Sound and vibration integrated cues for presenting a virtual motion

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Abstract

In the present study, we discuss the characteristics of sound and vibration integrated cuing for presenting virtual motions. Three dimensional sound via 7.1-ch speakers and cutaneous vibration stimuli on the back and thigh are controlled to create the sensation of motion of virtual objects and the self body. The cuing system is designed as part of a multi-sensory display for a ultra realistic experience. A fundamental motion perception was investigated by the system regarding onset timing factor for creating the sensation of motion.

Index Terms: H.1.2 [Models and Principles]: User/Machine Systems—Human factors, human information processing; H.5.2 [User Interfaces]: Input devices and strategies—Interaction styles;

1 Introduction

Spacial sound and cutaneous sensation are the important complement of visual perception in perceiving the motion of objects and the observer's self motion. The spatial sound induces the sensation of self-motion of rotation (circular vection) [1][2], although it is less compelling than visually produced vection [3]. The auditory induced vection is enhanced by vibratory stimulus [4] that is thought to impart the notion of a kind of vehicle on which the observer sit. The translational vection is also produced by moving virtual sound objects approaching to or receding from the observer[5][6].

These researches report self-motion induced with small number of sound sources and non-spatial vibratory stimulus to overload the vestibular sensation. This sort of sensory integration is effective for augmenting the quality of presentation in the VR system that is often built under restricted display performance. The sensory integration is beneficial in creating the presence of a virtual world so that the limited capability of display system can fulfill optimized presentation. Sound images of remote objects out of sight is assisted by cutaneous sensation, especially for the direction of elevation. The vertical self-motion is not definitely presented by an auditory image. It could be enhanced by a cutaneous sensation.

The cutaneous sensation, like vision, produces the apparent motion by vibratory stimulation [7]. This phenomenon can be used in conjunction with the sound image to represent an object motion in a space around the observer's body. This will create a new experience of space utility with a virtual motion that is localized in the air by an auditory presentation and The motion is perceived through all senses. The information from the senses needs to be integrated for cognition of the new reality. The new reality could be used in the data experience like visualization to understand data intuitively, or in the entertainment where a new spatial interaction is provided.

In the present paper, we investigate the basic characteristics of cutaneous perception of motion presented at the back and thigh. Just clarifying the point of the present research again, we pursue the method to create the motion sensation of self-body and related remote event, not to seek to develop direction indicators ([8],[9],[10]) nor the substitution of sense organs [11].

In addition, this report is intended for the introduction of only elements for the purpose. The spatial sound interaction and integration are to be discussed in the next report.

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20th International Conference on Artificial Reality and Telexistence (ICAT2010), 1-3 December 2010, Adelaide, Australia
ISBN: 978-4-904490-03-7 C3450 ©2010 VRSJ

2 Display for cutaneous sensation

The authors investigate the relation of motion perception between senses that give partial information cues. More specifically, the motion presented by tactile and sound stimulus presented separately in space and designed asynchrony. The tactile stimulation is provided by full-range speakers placed on the back and bottom of a seat as shown in Fig. 1. The stimulators were with a 5W driver amplifier and arranged in appropriately soft material so that they contact to the body skin compliant to the shape. The stimulators were driven by a 7.1-ch audio driver. The motion of an object that in contact or very near the body surface of the observer is depicted by an apparent motion.

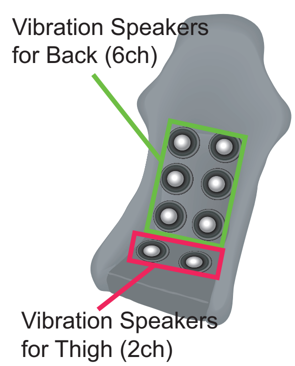

Figure 1: Cutaneous stimulator layout on a seat.

3 Display for Sound image

The object motion in an environment that is apart from the observer is perceived by hearing the sound as well as vision. 3D localized sound through a 7.1-ch speaker system set around the observer effectively gives the cue of the motion of the object. The surround speaker system localizes the sound image of an object with a standard HRTF (head related transfer function). The sound image localization in a 3D space is especially important when the object is out of sight. Although sound image localization is possible with stereo headphones, a HRTF quality is often insufficient to share among participants.

A spatially distributed speakers create spatial sound more accurately than headphones. We use 7.1-ch speakers around the seat in conjunction with the tactile speakers on the seat.

4 Basic experiment on tactile motion perception

Here we discuss basic characteristics of seat stimulators only.

4.1 Presentation of tactile stimuli

A short burst sound of 56 Hz, 0.5 s duration was presented with four spatiotemporal patterns depicted in Fig. 2. Speakers were placed with about an 85-mm interval. Ascend/descend patterns on the left produce the stimuli either from the seat bottom to the seat-back top, or reverse direction to create the object motion along the body surface or the self-motion. Rotational patterns on the right indicate the object's circular motion or the rotational (roll) self-motion.

In the vertical motion setting, two directions and directionless (synchronous) were randomly presented 10 times each for a preliminary investigation. Then, in the next experiment, three kinds of stimuli of clockwise, counter clockwise, and no rotation (synchronous) were randomly presented also 10 times each. The onset interval time was changed among 0 (synchronous), 10, 25, 50, 100 and 200 ms. The subject was asked to report from three choices of up, down, ans synchronous in the linear condition, and of clockwise, counter-clockwise, and synchronous in the rotational condition, respectively.

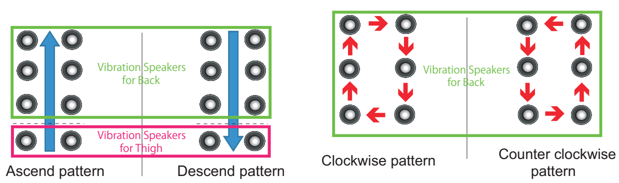

Figure 2: Temporal patterns of tactile stimulation.

4.2 Result

Figures 3 and 4 show the total error ratio for each onset interval time. The chance ratio was 33 %, then it looks that the 50 ms and longer interval time allows correct perception of direction. With the 50 ms interval, the total onset delay was only 150 ms in linear motion stimulus while 250 ms in rotational motion stimulation. The error ratio was larger in a linear motion than a rotational motion, which was due to the amount of total stimulation time.

On the other hand in a separate experiment, we obtained the result that spatial sounds placed in four directions 60 degrees apart in front of the observer were able to be distinguished clearly with from 200 to 300 ms onset interval. These values are the minimum perceivable spatial changes in our settings. It looks that relatively fast spatial change of synthesized stimulus in the near space is perceivable, and the spatial density of information can be raised to this range. The result is quite interesting in the design of continuous information rendering that covers both spatial hearing and cutaneous spatial motion recognition.

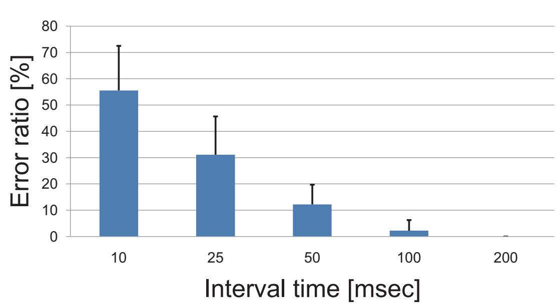

Figure 3: False recognition of linear motion

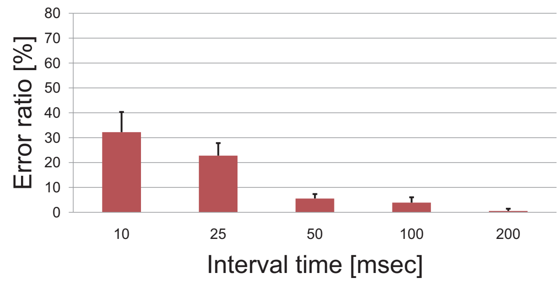

Figure 4: False recognition of rotational motion

5 Conclusion

A sequential tactile stimulation was provided to the back of the subject to investigate the accuracy of stimulus motion perception. A preliminary result showed that 50 ms and longer was a threshold to distinguish the direction of linear/rotational motion at the back.

The future work includes further experiments to cover stimulus conditions and the elucidation of perception when the spatial stimulus moves through both the near space and the body surface space. It will provide information how we capture physical vibration that moves in the merged spatial coordinates of the observer.

Acknowledgements

This work was supported in part by the funded research for the ultra realistic communication technology by an innovative 3D image technique from National Institute of Information and Communications Technology, Japan.

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