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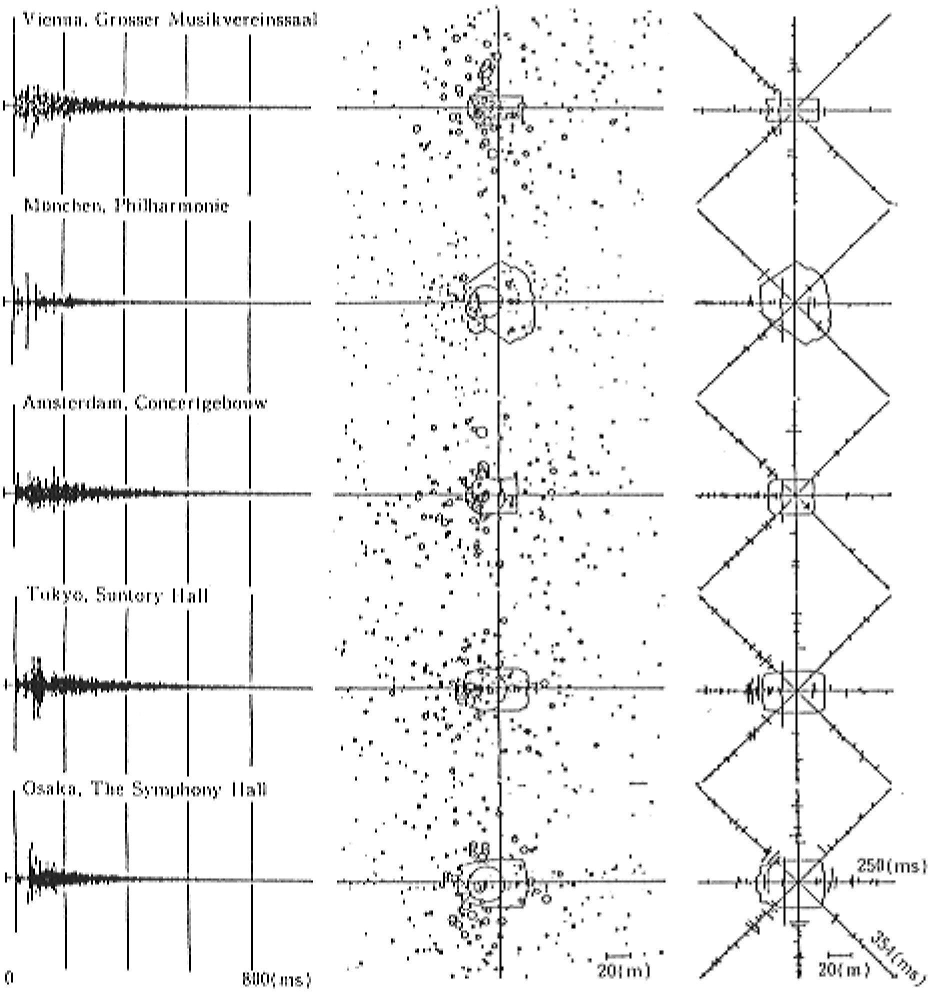
5. VISUALIZATION AND REPRODUCTION OF SOUND FIELD

5.1 Four Microphone Measurement

The four microphone measurement is a method to grasp spatial information of sound fields from impulse responses measured at closely located four points. These four points must not place on the same plane, usually we set them on the origin and the three points on the rectangular coordinate axes 5cm distance from the origin [6].



Impulse responses | Projected sound sources | Directional impulse responses

Fig.4 Results of the four microphone measurement

Three dimensional coordinates of direct and reflected sound sources are calculated by correlation technique or intensity technique. Figure 4 shows the results of the four microphone measurements in various concert halls; impulse responses, sound sources distribution projected to floor plane and the directional impulse responses obtained from it. In sound sources distribution, the center of each circle is the projected coordinate of direct or reflected sound source, the area of each circle represents the power of the corresponding source, and the cross point of the two orthogonal lines is the observation point, the outlines of the concert hall are also shown.

By convolution of the signal and each directional impulse response, the sound field reproduction is realized.

5.2 Wave-front synthesis

Based on the Kirchhoff- Helmholtz integral, an arbitrary sound field within an enclosed space can be determined by the normal component of particle velocities and the sound pressures on the surface of the space. The only restriction is that there are no sound sources within this space.

However, realization of this theory numerous number of loudspeakers are needed, for example up to 17kHz loudspeakers should be placed at 1cm intervals. Therefore we are obliged to reduce the number of loudspeakers. Figure 5 shows the wave front synthesis function W proposed by A.J.Berkhout, D.de Vries and P.Vogel [7][8] which reduce n discrete points on surface z=0 to 1 (n>1) on surface z=1 is introduced.

An experiment was done in an echoic chamber with 26 loudspeakers. Figure 6(a) shows the distribution of the sound sources measured in Aichi Art Concert Hall, Fig.6(b) shows the distribution of the sound sources in the reconstructed sound field.

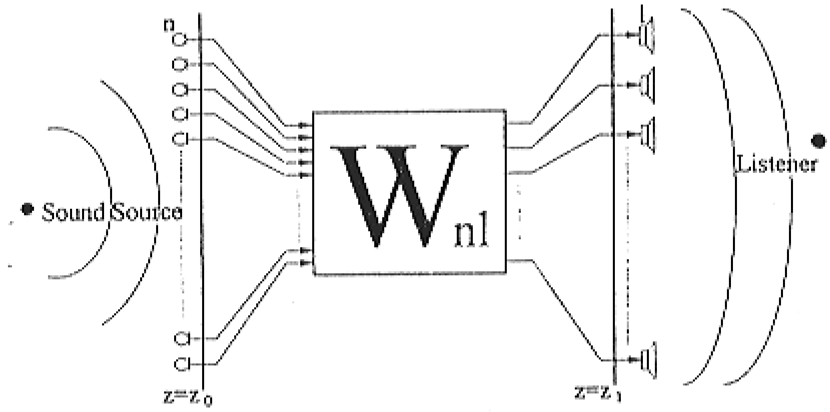


Fig.5 Wave-front synthesis

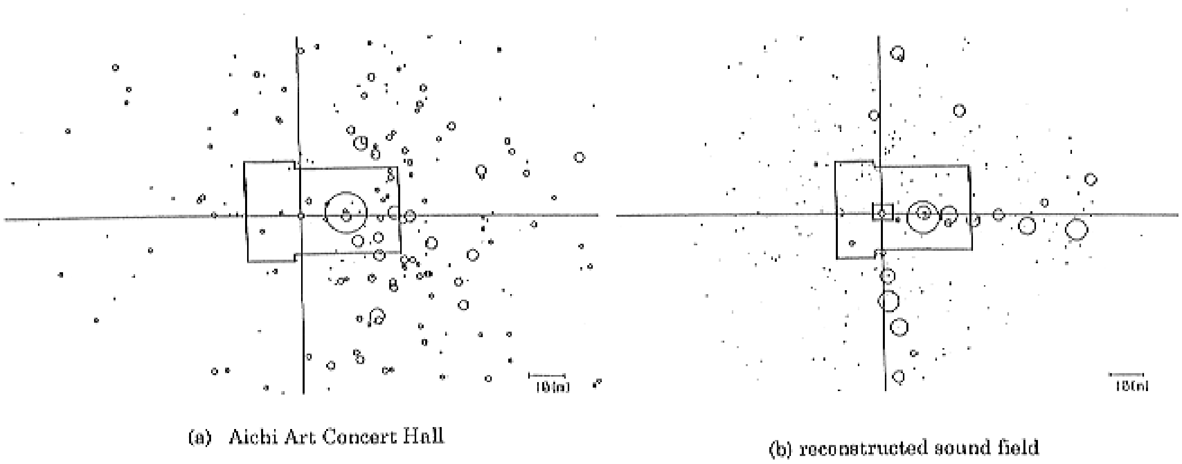


Fig.6 Wave-front synthesis

6. CONCLUSIONS

The visual information is recognized well to be very important in robot system and a lot of researches are done on robot vision. On the other hand, not so many studies on auditory information processing for robot are reported, although it is important as well. Sound plays an important role not only for the conversation but also for the environment understanding in human daily life.

In this paper we introduced three topics on sound technologies studied in Humanoid project. The first and the second research have been implemented in the experimental robot Hadaly which perform the task of the campus information guide with speech conversation and gesture. Our next target is to construct a totaled auditory system which works with vision system for Humanoid robot.

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