A Software for learning about Artificial Reverberation

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It is intended in this work to present software, developed using MATLAB, for learning purpose at the University of Alexandria. The software presents basic information about the acoustical phenomenon of reverberation. Help documentation is attached to the software to describe a digital signal processing algorithm based on a physical approach and to define the acoustical parameters involved in the algorithm. The software enables the student to synthesize the impulse response of his auditorium for optimum listening enjoyment. Moreover, it allows the student to calculate and understand various acoustical measures that are derived from the obtained impulse response such as the decay curve, the definition, etc. On the other hand, it may be employed to investigate the subjective effects of sound fields in enclosures.

Keywords: Software; Reverberation

1. Introduction

Artificial Reverberators [1] are designed to control the reverberation in auditoriums by using electro-acoustics techniques without requiring architectural changes. At the University of Alexandria a program is organized to insure student learning of reverberation. Within this program, software for learning about artificial reverberation is developed to improve the skills and the knowledge of the students and to help them to begin professional practice in the field of designing artificial reverberation.
This article is organized as follows: In the next section the educational objectives of the program developed are presented. Section 3 presents basic concepts of the reverberation and describes the structure of the software. Section 4 demonstrates how the software and the educational objectives are met. Section 5 summarizes the main conclusions.

2. Program Objectives

As the application of electro-acoustics techniques in auditoriums is accepted only if the artificially added reverberation is indistinguishable from the natural reverberation of real rooms, the overall aim of the program is to enable the student to synthesize reverberation for optimum listening condition. Moreover, the student begins professional practice in the field of room acoustics.
It is intended to improve the knowledge and skills of the student. The student should know and understand the subjective effect of reverberation, the elements that affect the reverberation, and the acoustical parameters that describe and/or measure it. Moreover, he should acquire some professional and practice skills such as the ability to design artificial reverberation and the ability to judge the quality of sounds perceived in rooms.

3. Design aspects of the software

3.1 Basic concepts of the design

In principle if a room is excited by a sound impulse of very short duration, an impulse response $g(t)$ is obtained at a certain listening position. The impulse response is expressed mathematically in Eq. (1).

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$$g(t) = \sum_n A_n \exp(-\delta_n t)\cos(\omega_n t + \psi_n) \qquad \textbf{(1)}$$

Equation (1) describes the decay process, which is called the reverberation of the room. It consists of a number of sinusoidal oscillations with different frequencies ω_n, each dies out with its particular damping constant δ_n. A_n is the gain of the oscillation[2][3].

The damping constant is related to the volume of the room V, the area S_i and the absorption coefficient α_i of each boundary. The relation is described in equation (2).

$$\delta_n = 42.38 \frac{\sum_i S_i \alpha_i}{V} \qquad \textbf{(2)}$$

3.2 Structure of the software

The software is composed of two main parts. The first part computes the reverberation of a certain room and reproduces the sound perceived from this room. The structure of this part is shown in Fig. 1. The second part of the software consists of a list of commands to improve the learning process. Figure 2 lists a set of these commands.

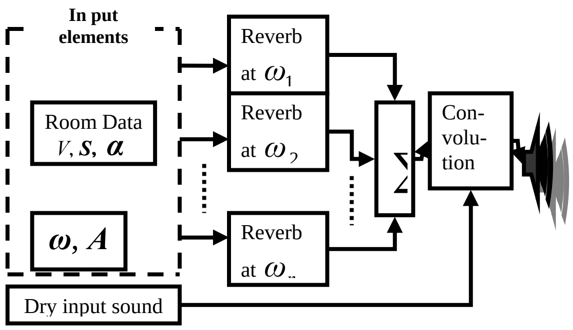

Fig. 1: Structure of the first part of the software that computes the reverberation for a certain auditorium.

C1. Plot decay curve
C2. Plot frequency response at certain frequency band
C3. Plot the whole frequency response
C4. Calculate the following acoustical parameters (Reverberation Time, Definition, etc.)

Fig. 2: List of implemented commands

As shown in Fig. 1, a set of frequency bands $\boldsymbol{\omega}$ and their corresponding gain $\boldsymbol{A}$, the room data that consists of the volume of the room V, a vector S that contains the area of each room's boundary and a matrix $\boldsymbol{\alpha}$ that contains the absorption coefficient of each boundary at each frequency band ω_n, and dry sound signal are inputs to the software. The reverberation is calculated over each frequency band, then they are summed together to obtain the whole reverberation of the room $g(t)$. Finally, the whole reverberation is convoluted with dry sound signals. The output sound of the convolution stage feeds a set of loudspeakers to judge the subjective effect of the reverberation.

4. Evaluation of the software

A list of physical elements and another list of perceived elements are described. Figure 3 lists the physical elements that are input to the software, whereas figure 4 lists the perceived elements of the sound output from the software.

I1. Damping constant

I2. Oscillation gain

I3. Oscillation frequency

Fig. 3: Physical elements-inputs to the software.

O1. Reverberation

O2. Artifacts

O3. Coloration

Fig. 4: Perceived elements-outputs from the software.

The damping constant and the oscillation gain that are listed in Fig. 3, each is a vector (1 x n), n is the number of frequency bands used. The oscillation frequency is a matrix (2 x n), the first row contains a set of the frequency bands whereas the second row consists of a set of the density of the frequencies in each band.

The relation between elements of different lists is introduced as follows:

Reverberation is mainly dependent on the damping constant at the different frequency bands. It is judged to be high or low according to the desired application. **Artifacts** and **coloration** cause degradation in artificial reverberators[1]. **Artifacts** consist of unwanted auditory events such as flutter. Flutter could be avoided by increasing the average density of the frequencies at which the calculation takes place. In this article, **coloration** refers to the unpleasant change in timbre that is perceived from artificial reverberators, and it depends on the flatness of the frequency response of the reverberation.

In order to fulfill the objectives of the program, stated in section 2, the student has to follow the learning schedule shown in Fig. 5. Figure 6 lists the outcomes of this learning schedule. The learning schedule, described in Fig. 5, enables the student to investigate the relations between the physical- and the perceived- elements, and hence the student begins professional practice in designing artificial reverberation.

5. Conclusion

Software is presented to insure student learning of artificial reverberation. Basic concepts of the reverberation phenomenon are discussed, physical elements that are involved in the software are defined and their relations to a set of perceived elements are discussed. The educational objectives are introduced, and the learning schedule is stated. It is obvious that by following this learning schedule, the student will be able to improve his knowledge and he will begin professional practice in the field of designing artificial reverberation.

L1. Vary one of the input elements listed in fig.3 L2. Hear the output sound of the convolution stage, as described in Fig. 1 L3. Judge the perceived reverberation (High, Low, no change) L4. State if Artifacts and/or coloration are perceived L5. Use the commands listed in Fig. 2 to measure the quality of the reverberation.

Fig. 5: Learning schedule

C1. Understanding the effect of each input element on the perceived reverberation C2. Ability to control the input elements in order to remove artifacts and/or coloration C3. Ability to use the acoustical parameters to judge the quality of sounds perceived in rooms. C4. Ability to design artificial reverberation for a particular application

Fig. 6: Outcomes of the learning schedule

References

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