The Relation Between Perception of Room Acoustics and Objective Parameters As Calculated Using a Binaural, Nonlinear Model

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Introduction

When acousticians assess the acoustical qualities of a room, most often they determine objective acoustical parameters from measured (or simulated) room impulse responses on single or multiple microphone positions. The most important room acoustical parameters and measurement procedures are specified in ISO 3382 [1]. However, this method of evaluating room acoustics has its shortcomings:

- Because of practical limitations impulse responses are mostly measured in empty rooms. However, it is known that the values for most acoustical parameters depend on whether a room is filled with people or not [2].
- The method of calculating objective parameters from impulse responses does not take into account the fact that we do not listen to the responses directly, but to the audio of the source(s) convolved with these responses. The temporal and spectral features of the source signal are important for the perception of room acoustics [3].

At TU Delft a new method was proposed for evaluating parameters related to room acoustical quality. The method is based on a binaural, nonlinear auditory model which is capable of predicting for parameters which are thought of as being important for the perceived quality of room acoustics [2]: reverberance, clarity, apparent source width and listener envelopment. The model determines these objective parameters directly from arbitrary binaural audio recordings. This way the parameters are calculated in a content-specific way and furthermore there is no need to perform impulse response measurements. From listening test results it follows that these parameters correlate satisfactorily with room acoustical perception. In this paper the method is discussed and the relation between the model outputs and the results of the listening tests is evaluated.

Model description

In order to derive room acoustical parameters based on the human auditory system, a model is needed which accurately models various psychoacoustic effects. Such a model is developed by Breebaart [4]. This model is basically a binaural version of the model originally proposed by Dau *et al.* [5]. A modified version of the binaural model is used in this research. A schematic version of the complete model is shown in figure 1. For a description of the various stages, the reader is referred to [6].

As discussed in [6], the nonlinear properties of the model are utilized to split the binaural input stream into two streams: one related to the source (direct) and one related to the environment (reverberant). Next, the four objective parameters mentioned in the introduction are estimated:

- **Reverberance:** This is estimated as the mean level of the reverberant stream L_{rev}.
- **Clarity:** The ratio between the mean level of the direct stream over the reverberant stream $L_{\mathrm{dir}}/L_{\mathrm{rev}}$.
- **ASW:** A combination of the mean level of the model output for low frequencies L_{low} and the standard deviation of the ITD over time in the direct stream $\sigma_{\mathrm{ITD,dir}}$.
- **LEV:** A combination of the mean level of the background stream L_{rev} and the amount of variation of ITD in the background stream $\sigma_{\mathrm{ITD,rev}}$.

Model validation

In order to validate the model, listening tests were conducted in which a group of five expert subjects had to rate the four attributes for various binaurally simulated rooms on a continuous scale. The tests were performed using an efficient procedure as proposed by Chevret and Parizet [7]. Two different stimuli were included: solo male speech and solo cello. These stimuli were chosen because of their different temporal and spectral features.

Examples of the model versus listening test results are shown in figure 2 for the attributes ‘reverberance’ and ‘LEV’. As can be seen, the model is able to predict the perceived attributes with a high correlation ($r = 0.96$ for reverberance and $r = 0.95$ for LEV). Also for clarity and ASW the correlation coefficients are high: $r = 0.95$ and 0.87 respectively.

Conclusion

Using the outputs of a binaural, nonlinear auditory model, objective parameters can be determined which predict the amount of perceived reverberance, clarity, apparent source width and listener envelopment. Since the model accepts arbitrary binaural recordings as input signals, these objective parameters can be determined without the need for measuring (binaural) room impulse responses. Instead, the acoustical qualities of a concert hall

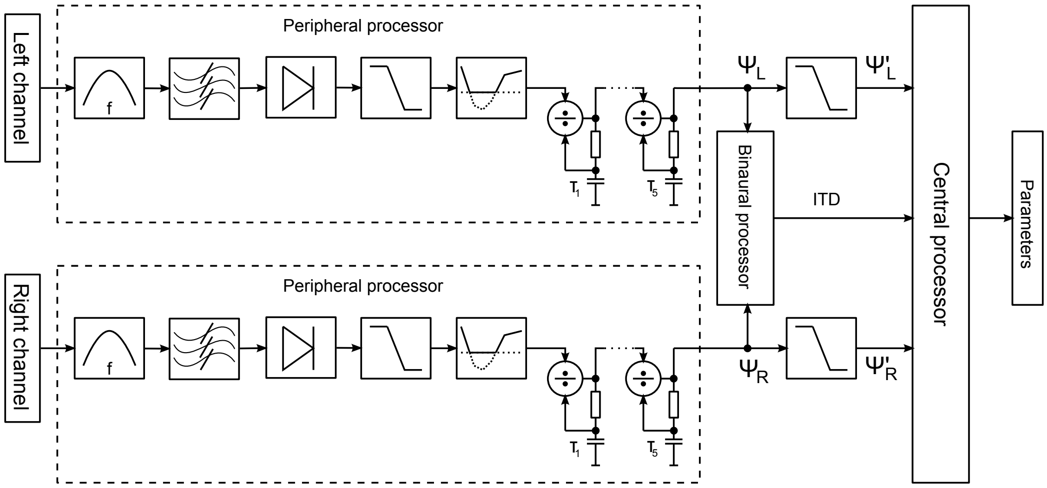

Figure 1: A schematic version of the binaural auditory model. The full model contains five adaptation loops, of which two are shown in the figure (with time constants τ_1 and τ_5).

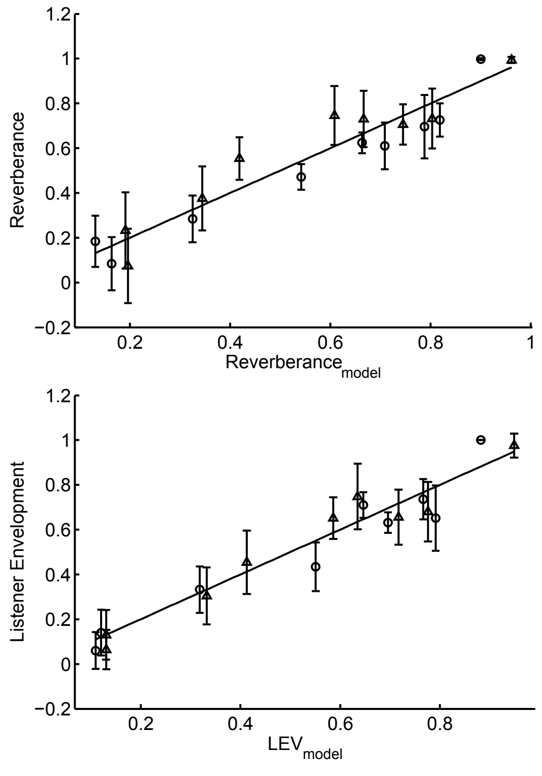

Figure 2: Example results of objective versus subjective results for nine different rooms for the attributes 'reverberance' (top) and 'listener envelopment' (bottom). The results for the 'male speech' sample are shown using triangles, the results for the 'solo cello' sample using circles. The error bars denote the standard deviation in the subjects' answers.

can be assessed by placing a dummy head in a concert situation, for example.

Also, the stimulus type is automatically taken into account, making it possible to test a room for multiple applications. A theatre can be tested for both speech and chamber music, for example.

References

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