The FABIAN head-related transfer function data base

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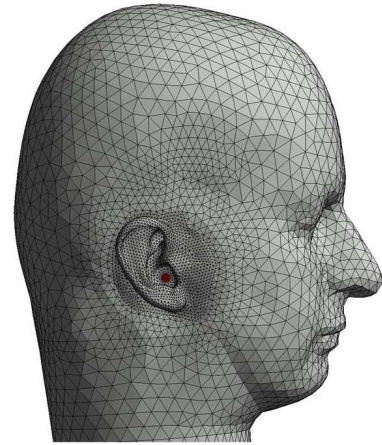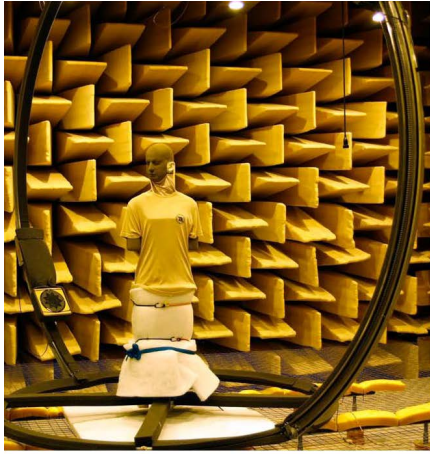**Markus Müller-Trapet, Rob Obdam, Michael Vorländer**

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General Information

In the following, the FABIAN [1] head-related transfer function data base is described in detail. It is provided under a Creative Commons BY-NC-SA licence, giving you the freedom to redistribute and edit the database for non-commercial purposes. For more information visit http://creativecommons.org/licenses/by-nc-sa/4.0/, and contact the authors for commercial use.

This documentation focuses on the structure and content of the data base. More information on the acquisition, processing and validation can be found in the accompanying Engineering Report published in the Journal of the Audio Engineering Society. If you use this data base please cite:

> Fabian Brinkmann, Alexander Lindau, Stefan Weinzierl, Steven van de Par, Markus Müller-Trapet, Rob Opdam, and Michael Vorländer:"A High Resolution and Full-Spherical Head-Related Transfer Function Database for Different Head-Above-Torso Orientations." *J. Audio Eng. Soc.*, 2017.

> Fabian Brinkmann, Alexander Lindau, Stefan Weinzierl, Gunnar Geissler, Steven van de Par, Markus Müller-Trapet, Rob Opdam, and Michael Vorländer: "*The FABIAN head-related transfer function data base*," 2017.

Data base description

1 HRIRs contains head-related impulse responses (HRIRs) for 11 head-above-torso orientations (HATO). Acoustically measured and numerically simulated HRIRs are stored in the SOFA format [2]. Spherical harmonics coefficients [3] of order $N = 35$ were calculated based on the complex HRTF spectra, and are stored in Matlab mat-files (cf. Figure 1a).

The files are named following the conventions `FABIAN_HRIR_acqusitionType_HATO_#`, where the `acquisitionType` is either *measured* or *modeled*, and `#` denotes the HATO, e.g. `FABIAN_HRIR_measured_HATO_0`. HATOs of 50° and 310° denotes that the head was moved 50° to the left and right, respectively. Azimuth angles $\phi = \{0, 90, 180, 270\}°$ specify sources to the front, left, back, and right, and elevation angles $\theta = \{90, 0, -90\}°$ denote sources above, in front, and below.

The HRIRs are accompanied by minimum phase common transfer functions (CTFs) stored in the SOFA format (cf. Figure 1b). According to Møller *et al.* [4], they were calculated by a weighted root-mean-square average of the HRTF magnitude spectra (HRTFs – frequency domain equivalent of HRIRs) across ϕ, θ, and HATO. Weights were estimated by calculating the area of spherical rectangular segments placed around each sampling point as shown in Figure 1c.

AKtools [5, 6] for Matlab can be used to load, or interpolate HRIRs to arbitrary source positions, and HATOs [7]. E.g. left and right ear HRIRs for $\phi = 45°$, $\theta = 15°$, and HATO = 10° are calculated by

```
[l, r] = AKhrirInterpolation(45, 15, 10)
```
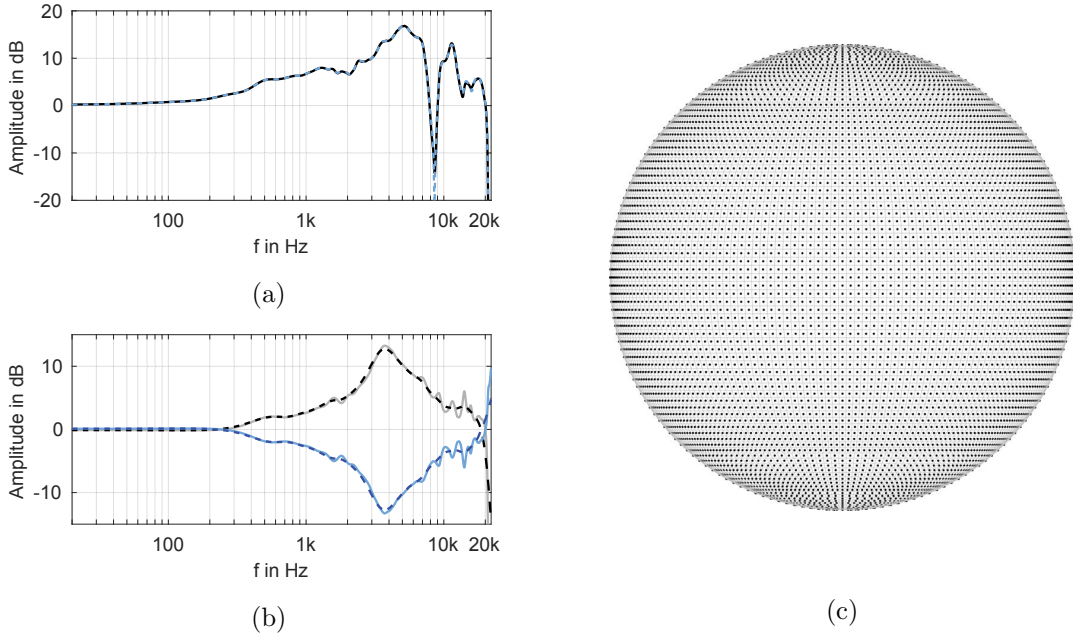

(a)

(b)

(c)

Figure 1: (a) example of a measured HRTF before (black) and after spherical harmonics processing (dashed blue). (b) CTFs calculated from measured HRTFs, and averaged across head-above-torso orientation. Light grey, and black dashed line: CTF, and 3rd octave smoothed CTF. Light blue, and dashed blue line: Inverted, and 3rd octave smoothed. (c) Spatial sampling points (dots) and spherical rectangles used to calculate the weights for CTF calculation.

2 SurfaceMeshes contains 3D surface meshes for all head-above-torso orientations in two resolutions, that can be used for numerical simulations up to 6 kHz and 22 kHz, respectively. BEM simulations were carried out on meshes with rigid surface impedances that were cut at the torso bottom (cf. Figure 2). Prior to this, the influence of an slightly absorbing torso bottom, as well as absorbing legs was tested but found to be negligible.

Figure 2: 3D surface meshes of FABIAN for numerical simulations up to 6 kHz, and head-above-torso orientations from -50° (left) to 50° (right).

3 Headphones provides headphone filters for equalization of a large variety of commonly used studio, and hi-fi headphones (cf. Figure 3). The filters should be applied when listening to HRIR based auralizations through headphones (they could be omitted if using DTF based signals). They were calculated based on 10-12 headphone impulse responses (HpIR) that were measured using swept sines. Headphones were reseated after each measurement. The headphone filters were designed using `AKregulatedInversion.m` from *AKtools* [5, 6] for Matlab by manually designing a regularisation function comprised of high-shelves, low-shelves, and parametric EQs. For convenience, the HpIRs and a plot documenting the filter calculation process are also included in the database.

Figure 3: Sennheiser HD600 headphones on FABIAN.

4 Auralization contains different auralizations for listening to the dataset after reading all the previous paragraphs and looking at the shiny pictures:

AnechoicFixed holds auralizations of a single source comparing (a) original HRIRs to their spherical harmonics based counterparts, and (b) measured to modeled HRIRs.

AnechoicMoving holds auralizations of moving sources in the horizontal , median, and frontal plane, and for comparing head-above-torso movements to source movements.

ReverberantFixed holds auralizations for a fixed source and receiver in the Concertgebouw (Amsterdam, Netherlands) for comparing measured and modeled HRIRs.

Free field auralizations (anechoic) were rendered with *AKtools* [5, 6] for Matlab, and the scripts for generating them are contained in the corresponding folders. The auralization of the reverberant environment are based on room acoustic simulation with RAVEN [8].
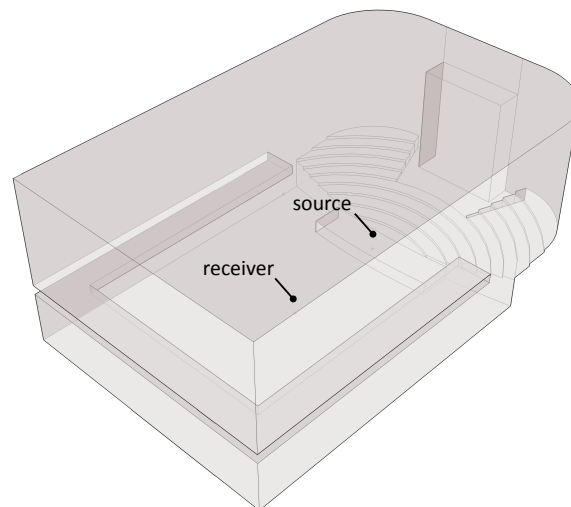

Figure 4: 3D model of the Concertgebouw, Amsterdam, Netherlands.

References

[1] A. Lindau, T. Hohn, and S. Weinzierl, "Binaural resynthesis for comparative studies of acoustical environments," in *122th AES Convention, Convention Paper 7032*, Vienna, Austria, May 2007.

[2] AES Standards Comittee, *AES69-2015: AES standard for file exchange - Spatial acoustic data file format.* Audio Engineering Society, Inc., 2015.

[3] E. G. Williams, *Fourier Acoustics. Sound radiation and nearfield acoustical holography*, 1st ed. Academic Press, 1999.

[4] H. Møller, D. Hammershøi, C. B. Jensen, and M. F. Sørensen, "Design criteria for headphones," *J. Audio Eng. Soc.*, vol. 43, no. 4, pp. 218–232, Apr. 1995.

[5] F. Brinkmann and S. Weinzierl, "Aktools—an open software toolbox for signal acquisition, processing, and inspection in acoustics," in *142nd AES Convention, Convention e-Brief 309*, Berlin, Germany, May 2017.

[6] ——, "AKtools - an open toolbox for acoustic signal acquisition, processing, and inspection," 2016. [Online]. Available: www.ak.tu-berlin.de/AKtools

[7] F. Brinkmann, R. Roden, A. Lindau, and S. Weinzierl, "Audibility and interpolation of head-above-torso orientation in binaural technology," *IEEE J. Sel. Topics Signal Process.*, vol. 9, no. 5, pp. 931–942, Aug. 2015.

[8] S. Pelzer, L. Aspöck, D. Schröder, and M. Vorländer, "Integrating real-time room acoustics simulation into a cad modeling software to enhance the architectural design process," *Building Acoustics*, vol. 4, no. 2, pp. 113–138, Apr. 2014.