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Sound Source Representation for Auralization

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ABSTRACT

For auralization in room acoustics there are several problems related to the sound sources. The anechoic recordings used for auralization can give problems due the microphone position used for the recording. In the room acoustic simulation there are other problems related to the source representation. Whereas some sources may be sufficiently represented by point sources with a fixed directivity, usually defined in octave bands, this will not be a good representation for other sources like many musical instruments. Instead a multi-channel representation has been developed, which leads to a more realistic 3D sensation of the source, and at the same time it allows the directional radiation to change during the performance. Sources of extended size introduce other problems, which may be solved by a number of uncorrelated point sources.

KEYWORDS : Auralization, Sources, Models

INTRODUCTION

Auralization is a technique that has developed to a state that allows many useful applications in research and in room acoustic design. The acoustic quality in the state-of-the-art auralization may be sufficient if the purpose of auralization is to demonstrate the difference between alternative room acoustic designs that give different reverberation times, or to demonstrate the difference between basic room shapes like rectangular, fan shape, circular shape etc. [1]. The modeling of the transfer function or room impulse response from source to receiver, and the modeling of the receiver by a head related transfer function (HRTF) has been developed to a high technical level and a very satisfactory agreement with dummy head recordings in real rooms has been obtained [2, 3]. However, the simple modeling of the sound source normally used today may not be sufficient for a more detailed study of room acoustic properties. Two problems are involved in sound source modeling, the anechoic recording of the sound, and the source modeling in the room acoustic simulation. The aim of this paper is to through some light on these problems and to discuss some suggested solutions.

ANECHOIC RECORDINGS FOR AURALIZATION

Anechoic recordings are usually made with a single microphone in the frontal direction of the source. If the source is the human voice such a recording will contain high frequency components that are considerably stronger than the average radiated sound power from the source. Ideally this should be compensated for by application of the proper directional characteristics of the source, but in practice this does not always work. The attenuation to represent less radiation in other directions is normally not sufficient, and the result is an auralization with too strong high frequency components. As an alternative the recording could be made in a direction off axis, e.g. 90° and the directional characteristic correction should then amplify the high frequency components in the frontal direction and attenuate the same in the backward direction. Here the problem is that very week frequency components cannot be amplified to represent strong radiation in other directions, and the result may sound too dull.

The distance of the recording microphone needs also careful consideration. Most natural sources contain near field noise components, like noise from finger or key movements, bow sliding on a sting etc. Therefore, a recording with a close microphone will sound unnatural when used for auralization in a longer distance from the source.

AURALIZATION USING THE SINGLE CHANNEL METHOD

Directivity Measurements. Fig. 1 shows a set up for measurement of directional characteristic of musical instruments [4]. 13 microphones were used and distributed in the horizontal and vertical plane, so simultaneous measurements could be made. Single tones were played and measured, and each tone was post-processed and filtered in octave bands from 125 to 8000 Hz. Finally, an averaged directivity was calculated in each octave band using all the tones of the instrument, see examples of results for three instruments in Fig. 2.

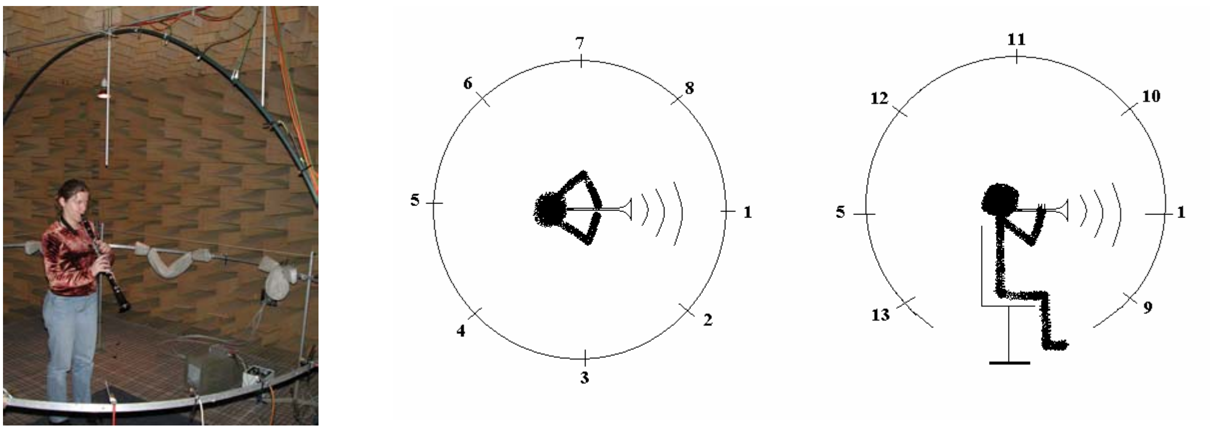


Fig. 1. Left: A musician during the directivity measurements using 13 microphones with a radius of 1,5 m in the anechoic chamber. Middle: Microphone positions in the horizontal plane. Right: Microphone positions in the vertical plane.

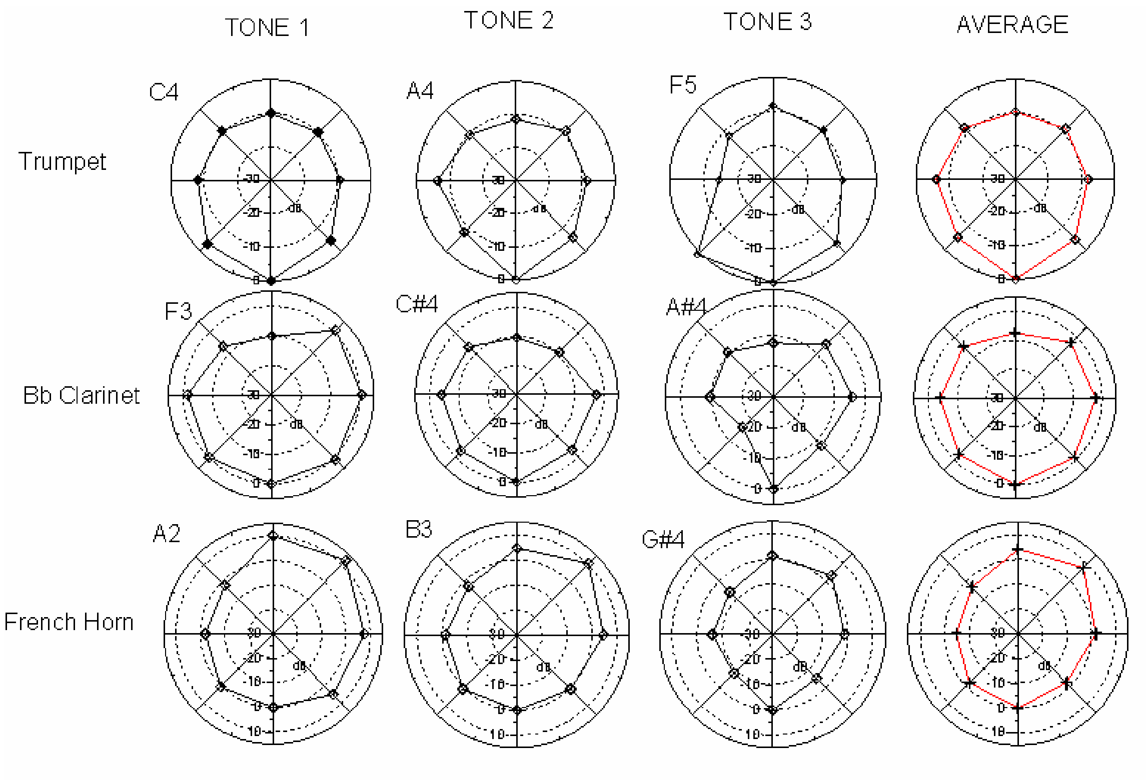


Fig. 2. Measured directivities for the trumpet, the clarinet, and the French horn for three different musical tones in the 1 kHz octave band in the horizontal axis. The front of the instruments is facing downwards. The averaged directivities in the right column correspond to the average over the whole pitch performing range of the instruments.

Reproduction Method. The room acoustic auralization uses a mono recording of the sound from the source, usually from a microphone position in front of the source (no 1 in Fig. 1). The room impulse response is calculated using a directivity, which can be different in each octave band. However, with this method it is not possible to use a directional characteristic that is correct for any tone played on a musical instruments. In Fig. 3 is shown examples of the calculated sound distribution in a concert hall using either a tone specific or an average characteristic. The results are shown for three different instruments, and in all cases are seen clear differences due to the different characteristics.

Evaluation of the Single-Channel Method. Listening experiments were made with auralizations in a computer model of the Elmia Hall, Sweden, using the ODEON room acoustic software. The source and receiver positions were as indicated in Fig. 3, having a distance of 8.93 m. Tests were made with the trumpet, clarinet and French horn, using two different directional characteristics for each, one of the single tone characteristics and the average characteristic, see Fig. 2. Short melodies of approximately 15 s were used for the auralization experiments. In a forced choice paired comparison test, the test persons were asked to evaluate Loudness, Reverberance, Clarity, Localization, and Timbre, and to give a preference to one of the directivities. For all three instruments the Loudness was found significantly different with different directivities. The change in Reverberance was significant for the Clarinet and the French horn, and the audibility of the Clarity was significant with the French horn, only. The differences of Localization and Timbre were not significant.

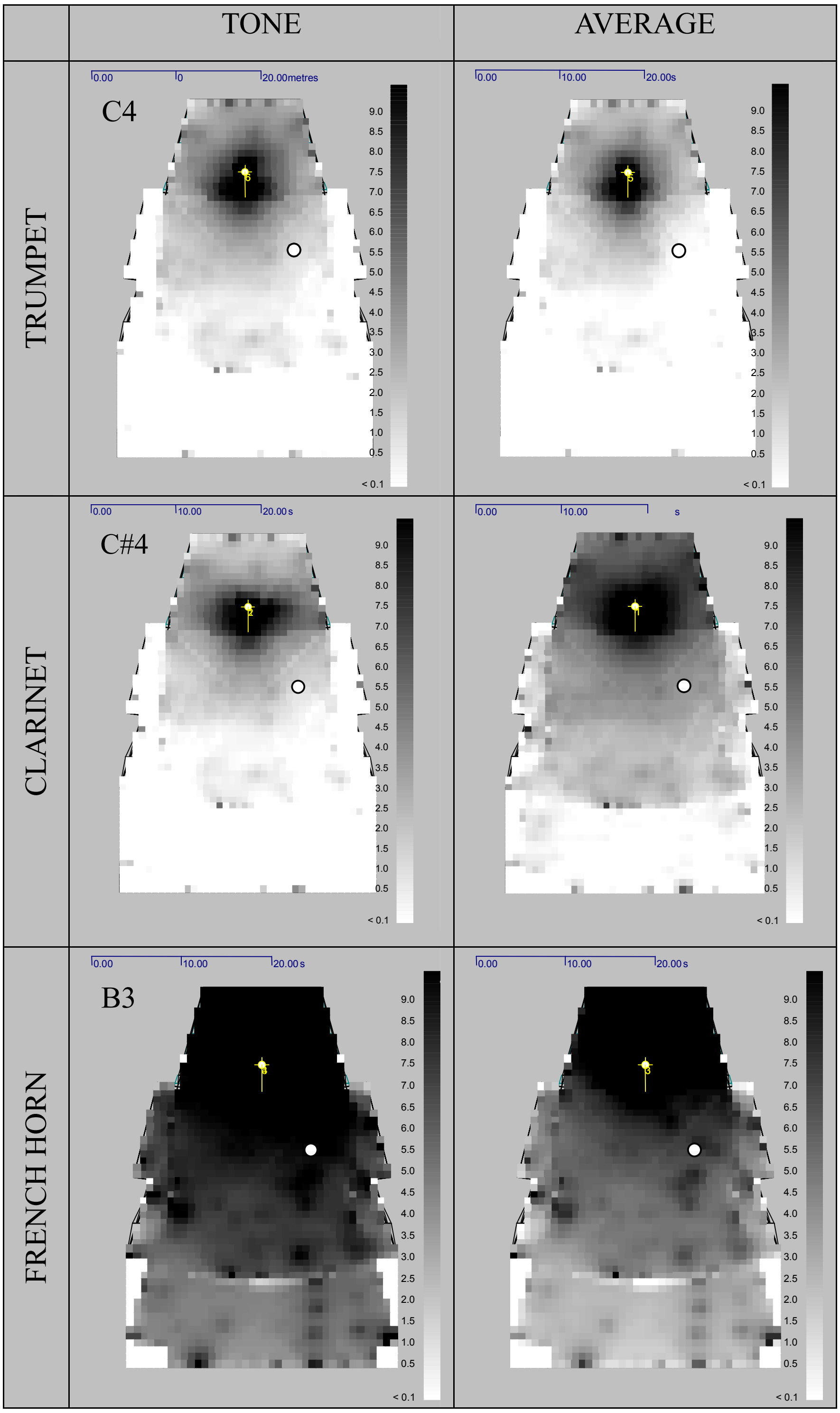


Fig. 3. Grid-response of the sound pressure level (SPL) of the three musical instruments in the 1 kHz octave band, simulated at the ELMIA concert hall with the directivity of a tone and the averaged directivity. The scale is relative and shown from 0 to10 dB with white and black as the minimum and maximum values, respectively.

AURALIZATION USING THE MULTI CHANNEL METHOD

Recording Method. One way to capture the sound radiated by the musical instrument in different directions is to perform simultaneous anechoic recordings with microphones in different positions around and above the source [5]. The sound recorded in different tracks will contain the spatial information of the source regarding asymmetries in the instrument, movements of the performers and changes in the radiation for different tones.

Reproduction Method. Once the multi-channel recordings of the instrument have been done, each of the particular recordings registered by the microphones should be played by a particular virtual source in the auralization, according to the original position in the recordings. This can be done in a room acoustic simulations program by defining sources that have a neutral omni directional pattern within a solid angle of radiation. Figure 4 shows an example of a setup for four-channel anechoic recording of a musical instrument used in a room auralization with a compound source consisting of four virtual sources. Each of the virtual sources in the figure has an omni directional characteristic within a span of a quarter of a sphere, radiating in different directions in the horizontal plane. The new compound source, consisting of the four virtual sources together, will radiate in a distinctive way in each of the four directions following changes in level, movements, asymmetries and orientation of the original source, as recorded by the individual microphones.

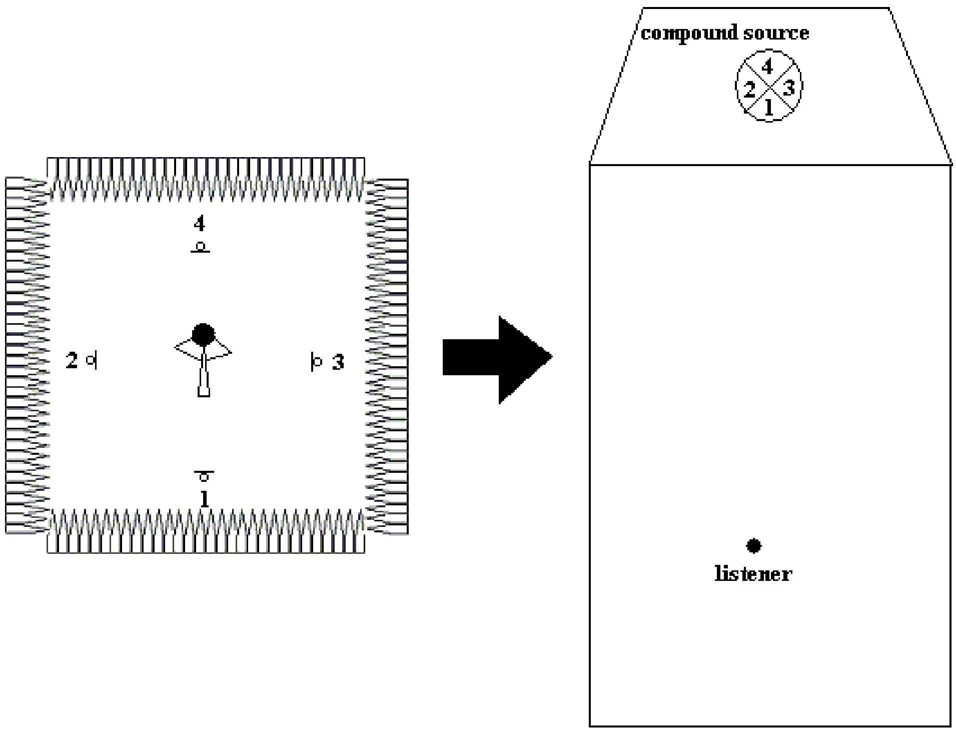


Fig 4. The principle of the multi-channel method, here shown with four channels. Left:Anechoic recording of the source with four microphones, Right: Room simulation with the source represented by four directive partial sources.

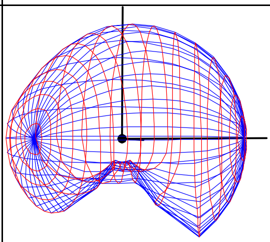
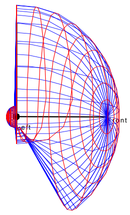
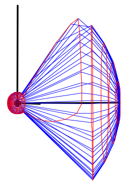
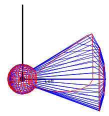
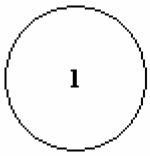
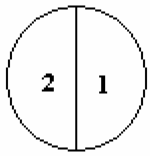
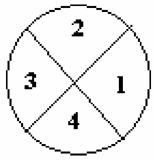
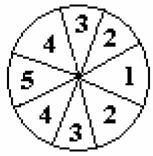
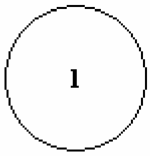
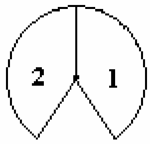
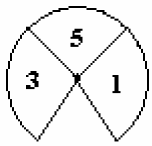
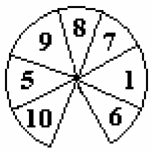
Type	**1 Channel**	**2 Channels**	**5 Channels**	**10 Channels**
Directivity of Partial Sources				
Position in Horizontal Plane				
Position in Vertical Plane				

Table 1. Partial sources used for room acoustic simulations with the multi channel method.

Evaluation of the Multi-Channel Method. Listening experiments were made with recordings of a Bb clarinet and room auralizations were made with one, two, five, and ten channels as shown in Table 1. The results of the tests for the quality of the naturalness of timbre proved that the method represents a clear improvement when compared with the averaged directivity representation; they showed in all cases a significantly higher preference for the representations with the method. There was also in general a preference for configurations with more virtual sources (five or ten). There was no clear difference in spaciousness, which is no surprise since spaciousness is related to the room acoustic conditions at the receiver. However, there seems to be an audible effect related to the source, which may be described as giving a 3D depth to the source. In comparison, the source sounds flat with the single-channel method.

AURALIZATION OF EXTENDED SOURCES

Synchronised Sources, an Orchestra

Anechoic recordings of orchestra music are some times available in stereo (e.g. Denon CD with anechoic recordings). This offers the possibility to make auralizations with two source positions to represent the left and right side of the orchestra. This can lead to clear improvements compared to a mono source auralization, mainly in terms of the Apparent Source Width (ASW). However, it is not recommended to use more than one source position for each channel; multiple source positions will lead to a blurring of the room impulse response, and both localization and timbre may suffer. For the same reason it is not a good idea to use a surface source to represent an orchestra. As a rule of thumb each anechoic recorded signal should be combined with one well-defined room impulse response.

Uncorrelated Sources

Examples of extended uncorrelated sources are noise from a train, rain on the roof, or hand clapping in an audience. In these cases there is normally only a single anechoic recording available, but the sources are distributed and a single point source would not be acceptable, mainly because the localization will be wrong. It can be a solution to use a large number of source positions, but they should be separated in distance by at least half a wavelength of the lowest frequency of importance, and it is advisable to apply different time delays to each source to ensure uncorrelated contributions from each room impulse response.

AURALIZATION OF MOVING SOURCES OR RECEIVERS

One of the big challenges in auralization is the case of moving sources or receivers. The first problem is one of computer capacity, because the room impulse response is changing, and each new calculation is expensive in computer power. The next problem is the fading from one impulse response to the next during the auralization.

An Example, India Song

This is an example of an auralization made with a moving receiver (Acoustic Installation by Solvej D. Andersen, made at DTU 2003). The receiver was supposed to be dancing in the room and at the same time listening to a piano in the corner, a fan in the ceiling and the rain heard through some open windows, see fig. 5.

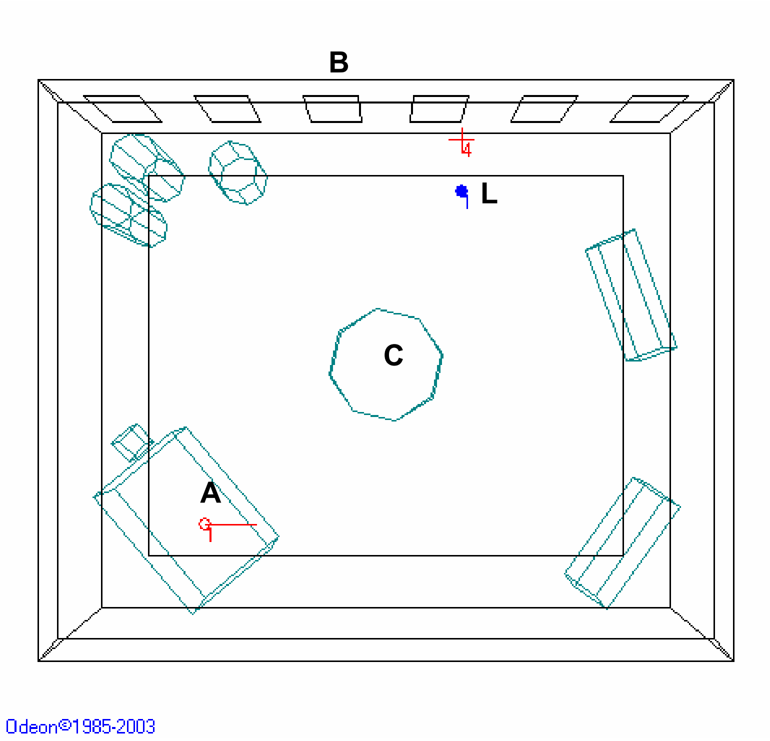


Fig. 5. The room set-up for the "India Song" auralization.
L: The listening position (a dancer moving around in the room) the cross 4 is the direction of observation,
A: The piano sound source,
B: The sound of rain heard through open windows,
C: The noise from a slowly rotating fan in the ceiling.

Moving the receiver. This was made in the following way:

- Static simulations for a number of time steps (dancer position and orientation)
- 260 different receiver positions /orientations
- Length of time steps 0.2 – 1 second, depending on the speed of movement (the optimum might be steps of around 50 ms).
- Fade between static simulations as dance is progressing

The fading process.
Problem:

- If fading is too fast, pumping will occur
- If fading period is too long, directional information will be lost

Solution:

- Duration of transition 0.1 seconds as a compromise
- Function used for fading: Sine-function

CONCLUSION

Although the usual single-channel method may be sufficient for many applications of auralization, a new multi-channel method has been developed for improved realism. With this method the sound source may have an audible acoustic depth and a more natural timbre. Extended sources can be modeled, but it is recommended to apply one single room impulse response to each independent recording/channel. Moving sources or receivers can be used for auralization, but many problems remain to be solved before this can be used in a larger scale.

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