Acoustics and sound system technologies in arts facilities of the future

Robert Essert

Artec Consultants Inc, New York
Now at Sound Space Design, London, UK
Bobessert@soundspacedesign.co.uk

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Speaking outline

I. Introduction

Most of us seem to believe that the human element is at the essence of performing arts. As long as there are performing artists, there will be live performances.

The science and application of acoustics and various electro-acoustic technologies are intersecting more and more. As in most scientific fields, the knowledge base is increasing faster and faster. Technology is enabling this research. Computer technology is enabling the modeling of rooms before they are built. And digital audio technology is enabling ever more sophisticated sound systems and new breeds of electroacoustic enhancement systems. I'll try to touch on recent developments in these areas and peer a bit into the future.

II. Technology in acoustical design

A. Today's concert halls host music that was written over several centuries, for a wide variety of acoustical environments and performing forces. We ask one hall to provide acoustical excellence for a violin recital, an organ recital, a 30 piece string orchestra, a 95 piece wind band, an orchestra of 100 plus a chorus of 200, pops concerts, jazz, highly amplified popular music, conferences, religious services.....and more. And this is for a so-called "pure" concert hall. In North American multipurpose halls the range to be housed is even greater.

As we begin to plan for global audiences, global arts centers and *virtual* arts centers, we need to think about the performing arts from multiple cultures, multiple musical, theatrical and dance traditions.

B. We have been designing variable acoustics into halls for several decades in order to accommodate, as well as a budget can allow, the increasing variety of events and acoustical preferences. A great deal of our work has incorporated technology, but what is sometimes referred to as "low technology." It is essentially flexible architecture.

C. For the first half of this century, attention to reverberation time was the beginning and the end of acoustical design. The post-war years have seen important advancements in concert hall and opera acoustics. Audio and computer technologies have both enabled and been enabled by the room acoustics research.

D. We have just been looking at graphical renderings of computer models. And the other day we listened to computer facilitated musical instruments. Over the last decade computers have become increasingly capable tools for modeling room acoustics. This has applications in new buildings and also diagnostics of existing buildings.

We start with a computer model of the architecture -- it can be the same 3D model that the architect and theatre consultant are exploring. We program certain laws of physics into the software, and let the computer determine how the sound bounces around in the room. It can show us quickly which walls have what sort of effect on the development of the sound in the room.

Numerical and graphical analyses are useful to the acoustics professional, but the physical propagation of sound in auditoria and humans' acute powers of aural perception are so complex that no table of numbers and no impressive graphics can project the quality of the entire experience. So we use computers to "play" music or speech through the computer model. Just as one can only truly appreciate the architecture of an interior space by being in and moving through the actual space, one can only truly appreciate the acoustics by listening in the space. And just as 3-dimensional architectural models give us a better feel for the look of the final building than two-dimensional drawings alone, the three-dimensional "sound rendering" is a more realistic representation than simple mono or stereo. We have developed a sound rendering system that allows one to listen to music or speech (or, indeed, any sound) as performed in the computer models. This is now being called *auralization*, with the parallel to "visualization".

Acoustical modeling and auralization are till in their infancy. We do not base new hall designs solely on acoustical modeling results. The software and its control and interpretation are at this point experimental. And the degree of subtlety we hear is much greater than the models can deliver. But this will change. Increase in computer power and decrease in cost, in parallel with further advances in modeling software, will make the models more and more realistic.

III. Electronic sound systems in venues

A. Sound system technology has evolved quite a bit in the past 40 years. This is clear to anyone who has had to find the money to replace a theatre sound system. The average useful life of the loudspeakers and amplifiers is approximately 7-10 years, and for consoles and electronics it is shorter. These life spans are short, not because the equipment wears out, but because the artists and producers want ever better sound, and because equipment is getting better and better. And there is definitely some measure of marketing hype involved.

B. Sound system technology is driven in part by popular culture and consumer products. Popular music and home hifi have evolved together. Home theatre and laser disks are bringing higher quality audio and video together. In the future, I imagine we will all have 3D displays, perhaps holograms, instead of picture tubes. And we will have in our living rooms 3D audio systems that provide virtual acoustical environments both more realistic and more controllable than what we heard upstairs.

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C. Sound effects have evolved from manual (radio) to tape of various formats, to audio CDs (just an easier to use and more robust version of the tape) -- to now computer controlled playback from hard disk or optical disk.

1. Through all of this, the sound operator for the show (a human) has been an artistically important person -- the nuances of timing and controlling the loudness relationship to the performers has been in the hands of the sound effects artist or the sound system operator.

2. Today, with computer assistance, the sound designer and operator can control the placement in space of each effect, as well as frequency, loudness and time. The current state of the art digital control systems are cued, much like lighting control as been for some time.

3. The future holds "real time" control of theatre sound effects -- where the effects are cued directly by performers, much like the musical instruments that Todd Machover has showed us, but in non-musical contexts as well. Improved control technologies and digital signal processing will facilitate theatre of much greater interactivity.

4. Technology will enable improved detail and more dimensions in the control of what R. Murray Shaeffer calls the "soundscape" -- some theatre will involve more realistic synthesis of real sound environments ... and unrealistic sound environments.

D. Sound reinforcement

1. Digital revolution has changed the audio industry. Many loudspeaker "systems" incorporate processing electronics to improve the sound of the speakers themselves and combinations of several speakers
   Digital sound control consoles are widely available now.

2. Computer control of spatial cues is a nascent technology, but will advance rapidly. There are a couple of systems in use --
   a. Delta-stereophony (AKG) -- used on Will Rogers Follies and a few other shows.
   b. Jonathan Deans system -- now in use on Damn Yankees, and in Vegas.

   c. Development of technology based on "wave front synthesis" with large arrays of loudspeakers at Delft University of Technology.

   These systems attempt to locate the amplified sound image where the human performer is. The first two require human control, either in real-time, or as pre-set cues, like lighting consoles.

E. So called "electronic enhancement" of natural sound -- which started as artificial reverberation -- has been evolving since the 1940's.

1. Reverberation chambers with loudspeakers and microphones, borrowed from recording studio design.

2. Today, intelligent digital signal processing can provide greater realism, but it takes a capable designer.

3. Electronic enhancement of acoustics has been used mostly where something is need of enhancement -- that is, improvement of existing facilities.
   - Early systems in the Royal Festival Hall, and the Orpheum in Vancouver, both of which are now in the process of being replaced.
   - Current systems include Lexicon's LARES, which you heard in the studio upstairs. There is another installation in Toronto at the Elgin Theatre. The Dutch and Scandinavians have also done quite a bit with these sort of systems, <u>but none of these is up to the quality level desired by most communities and musicians for a **new** hall</u>.

4. Practice/Rehearsal Rooms
   Wenger is now marketing an off the shelf practice room module with a Lexicon system in it. This seems to be a valid use of even today's imperfect technology.

5. Large Theatre
   There is at least one example of a large multi-purpose theatre designed from the ground up with electronic enhancement -- the Hult Center in Eugene.

6. Hybrid Reverberation Chambers
   There are halls with architectural reverberation chambers, where the chambers can be supplemented in one way or another with electronics and microphones and loudspeakers. We included this feature in the design of the Kravis Center. Electronics are not used for symphony or opera there, but the provisions are there for the future.

IV. Virtual sound environments

A. The sound reinforcement or "electronic acoustics" in most performance venues are so far passive, not part of the composition.

B. The acoustical part of Virtual Reality is virtual sound environments, and as VR impacts theatre, so the virtual acoustical environment will be part of it.

C. Much of 3D sound environments have their technical roots in military R&D and video games. Head mounted displays have audio earphones, and computers can control the sound field in real time to match the visual display.

You can buy head tracking 3D displays off the shelf today. A simple 3D audio board can be had for a few hundred dollars US. Each participant is totally enclosed in an artificial environment. This denies any real human interaction.

Today you can have loudspeaker in your own living room (or car) and electronics offering a selection of concert halls. Much of it is hype, at least as far as consumer equipment is concerned. The approximation to sitting in the actual hall is limited, at best. But much better systems are in the lab, and will be available soon. The big problem now is getting the details of the intended sound rendered at more than one head location at a time.

D. One of our tasks -- your tasks -- in the future is connecting live venues to homes. The group experience -- physical assembly spaces with virtual acoustical (and visual) environments -- allows independence of sound and visual environments from each other and from the actual physical (architectural) environment.

1. One question is how tolerant will we as humans be to a mismatch between the visual and acoustical environments.

2. Spaces and electronics for creating virtual sound environments are not yet in high quantity or quality.
   a. IMAX and OMNIMAX theatres and the best Dolby THX cinemas are "playback only" venues; their events are not live performances. Yet. But the experience is an influence on audience expectations for technical wizardry.

   b. Pierre Boulez and others at IRCAM have been creating musical works for technology and space. One of the best known - perhaps as a classic in this genre -- is "Repons", which has several groups of musicians and loudspeakers distributed around the room, a lot of computer and audio mixing equipment to distribute sound around the space. But this is not attempt to change the acoustics of the space.

c. More recently the folks at IRCAM have developed a computer hardware/software system for use in perceptual research on how we hear spaces, and for use as a performing instrument. With this "spatializer" the performer "plays" the spatial aspects of the sounds, which can be natural or synthesized. In addition to loudness, timbre and time of each sound, the musicians control acoustical placements in space, the perceived acoustical size, and motion are controllable. The "room acoustics" are created electronically and can be varied in real time. Specific movements can be scored by the composer or improvised in real time. The first versions worked for one listener at a time, but the system is being extended to work for a room full of listeners. One of the first pieces including this system is a piece for 2 violas by George Bloch, which has been performed in the Espace de Projection at Ircam.

E. In the evolution of Western music, first we had Antiphonal alternation between locations -- e.g., Gabrieli in the cathedral; and then later depiction of specific environments and distant sound sources in orchestrations -- so called "nature music". Now we have "movement" of the sound sources in music, but I think that has a lot farther to go when realistic surround sound becomes more widely available in halls and homes.

F. We have been attempting to plan performance spaces with provisions for greater creative use of space in musical performance.

- In the Meyerson Symphony Hall in Dallas the reverberation chamber surrounding the hall has been used as a location for offstage brass several times, including the Berlioz Requiem, Mahler's 2nd and the 3rd Leonore overture. It has been used for the women's chorus at the end of the Planets by Gustav Holst. The Dallas Symphony did a piece by Henry Brant where 2 high school orchestras and a steel drum band were in the reverberation chamber.

- Depending on the application, new ways to distribute sound don't necessarily require acoustical devices of loudspeakers. At the new Opera in Lyon a couple of weeks ago Russ and I saw Prokoffieff's Love for 3 Oranges, in which the chorus spent a significant part of the performance out among the audience. And this in an otherwise formal, traditional room and setting.

V. Future Trends

We have heard this week that in the future we can expect to attend virtual assemblies of people, where some people are in venues, some at home. Rather like Pay-per-view cable that's done for boxing matches.

A. Will the people in the home audience see images of the same scenery that the people in the live audience see in the theatre? Or will the scenery be created (generated) in their homes? Will the scenery be 3D holograms?

B. The acoustical corollary is virtual 3D acoustical space in your home, along with the 3D visual images, and controlled by the electronic link to the theatre.

VI. Quality of Experience

But at the end of it all, the quality of live performance acoustics will gain more importance, not less. Venues of the quality of the Musikvereinssaal will become much more common.

A. First of all, building Owners such as those in Singapore and Mississauga are committing to excellence. They are adopting lower seating capacities and higher acoustical goals. The competition between venues for top performers and their audiences will become more intense. We see this in Tokyo, London and Toronto.

B. Second, technology is molding expectations and tastes. "Home Theatre" will get better with time.

C. We're getting better at acoustical design.

VIII. Closing

In closing, I'd like to solicit more compositions for acoustically variable spaces, where the environment is altered during the course of the piece, or even an individual phrase. We need pieces like that for opening the halls of the 21st century.