5 s) RIRs for the Genelec 8020c were measured for 4 orientations with the following labels and x/y/z orientation vectors according to the scene's global coordinate system: `positiveX`: $[1 \quad 0 \quad 0]$ `positiveY`: $[0 \quad 1 \quad 0]$ `negativeX`: $[-1 \quad 0 \quad 0]$ `negativeY`: $[0 \quad -1 \quad 0]$
Comment(s):	The room has a considerable volume above its ceiling, which is included in the 3D model and might be excluded or simplified for acoustic simulation. The volume is coupled by large connections at the stage, and small connections on the ceiling.
WARNING:	The level of the RIRs was manually corrected by 6 dB to meet the expected direct sound level.

Scene 11: Large room (auditorium)



Short description:	The Auditorium Maximum at TU Berlin was chosen for the large room because of its relatively simple and easy to describe geometry.
Temperature:	20.9 °C
Humidity:	37.5 %
Sampling rate:	44100 Hz
Scene geometry:	scene11_RIR.skp scene11_BRIR.skp scene11.skp (geometry only)
Output IRs:	50 RIRs; 5 BRIR sets (154,350 samples duration – 3.5 s) RIRs for the Genelec 8020c were measured for 4 orientations with the following labels and x/y/z orientation vectors according to the scene's global coordinate system: `positiveX`: $[1 \quad 0 \quad 0]$ `positiveY`: $[0 \quad 1 \quad 0]$ `negativeX`: $[-1 \quad 0 \quad 0]$ `negativeY`: $[0 \quad -1 \quad 0]$
Comment(s):	The model provides a high degree of detail that can be reduced depending on the needs of each participant.
WARNING:	The level of the RIRs was manually corrected by 6 dB to meet the expected direct sound level.

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