FABIAN - An instrument for software-based measurement of binaural room impulse responses in multiple degrees of freedom

(FABIAN – Ein Instrument zur softwaregestützten Messung binauraler Raumimpulsantworten in mehreren Freiheitsgraden)

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Abstract

FABIAN is an instrument for the **F**ast and **A**utomatic **B**inaural **I**mpulse response **A**cquisitio**N**. It uses a new head and torso simulator whose orientation can be controlled in multiple degrees of freedom via a servo-motorized neckjoint, while the whole torso can be rotated on a motorized turntable device. A Matlab® application is controlling the measurement process acquiring binaural room impulse responses in high spatial resolution. They shall be used for the simulation of natural soundfields as well as electroacoustic reproduction setups by auralisation through binaural technology.

1. Concept

Nearly all perceptual information used for orientation in our auditory environment is coded in the sound pressure at our eardrums. Hence, natural or artificial soundfields can be simulated on the basis of binaural room impulse responses (BRIRs), representing the acoustical transmission path from a sound source to the listener. Precision and stability of source localization as well as the depth of immersion during auralization can be increased by means of dynamic headtracking to account for movements of the listener in the simulated environment.

Available head and torso simulators (HATS) for the measurement of BRIRs such as the the Kemar-maniquin [1], the Head Acoustics HMS-II/III series, the Bruel & Kjaer 4100, and the former Cortex (now Metravib) Mk1 as well as systems in the academic area such as the Valdemar-HATS [2] or the Aachen-head [3] are static systems with only limited

possibilities to emulate movements of head, shoulders, and torso. For the development of the BRS-processor a Neumann KU100 was used to measure BRIRs for horizontal and vertical directions by manual step-by-step reorientation [4]. A HATS-system developed at the TU Berlin [5] was the first to allow for an automated measurement of BRIRs for a horizontal rotation range of ±75°.

The measurement of complete sets of BRIRs in high spatial resolution is a lengthy process already for single-point auralisations. When the listener shall be allowed to move freely on a two-dimensional grid of BRIR-sets during binaural simulation the system not only has to take into account different orientations of head and torso relative to each other, but also speed and automation of the measurement process become relevant.

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2. System Design

For those applications an existing HATS system [6] was extended. Horizontal rotation and tilting of the dummy head in arbitrary angles is now possible by means of an servomotorized neck joint (sFigure 2). By reversing the joint's position the third rotational degree of freedom (lateral flexion) becomes accessible. When mounted on a special turntable the torso can be rotated as a whole (Figure 1). Thus, any spherical grid of head and torso orientations can be defined for the measurement of binaural impulse responses. The used devices allow exact and fast reorientation with negligible effect on the actual measurement duration.

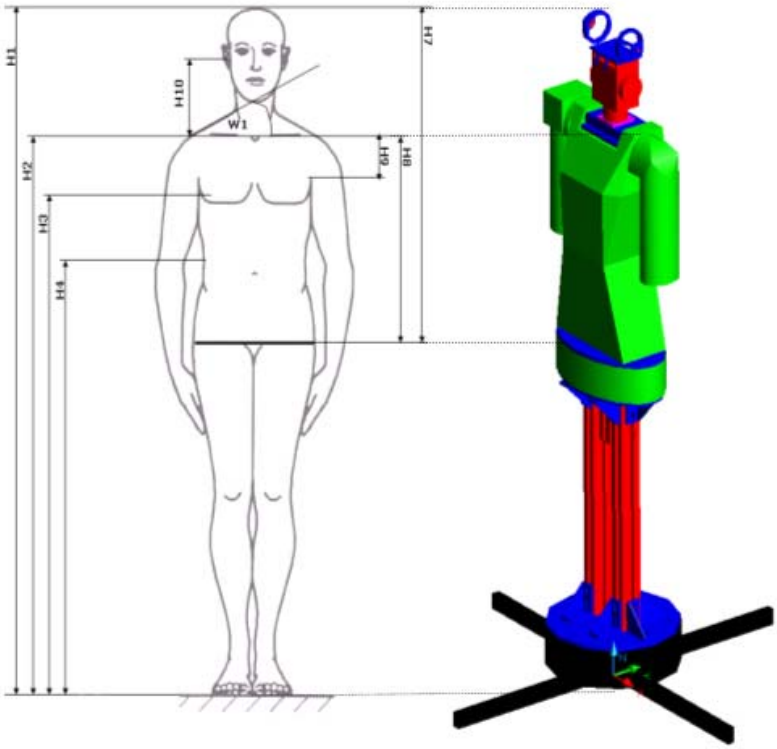

Fig.1: Anthropometric measures and the resulting 3D-CAD drafts of the modular torso

An new unisex corpus has been designed according to anthropometric data representing the 18-65 year old german population's median values [7]. For measuring in sitting or upright position the corpus was designed to be modular to some extent and can be detached from turntable and supporting stands.

Fig. 2: Close-up view of the FABIAN dummy head with uncovered neck joint

The outer silhouette was formed (Figure 2) according to anthropometric models from [8] to get a more human-like appearance. Since most HRTFs measured on randomly selected individuals result in better localization performances than those measured on all commercially availabe artificial heads [9], the head used for FABIAN is a gypsum mould from a human individual [6]. Its perceptual performance has already been evaluated [10]. The complex fine structure of the outer ear is preserved by silicone moulds made from individual human ears. The ears are exchangeable and equipped with low noise miniature condenser microphones DPA 4060 (ø 5.6mm).

The dummy head's microphones are located at the bottom of the cavum conchae at the beginning of the ear canal entrance. From this point to the eardrums there exists no directional dependence of the transfer functions [11]. The influence of microphones and reproduction setup has to be compensated by post-equalizing the BRIRs.

3. Measurement Process

A mobile PC controls head and body movements. It also conducts impulse response measurements using swept sine technique with additional noncyclic IR-deconvolution [12].

A custom multi-channel impulse response measurement application has been implemented. Hard- and software is supporting 44.1 to 96 kHz sampling frequencies and 8 to 32 bit wordlength for audio data. The two input signals of the dummy head's microphones are acquired while up to 8 simultaneously connected outputs can be used to drive different source-positions. By successively stimulating the sources before reorientating the dummy the measurement process is accelerated considerably.

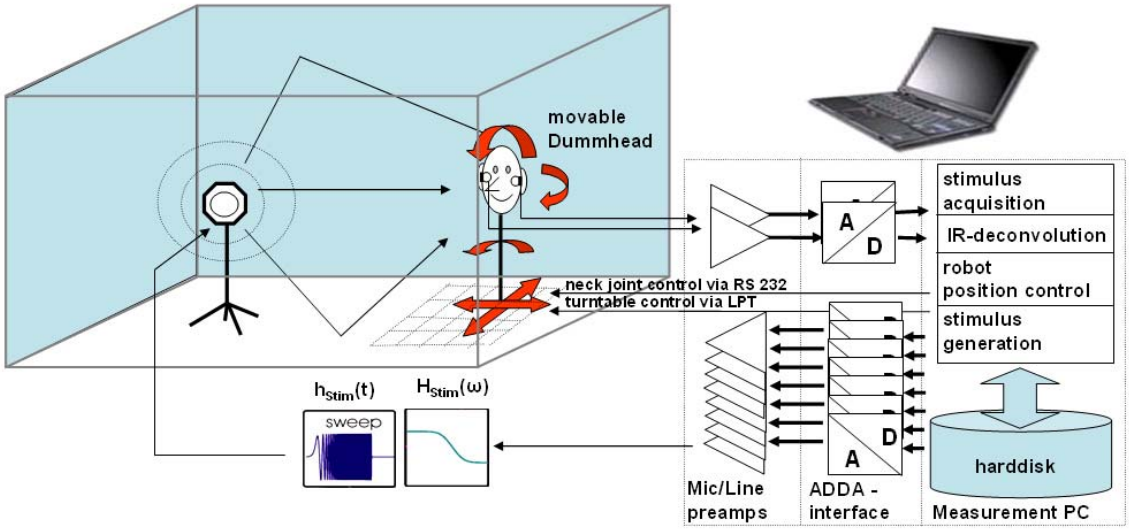

Fig. 3: Complete setup for the measurement of room impulse responses in multiple degrees of freedom

Measurements properties as level, duration (FFT-block-size) and spectral coloration of the stimulus and the number of averages can be chosen to adapt the measurement to ambient conditions such as noise level or reverberation time. In this respect the swept-sine measurement has convincing advantages compared with other measurement methods as MLS or TDS [12]. If input clipping is detected, the stimulus level is lowered and the measurement will be repeated automatically. Also if SNR temporarily falls below a given threshold while acquiring data a repetition of the last measurement is initiated.

During a first trial a 7 channel surround setup has been measured in a recording studio environment. 14.000 BRIRs with 1° horizontal and 5° vertical resolution were collected at the sweet spot during 33 h of unattended measurement. A mean SNR of 107dB ipsilaterally resp. 99dB contralaterally was reached using a bass-emphasized linear sweep of FFT-order 17 with two averages.

4. Outlook

Further research will be focused on the comparison of natural auditive perception versus electroacoustic representations by different recording and reproduction techniques, simulation-based in-situ comparison of room acoustics, and auralisation of sound fields where the listener is allowed to move freely in binaurally sampled acoustical environments.

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5. References

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