A System For the Auralisation of Synthetic Sound Scenes Using Headphones and Head-Tracking

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Auralisation is the process of rendering virtual sound fields. It is used in areas including: acoustic design, defence, gaming and audio research. As part of a PhD project concerned with the influence of loudspeaker directivity on the perception of reproduced sound, a fully-computed auralisation system has been developed. For this, acoustic modelling software is used to synthesise and extract binaural impulse responses of virtual rooms. The resulting audio is played over headphones and allows listeners to experience the excerpt being reproduced within the synthesised environment. The main advance with this system is that impulse responses are calculated for a number of head positions, which allows the listeners to move when listening to the recreated sounds. This allows for a much more realistic simulation, and makes it especially useful for conducting subjective experiments on sound reproduction systems and/or acoustical environments which are either not available or are even impractical to create. Hence, it greatly increases the range and type of experiments that can be undertaken at Surrey. The main components of the system are described, together with the results from a validation experiment which demonstrate that this system provides similar results to experiments conducted previously using loudspeakers in an anechoic chamber.

Conducting Subjective Listening Tests with Loudspeakers

Research into the perception of reproduced sound often involves carrying out listening tests. Typically, listeners are invited to audition stimuli which are reproduced via different means (depending on the parameters under investigation) before judging the stimuli based upon some subjective measure (such as timbral fidelity, loudness etc). This research project is concerned with the relationship between loudspeaker directivity and the perception of reproduced sound in domestic rooms. Given that most changes in the sound field as a result of changes in loudspeaker directivity are dependent on the listening environment, it means that both directivity and room characteristics need to be considered in order to determine the relationship between directivity and perception.

Listening tests typically allow listeners to switch between stimuli instantaneously, so that an immediate judgement can be made based on the comparisons between successive stimuli. Subsequently, a way of manipulating both loudspeaker directivity and the room characteristics instantaneously is required in order to measure this relationship. Whilst a range of solutions exist so that loudspeaker directivity can be compared in this way, instantaneous switching between room characteristics is practically impossible. Therefore, an alternative method is required.

One option is to use acoustic modelling to design virtual sound sources/environments which exhibit changes in the parameters of interest. The virtual sounds field can then be reproduced via headphones, allowing listeners to instantaneously compare between them.

System Description

A system has been designed which allows users to compare the reproduction of audio material in a range of virtual environments, as shown in Figure 1.

The development process involves firstly designing the source and environment parameters using acoustic modelling software. The directivity of the virtual sources and the boundary characteristics of the environment (size, position, absorption coefficient, diffusivity) can be defined at this stage. Binaural impulse response data is then calculated within the virtual environment. A number of these are stored, representing the range of experimental conditions. The reproduction software allows an impulse response to be convolved with the audio material in real time, and enables the listener to rapidly switch between impulse responses. This allows the listener to compare several virtual environments instantaneously and, therefore, sensitively judge the effects of changing the manipulated parameters.

To give an additional degree of realism, 61 impulse responses are extracted per virtual environment, corresponding to 61 horizontal virtual receiver positions (-30 to 30 degrees). A head-tracker, which is mounted on top of the listener's headphones, 'tracks' the angle of the listener's head and feeds positional data back into the convolution software so that the corresponding impulse response can be selected. This means that the listener's head-angle determines the virtual receiver angle used for a given virtual environment.

Validation Experiment

In order to validate the subjective accuracy of the system, it was used to simulate an experiment configuration previously employed by Toole using real loudspeakers [1]. In Toole's experiment, listeners were asked to increase the level of a series of 'reflections' (which were delayed versions of an on-axis signal, reproduced by an identical loudspeaker off-axis), until they perceived a change in the reproduced sound. A second test asked listeners to change the level until the perceived shift in 'image' became significant, and/or a reflection became separately identifiable. This led to two thresholds being determined: the *absolute threshold* and an *image-shift threshold*.

The new system was used to create a virtual auralisation of the same setup, and listeners were asked to categorize their perception of the each reproduction, according to the terms used in Toole's tests.

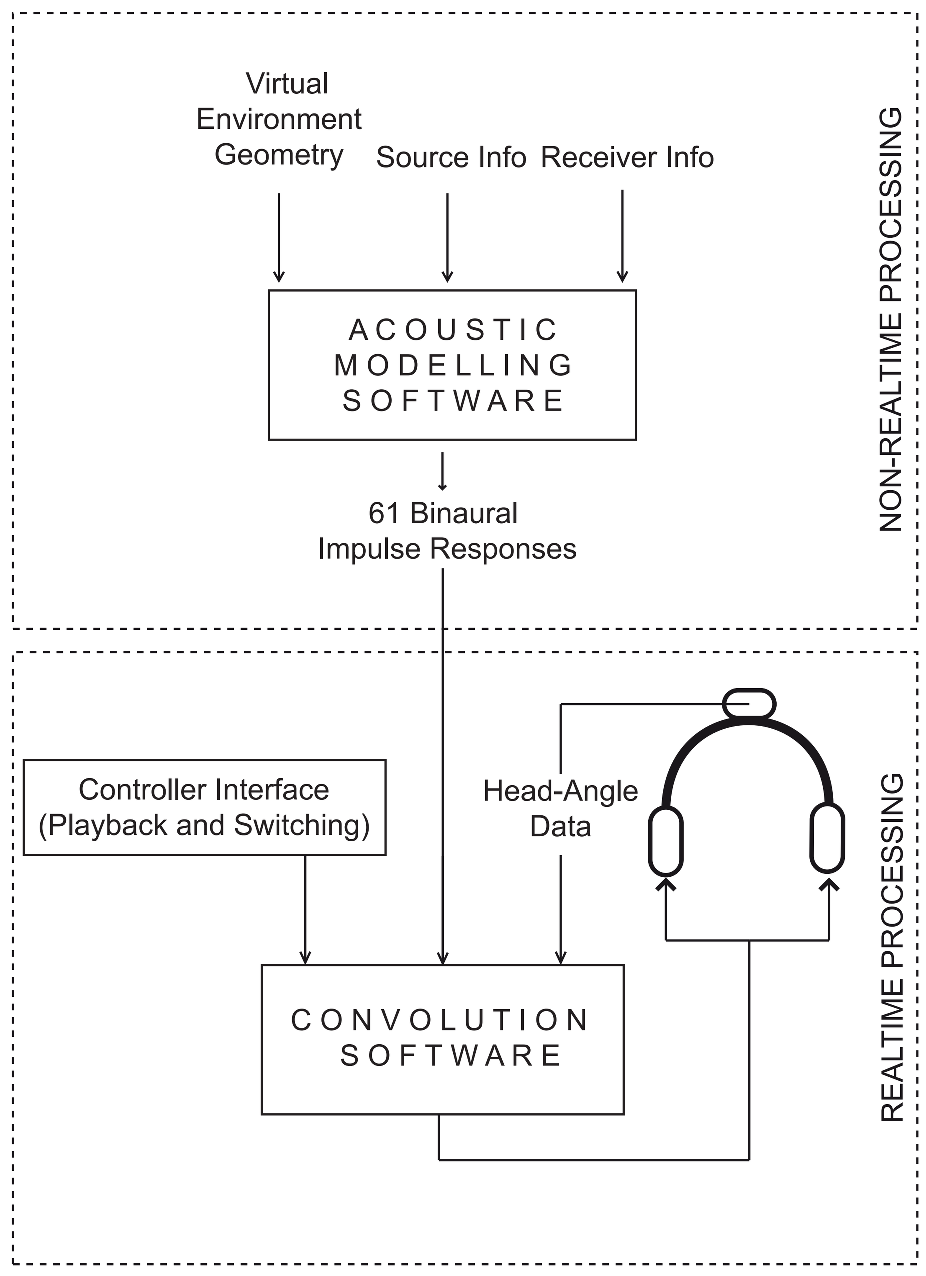

Figure 1: System Flow Diagram

The results, shown in Figure 2, indicate that the judgements provided by listeners using the auralisation system closely match those produced by Toole. Listeners commented that the system allowed them to compare the different environments with ease, and that subtle perceivable differences were audible for each parameter change.

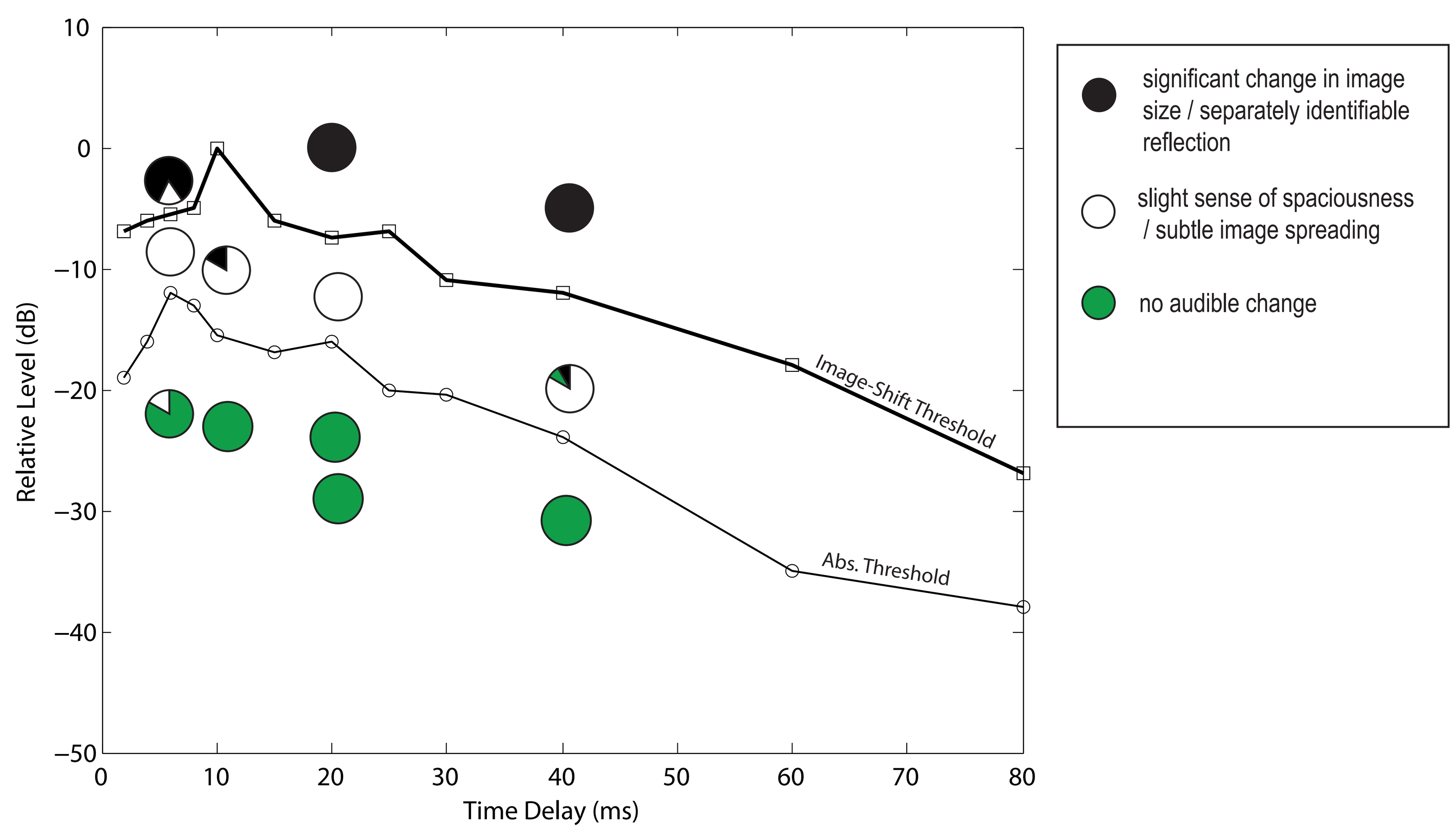

Figure 2: Results from the validation experiment compared to the thresholds measured by Toole [1]. The pie charts indicate listener responses using the auraliation system.

Conclusions

The auralisation system described offers a flexible and practical method for conducting listening tests in which the acoustical environment is changed. This allows changes in loudspeaker directivity and room characteristics to be compared instantaneously, which would not be practical in a real environment. The system has been validated by using it to simulate a previous experiment configuration. It was found that the results were similar between the previous experiment using loudspeakers and the current system using virtual auralisation over headphones. Hence, it appears that the system is suitable for use in similar subjective experiments.

References

[1] S.Olive and F.Toole, "The Detection of Reflections in Typical Rooms," *J.Audio Eng. Soc., Vol.37, No. 7/8, July/August 1989*