A modeling of distance perception based on auditory parallax model

Yōiti SUZUKI, Hae-Young KIM, Shouichi TAKANE, Toshio SONE
Research Institute of Electrical Communication, Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai, 980-8577 JAPAN

Abstract: Auditory distance perception is modeled by use of the difference in HRTF due to the parallax angle given by the direction from each ear to the source. This "auditory parallax model" was examined by a psychoacoustic experiment. The results are compared between those for an actual sound source and those for HRTF synthesized as precisely as possible. The relation between the perceived and simulated distance obtained for sound based on the auditory parallax model showed very similar tendencies between an actual sound source and the simulated HRTF. These results indicate that the cues for the distance perception derived by the auditory parallax model is almost satisfactory for a sound source close to a listener (within about 1.2 m).

INTRODUCTION

In order to investigate the process of auditory distance perception for a sound source close to a listener, a model named "auditory parallax model"[1] is discussed in this paper. A psychoacoustic experiment was conducted to examine the validity of this model. Experiments with an actual sound source and with digitally synthesized HRTF's were also made for comparison.

EXPERIMENTAL METHODS

The sound source was at one of the azimuthal angles of 0, 45, 135 and 180 degree, where 0 degree means the frontal direction and 90 degree shows the left hand side. A subject sits on a chair in an anechoic room (7.0×4.6×2.5m) with its head fixed on a small headrest. The level of sound stimuli was always kept constant at 60 dB SPL at the subject’s position so that the subject could not use the loudness as a cue. The subjects were four young males with normal hearing.

(a) Exp.1 : Distance perception of an actual sound source was carried out by using a small computer-controlled movable loudspeaker installed in the anechoic room. The position of the loudspeaker was at one of 25, 50, 75, 100, 125, 150, 175, and 200 cm from a subject. A curtain was hung between a subject and the loudspeaker. The number of repetition for each experimental condition was 10.

(b) Exp.2 : The distance perception of a sound image by use of simulated HRTF's from a virtual sound source to the listener's ears was observed. Schematic diagram of the method to simulate HRTF's using two loudspeakers [2] is shown in Fig.1. HRTF's for distances of 25, 50, 75, 100, 125, 150, 175, and 200 cm were measured with a computer generated pulse signal [3] for each subject and then were simulated by the two loudspeakers placed in the anechoic room. The two loudspeakers were located at 1.2 m, ±45 deg. in the horizontal plane. The number of repetition for a experimental condition was six.

(c) Exp.3 : The auditory parallax model is based on an assumption that the auditory distance perception is made depending on the parallax angle given by that between the directions from each ear to a sound source. The validity and limitations of this model were examined by a psychoacoustic experiment. Figure 2 shows the schematic diagram to synthesize a virtual sound image based on the auditory parallax model. Transfer function from a virtual sound source A to the listener's right ear $D_{AR}$ and that from another virtual sound source B to the listener's left ear $D_{BL}$ are measured. Then, by using the two loudspeakers SP1 and SP2, $D_{AR}$ and $D_{BL}$ are synthesized at the listener’s right and left ears, respectively. Moreover, $D_{AR} = D_{BL} = 0$ is also synthesized at the same time. If the auditory parallax model stands, the listener localizes a sound image at the point $P$ where the line from virtual sound source A to the right ear and the line from virtual sound source B to the left ear cross. Based on this principle, sound images with distances of 10, 20, 25, 30, 40, 50, 60, 75, 100, 125, 150, 175, and 200 cm were synthesized by changing the parallax angle $\alpha$. The number of repetition for an experimental condition was six.

RESULTS AND DISCUSSION

Examples of the results of Exp.1 for a subject are indicated in Fig.3 (a). The figure shows that the perceived distance is underestimated when the actual distance between the subject and an actual sound source is greater than 50 cm. Moreover, the perceived distance increases along with the actual distance until the actual distance is up to about 1.2 m as previously reported [4]. The experimental results of Exp.2 is shown
FIGURE 1. Schematic diagram of the HRTF simulation system using two loudspeakers (Exp.2).

FIGURE 2. Schematic diagram of a simulation system based on an auditory parallax model (Exp.3).

in Fig.3 (b). This shows that the perceived distance of a sound source synthesized by simulating HRTF’s is almost the same as that with the actual sound source and increases with the simulated distance up to about 1.2 m. If the simulated distance exceeds about 1.2 m, on the other hand, the perceived distance no longer increases. In all of the two experiments, the perceived distance monotonically increased along with the increase of the physical distance up to around 1.2 m. The results indicate that the change in HRTF as a function of distance can be a significant cue for the distance perception up to about 1.2 m in the absence of information based on loudness and reflections. Moreover, this means that the change of HRTF can be perceived within this range of distance. Moreover, this distance coincides well with the physical observation of the change of HRTF as a function of distance [4]. Figure 3 (c) shows the results of Exp.3, where the

FIGURE 3. Examples of results of subjective experiments.

perceived distance was obtained based on HRTF synthesized with parallax information. This shows that the relation between the simulated and perceived distance is almost the same as in both the actual source and simulated HRTF. It indicates that the information in HRTF due to auditory parallax angle is an important information in the auditory distance perception for a sound source placed near a listener.

CONCLUSION

The perceived distances of sound images synthesized with the auditory parallax model shows very similar tendencies to those with actual sound sources and with simulated HRTF’s. It suggests that the cues provided by the auditory parallax model is effective in the auditory distance perception of a sound source placed near a listener.

REFERENCES