Three-dimensional Sound Image Localization by Interaural Differences and the Median Plane HRTF - Part I. A New Sound Localization Method Based on Lateral and Vertical Angle Perception -

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Morimoto and Ando have shown that 3-D localization can be attained, if HRTF are accurately simulated. However, a numerous number of HRTF are required to represent the entire 3-D auditory space. Furthermore, decrease of the localization accuracy due to the individual difference of HRTF remains unsettled. One of solutions of these issues is to reduce the number of HRTF to be used. Morimoto and Aokata have reported that the lateral and vertical angles of a sound image are determined by the binaural disparity cues and spectral cues, respectively. Moreover they suggested that the spectral cues are same in any sagittal plane. In this study a new 3-D localization method by simulating interaural differences and the HRTF in a sagittal plane was proposed. Localization tests were performed to examine the method. The results indicate that the perceived lateral and vertical angles agree with the simulated ones.

INTRODUCTION

Morimoto and Ando [1] have shown that 3-D localization can be attained, if HRTF are accurately simulated. Almost of the recent studies on 3-D localization are based on this principle. However, a numerous number of HRTF are required to represent the entire 3-D auditory space. Furthermore, decrease of the localization accuracy due to the individual difference of HRTF remains unsettled. One of solutions of these issues is to reduce the number of HRTF to be used. Morimoto and Aokata [2] have demonstrated that the lateral angle α and vertical angle β of a sound image are determined by the binaural disparity cues and spectral cues, respectively, by using the coordinate system shown in Fig. 1. Moreover, they suggested that the spectral cues are same in any sagittal plane. In this study, based on these findings, a new 3-D localization method by simulating interaural differences and the median plane HRTF is proposed, and its localization accuracy was examined.

METHOD OF LOCALIZATION TESTS

Localization tests were carried out to confirm the localization accuracy of the proposed method. The HRTF of the subjects in the upper median plane were measured at every 30° from the front to the rear. Interaural differences were also measured at the four lateral angles (0°, 30°, 60°, 90°) in the right side of the horizontal plane. The source signal is the band-limited white noise (280Hz - 11.2kHz). Stimuli were prepared by convolving the noise with the measured subject's own median plane HRTF, and adding interaural differences to them. Twenty-eight kinds of stimuli (7 HRTF x 4 interaural differences), which simulated the sound sources in the upper hemisphere, were presented to the subjects by the sound field simulation system through near-ear loudspeakers. The duration of the stimuli was 1s. The task of the subjects was to mark down the perceived azimuth and elevation of the sound image on the recording sheet. They were transformed into α and β after the experiment. Subjects were four males with normal hearing sensitivity.

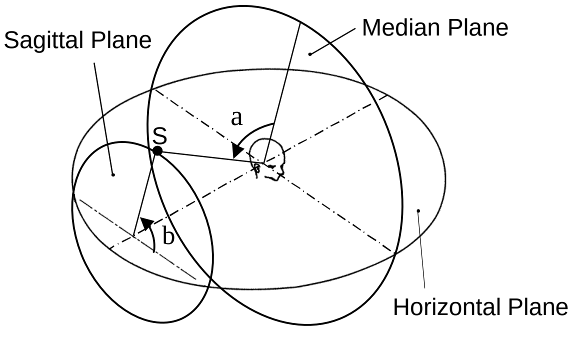

FIGURE 1. Definition of the coordinate system. α is the lateral angle and β is the vertical angle.

RESULTS AND DISCUSSIONS

The subjects reported that they perceived all sound images outside the head. Figure 2 shows examples of the responses (subject: IT, α = 0°, 30°, 60°, β = 0°, 90°, 180°). The circular arcs denote the lateral angle α, and the straight lines from the center denote the vertical angle β. The simulated α and β are shown in bold lines. The intersection of two bold lines indicates the simulated direction. This figure shows that the perceived lateral angles almost agree with the simulated ones. The localization accuracy, however, decreases to some extent for α = 60°. With the vertical angle, the localization accuracy is high at the front and rear of the subjects, but relatively low at the above. This behavior is similar to the responses for the real sound source [3]. The perceived vertical angles agree with the simulated ones even in the cases of the lateral sound sources. In addition, no front-back confusion is observed. These were common behavior to other subjects.

Furthermore, the mean localization error, *e* was obtained by Eq. (1).

$$e = \overline{\left| R - S \right|}, \qquad (1)$$

where *R* is the perceived angle, and *S* is the simulated angle. Table 1 shows the errors of the lateral and the vertical angles for each lateral angle of the simulated sound source. The larger simulated lateral angle becomes, the larger lateral angle error becomes. These errors show the similar tendency to the jnd of horizontal plane localization [3]. The vertical angle error is almost the same as the localization error in the median plane[3]. However, the vertical angle error shows relatively large at α = 60°. The reason seems to be that a change of vertical angle along a circular arc in the lateral sagittal plane is sensitive when its radius is small.

Table 1. Mean localization error

	Simulated Lateral Angle α (deg.)			
	0	30	60	90
Lateral Angle Error(deg.)	1	7	16	23
Vertical Angle Error(deg.)	15	13	21	-

CONCLUSION

The localization tests demonstrate the realization of 3-D localization by simulating interaural differences and the median plane HRTF.

REFERENCES

1. M. Morimoto and Y. Ando, J. Acoust. Soc. Jpn. (E), **1**, 167-174 (1980).

2. M. Morimoto and H. Aokata, J. Acoust. Soc. Jpn. (E), **5**, 165-173 (1984).

3. J. Blauert, *Spatial Hearing*, Cambridge: The MIT Press, 1983, pp. 97-116

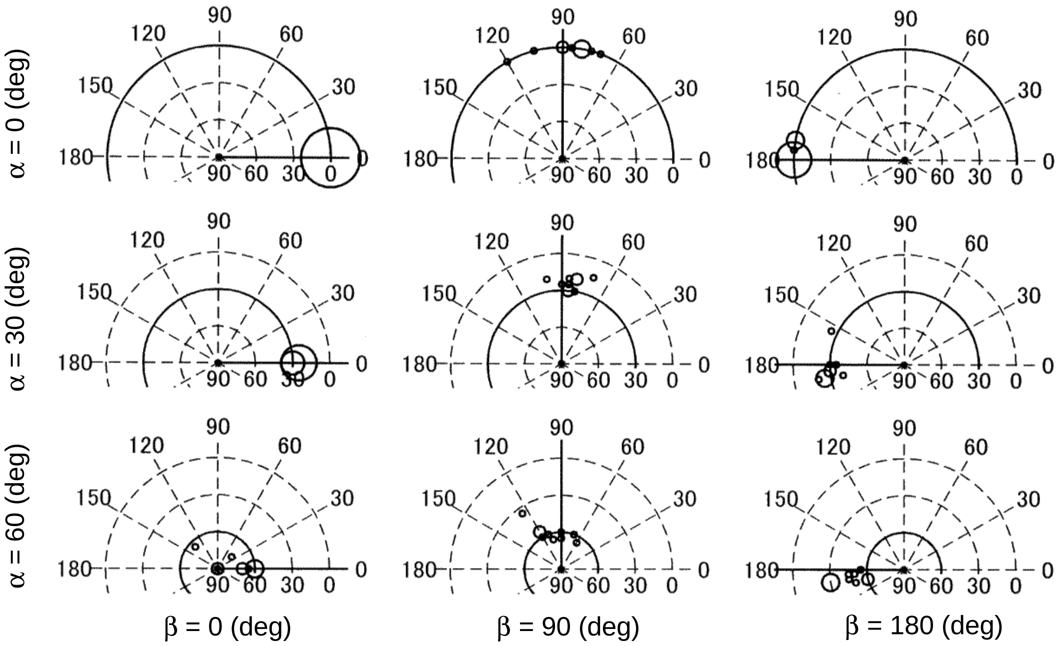

FIGURE 2. Examples of responses to the stimuli simulated by using median plane HRTF and interaural differences. Bold lines indicate simulated lateral angle α and vertical angle β.