Auralization as a tool in room acoustics education

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Introduction

Since room acoustics deals with the audible but invisible, conventional book and lecture based education often is less satisfactory for enhancing students' learning. Even though the meaning of such specific terms as direct sound, reverberant sound, flutter echo, early/late ratios can be superficially understood by intuitive and simple reasoning, their audible meaning is less easy to understand. It is essential that the students after finishing a course on room acoustics are able to have an impression of the meaning and validity of various room acoustics concepts and metrics. Auralization, audible sound field simulation of room acoustic conditions – the aural equivalent of visualization – can help in this learning. Auralization then is a natural complement in multimedia learning.

Since 1992 we have successfully used auralization in our acoustics education at Chalmers' Department of Applied Acoustics. The method has been used in courses on room acoustics as well as in many other teaching activities. Students are now much better motivated and have more confidence in the room acoustics planning process. For example, in undergraduate and graduate education it is seldom possible for the students to travel between various auditoria within a large enough range of acoustics variation, which would otherwise give the students a possibility to "anchor" their knowledge.

Auralization will also help in answering the many „What if ..." questions students may ask. For example, in a real auditorium it is usually not possible to change the set-up on stage or the angles of reflectors and even it were the time span involved between the listening occasions would make efficient comparison of the acoustical conditions difficult.

Our experience shows that even persons having considerable knowledge of acoustics may gain further insight into room acoustics by the use of auralization. Auralization will play an important role in future education in room acoustics. Below I will describe two uses of auralization in multimedia based learning.

Undergraduate course on Room Acoustics

The current course on room acoustics is directed towards engineering students having backgrounds either in electronics, physics, computer or civil engineering. The course comprises twenty forty-five minute lectures, one measurement exercise and one lab/home room design/CAD/Auralization exercise. The lectures basically follow the contents of H. Kuttruff's book „Room acoustics". The measurement exercise is done according to the ISO standard 3382 and, until last year, concerned characterization of a large lecture hall using the MLSSA measurement system. For reasons of cost this room was no longer available to us so both auralization and measurement this year concerned a small auditorium.

Traditionally courses in room acoustics focus on the use of geometrical acoustics for room design, using manual graphics ray tracing or image source construction. Typically, room acoustics curriculum includes psychoacoustic results, which have been made under variously well controlled conditions, and on measures or figures of merit, which may have been more driven by the engineering possibilities at the time of their conception, than on accurate modeling of the characteristics of human hearing.

Our use of auralization, as a complement to book learning, was originally primarily utilized in demonstrating to the students the basic concepts of psychoacoustics as applied to room acoustics. This was done using a simple audio mixer, a multichannel delay unit built in our laboratory and a commercial digital reverberator. These signals were played back to the students in the regular lecture halls, were the course was given, with no special regard to the acoustic conditions, since at that time personal computers were not widely available to the students.

The room design/CAD/Auralization exercise now used is done to give the students more hands-on experience in the design issues in room acoustics. The exercise is based on the use of the commercial CATT-Acoustic auralization software. This software needs input data for the hall to be studied in the form of corner coordinates, surface material data as regards absorption and diffusion properties and of course also sound source and receiver data. Since it was felt that there was not sufficient time in the course for the students to develop their own hall model, it was decided to provide them with a "generic" hall ("Hall-In-One") which could be changed into most common hall shapes by simple parameter changes. In addition all surfaces have symbolic absorption names so that high level constructs such as:

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ABS wood = <12 10 8 7 6 5> ; absorption 125 to 4
kHz octave bands %
ABS stage_wall = wood
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can be used. To limit the degrees of freedom, a default scattering coefficient is assigned to all walls in "Hall-In-One", and audience absorption and source directivity are held fixed. For those students that want to spend some extra time on the task, side-wall and ceiling reflectors have been included, which can be switched on/off, translated/rotated, as well as changed in size and absorption/scattering characteristics.

In their use of the "Hall-In-One" the students have the possibility to chose various visual input, such as perspective views of the auditorium, ray paths, coverage areas plotted according to various room acoustic quality measures etc. the "Hall-In-One" is both an advantage and a disadvantage from the standpoint of learning. By the availability of the "pre-data-entered" hall considerable time is saved. Students can now concentrate on room shape and on surface absorption and scattering properties and thus, within a short time, come to a result. The students are subdivided into project groups of 2 to 4 students. One can see a tendency for the resulting hall of each group to become fairly similar. There are two reasons for this: 1) the fairly simple shape always giving quite open rooms without balconies, 2) the default diffusion has a smoothing action, removing some of the shape dependent audible character of the room.

Interestingly, the students seldom reflect over the perceptual difference between the acoustic characteristics of the real room, in which they do their measurements, and the characteristics of the various simulated rooms, resulting from their computer modeling and the auralization. If the students had more time to get acquainted to auralization, they would no doubt notice these differences. This would be good, because it would encourage them to think of why these differences are present, and what one could possibly do to eliminate their causes. It is also interesting to note the students' lack of criticism of the approach. Most student attribute the resulting, less than optimally sounding halls to their own inexperience and that they do not know what to expect because of their limited familiarity with the auralization method.

A short course on Auralization

Since 1996, the author has given several courses on auralization to international audiences. The target audience for these courses is *"consultants and engineers who are interested in the background, techniques and applications of auralization"*. In order to be of sufficient interest to the practicing acoustician the course offers *"audible samples using auralization of various auditoria, concert halls, etc, as well as simplified cases"*.

Some elementary goals were set at the very start of the course planning. The course should neither be advertising for, nor or a demonstration on how to use, a particular set of computer software for auralization. The goals were broadly stated as follows:

1. By use of multimodal presentation provide a possibility to put auralization alongside visualization to enable a better insight into modes of thinking, analogies, possibilities and current status.
2. Personal audio playback of all sound samples to provide optimum audio quality.
3. To provide an opportunity to study the audibility of the various approximations needed to make auralization feasible on today's personal computers
4. To enthuse course attendants to start using auralization and by their feedback obtain more knowledge on the possibilities and limitations of auralization..

Practical implementation

The course notes were prepared on computer using ClarisImpact™ on Macintosh computers, scanning a considerable number of both negative and positive photos, and drawing a lot of graphics. The final course material included approximately 250 slides and about 50 sound illustrations. Managing the slide show material efficiently, so that the course material including sound samples could be reused easily in other courses, turned out to be very time consuming. Rather than using presentation software, such as Microsoft's Powerpoint™, it would be advantageous to use a simple database type system. This would make it to use the same transparency collection in many situations but in different order or selections.

The sound samples suitable for a course on auralization can be broadly classified as follows.

1) Those illustrating basic properties of sound reproduction: concepts of mono, stereo, bandwidth, equalization etc
2) Those illustrating sound reproduction methods: microphone equivalent, ambisonics, binaural, transaural etc
3) Those illustrating variously complex auralization: orders of reflection, scattering, reverberation simulation methods etc.
4) Those illustrating the audibility of various acoustical phenomena and simulations: influence of reflections, propagation attenuation over audience, edge diffraction, electroacoustic feedback etc.

Most sound samples were produced using the CATT auralization software, but some special implementations of acoustic phenomena and equalization had to be done in MatLab™. Convolutions were done in software using the CATT software using a fast PC and on hardware using a Lake digital filter.

At the lectures, the binaural audio signals were distributed through a cable network to the individual headphones of the participants. All of the sound samples were also made available to the course participants on Compact Discs, so that they would also be able to listen at home or in the office, after the course.

Results and Experience gained from the short course

Some criticism was voiced in the course questionnaires, primarily with the synchronization of the sound samples with the visual material, and with the lack of comparisons of real and simulated halls.

2) It would be advantageous to have a transparency which featured the conditions for each sound sample and if possible also a visual representation of the binaural impulse response in some way.

3) Comparisons of real and simulated halls is more in the realm of those writing and selling the individual software packages than of researchers and university laboratories.

Originally a truly interactive part was planned for these courses as well. However, because of time constraints, it has not been possible to implement this part in practice, which is problematic since hands-on experience further improves learning. Ideally it should be possible for each attendee to have his/her own PC with software and sound cards, so that each course attendant could work single and have quick response. In our in-house room acoustics course at Chalmers, we have found that it is possible to still have adequate interactivity, in groups of 2 - 4 persons. With the current rapid development and price reductions in computer hardware, it should be possible to let each individual use their own computer. By using a master computer and suitable software, the practical experience auralization session could then be more like a session in a language laboratory.

Conclusions

Auralization can be used to advantage in multimedia based learning of room acoustics. The possibility to listen to examples, and the possibility to interactively listen to changes in room design, provides a means to add a considerable understanding in the otherwise psychoacoustics, signal processing, metrics, and optics based room acoustics education.

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