Projection-based Vibrotactile: Vibration Unit for Recognition of Shape Image Projection onto Whole Body

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***Abstract*— Contents using users' whole-body motion is now becoming popular, along with the spread of the low-cost whole-body motion capture systems. To present tactile signals to the whole body, latency of the system becomes a critical issue because it leads to spatial gap between the desired position and actual stimulation position, and also leads to spatially unsharped sensation. To reduce latency, we have proposed to use a linear resonant actuator as a high response vibrator, and use projection light to be a input signal for vibrator control so as to eliminate latency derived from PC-sensor communication. To evaluate our idea, we had developed a vibration unit and conducted the experiment of shapes recognition. The result showed that high-response vibrator and larger number of vibrators are both effective for achieving quick recognition.**

I. Introduction

With the spread of whole-body capture devices for game machines in a home, using users' whole-body motion as a form of input control is becoming popular. To make user keep eyes on his/her own motion, Cassinelli et al. [1] proposed an interactive content SkinGames, in which the visual information of the game is not showed in HMD (Head Mounted Display) or LCD but projected to the users' body so that user can see image projection and his/her body's actions controlling the game. This approach is considered to be effective to enhance the immersive of the experience. However, visual is unable to provide experience of touching sensation to user. In this paper we will introduce a vibration unit that we are developing for user to sense as if his/her whole body getting contact with shapes of image projection (Fig. 1).

Vibrotactile is also being studied and it has been founded to be able to improve the quality of movie or music experience [2][3][4][5][6]. Sato et al. [7] proposed an entertainment called Ants in Pants which presents insects crawl experience on the arm of the user. The vibration vest for an interactive game was developed to present the information of tactile sensation onto the whole-body [8]. However, current methods of using vibrator are not sufficient to present tactile sensation onto the whole-body that is moving because of the latency of vibrators. Latency of vibrators is critical issue that has to be solve because it will provide incorrect information of shape image to user.

Latency may occur due to the efficiency of vibrator itself or vibrators controlling design. To get low latency for our vibration unit, we use high-response voice coil actuator and light sensor to be as its ON/OFF vibration switch. In addition, we do not control numerous of vibrators mounted on whole body of user with a computer but we made each vibration unit be able to vibrate only depending on its own light sensor information. The light sensor detects the light of image projection and transform the information to tactile by the vibrator. With this method, the latency caused by line communication between vibrator and vibrator or computer will not occur. Moreover, using light from projector as the input of vibration unit provide not only high speed response but also the advantage of large range projection [9].

A method of using the light to control units that called Display-based Computing (DBC) are proposed Sugimoto et al.[10]. The method we proposed can be said apply the DBC to whole body vibration system for user action [11].

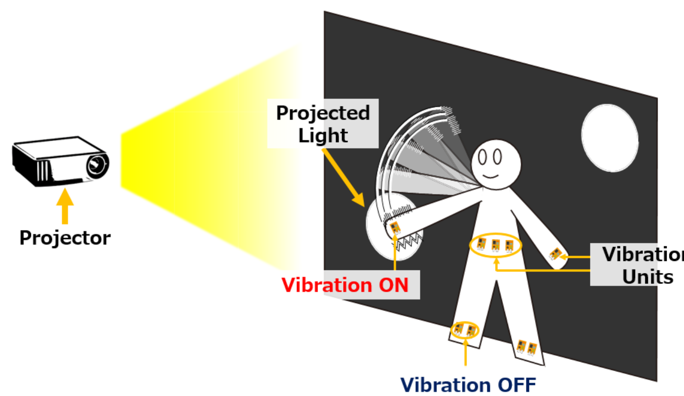

Fig. 1 Overview of the system (whole-body of user attached by vibration units)

This paper shows the result of our preliminary experiment for evaluation the efficiency of our vibration unit mounted in a hand. We compared the unit using linear resonant actuator (LRA) to the one using eccentric rotating mass (ERM). We also examined the effectiveness of the number of vibration units. We found that, the unit is possible for user to recognize simple shapes projected from projector.

II. Vibration unit

Figure 2 shows the vibration unit we developed. It composed of a linear resonant actuator (LRA), a lithium ion polymer battery, a phototransistor and an oscillation circuit for controlling the LRA.

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LRA was selected due to its fast response and small size. Its response time is about 20ms. It is very shorter than ERM (170ms) which is often used in the conventional method of tactile stimulation.

The resonance frequency of oscillation circuit for LRA control is constantly 150Hz. The switch ON/OFF of vibrator of the unit is controlled by the amount of projector light that reaches on the phototransistor. The capacity of lithium ion polymer battery is 40mAh and it can last about 20 minutes for continuous operation. By mounting large number of vibration units on a whole-body, user can feel tactile stimulation of various large images with different brightness from the projector.

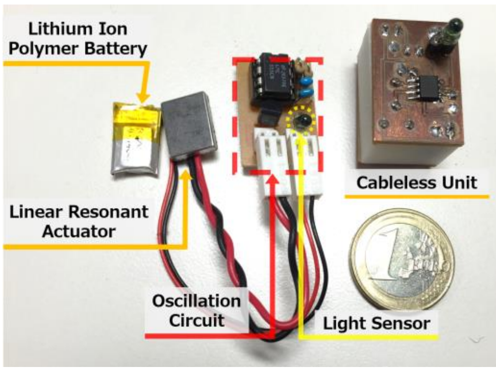

Fig. 2 Overview of the vibration unit

III. Experience

To evaluate the efficiency of our vibration unit, we did an experiment that comparing the vibration unit using the LRA to the one using the ERM which is used in the conventional methods. Furthermore we evaluated the effect of increasing number of the unit and accuracy of shape discrimination by the vibration units.

A. Procedure

Each subject was asked to wear vibration unit on the right hand, stand in front of the screen and closed the eyes (Fig.3). Subjects were able to move the hand freely but not to move the foot out of the fixed position. During presenting tactile sensation from the projector, subjects were asked to answer the shapes.

Conditions of the vibrator were three kinds, one ERM unit, one LRA unit and nine LRA unit (the units were arranged as 3x3 array). Projection images were four kinds as shown in Figure 4, "square", "circle", "triangle" and "cross". Each shape was randomly presented five times in one condition, so it was 60 trials in total for each subject. Six subjects (all male, age range from 21 to 24 years) participated this experiment.

Fig. 3 Condition of an experiment

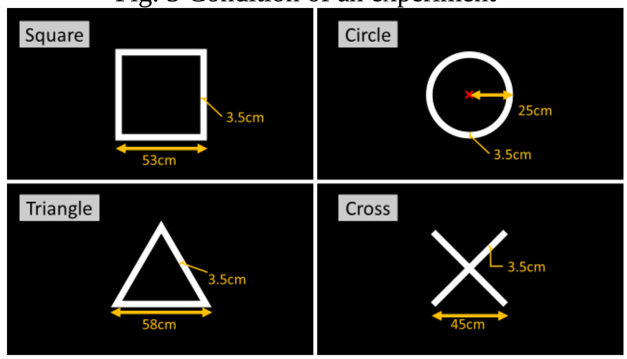

Fig. 4 Projected shapes

B. Result

Figure 5 shows the average comparison of time response for each vibrator condition. Figure 6 shows the average comparison of correct answers for each shape.

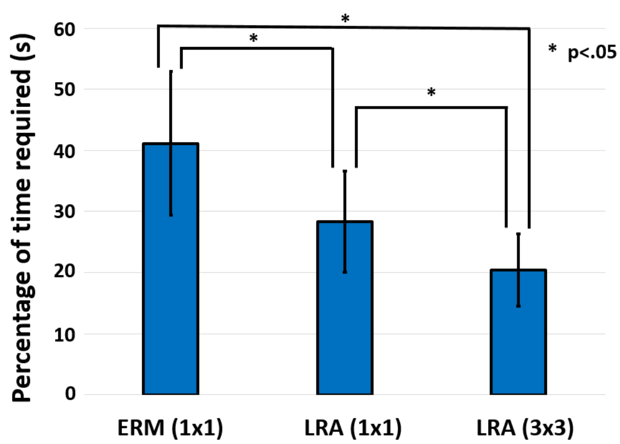

Fig. 5 Average of response time for each vibrator condition

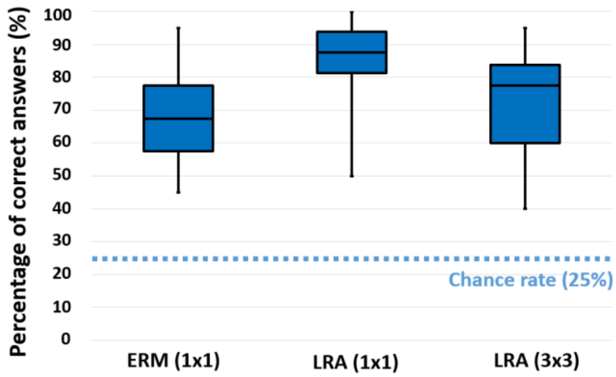

Fig. 6 Average of correct answers for each presented shape

Required time to recognize the shapes is short in order of ERM unit, one LRA unit and nine LRA unit. Furthermore there are significant different between each method ($p<.05$). From the results, the ERM took longer time to discriminate than the LRA. This is considered that the ERM cannot provide the correct shape due to the latency occurring during fast movement of the hand. Thus the ERM is not suitable for tactile shape recognition during user moving. In contrast, using LRA, user were able to recognize the shapes better and the required time for recognition became short when the number of unit was increased. This is probably because the simultaneous search range expanded by the number of the vibrator.

On the other hand, the difference of correct answer rate between each projected shape was not observed. The result showed that our vibration unit has potential for user to recognize tactile shape projected by the projector by moving his/her hand. It also can be used to provide the experience of shape touching with the whole body.

IV. Conclusion

In this paper, we proposed the method to project tactile shape onto the whole body and user is able to recognize the shape with his/her movement. Furthermore we developed a low latency vibration unit using LRA and light sensor. The experiment showed that the required time for recognition the shape became short and the accuracy became high when using and increasing the number of LRA vibration unit.

Currently we evaluated vibration unit only on the palm. Our future work we will expand the equip range of vibration units such as the belly, and develop the interactive content using units controlled by user motion.

Acknowledgement

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