On the Effect of Various Acoustic Simulation Methods on the Synthesized Impulse Response

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Abstract

In this article, the impulse response of rooms is estimated by means of different acoustic simulation methods such as the acoustical specular-radiant, the mirror-image source, the artificial reverberators or any combined methods. Acoustical parameters are calculated for the response simulated by each method and the acoustic performance of the synthesized response is investigated.

Introduction

Digital computers have been introduced into the field of the acoustic simulation of enclosures. Methods that are based on geometrical acoustics have been widely used. Radiosity methods that assume totally diffuse reflections have been used. Another method, namely the acoustical specular-radiant method, has been introduced. The latter method integrates the specular and the radiant approaches. However, the complexity of the computation of the room impulse response increases for large length of the calculated response. Therefore, several methods have been introduced to calculate the room response by combining geometrical methods and artificial reverberators.

In this article, the mirror-image, the specular-radiant methods, and a combination of the latter method and artificial reverberators are discussed. Moreover, the acoustic performance of the room response, that is simulated by means of each method is evaluated and compared to each other.

The mirror-image and the acoustical specular-radiant methods

By applying the mirror-image method to an enclosure of arbitrary shape [1], the sound reflections are replaced by a pattern of image-sources. The position of each image-source is calculated by applying the law of specular reflections to the boundaries of the enclosure. The distribution of the absorption coefficient over the room boundaries determines the energy of each image-source.

The specular-radiant method is applied to calculate the acoustic response of rooms with boundaries of partially specular reflectivity. Each room boundary is divided into patches. An absorption and a diffusion coefficients are assigned to each patch. The method [2][3]integrates the radiant and the specular approaches, so that any combinations of specular-specular, specular-diffuse, diffuse-specular, and diffuse-diffuse reflections are handled.

In [4], the effects of the acoustic simulation of rooms by means of each method are discussed, and the quality of the corresponding room response is evaluated subjectively.

Artificial Reverberators

Artificial reverberators have been widely used to simulate the part of the impulse response that contains the late reflections. Various configurations that combine comb and all-pass filters have been used[5].

In this section, an artificial reverberator is simulated. Its response is similar to that of a comb filter whose response decays exponentially. Figure 1 shows the impulse response of the reverberator. T is the pulse repetition of its impulse response.

Combining the specular-radiant method and artificial reverberators

The part of the response that contains the early reflections is calculated by means of the specular-radiant method. This part of the room response is calculated up to a certain time τ and up to a certain order of reflection n. Then it is convoluted with the response of the reverberator to obtain the response of the room over the whole time, as shown in figure 2. The maximum value of τ is estimated by multiplying the average time of one reflection with the order of reflection used, i.e. $\tau \le \frac{4V}{SC} * n$, where V, S and C are the volume, the total area of the room boundaries and the speed of sound respectively.

The impulse response calculated according to the configuration shown in figure 2 suffers from artifacts that result from the pulse repetition of the comb filter.

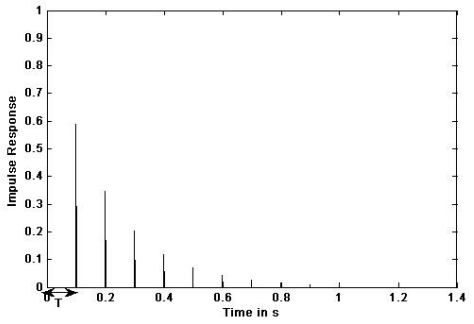

Fig 1: Impulse response of a comb filter, that decays exponentially

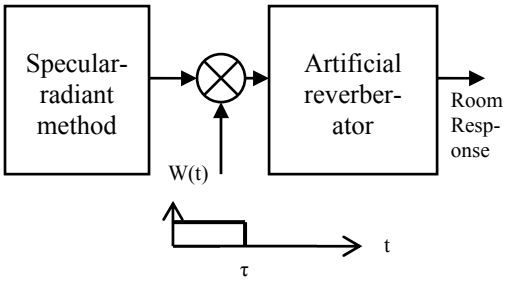

Fig. 2: Block diagram for combined specular-radiant method and artificial reverberator.

Evaluation test

In this section, a rectangular room of dimensions 11 x 7 x 3 (m), a uniform absorption coefficient of 0.08 and a diffusion coefficient of 0.7 is simulated by means of each of the three methods discussed in the previous sections: the mirror-image method, the specular-radiant one, and that combining the specular-radiant method and artificial reverberators. Figure 3 shows the decay curves and the impulse responses of the room that are simulated by means of each method.

Objective criteria [6] such as, the reverberation time (RT), the definition (D), and the rapid speech transmission index (RASTI) are introduced to measure the acoustic performance of enclosures. A set of the three objective criteria is calculated for the response of the room that is simulated by each of the three methods, as shown in table 1.

Conclusion

Various methods are presented for acoustic simulation of enclosures, and the acoustic performance of the impulse response obtained by each method is evaluated by means of objective criteria.

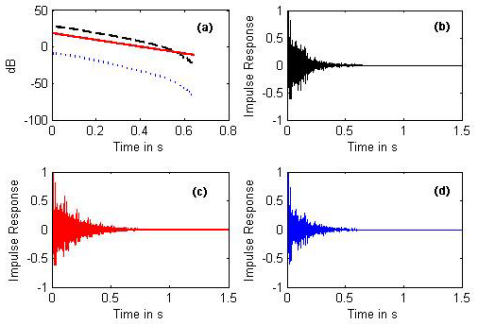

Fig. 3: (a) Decay curves: _ _ _ specular-radiant method, ____ combined method, …… mirror-image method. From **(b), (c) and (d)** are the corresponding impulse responses respectively.

Table 1: reverberation time, the definition and the RASTI.

Method		**RT in s**	**D**	**RASTI**
Mirror-image		1.2	0.3403	0.299
Specular-radiant		1.2	0.4078	0.3378
Combi-ned Method	τ = 0.2 s	1.2	0.2915	0.2532
T = 0.1 s	τ = 0.1 s	1.2	0.3792	0.2672

References

[1]Borish,J., " Extension of the image model to arbitrary polyhedra", JASA 75 (2), 1927 – 1836, 1984.

[2] Korany, N. , " A model for the simulation of sound fields in enclosures integrating the geometrical and the radiant approaches", Doctor thesis, Alexandria Uni., Egypt, 2000.

[3] Korany, N. and Blauert, J. and Abdel Alim, o., "Acoustic simulation of rooms with boundaries of partially specular reflectivity", Applied acoustics 62, 875 – 887, 2001.

[4] Korany, N., "Computer modeling and auralisation of sound fields in rooms – an overview", ICA 2004, Kyoto, Japan, Mo4.B2.1: I-277 – I-280

[5] Schroeder, M.R., "Natural sounding artificial reverberators", AES vol 10 (62), 219-223, 1962.

[6] Kuttruff, H., Room acoustics, Elsevier Science publishers, 2000.