LISTENER ADAPTIVE FILTERING STRATEGIES FOR PERSONAL AUDIO REPRODUCTION OVER LOUDSPEAKER ARRAYS

Marcos Felipe Simón Gálvez and Filippo Maria Fazi
Institute of Sound and Vibration Research, University of Southampton, Southampton, 1BJ, UK
M.F.Simon-Galvez@soton.ac.uk

ABSTRACT

By the use of cross-talk cancellation techniques, it is possible to reproduce binaural audio with loudspeakers. One drawback of such systems is that they have a very narrow sweet-spot, which constraints the listener to be in a specific position with respect to loudspeakers. As to overcome this difficult, a formulation has been developed that adapts the cross-talk cancellation filters of a loudspeaker array to the listener´s position, which is estimated by means of a computer vision head-tracking system. To perform the adaptation, the cross-talk cancellation filters are decomposed into a series of gain-delay individual elements to control the radiation pattern of the loudspeaker array and a finite impulse response (FIR) equalisation filter. The formulation has been implemented in a loudspeaker array consisting of 28 small-size radiators, allowing a sweet-spot-free binaural reproduction for a single listener.

PRECIS

The development of small size loudspeaker arrays has made possible to control the soundfield with large degree of accuracy inside everyday rooms. An application of these arrays is, for example, to reproduce different audio signals for various listeners inside a common space, what is known as personal audio reproduction. Other application of such devices can be to reproduce a set of binaural signals at the ears of a listener, hence allowing to recreate a 3D virtual sound-field. Actual methods for providing a personalised audio reproduction are based on the creation of a set of inverse filters, which allow controlling a sound-field in a manner as close as possible to a desired pressure target. The pressure target is defined by maximising the acoustic pressure in a given listener position and minimise it in the other listener position to maximise the reproduced program difference between both listeners.

Classical techniques used for personal audio reproduction are *sweet-spot* dependent, which make such approaches sensitive to the listeners' position. In this case, if the listeners move out of their intended position the channel separation between both audio signals will be lost, with both listeners listening to a mixture of both their signals. If, however, it is desired that both listeners listen only to their intended signals regardless of their listening positions, it is needed to update the loudspeaker array control filters they use according to their position, which requires a more complex signal processing scheme in order to obtain an artefact-free audio reproduction.

The approach presented in the paper introduces a novel technique for filter updating. In this case, the filters are created using a least-squares approach, with each filter expressed as a summatory of sparse gain-delay elements obtained by the decomposition of a least-squares inverse problem. The value of each gain-delay element is adjusted depending on the position of the listener with the loudspeaker array, assuming each loudspeaker behaves like a point-source monopole radiator. The proposed filters are further decomposed into a set of IIR filters that govern the equalisation of the frequency response, and a set of FIR filters which control the radiation pattern of the loudspeaker array. This allows monitoring both processes independently, being able to control them in a separate manner. The IIR filters are implemented as a cascade of biquadratic filters, hence assuring the stability of the equalisation filters.

The paper first introduces the problem and then the theory and DSP schemes used for the proposed formulation. Simulations using point-source radiators are then introduced, which study the performance of the loudspeaker array to provide a personalised audio reproduction, by looking at the frequency responses and radiation patterns, in comparison with those obtained with existent least-squares filter creation approaches.