THE AUDIO COMPONENT OF A VIRTUAL REALITY

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INTRODUCTION

For a variety of applications (e.g. entertainment industry, asistive technologies, simulations of environment) it is desirable to be able to create an illusion of surrounding sound-source location. Human ears detect sound source position on the basis of several physical effects: loudness for determination of distance, interaural level difference (ILD) and interaural time difference (ITD) for estimating an angle in the horizontal plane, and frequency dependent damping for finding the elevation angle. [1]

There are two different methods of surround sound simulation. The first one uses numerous loudspeakers placed around a room, the second one uses stereophonic headphones. In our work, the second method was investigated. This method requires a sophisticated personalized numerical processing of the signal. The free parameters of the processing can be determined by acustic measurements for individual listeners. It is used to construct databases of the measurements to enable a generalization and a direct application in future (cf. e.g. [2]).

In the present contribution, we give results of our measurements of the sound perception.

PRINCIPLE OF DIRECTIONAL SOUND-SENSITIVITY

The most important modification of sound wave is due to interference on the auricles. These interferences cause a human ability to determine sound-source location. There is no distortion on the auricles when a subject listens the sound using stereo headphones, so a computation of the corresponding sound modification is needed. All differences like ILD, ITD and frequency dependent damping can be described by Head Releated Impulse Response (hereafter HRIR). It is a response measured at the ear entrances to a Dirac delta-function signal from a particular position. The general signal is then to be convolved with the HRIR.

Example of the HRIR in medial plane is depicted on Fig. 1. Angle 90° means signal from left side, 0° for a front sound-source and −90° shows HRIR from right. This response was measured for the left ear with frequency of sampling $44100Hz$. The main effects, which can be seen in the graphs, i.e. the gradual damping of the amplitude and the increasing delay from the uppermost to the bottom curve, are due to ILD and ITD, resp.

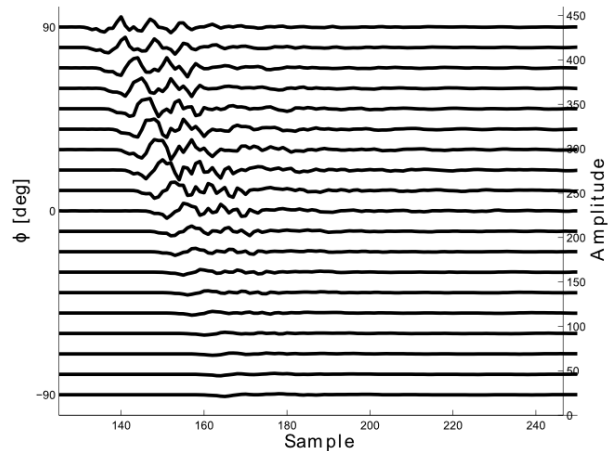In practice, the Fourier transform of HRIR called

Fig. 1. Example of the HRIR

Head Related Transfer Function (HRTF) is thus important. The amplitude of HRTF shows directly the sensitivity to different frequencies from given location.

Fig. 2 shows logarithms of Fourier transforms of the HRIR-curves plotted in Fig. 1. The frequency dependent damping can thus be read from this graph (cf. the scale on the right-hand side ordinate).
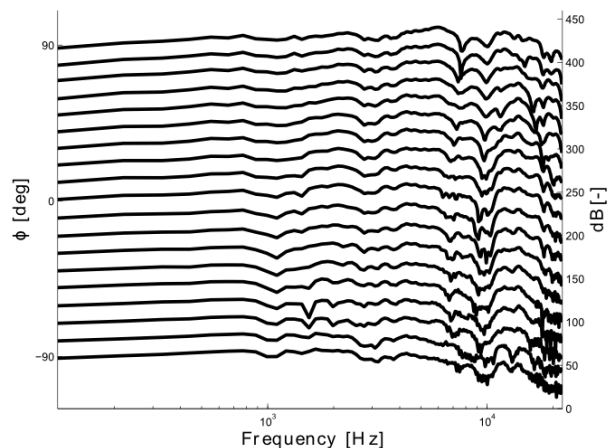

Fig. 2. Example of the HRTF

The HRIR (and HRTF) is different for every direction and distance of the sound-source and it mainly depends on the anthropometric parameters of the subject. This means that there is not a universal HRIR for everybody and the personalization is needed if applying a sound system based on binaural listening to different people.

MEASURING HRIR

Generally there exist two methods of measuring the response, the classical and the reciprocal one. The for-

mer applies a one loud-speaker in distance about one meter from the subject and two microphones placed at the ear entrances. System response is then measured directly.

Block scheme of our measurement is shown in Fig. 3. Subject was sitting on the rotable chair (A) with microphones (B). The loud-speaker (C) was connected to a sound-card (D) through a power-amplifier (E). The sound-card was connected to laptop (F) via IEEE 1394 connection (also known as FireWire).
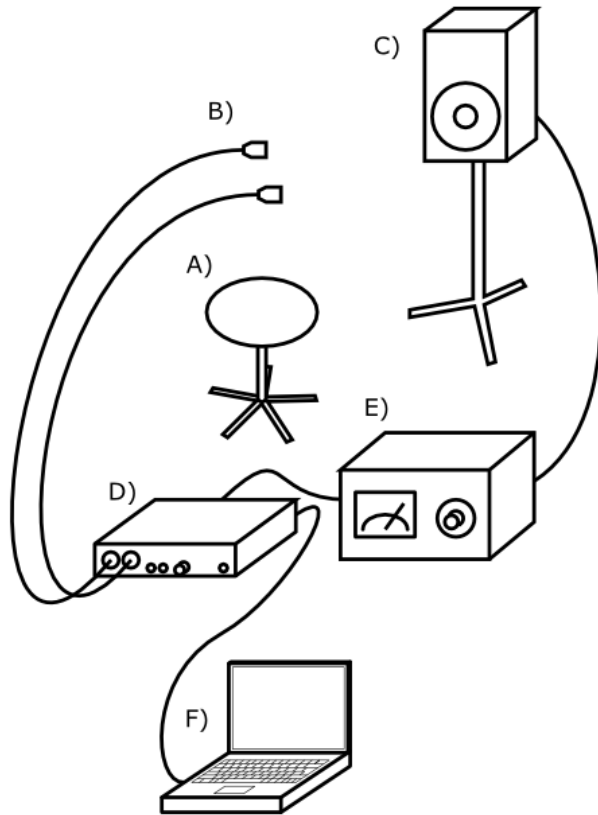

Fig. 3. Block scheme of measurements

This method is precise and it yields the response for the whole frequency spectrum of the audible sound easily. Disadvantage of this method is a slow speed of the measuring even in a professional laboratory.

The alternative reciprocal method places two speakers at the ear entrances of the measured person and a set of microphones outside. This method requires both the microphones and the speakers to have spherically symmetric characteristics. This method is much faster than the classical one, because it is possible to detect the signal from more microphones placed around the subject's head. This method is, however, more difficult to run in places without a good sound isolation because the speakers must not be too loud. We have not used this method also because its requirements for many high-quality microphones and soundcards make the equipment very expensive.

We have measured the HRIR for two subjects in 3 elevation angles and 19 different horizontal directions from distance 1 m. These measuring points are shown

in Fig. 4. We applied the classical method of measuring the response, using the software EASERA [3]. It creates samples of the Maximum Length Sequence (MLS, i.e. a kind of a pseudorandom binary sequence), records the response, calculates HRIR by deconvolution with the MLS and saves it to a wav-type file on the harddisk of the computer. Further processing and visualisation has been done using the MATLAB [4].
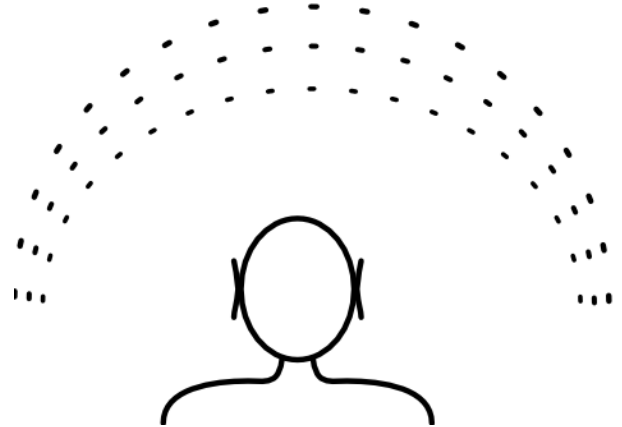

Fig. 4. Directions from which the HRTF was measured

CONCLUSIONS

We have verified that the HRTF is measureable using the above described method and equipment with sufficient precision. More measurements will be needed to collect data sufficient for conclusions on the relation between HRTF and physiognomy of different listeners.

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