Simultaneous presentation of tactile and auditory motion on the abdomen to realize the experience of "being cut by a sword"

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Abstract. For gaming applications, we propose the idea of a multimodal interface worn on the abdomen to realize the sensation of "being cut by a sword". Tactile and auditory sensations are simultaneously presented on the abdomen by using sparsely located tactors and densely located speakers. We compared the motion of the two modalities and compared tactile apparent movement with auditory motion, focusing on the position and speed. Subjectively equivalent position and velocity of the two modalities matched well.

Keywords: *haptic display, fusion of hapitc and sound, apparent movement, being cut by a sword*

1. Introduction

Many haptic devices have been proposed and used for gaming applications. Commercial videogames commonly use vibration motors placed inside the control pads, and force-controlled joysticks and handles enhance reality.

The easiest haptic representation is to use a stick-type controller with a vibration motor, as we see in Nintendo's Wii [1]. In the research field, haptic "shock" can be presented in many ways. For example, Virtual Chanbara [2] uses a DC motor and a brake and generates an impact by suddenly stopping the motor. There are already some wearable devices for games that impart a shock to the user through vibrators, but the shocks are just unpleasant primitive ones.

However, most haptic devices for gaming have concentrated on sensation to the user's hand. This is inadequate for certain gaming situations. Consider, for instance, the world of "Sword and Magic". In this game, as we engage enemies in sword fights, we are sometimes cut by them. Our aim is to develop a wearable haptic device that imparts a sensation of "being cut". For this purpose, to impart a sensation that the user feels is realistic, we need more than just a primitive shock. Though true realism is not necessary, the sensation of should at least be realistic enough to convince the users they have been cut.

We propose 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 assumed that the sensation of "being cut" is enhanced by their motion. Various methods of presenting tactile icons on the abdomen have been reported [3][4][5], but they do not present tactile and auditory sensations simultaneously.

Our idea is to present tactile and auditory sensations simultaneously on the abdomen by using sparsely spaced tactors and dense speaker configuration. We compare motion of the two modalities, and compare tactile apparent movement with auditory motion, focusing on the position and speed.

2. System

2.1 Haptics part

Four vibrators are put inside a belly-band in a row. As we want to present apparent motion that needs 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).

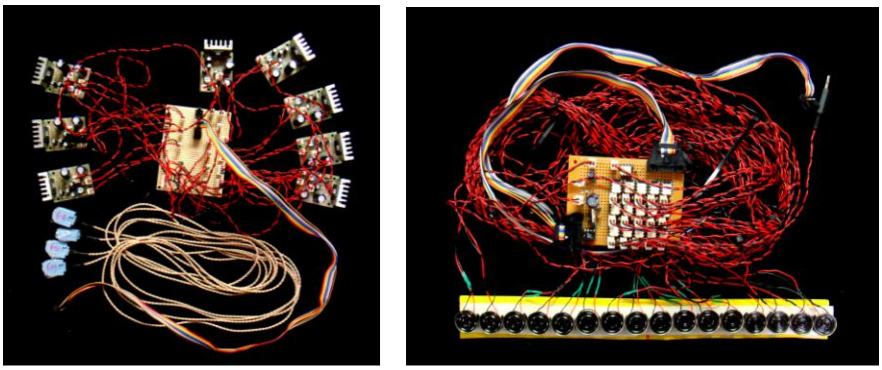

Fig. 1. Haptics part (left) and sound part (right).

2.2 Sound part

Sixteen speakers are put outside the belly-band in a row. The diameter of the speaker is 20 mm. Our future system will be composed of a few tactors and a few speakers, which will be sufficient for producing apparent motion. In our preliminary system, however, we prepared numerous speakers densely allocated for auditory sensation. This is because one of the aims of this work was to psychophysically evaluate the tactile apparent motion with reference to auditory motion.

For such an evaluation, we need a system to switch the active speaker from one to another. 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 DO port.

3. Experiment

As a first step to realize a realistic feeling of "being cut", we focus on the fusion of tactile and auditory sensations on the abdomen from two aspects: position and speed.

3.1 Experiment 1: Equivalent position of audio and tactile sensations

3.1.1 Method

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

The equivalent position of audio and tactile sensation (i.e. the speaker's position that the participants felt identical with the tactile stimulation) was obtained by the method of limit. One tactor was chosen randomly and stimulated for 0.4 s. Simultaneously, one speaker was chosen and stimulated. The participant was asked to report whether the speaker was positioned right or left of the tactor. The speaker's position was shifted until the report changed.

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

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

3.1.2 Results

Fig. 2 shows the subjectively equivalent positions of the two modalities. They matched well. Equivalent positions of the speaker for the tactors with the distance of 5 and 11cm from the center were 7.9 and 12.0 cm.

However, the result for participant A shifted. Afterward, it was revealed that participant A looked straight ahead, while the other participants looked down at their belly during the experiment. Therefore, there is a big possibility that positional fusion of the two modalities is affected by the head direction, although we cannot confirm this at present.

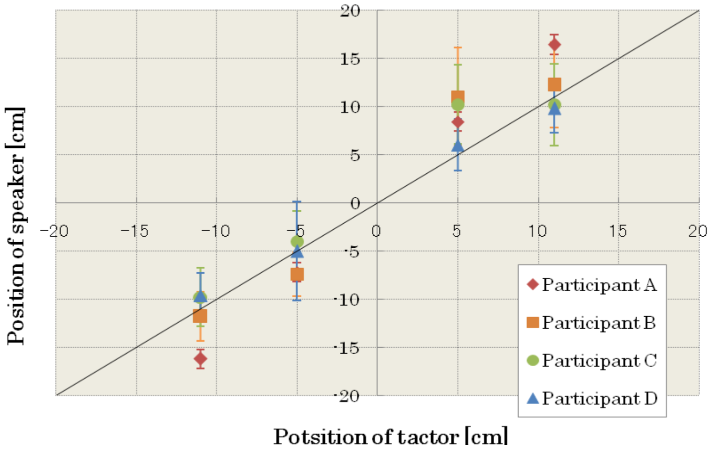

Fig. 2. Subjectively equivalent position.

3.2 Experiment 2: Equivalent velocity of audio and tactile sensations

3.2.1 Method

The equivalent velocity of audio and tactile sensations (i.e. the speaker's velocity that the participants felt 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, + means left to right) were chosen. The left-most or right-most tactor and speaker were stimulated simultaneously, then subsequent tactors and speakers were stimulated in series until we reached the other end. The participant was asked to report whether the sound velocity was slower than the tactile velocity. The sound velocity was shifted until the report changed.

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 the 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. 3 shows subjectively equivalent velocity of the two modalities. They matched well. Subjectively equivalent velocity deviated 0.07, 0.2, 0.05, 0.1 and 0.02m/s from standard average tactile velocities (0.62, 0.71, 0.80, 1.23 and 1.60m/s)

After the experiment, some participants commented that they might not hav actually compared the velocity, but instead answered on the basis of the duration of the stimulation by focusing attention to the timing of the last stimuli. Therefore, we tried to change the start timing 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 of the start timing. We will need to shade the start and end timing by changing the volume in a future experiment, but the current observation tells us that matching the timing of stimulation may be more important than matching true velocities for the fusion of tactile and auditory motion.

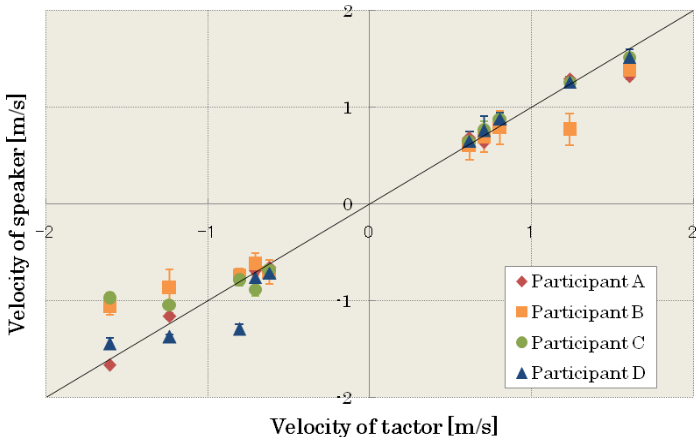

Fig. 3. Subjectively equivalent velocity.

4. Conclusion

We proposed the idea of wearable haptic device that imparts a sensation of "being cut". We especially focused on the fusion of tactile and auditory sensations when they move because we assume that sensation of "being cut" is enhanced by their motion. Two sensations were simultaneously presented on the abdomen by using sparsely spaced tactors and densely configured speakers. We compared the motion of the two modalities and compared the apparent tactile movement with auditory motion, focusing on the position and speed. In the near future, we will examine the effect of head direction and compare the results and develop a wearable device that actually gives a sensation of "being cut".

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