Simultaneous Presentation of Tactile and Auditory Motion to the Abdomen to Present the Feeling of Being Slashed

Sayaka Ooshima[1], Yuki Hashimoto[1], Hideyuki Ando[2], Junji Watanabe[3], and Hiroyuki Kajimoto[1]

[1]Department of Human-Communication,
The University of Electro-Communications, Tokyo, Japan
{ooshima, hashimoto, kajimoto}@kaji-lab.jp
[2]Osaka University, Graduate School of Information Science & Technology, Osaka, Japan
hide@ist.osaka-u.ac.jp
[3]Japan Science and Technology Agency, Kanagawa, Japan
watanabe@avg.brl.ntt.co.jp

Abstract: For gaming applications, we propose the idea of a multimodal interface worn on the abdomen to present the feeling of being slashed. Tactors and speakers produce tactile and auditory stimuli on the abdomen. We compared the tactile apparent movement with auditory motion, focusing on position and speed. The subjectively equivalent position and velocity of the two modalities matched well. In addition, we devised an improved device that can present "deep perception", presenting a stimulus through the body using full range speakers that work as tactors.

Keywords: *haptic display, fusion of haptic and auditory stimulations, apparent movement, being slashed, deep perception*

1. INTRODUCTION

Vibration displays have been rapidly brought into everyday communication and entertainment [1]. Many displays have been proposed and used for gaming applications. Commercial videogames commonly use vibration motors placed inside control pads, and force-controlled joysticks and handles give the impression of reality.

The easiest haptic representation is to use a stick-type controller with a vibration motor, as in Nintendo's Wii [2]. In the research field, haptic "shock" can be presented in many ways. For example, Virtual Chanbara [3] uses a DC motor and a brake and generates an impact by suddenly stopping the motor. There are already wearable devices for games that impart a shock to the user through vibrators, but the shocks are primitive and unpleasant.

This is less than ideal because game characters experience a wide range of haptic sensations in different situations. However, most haptic devices for gaming have concentrated on conveying sensations to the user's hand. Consider, for instance, the world of fantasy. In sword play, a player destroys enemies, but he also may be slashed by them.

Our aim is to develop a wearable haptic device that imparts a sensation of "being slashed". For this purpose, to impart a sensation the user feels is realistic, we need more than just a primitive shock. Though true realism is not necessary, the sensation should at least be realistic enough to convince users they have been cut.

We propose mainly presenting tactile and auditory sensations to the user's abdomen. We especially focus on the fusion of the two modalities as they move across the abdomen, because we assume the sensation of being slashed is enhanced by their motion. Various methods of presenting tactile icons on the abdomen have been reported [4][5], but they do not present tactile and auditory sensations simultaneously.

To determine the relation between simultaneous tactile and auditory sensations on the abdomen, we prepare sparsely spaced tactors and a dense speaker configuration and compare tactile apparent movement with auditory motion, focusing on the position and speed.

Finally, to enhance the feeling of being slashed, we then present a new device that produces "deep perception". We propose to use array of full range speakers to enable deep perception.

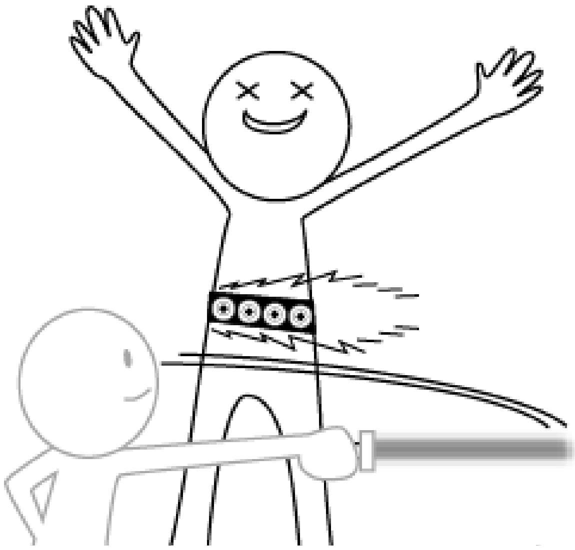

Fig. 1 Sensation of being slashed.

2. SYSTEM

The prototype has haptic and auditory parts. Fig. 2 shows the system configuration.

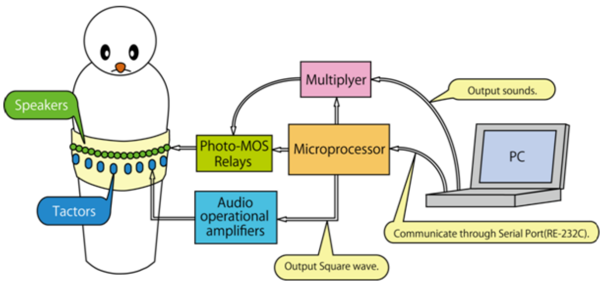

Fig. 2 System configuration.

2.1. Haptic part

Four vibrators are placed in a row inside a waist-band. As we want to present apparent motion that requires temporal resolution, we chose voice coil actuators, or tactors (Audiological Engineering Corp., Skin Stimulator) instead of vibration motors. The tactors are driven by power operational amplifiers (Toshiba, TA7252AP). Square waves of 200 Hz are generated by a microprocessor (Renesas Technologies, H8-3048).

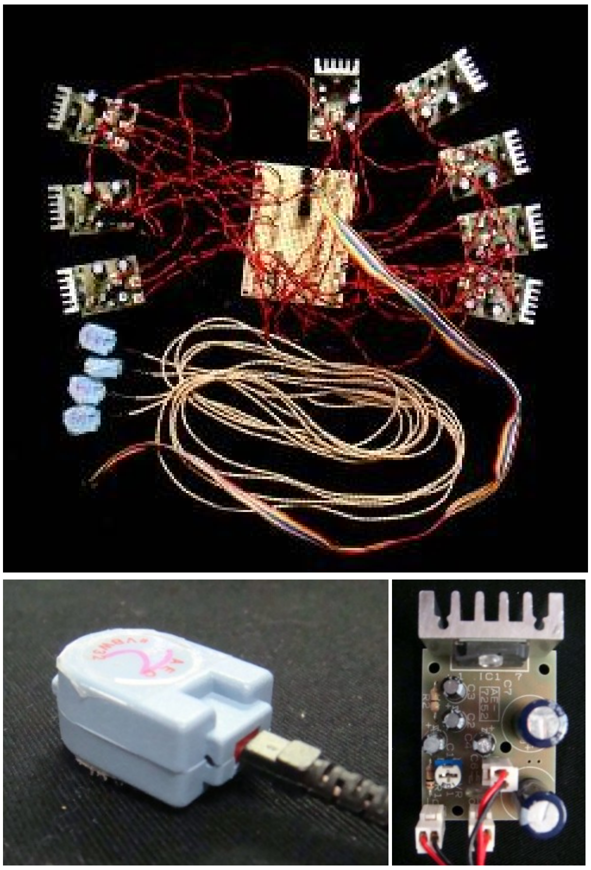

Fig. 3 Haptic part.

2.2. Auditory part

Sixteen speakers are placed in a row outside the waist-band. The diameter of each speaker is 20 mm.

Apparent motion can be adequately generated with a few tactors and a few speakers. In our preliminary system, however, we prepared numerous speakers densely distributed for auditory sensation. This was because one of the aims of this work was to psychophysically evaluate tactile apparent motion with reference to auditory motion.

For such an evaluation, we need a system to switch between speakers. We used an analog switch (Photo-MOS relay, Fairchild Semiconductor, HSR312) for each channel. A track of sound from a PC is fed to all 16 switches. Each speaker is activated when the microprocessor feeds the activating signal to the switch via its data output port. We used an analog multiplier (Analog Devices, AD633) between the PC and the analog switches. Just before the switch state changes, the sound volume is decreased to avoid switching noise. After the switch state changes, the volume recovers. These operations were performed using a volume signal generated by the microprocessor.

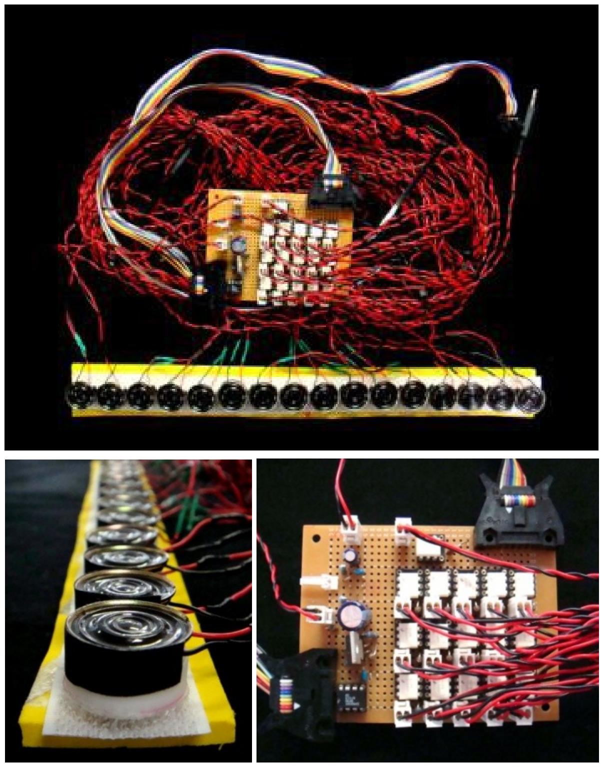

Fig. 4 Auditory part.

3. EXPERIMENT

As a first step to present a realistic feeling of being slashed, we look at the fusion of tactile and auditory sensations on the abdomen from two aspects: position and speed.

3.1. Experiment 1: equivalent position of auditory and tactile sensations

3.1.1. Method

We put the waist-band on the abdomen of a participant. Four tactors were placed inside the waist-band, 5 or 11 cm from the center. Sixteen speakers were placed on the outside of the waist-band. There were no gaps between the speakers.

The equivalent position of audio and tactile sensations (i.e. the speaker position that the participant felt corresponded to the tactile stimulation) was obtained by the method of limit. One tactor was chosen randomly and stimulated for 0.4 s. At the same time, one speaker was chosen and stimulated. The participant was asked to report whether the speaker was positioned to the right or left of the tactor. The speaker position was shifted until matching was reported.

The tactor frequency was 200 Hz. The sound was a typical sound effect used in video games to represent a body being slashed by a sword. Its power spectrum was similar to that of white noise. Four participants, three males, one female, 22–23 years old, participated in the experiment. The subjectively equivalent points were measured 40 times for each participant.

In rare cases, participants reported the tactor position was further to the left than the left-most speaker, or further to the right than the right-most speaker. In these cases, we tentatively regarded that the equivalent points were left-most, or right-most, for numerical processing.

3.1.2. Results

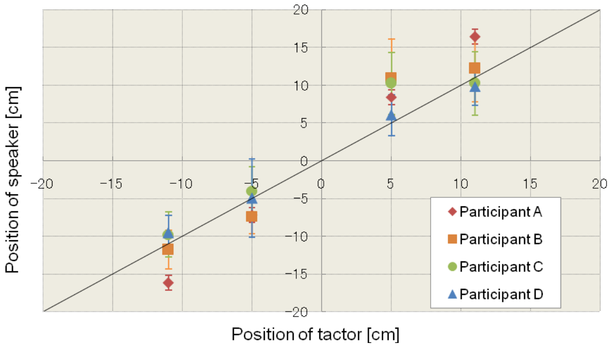

Fig. 5 Subjectively equivalent position. [6]

Fig. 5 shows the subjectively equivalent positions of the two modalities. They matched well. Equivalent positions of the speaker for the tactors 5 and 11 cm from the center were 7.9 and 12.0 cm from the center, respectively.

However, the result for participant A was shifted. Afterward, it was revealed participant A looked straight ahead, while the other participants looked down at their abdomens during the experiment.

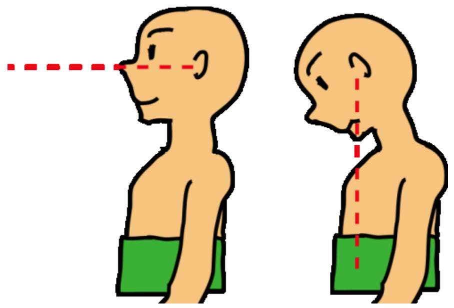

Fig. 6 The direction problem of a head.

As it might suggest that head direction is important for the position sensing, we conducted the experiment once again with the head facing forward.

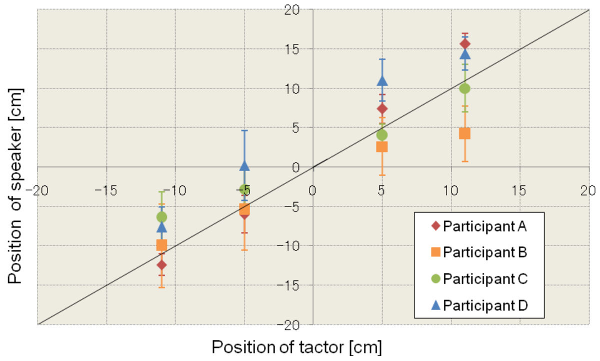

Fig. 7 Subjectively equivalent position (head facing forward).

Fig. 7 shows the subjectively equivalent position of the two modalities with the head facing forward. They also matched well. Equivalent positions of the speaker for the tactors 5 and 11 cm from the center were 4.9 and 10.1 cm from the center, respectively.

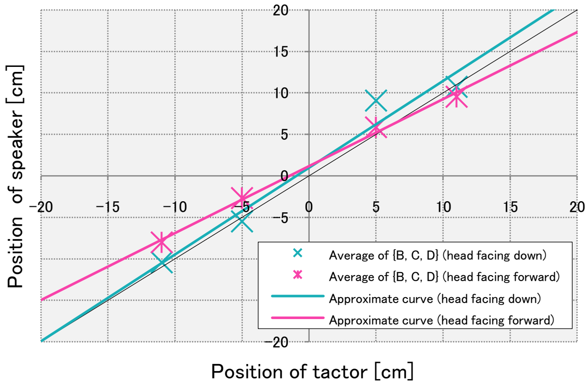

Fig. 8 Approximate curve about average of {B, C, D}.

Fig. 8 shows approximate linear curves about average of participant {B, C, D}. The approximate curve for the head looking at the front is more parted from the approximate curve for the head looking down at the abdomen.

However, there was no great difference in two curves. Therefore, it is clear that the positional fusion of the two modalities does not depend on the head direction so much. It is also clear that the ability to search for the subjectively equivalent position has variety among people; this was shown by the result for participant A again having a shift.

3.2. Experiment 2: equivalent velocity of auditory and tactile sensations

3.2.1. Method

The equivalent velocity of auditory and tactile sensations (i.e. the speaker velocity that the participants felt was identical with the tactile stimulation) was obtained by the method of limit.

Ten standard tactile velocities (+/- 0.62, 0.71, 0.80, 1.23 and 1.60 m/s, where + refers to left to right motion) were chosen. The left-most or right-most tactor and speaker were stimulated simultaneously, then subsequent tactors and speakers were stimulated in series until the other end was reached. The participant was asked to report whether the sound velocity was slower than the tactile velocity. The sound velocity was shifted until matching was reported.

The motion direction (left or right) was chosen randomly. The number of tactors and speakers were the same as in the previous experiment, but the interval of the tactors was changed so that the left-most and the right-most tactors were positioned identically with the left-most and right-most speakers. The same participants as in experiment 1 participated in the experiment. The subjectively equivalent velocities were measured 50 times for each participant. The tactor frequency was 200 Hz.

3.2.2. Results

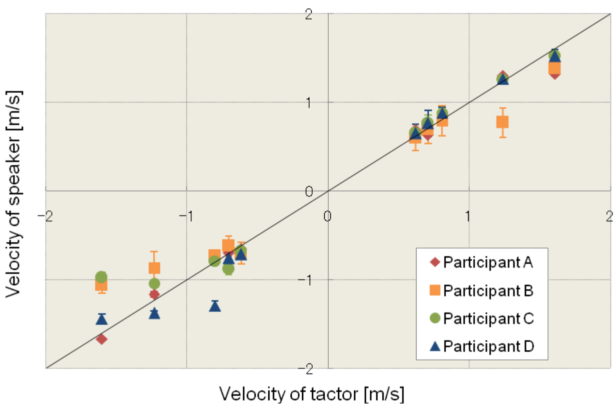

Fig. 9 Subjectively equivalent velocity. [6]

Fig. 9 shows the subjectively equivalent velocity of the two modalities. They matched well. The subjectively equivalent velocity deviated 0.07, 0.2, 0.05, 0.1 and 0.02 m/s from standard average tactile velocities (0.62, 0.71, 0.80, 1.23 and 1.60 m/s)

When the tactile velocity was 0.8 m/s or less, the subjectively equivalent velocity had a high accuracy. However, when the tactile velocity was faster than that, the subjectively equivalent velocity was dispersed among participants.

For each individual, however, the decentralization of subjectively equivalent velocity was little. The cause of the individual variation is not clarified yet.

After the experiment, some participants commented that they might not have actually compared the velocity, but instead answered on the basis of the duration of the stimulation by focusing attention on the timing of the last stimuli. Therefore, we tried to change the start timings of the stimulations so that both tactile and auditory stimuli passed through the central position at the same time. However, in this case, the participants became more aware of the mismatch at the start of the stimulations. We will need to shade the start and end timings by changing the volume, but the current observation tells us that matching the timings of the stimulations may be more important than matching the true velocities for the fusion of tactile and auditory motions.

4. DEEP PERCEPTION

The prototype used in the two experiments produced only a tiny stimulus and the sensation moved only on the surface of the skin.

However, to present the sensation of "being slashed", we should somehow give a sensation inside the body. Here we simply powered up the tactile stimulator by using full range speakers (Aurasound, NSW1-205-8A). The speaker is 25mm in diameter, and its maximum electric power is 20W. The speakers are attached to a waist-band with rings that confine the vibrations within each area.

Fig. 10 Full range speakers and rings.

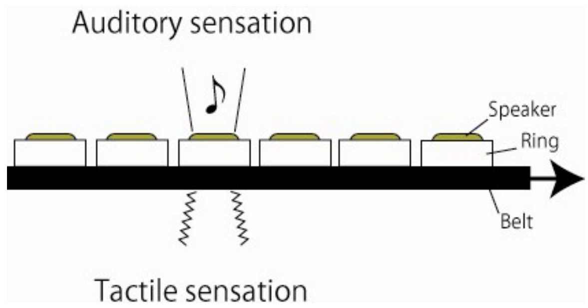

Fig. 11 Mechanism of full range speakers.

As, the full range speakers can produce normal sounds, as well as tactile stimulation, it naturally becomes multimodal interface. As the tactile and auditory sensations come from the same location, the reality of the sensation is enhanced.

As our next step, we are now designing a multimodality interface that present the feeling of being slashed by tactile, auditory and visual means. The user would be equipped with a waist-band with speakers and a head mounted display. When a swordfight is presented by the display, the speakers are sequentially vibrated in tandem with the visual information.

Fig. 12 Application image.

5. CONCLUSION

We proposed the idea of wearable a haptic device that imparts a feeling of being slashed.

First, because we assume the feeling of being slashed is enhanced by the motions of tactile and auditory stimulations on the abdomen, we showed the subjectively equivalent position and velocity matched well. The experiments used sparsely spaced tactors and densely configured speakers. It was found that changing the timings of the stimulations was an effective way of enhancing the feeling of being slashed.

In addition, we presented an improved device that used full range speakers that function as tactors to produce a "deep perception", which is a stimulus into the body. As our next step, we are now designing a multimodality interface conveying three sensations of being slashed, namely vibrations and sounds from speakers and a visual scene presented in a head mounted display.

REFERENCES

[1] C. C. Collins: Tactile television - mechanical and electrical image projection, IEEE Man-Machine Systems, 1970.
[2] Nintendo: Wii, http://www.nintendo.co.jp/wii/index.html
[3] Koga et al.: Virtual Chanbara, Conference Abstract of SIGGRAPH 2002. -http://www.siggraph.org/s2002/conference/etech/virtual.html
[4] T. Izumi, A. Yamamoto, S. Shirogane, T. Tanaka, H. Kuroki, S. Ino and T. Ifukube: Directional Information Interface using Vibro-tactile Sense, Proceedings of the Virtual Reality Society of Japan annual conference 8, 257-260, 2003
[5] Erp: Vibrotactile spatial acuity on the torso: effects of location and timing parameters, WorldHaptics 2005.
[6] S. Ooshima, Y. Hashimoto, H. Ando, J. Watanabe and H. Kajimoto: Simultaneous presentation of tactile and auditory motion on the abdomen to realize the experience of "being cut by a sword", Euro Haptics 2008.