19th INTERNATIONAL CONGRESS ON ACOUSTICS
MADRID, 2-7 SEPTEMBER 2007

Auditory evaluation of impulse response reconstructed by correlation factor

PACS: 43.55.Cs

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ABSTRACT
When sounds are radiated in a room, the reflection sounds are generated from the walls, floor, ceiling and the other objects. In the auditory sense, these reflection sounds are important at the receive point. The impulse response includes the transmission between the radiated point and the received point. We select any signal in the impulse response that is called an early reflection signal. We calculate the correlation function between the early reflection signal and the impulse response every sampling period as a function of lag. We set a threshold for the correlation function. Following this threshold, we generate a new signal from the high correlation factor with the early reflection. We compare the new constructed impulse response with the original impulse response by the auditory test.

1 INTRODUCTION

When sounds are radiated from a loudspeaker in the room, the sounds measured at a point are constructed with an incident sound and reflection sounds. To evaluate acoustic characteristics of the room, we need detect correlation factors between the early reflection sound and the reflection sounds. We calculated the correlation coefficient between an early reflection sound and the reflection sounds. The early reflection sound is defined the incident sound from impulse response. In this paper, we calculated an impulse response between the driving sound from the loudspeaker on the stage and sound measured at the center of a seat area. We separated the early reflection sound and the reflection sounds from the impulse response. The correlation coefficient function between the early reflection sound and the impulse response is estimated. This signal called self correlation function. We set the threshold level for the self correlation function, and detected the absolute correlation value larger than the threshold level, and we set the absolute correlation value smaller than the threshold level for zero. Following this algorithm, we generate a new signal with the high correlation factor for the early reflection. We estimated the impulse response that is constructed by the early reflection sound and that new signal, and compared that new signal to the impulse response measured in the room.

2 THE MEASUREMENT OF IMPLUSE RESPONSE

Measuring an impulse response is carried out at a lecture hall. This hall is in Toyosu campus, Shibaura Institute of Technology. The seating capacity of this hall is 520.The size of the concert hall is 17.38 meters in width and 32.4 meters in depth. The lecture hall is shown in Fig.1. The measurement setup is shown in Fig.2. The loudspeaker is set on the stage point S. The TSP signal is radiated from the loudspeaker. The microphone is set on the stage point R in Fig.2. For improving the signal to noise ratio, the time of averaging is 20. Sampling frequency is Fs = 20kHz.

Fig.1 Picture of lecture hall.

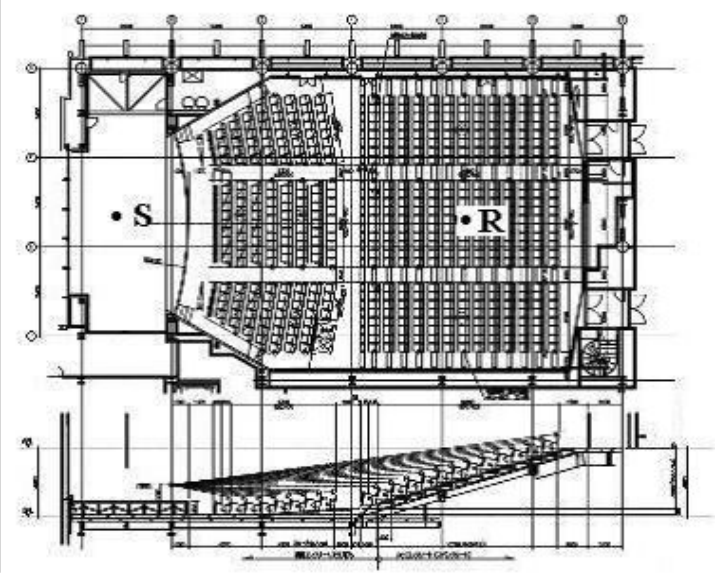

Fig.2 Measurement setup.

The impulse response from the loudspeaker to the microphone is estimated by the cross spectrum method. The estimated impulse response is shown in Fig.3. The impulse response are separated the early reflection sound and the reflection sounds.

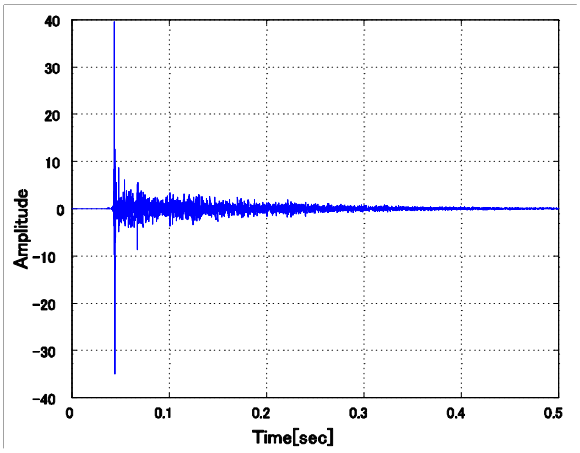

Fig.3 Impulse response.

3 SELF CORRELATION FUNCTION

3.1 Self correlation function

In the impulse response **h**, we select a time window, and estimated a correlation function between the time window and the impulse response. Then, This function called self correlation function. The early reflection sound is selected from impulse response by using of the time window. The early reflection sound defined from 43.50msec to 44.95msec. The duration of the early reflection sound is 1.0msec. Let the impulse response = **h**, the early reflection sound = **x**, the reflection sounds = **y**. These equations are expressed as follows:

$$\mathbf{h} = [h_1, h_2, ..., h_N] \quad \text{(Eq.1)}$$

$$\mathbf{x} = [h_k, h_{k+1}, ..., h_{k+n-1}] \quad \text{(Eq.2)}$$

$$\mathbf{y} = [h_i, h_{i+1}, ..., h_{i+n-1}] \quad (i = 1,2,...,N-n) \quad \text{(Eq.3)}$$

The self correlation function is calculated the correlation value between the early reflection sound and the reflection sounds every sampling period. These equations are expressed as follows:

$$g_i = \frac{\sum_{j=0}^{n-1} h_{k+j} h_{i+j}}{\sqrt{\sum_{j=k}^{k+n-1} h_j^2} \sqrt{\sum_{j=0}^{n-1} h_{i+j}^2}} \quad \text{(Eq.4)}$$

Then, Stronger the correlation value, the absolute correlation value is near 1. Weaker the correlation value, the absolute correlation value is near zero.The results of self correlation function are shown in Fig.5.

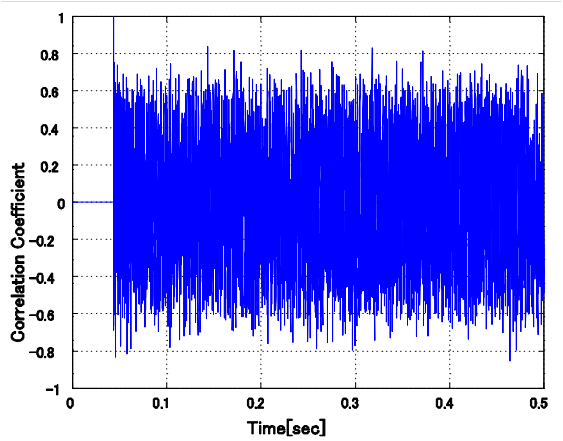

Fig.4 Self correlation function.

4 MAKING INPLUSE RESPONSE

4.1 Threshold level

For making a new time signal with the high factor for the early reflection sound, we set a threshold level from 0.1 to 0.9 for the self-correlation function. We detect the absolute correlation value larger than the threshold level and the value that conforms to the condition is

kept and the other is set zero. The results of the self correlation function that the threshold level is set are shown in Fig.6. The result under the condition of threshold level = 0.6.

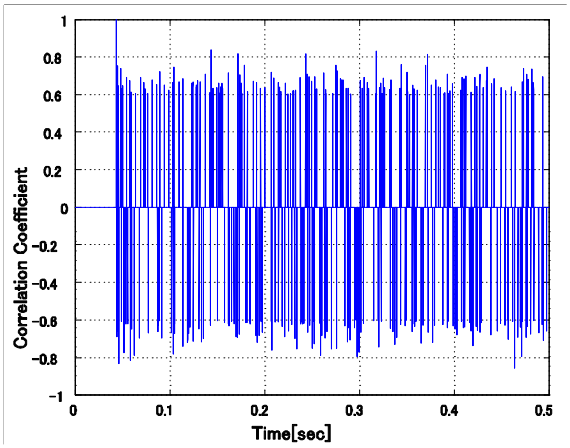

Fig.5. Self correlation function, threshold level is 0.5.

4.2 Making a time signal with the high the correlation factor

We generate the new signal with the high factor for the early reflection sound. We estimated the impulse response from the self correlation function with high factor by convolution the early reflection sound and the self correlation function. In addition, we multiplied this impulse response by decay curve. That decay curve coefficient is the same as the one impulse response is measured in the hall.We estimated new impulse response from the self correlation function. The results of the new impulse response that is estimated from the self correlation function that the threshold level is set 0.6 is shown in Fig.10.

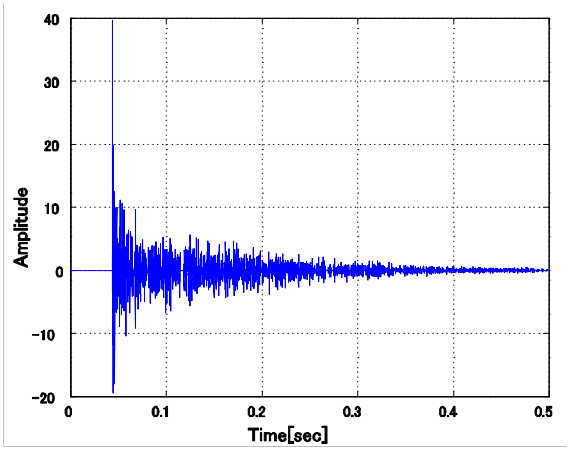

Fig.6. New impulse response, threshold level = 0.5.

5 auditory evaluation

We compared that new impulse response to the impulse response measured in the room. We provided three kind of sound source. These sound source are jazz, male vocal and female vocal. The person being tested is listened and compared two music that is convoluted the measured impulse response and the new impulse response. If the person being tested is feel that two kind of music is same, he put 1 in writing. If the person being tested is feel that two kind of music is differ, he put 0 in writing.The results of the auditory evaluation is shown in Fig.10.

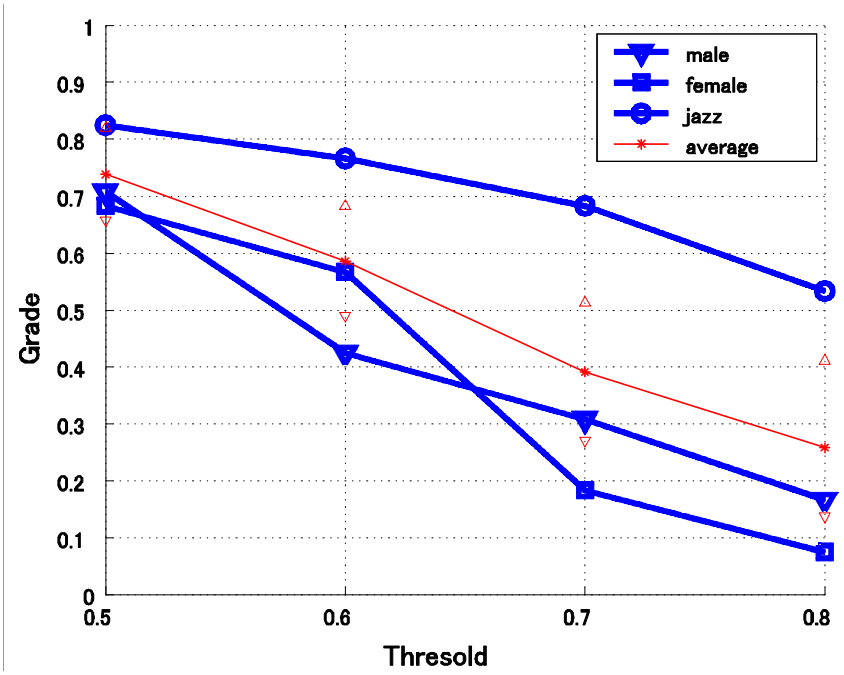

Fig.7.The result of auditory evaluation

6 CONCLUSIONS

To evaluate acoustic characteristics of the room, we need detect correlation factors between the early reflection sound and the reflection sounds. We calculated the coherence function between an early reflection sound and the reflection sounds. The early reflection sound is defined the incident sound from impulse response. In this paper, we calculated an impulse response between the driving sound from the loudspeaker on the stage and sound measured at the center of a seat area. We separated the early reflection sound and the reflection sounds from the impulse response. The correlation function between the early reflection sound and the impulse response is estimated. This signal called self correlation function. We set the threshold level for the self correlation function, and detected the absolute correlation value larger than the threshold level, and we set the absolute correlation value smaller than the threshold level for zero. Following this algorithm, we generate a new signal with the high correlation factor for the early reflection. We estimated the impulse response that is constructed by the early reflection sound and that new signal, and compared that new signal to the impulse response measured in the room. The making impulse responses those are set the threshold level from 0.1 to 0.7 have the acoustic feature of the measured impulse response. But, the making impulse responses those are set the threshold level 0.8 and 0.9 don't have the acoustic feature of the measured impulse response.

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