Simulation and Calculation of the Four Acoustic Parameters in Rooms Acoustical Fields

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A concise algorithm has been suggested based on Image-Source Method that can implement the quick judgment to the position of next image. Visualization simulation of room sound field has been realized by a program in Matlab, Impulse Response of specified receivers in a room can be also obtained. According to the theory of four orthogonal physical factors that influence room acoustics that has been proposed by Yoichi Ando, the program in Matlab developed by this paper can calculate these four orthogonal physical factors at any receivers in the room. Also, the Scale Values (SV) of subjective preferences at any specified receivers are calculated and the isolines of these parameters are rendered respectively, the total SV of subjective preferences of three acoustic parameters is also obtained, these calculated results are well consistent with the conclusions of existing literatures.

Keywords: Four acoustic parameters, Acoustics simulation, Room acoustics field

1. INTRODUCTION

The theory of subjective preference proposes that the acoustics of a room could be decided by the following four orthogonal acoustical parameters: the listening level (*LL*), the initial time delay gap between the direct sound and the first reflection (Δt_1), the subsequent reverberation time (T_{sub}) and interaural cross-correlation function (*IACC*)[1].

Simulation and calculation of the four acoustic parameters in rooms acoustical fields will lay the foundation for subsequent study on optimization of a music hall.

2. SIMULATION OF ROOMS ACOUSTICS

A typical hall with which is similar Grosser Musikvereinssaal was selected as study object for acoustics simulation in this paper, the hall was 20m wide, 30m long and the ceiling was 15m above the floor, as shown in Figure 1[2]. For simplification, sound reflection and diffusion of the floor was ignored.

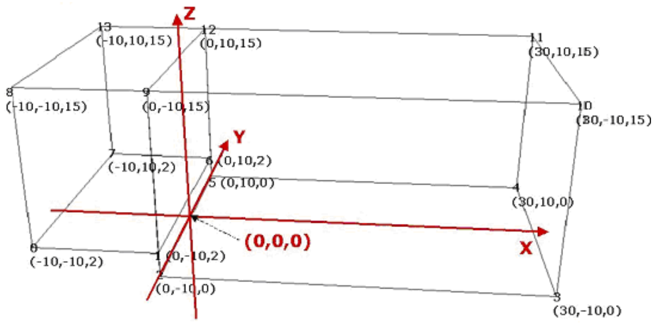

Fig.1. Three-dimensional model of the music hall

2.1 Receiving Points and Sound Source

A single sound source was placed at the centre line of the stage, its coordinate was (-2,0,3.2). the average values of *IACC* of five music samples (A,B,C,D and E) were selected as calculation value of this paper.

Nine receiving points were selected, and their coordinates were as follows: R1(5,8,1.2), R2(5,-3,1.2), R3(10,6,1.2), R4(10,-2,1.2), R8(25,7,1.2), R9(25,-8,1.2) . The sound source was assumed to 1.2m above the stage floor, and the receiving points were 1.2m above the floor of the hall.

2.2 Simulation Results

Since the nine receiving points were evenly distributed in the whole auditorium, the calculation results will well describe sound field distribution of the hall. It was assumed that absorption coefficient of the floor was 1 and other five retaining structures were 0.2. Sound rays distribution of the receiver point R1 and R9 were shown in Fig.2. and Fig.3.

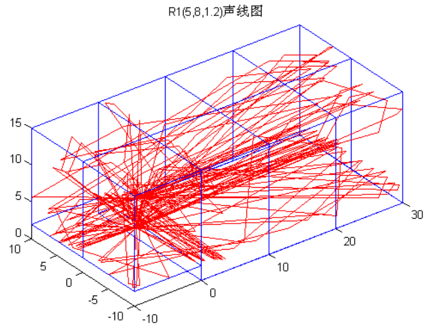

Fig.2. IR and sound rays of the receiveing point R1

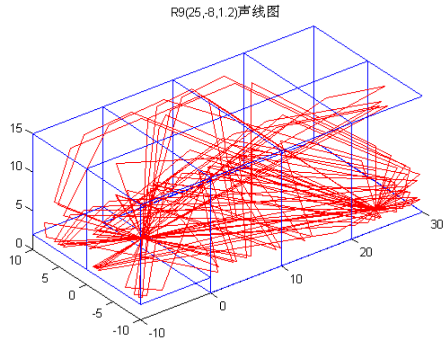

Fig.3. IR and sound rays of the receiving point R9

3. CALCULATION OF ACOUSTICS

3.1 listening level (*LL*)

When sound field of the hall reachs steady state, the sound pressure level L_p of a receiving point from which is d_0 away sound source could be expressed as follows[1]:

$$\begin{cases} L_p = L_w + L \\ L = 10\lg(1+A^2) - 20\lg d_0 - 11(dB) \end{cases} \quad (1)$$

Based on model of the hall, sound source and nine receiving points, a program in Matlab has been developed by this paper for calculating *LL* and drawing contour lines of *LL*, see the figure 4 and 5.

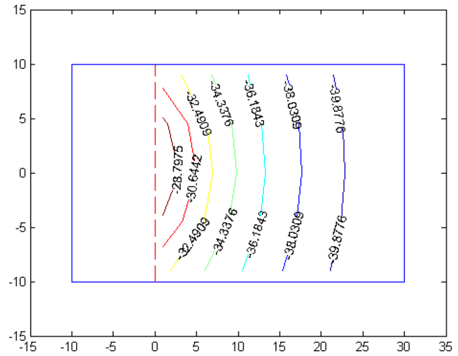

Fig.4. Contour lines of *LL* in the music hall

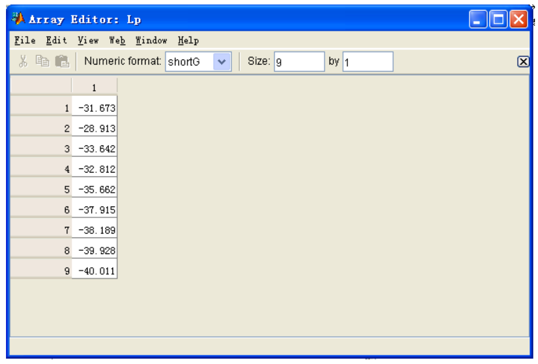

Fig.5. Values of *LL* of the nine receiving points in the music hall

3.2 Initial time delay gap (Δt_1)

The initial time delay gap between the direct sound and the first reflection can be calculted by:

$$\Delta t_1 = (d_1 - d_0)/c \quad (2)$$

The contour lines of Δt_1 was obtained by the program, the maximum of Δt_1 appears in central line around sound source, the results well coincide with those of some researchers[1] (Figure 6).

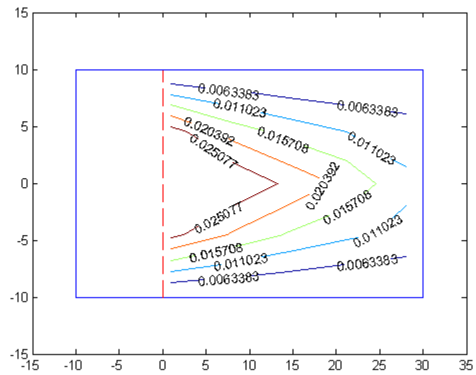

Fig.6. Contour lines of the time delay of early reflection

3.3 *IACC*

It was assumed that $\tau = 0$, the average values of *IACC* of five music samples (A,B,C,D and E) were taken as calculation value for the program. The contour lines of *IACC* and calculated values of the nine receiving points were shown in Figure 7 and Figure 8.

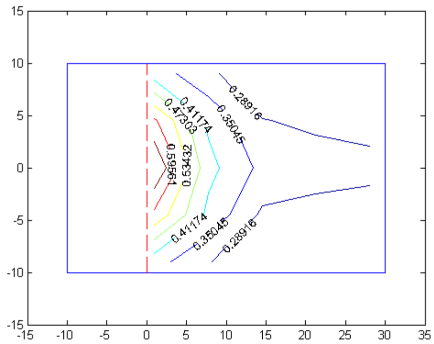

Fig.7. Contour lines of *IACC* in the music hall

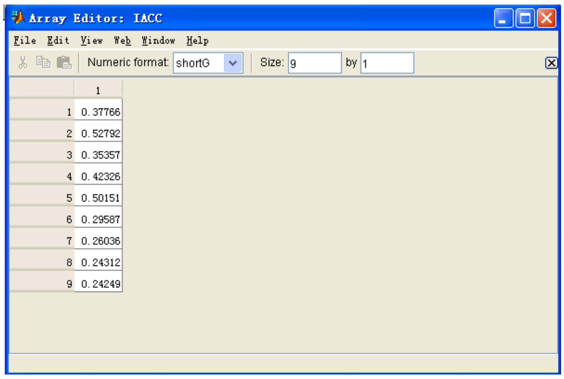

Fig.8. Calculated values of *IACC* of the nine receiving points

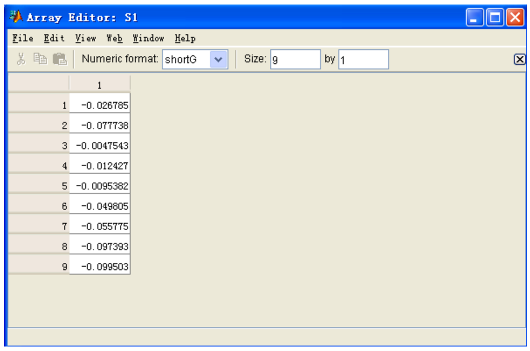

Fig.9. SV of *LL* of the nine receiving points in the music hall

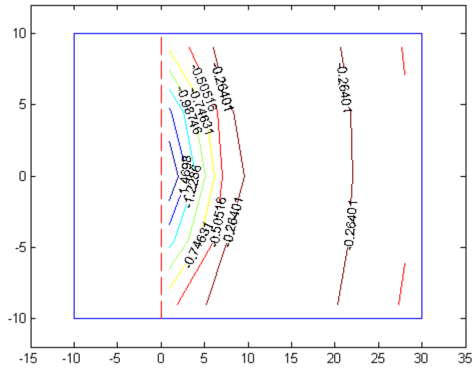

Fig.10. Contour lines of Scale Value of *LL* in the music hall

4. CALCULATION OF SCALE VALUES

4.1 ScaleValue of *LL*

According to the theory of subjective preference, SV of *LL* can be obtained:

$$S_1 = g(x_1) \approx -\alpha_1 |x_1|^{3/2} \quad (3)$$

Here, α_1 is a coefficient and the parameter χ_1 can be calculated by:

$$x_1 = 20\lg P/[P]_P = 20\lg(10^{\frac{L_n}{20}}/10^{\frac{L_p}{20}}) = L_n - L_p \quad (4)$$

Where L_n is SPL of certain receiving point, and L_p is preferred SPL of somewhere in the hall. Music B ($\tau_e = 43(ms)$)[1] was chosen as calculation sample, preferred SPL was assumed to be in the central line of the hall and 15m away from the sound source. Preferred SPL 35.28dB was derived in this case. Therefore, SV of *LL* in everyplace of the music hall can be obtained, see Figure 9 and Figure 10.

4.2 ScaleValue of Δt_1

The scale value of subjective preference of the initial time delay gap between the direct sound and the first reflection can be expressed as follows:

$$S_2 = g(x_2) \approx -\alpha_2 |x_2|^{3/2} \quad (5)$$

Music B was chosen as calculation sample, the results were shown in Figure 11 and Figure 12.

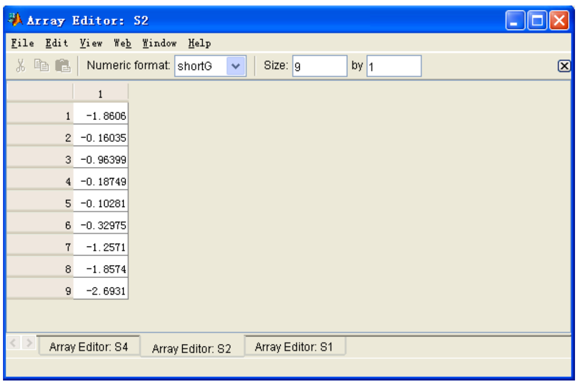

Fig.11. Scale Value of Δt_1 of the nine receiving points in the hall

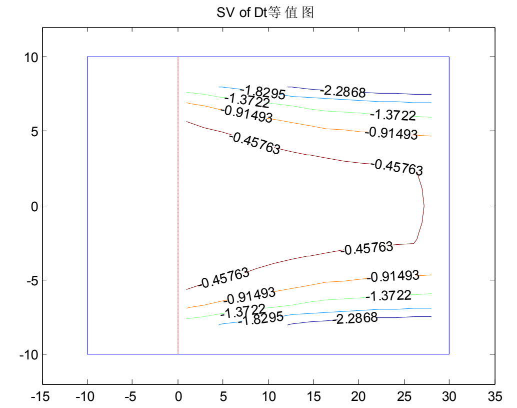

Fig.12. Contour lines of Scale Value of Δt_1 in the music hall

4.3 ScaleValue of *IACC*

The scale value of *IACC* can be derived as follows:

$$S_4 = g(x_4) \approx -\alpha_4 |x_4|^{3/2} \qquad (6)$$

Where $x_4 = IACC$ and $\alpha_4 \approx 1.45$, the results were obtained by formula (6):

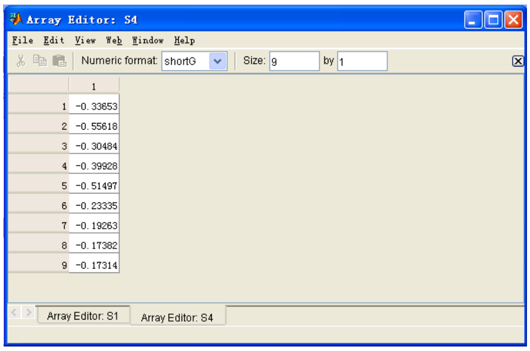

Fig.13. SV of *IACC* of the nine receiving points in the music hall

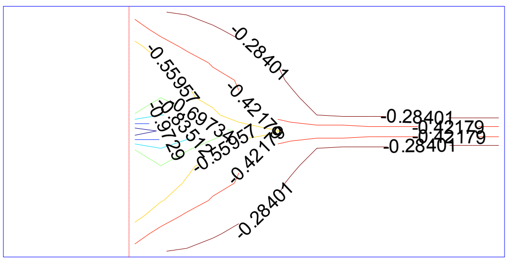

Fig.14. Contour lines of SV of *IACC* in the music hall

4.4 Total ScaleValue in the Hall

On the basis of calculation results above and principle of linear superposition, The total scale value of subjective preference in the hall can be calculated, that is, the acoustic parameters can be predicted in the stage of scheme design of a music hall.

The scale values of subjective preferences of the nine receiving points and contour lines of total Scale values in the music hall were shown in Figure 15 and 16.

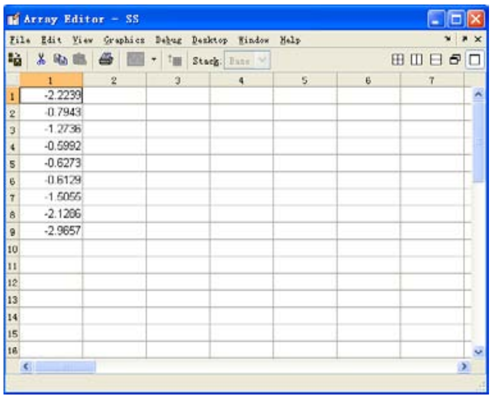

Fig.15. SV of subjective preferences of the nine receiving points in the music hall

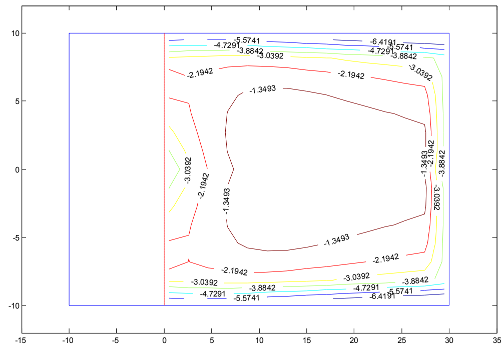

Fig.16. Contour lines of total Scale Values of subjective preferences in the music hall

5. CONCLUSIONS

The program developed by this paper can calculate orthogonal acoustical parameters of any place in a auditorium. Meanwhile, The total scale values of subjective preferences of a hall could obtained, and contour lines of total Scale values were drawn as well.

REFERENCES

[1] Yoichi Ando (1985) Concert Hall Acoustics. Heidelberg: Springer-Verlag.

[2] S. Sato, K.Otori. A, Takizawa, et al, Applying Genetic Algorithms to the Optimum Design of A Concert Hall . Journal of Sound and Vibration, 2002,258(3):517□526

[3] Ando, Y. (1998). Architectural Acoustics-Blending Sound Sources,Sound Fields, and Listeners-. AIP Press/Springer-Verlag, New York

[4] A. Krokstand, S.Strm and S. Srsdal. Calculation The Acoustical Room Responded by The Use of A Ray Tracing Technique, J. Sound Vib, 1968,8(1):118-125