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Study on model of stochastic room impulse response and method for estimating parameters of its model

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Rooms are designed to fit to purposes of the rooms. Room acoustic indices such as speech transmission index (STI), reverberation time (T_{60}), and Deutlichkeit (D_{50}) are used to assess speech transmission quality in the rooms as important objective measures. The room acoustic indices are calculated using room impulse response (RIR). When the RIR is measured, it is necessary to have high-intensity observation signals such as impulses or long observation signals. For this reason, in order to measure the RIR under our daily-life and public acoustic environments, it is necessary to wear equipment for protecting human ears. However, keeping wearing the equipment is difficult in these situations. Therefore, it is impossible to measure the RIR. In recent years, for example, when disasters occur, it is important to present appropriate evacuation guidance to people in these place. In such a situation, it is difficult to measure RIR, and the method to estimate the room acoustics such that the measurement of RIR can be substituted is necessary. Therefore, blindly estimation method of room acoustic indices is required to such that RIR can be estimated from room sound.

The methods of blindly estimation of room acoustic indices were proposed by some research groups. In time domain, blindly estimating method of T_{60} has been proposed by Unoki et al., using power envelope inverse filtering method. In modulation frequency domain, blindly estimating method of STI, D_{50}, and T_{60} have been proposed by Hiramatsu & Unoki, Sasaki & Unoki, Miyazaki et al., using modulation Spectrum features. In these method, parameter estimating methods of the RIR models were used. However, these methods have problems of estimation accuracy. For this reason, (1) current stochastic RIR models using the parameter estimation cannot accurately approximate actually measured RIRs. (2) these estimation methods have constraint dependent on the modulation index and it is difficult to apply the methods in the public acoustic environment. In this report, to solve these problems, the following two issues are discussed: (I) we propose a model with improved approximation in the stochastic RIR model. (II) we propose constraint conditions not depending on modulation index and confirm that it is effective.

Schroeder's RIR model and generalized RIR model were proposed as stochastic models of RIR. Schroeder's RIR model models reverberation based on exponential decay. Since this model is simple, growth part of RIR cannot be described. The generalized RIR model is a model that can describe growth part of RIR. However, since growth and decay parts of RIR model are dependent, it is impossible to represent accurate reverberation characteristics. To solve problems in the previously proposed models, we propose an extended RIR model that can describe growth and decay parts of RIR independently. In order to evaluate whether this model is valid, we apply previous stochastic RIR models and the proposed RIR model to approximate actually measured RIRs. The total number of the measured RIRs is 43. As a result, the proposed RIR model is able to approximate the measured RIRs in the time domain better than the previous RIR models are, and the proposed RIR model is also able to approximate the measured RIR in modulation frequency domain comparable to the previous RIR models. The room acoustic indices are estimated from the estimated RIRs. The estimation accuracy of D_{60} in time domain using the extended RIR model becomes better, and other indices can also be estimated accurately comparing with the previous RIR models. In summary of these results, the extended RIR model is able to express the actually measured RIR as the same or better than the previous RIR models. Therefore, the problem of (I) is solved.

In order to solve the problem (II), we focus on the shape of the periodic signal without reverberation. When local-maximal values and local-minimal values are obtained from power envelope of the periodic signal, the local-maximal values are equal and the local-minimal values are also equal. When regression lines are drawn for the local-maximal and minimal values, it is shown that the slope of the regression lines must be flat. Drawing a regression line is equivalent to obtaining the upper and the lower envelopes of the signal. If this procedure is applied to power envelope of a reverberant periodic signal, the slope of the upper and lower envelopes are not flat. Thus, we can evaluate whether reverberation is added or not to the signal by finding the slopes of the upper and lower envelopes. This rule is applied to each RIR model and we confirmed that parameter estimation of each RIR model can be performed appropriately on the simulation. As a result, parameters can be estimated appropriately for any RIR models. Then, we estimate the parameters assuming the public acoustic environments using the extended RIR model applied this constraint. As a result, the parameters related to T_{60} can be estimated. Therefore, the problem of (II) can also be solved.