

Binaural Room Scanning - A new Tool for Acoustic and Psychoacoustic Research

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Summary: A new method for auralization, called *binaural room scanning*, is introduced. It allows the virtual reproduction of a loudspeaker setup within an existing room by headphones. In contrast to model-based auralization methods, which employ simulated discrete reflections, derived from e.g. ray-tracing techniques, this new method is based on real-measured data. The convolution of long room impulse responses with the input data is dynamically controlled by a head-tracker. Possible applications are suggested in the fields of room acoustics, loudspeaker monitoring, loudspeaker and control room listening tests, as well as psychoacoustic research. Examples are given.

INTRODUCTION

The advantage of model-based auralization systems is their flexibility, regarding the possible free choice of parameters, e.g. those related to the room geometry, the number, the positions and the different attributes of sound sources. With given positions of the sound sources, surrounding walls and various sound-absorbing or -scattering objects, the entire soundfield can be calculated. This makes such systems ideal tools for synthesizing rooms, including abstract rooms which do not, and maybe even can not exist in reality.

The relevance of head movements in binaural localization is already known [1-3]. For example, in the late sixties Thurlow and Runge discovered that mainly head rotations (i.e. head movements around the *z*-axis) are used by (human) beings to reduce ambiguities in sound localization. They found that front-back-inversions vanish when these dynamic cues are applied [3]. Their results indicate that head rotations should be taken into account in auralization systems, in order to enable a better localization in the horizontal plane.

This has been confirmed in recent experiments [4-6]. A step motor system was used to turn a dummy-head, controlled by the listener's head rotations with the aid of a head-tracker. The dummy-head was placed in the so-called *sweet spot* in a typical surround sound loudspeaker arrangement according to ITU-Rec. BS.775 (3/4 stereo format). Both, a listening room according to the EBU Tech 3276 standard, and an anechoic room were used. The headphones (in accordance with ITU Rec. BS.708) and the dummy-head were *diffuse-field* equalized [7]. The total system's latency time was sufficiently small to not be perceived [5,8,9].

Considering head movements as localization cues, not only front-back-inversions vanish, but the localization performance nearly equals that of natural hearing [4]. Even, if the typical spectral cues of the pinnae are absent the localization in the horizontal plane remains good, as long as head-tracking is enabled, though elevations are reported [5]. Thus, an auralization system has to allow for head movements to enable sound localization that is comparable to normal hearing [10].

BINAURAL ROOM SCANNING

The basic idea of the *binaural room scanning* (BRS) method is to measure *binaural room impulse responses pairs* (BRIR) with a dummy-head. The novelty is that the loudspeakers of a standardized (multi-channel) stereo arrangement are used and the dummy-head is rotated at defined lateral displacement angles (whereas the "torso" remains fixed). For each loudspeaker of the stereo setup and orientation of the dummy-head, a new BRIR pair is measured and stored in a room data base [11] (see also Fig. 1). The measurements are carried out by means of an MLS-technique. With the described method, the whole characteristics of a room including the loudspeakers, assuming a locally time-invariant system, can be captured at the optimum listening point.

The binaural rendering of the pre-measured acoustical environments is performed by the so-called *BRS-Processor*. The input signals, which correspond to the signals that feed the virtual loudspeakers, are convolved with their corresponding BRIRs, depending on the actual orientation of the listener's head. Binaural room impulse responses of intermediate positions are interpolated using a newly developed frequency domain algorithm, resulting in smooth transitions between adjacent binaural filters [11]. The achieved high authenticity and fidelity mainly results from the dynamic adaption of the rendered room, controlled through the listener's head movements by means of a head-tracker [6].

If the aim is to produce an authentic image of an existing room where stationary sources (loudspeakers) are positioned, then the data-based BRS method is the better choice. For certain applications it is a certain drawback that the room is displayed only for fixed positions of sources (loudspeakers) and listeners, according to the measuring situation.

In contrast, model-based auralization methods do allow the display of moving sound sources (with respect to the room) or a moving listener. Time-variant filters can be integrated into model-based systems to simulate non-linear behaviour, e.g. non-linear distortions, the doppler effect, etc. Specific artificial rooms can be rendered or certain parameters of the room investigated. For example, the influence of a room with only two early lateral reflections and a single reflection from the floor could be generated, which does not exist in reality.

Using only headphones for the display, low-frequency vibrations are not transmitted. A system using nearfield two channel stereo loudspeakers and crosstalk-cancellation filters and/or a subwoofer might fix this problem. Incorrect elevations of virtual sources in the median plane are reported in some occasions. Recent studies indicate that this elevation effect can be reduced if the elevation angle is head-tracked as well [6].

BRS – A NEW TOOL FOR ACOUSTIC AND PSYCHOACOUSTIC RESEARCH

With the BRS method new possibilities in sound engineering arise, as well as in acoustic and psychoacoustic research.

It is well-known that the acoustics of an OB van is less convenient than that of a studio control room. However, if the sound engineer's control room is *binaurally scanned* and loaded into the BRS-Processor, he will have a listening experience via headphones, comparable to normal hearing in a familiar studio environment. Because several rooms can be stored in the BRS-Processor, a multi-channel-control room or a surround-sound-movie theater as well as an "average" listening room can be chosen.

On the other hand a new approach to comparison studies can be envisaged. For example, loudspeaker assessments, or room comparisons, e.g. different cars or control rooms, can be carried out easily simply by switching between them.

Leaving the field of comparative studies in acoustics, the BRS method can be applied likewise to psychoacoustic studies. Binaural room scanning can be carried out not only for the rotational head movements in the horizontal plane, but for tipping and pivoting movements as well. Therewith, their relevance to localization can be studied, while no constraints or losses due to a model-based synthesis arise. As another example, an experiment by Wallach, where he varies the perceived elevation [2], could be easily carried out again, by simply altering the translation ratio between listener's head movement and dummy-head movement. Also, the relevance of monaural localization cues could be studied under natural listening conditions, including head movements. In summary, it seems to be worthwhile to repeat certain experiments, carried out so far only with the (dummy-) head held still. The influence of so-called directional-bands can be investigated, while allowing head-rotations.

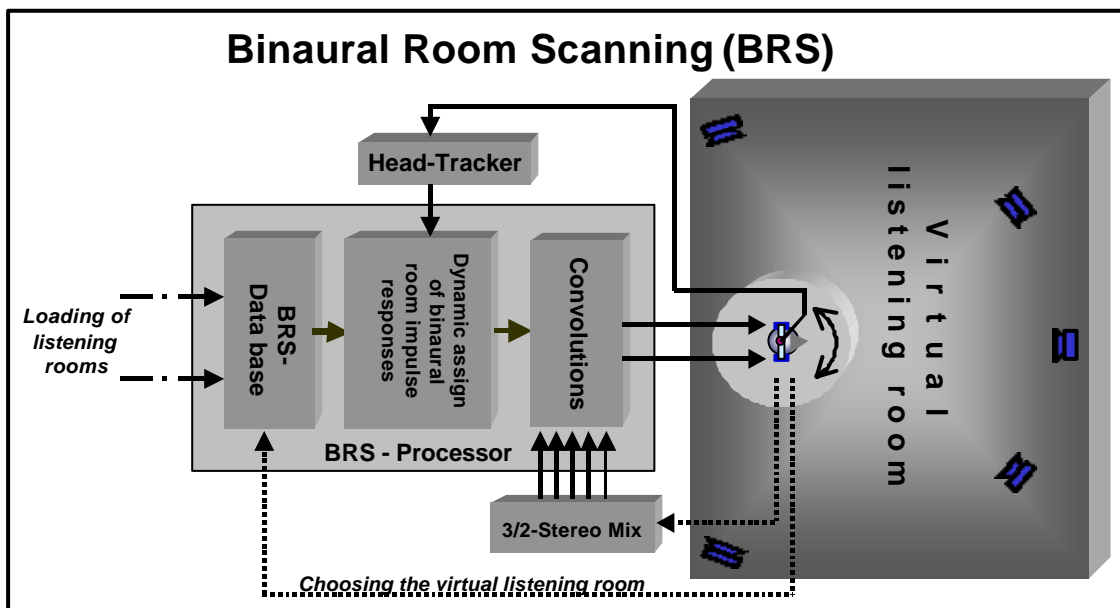


FIGURE 1, Functional outline of the BRS-Processor

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