A Novel Framework for Simulation and Auralization of Massive Multichannel Systems

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In the current discussion of spatial audio reproduction, the number of loudspeakers on the reproduction side is constantly growing. Extensions of 5.1 [1] up to 22.2 [2] enable the reproduction of height information. Recent developments in Wave Field Synthesis [3] and Ambisonics [4] have enabled the use of these technologies in practical and commercial applications. For the design of such systems, the simulation of free field speaker placements and sound pressure level distribution is state-of-the-art but for the perceptual evaluation the reproduction room cannot be neglected. This paper presents a framework which enables the simulation and dynamic realtime binaural auralization of such systems in different acoustic environments. The reproduction room and the used algorithm can be exchanged independently to enable the evaluation of algorithms and system design. A complete smooth work flow is possible due to the custom extensions of standard tools like MATLAB, EASE [7] and the Spatial Audio Processor [8].

Requirement Analysis

In the development and evaluation of spatial audio systems the binaural simulation is a widely used tool. In listening experiments, often a binaural auralization of existing setups is used to enable a fast and smooth switching between different configurations [5]. Very important is a dynamic auralization to minimize the influence of binaural headphone reproduction on the results [6]. Mostly, two settings are used: A free field simulation of a setup or a dummy head measurement of an existing system. Using these two approaches, it is not possible to simulate non-existing setups including the influence of the room. The aim of the framework presented in this paper can be summarized as follows:
Flexible simulation and auralization of non-existing spatial audio setups including room properties.
Therefore the following use cases for the framework have been defined:

- Binaural auralization of simulated spatial audio setups including room properties
- Dynamic binaural auralization
- Realtime spatial audio rendering independent from the simulation of the setup
- Flexible use of different HRTF sets independent from the simulation of the room
- Include measured loudspeaker directivities in the simulations

The two scenarios mentioned above will also be possible because these are a subset.

Implementation

The processing can be separated into two main steps. In the offline phase, the binaural impulse responses for each loudspeaker are generated. These sets are used afterwards during the realtime processing, the auralization of the setup. Figure 1 presents a block diagram of the whole framework.

Offline Processing

In the offline pre-processing, the binaural room impulse responses (BRIR) are created. Based on the loudspeaker setup (coordinates and angles) a loudspeaker geometry file is generated. In conjunction with a room model and the model of the used loudspeakers EASE and module AURA is used to generate a direction dependent impulse response file (response file). This is the description of the sound field for a particular listening position. The impulse response in this point is represented in a direction dependent way. Using an extended EARS module, this representation can be convolved with head related transfer functions (HRTFs) to generate a binaural impulse response for each view direction of the listener. The HRTF sets have to be available in a specific format which can be generated using a MATLAB script and imported to EARS afterwards. The result is a set of WAV files and corresponding timing information representing each view direction to specify the temporal alignment in order to generate a single BRIR database.

Realtime Processing

The realtime part of the processing is implemented on the Spatial Audio Processor platform. The key element is the binaural auralization plug-in. As an input, this convolution engine gets a loudspeaker setup and a set of binaural impulse responses. For each speaker, a set of binaural impulse responses exists which includes all desired viewing directions of the listener. In combination with the loudspeaker setup this enables the correct choice of the BRIR for each speaker depending on the head tracking of the listener. The inputs for the binaural auralization are audio signals for each loudspeaker. Using this architecture, a realtime spatial audio rendering can be connected. Systems of various kinds (e.g. Wave Field Synthesis or Higher Order Ambisonics) can be used and by switching the input of the auralization such systems can be compared directly.

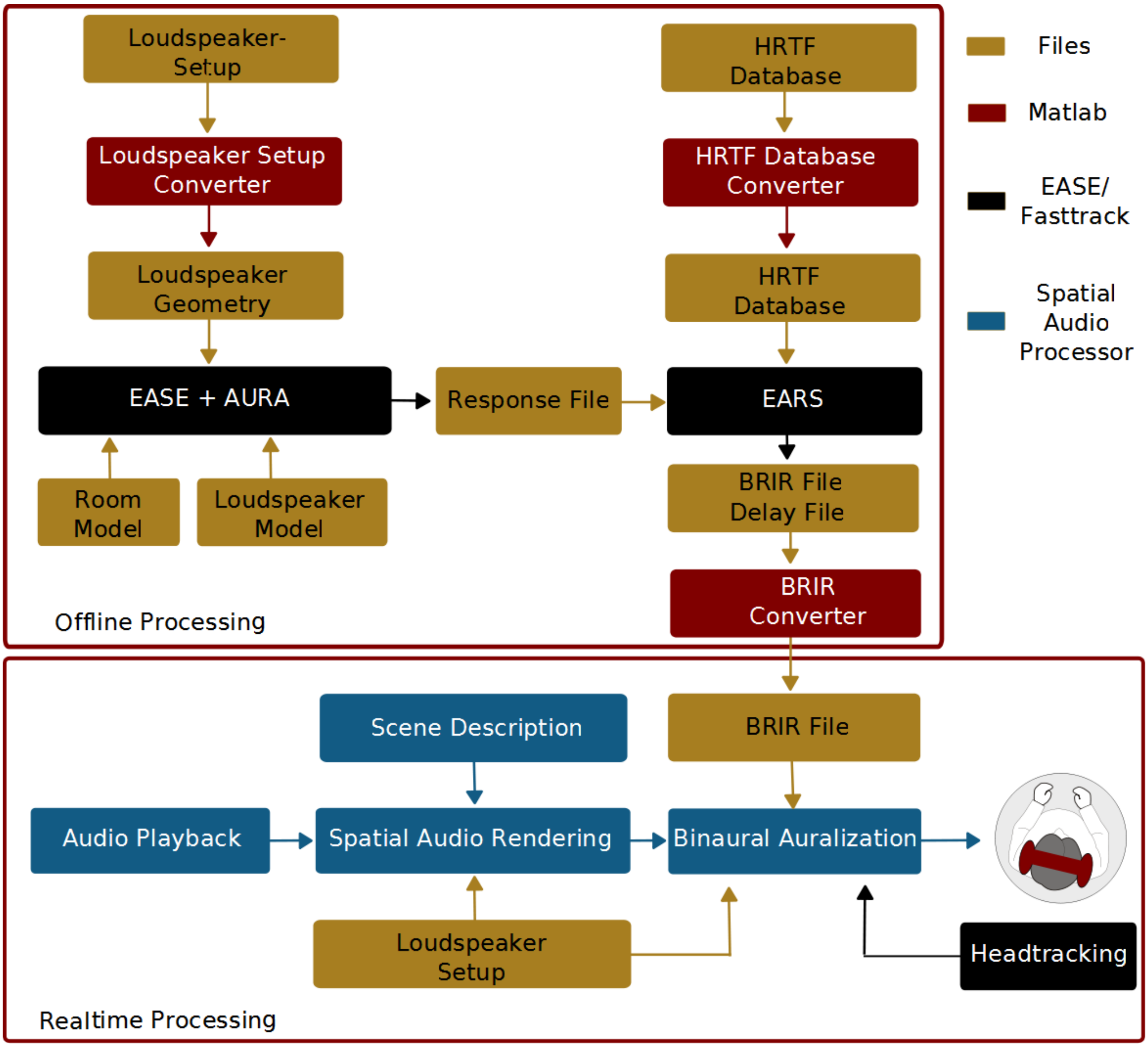

Figure 1: Block diagram of the two main processing chains of the auralization framework.

Conclusion and Future Work

This paper described a research tool for optimizing spatial audio rendering technology. The system has been used to verify the perceptual quality of spatial audio reproduction in several real-life situations. In complex and large scale situations an auralization is an useful tool to verify the quality of algorithms and loudspeaker setups.

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[7] EASE Homepage, URL: `http://ease.afmg.eu`

[8] IOSONO Homepage, URL: `http://www.iosono-sound.com`