Using nonlinear signal processing in detecting reflections in room impulse response

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Abstract. In recent years, the increased usage of non-standard methods in acoustics is evident. Some of them involve applications of wavelets or multifractals, which are trying to solve a number of problems in this area. In the acoustic design of concert and opera halls, the analysis of room impulse response is very important. The early part of the room impulse response is characterized by strong isolated early reflections, which introduce sound coloration in the perceived sound. Early reflections produce the effect well known as comb filter, because of their coherent superposition with the direct sound.

The main characteristics of early reflections are their intensity and position in time, which makes them easily distinguishable. However, not all early reflections are strong enough and isolated along the time axis so to be easily detected. Something that is not easily noticed in the impulse response is the form of the reflections. Authors believe that multifractals could provide some answers to the current problem and ensure the ability to automate the process of detecting important early reflections in room impulse response. The assumption in this paper is that acoustic impulse response has caracteristic of self-similarity, which can be used for multifractal analysis.

Application of multifractal theory in the analysis of the acoustic impulse response is a novelty in the field of acoustics. In several studies, the acoustic impulse response was presented as a signal that was analyzed using its characteristic MF spectrum. It was found that the width of the MF spectrum is directly related to the complexity of the structure of the impulse response.

In our previous research we had gained some algorithms for detecting a certain number of early reflections in the impulse response of concert halls by using multifractal analysis. Additionally, we tried to classify a number of room impulse responses by calculating their multifractal spectrums first and then using Kohonen neural network for classification of obtained MF spectrums.

In this work we further increase the efficiency of using multifractals by combining them with other methods for nonlinear signal processing The proposed method introduces discrete wavelet transform over room impulse response. Filter banks at discrete wavelet transform are used for dividing the signal into frequency ranges, for calculating the coefficients of approximation and details. Then, the coefficients of approximation are the input signal in multifractal analysis for determining the distribution of Hölder exponent. The values of Hölder exponent that indicate relatively high temporal fluctuations of the signal density are extracted by additional signal processing. Finally, bidirectional mapping between the time positions of selected Hölder exponents and the time positions of important reflections in acoustic impulse response is done.

The obtained results confirm good efficiency of proposed algorithm in detecting early reflections in room impulse response.

Keywords: room impulse response, multifractals, discrete wavelet transform, early reflections, self-similarity