
Velvety Massage Interface (VMI): Tactile Massage System Applied Velvet Hand Illusion

Yuya Kiuchi

Graduate School of Design,
Kyushu University
4-9-1, Shiobaru, Minami-ku,
Fukuoka, Japan
2ds12084t@s.kyushu-u.ac.jp

Ryoko Ueoka

Graduate School of Design,
Kyushu University
4-9-1, Shiobaru, Minami-ku,
Fukuoka, Japan
r-ueoka@design.kyushu-u.ac.jp

Abstract

Velvet Hand Illusion (VHI) is a tactile illusion that generates sensation of soft and smooth feelings. We propose to apply this illusion to develop the novel interface called Velvety Massage Interface (VMI). This system gives realistic sensation of being massaged on surface of sole of foot like reflexology. We conducted an experiment to verify if the VHI is generated to the sole of foot and if the VHI has an effect on the body in order to make a prototype device. It was observed that the device was able to generate VHI automatically and had some reflexology effect. It suggests the possibility that VHI is applied to tactile displays, which generate smooth feeling of massage.

Author Keywords

Velvet Hand Illusion; tactile massage system;
Reflexology

ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces - Haptic I/O, Prototyping.

General Terms

Design; Experimentation; Human Factors.



**Figure 1: Velvet Hand Illusion
(wire mesh type)**

Introduction

The phenomenon called tactile illusion such as Velvet Hand Illusion [3, 4, 7, 8, 9, 11], Comb Illusion [5], and Rubber Hand Illusion [1] is known to cause pseudo tactile sensation to us rather than gives solid tactile feedback. In this research, authors especially focus attention on Velvet Hand Illusion (VHI), which is generated by wire mesh as shown in Figure 1. Rubbing hands across wire mesh generates the sensation of soft and smooth feelings [8] known as VHI. Most of people who experienced VHI comment that they felt very comfortable. In order to take advantage of this soft and smooth tactile feedback on surface of the skin, we propose to apply this illusion developing a novel interface called Velvety Massage Interface (VMI). We expect that the VMI could be especially applied for desk workers to give realistic sensation of being massaged on surface of sole of foot. Since the long-time work disturbs concentration, it will be effective to be massaged. However, as hands are always doing many tasks such as PC works, frequent massage to hands is difficult. Thus the device which stimulates foot is practical to give massage.

As a first step to develop VMI, we conducted a prototype experiment to verify if the VHI is generated to the sole of foot. This device gives us VHI feeling automatically by putting our foot on the device. From our previous research, force of repulsion from the device against one's skin is related to the generation of VHI. Thus as a first step to make a prototype, we performed an experiment by controlling the repulsion using water bag and verified if the VHI has a massage effect on the body.

Related works

There are a number of researches which discuss VHI mechanism from the perspective of brain science. VHI is caused by brain activity called filling-in [8], and SAI plays a role in the mechanism of VHI [3, 9, 11]. And there are researches about the wire condition discussing VHI being caused not only by a wire mesh but also by parallel wires [4, 8]. These previous researches are scientifically important to endorse the illusion that is generated physically with a certain condition. However, these focus on theory construction and do not intend to apply the phenomena to practical device. The purpose of this research is different from the related works and thus the challenge to apply VHI to different parts of the body, except for hand, was not conducted before. Our research intends to apply the phenomena to practical use for proposing Velvet Massage Interface.

Regarding to the works of massage interface, several new methods are proposed: Touch Sensitive Apparel [15] allows massage to be customized and controlled by people while on the move. This proposes a novel interface to sooth a user anytime by applying massaging function to wearable device. Massage me [13] is a wearable interface that turns a video game player's motion into a back massage for a bystander. This work realizes a novel interface to transform gaming behavior into practical use, which establishes win-win relationships between a game player and a massaged person. Our proposed interface is very different from these related works from the point of using tactile illusion as well as massaging stimulus. The related works propose function to give stimulus of pressure, which triggers a point massage. These massages give a pain on the point, whereas our

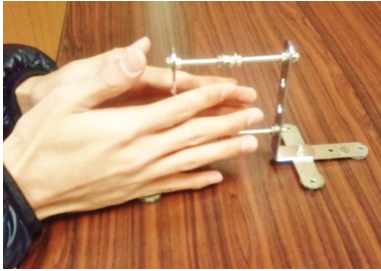


Figure 2: Evaluation of VHI in manual

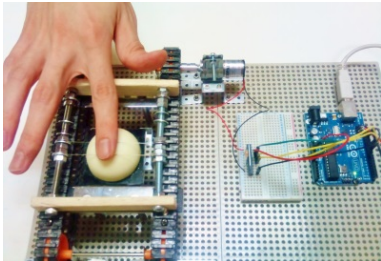


Figure 3: VHI generation device for fingertip

proposed interface has a goal to give spatial stimulus of being massaged on the surface of skin. This kind of massage is called reflexology. As reflexology is known to improve fatigue [6], many companies have reflexology room in England, and this has effect on decrease in absence, improvement of the productivity, enthusiasm for work [10]. It is also known that softly routine stimulus is important rather than stimulus with pain at short times for reflexology because of the link between sole of foot and body [6]. The spatial stimulus of a part of sole has influence on a part of body corresponding to there, and the influence improves the function of the body. Thus, the routinely spatial stimulus without pain is suitable for reflexology, and we propose to apply VHI feeling to reflexology. The smooth feeling of VHI is able to encourage natural massage.

Several interface give tactile stimulus on foot [12]. Touch Is Everywhere [16] discussed that haptic communication via floor surfaces enhance many computer-supported activities that involve movement on foot. Haptic Walker [14] was developed for major application in gait rehabilitation. VMI is different from these interfaces in terms of focusing on feel of touch. As our foot approximately always contact with ground, it is necessary to verify if VHI feeling have an effect on sole of foot.

Previous research

Our previous research developed the range of VHI study by verifying the conditions to generate VHI of fingertip which is the most sensitive part of body. We tested and clarified parameters of generating VHI sensation both manually and automatically as shown in Figure 2 and 3. In manual case, we found the best conditions shown in Figure 4 to generate VHI feeling by

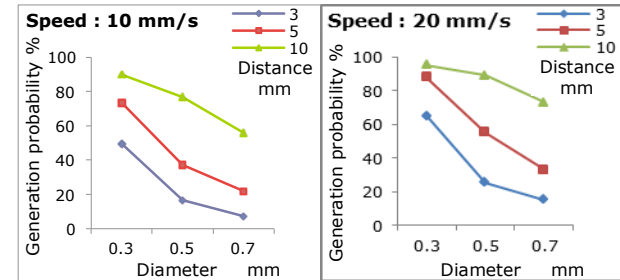


Figure 4: VHI probability on fingertips

controlling 3 factors; a diameter of a wire, distance of adjacent wires, and a speed of hand motion. For testing the automatic case, we made a motorized device automatically receiving VHI to one's fingertip. VHI feeling was generated by the device with silicone object. Then in order to develop practical VHI device, we applied this illusion to massage, especially reflexology on foot.

Preliminary test of VMI on foot

We made a device to give VHI on foot, and conducted an experiment to verify if VHI is generated to the sole of foot with the device. First, we made a wire equipment with parallel nylon wires and a frame made from stainless steel to stimulate the surface of skin. Our previous research showed that the best conditions of 3 factors (a diameter of a wire, distance of adjacent wires, and a speed of hand motion) to generate VHI feeling are in proportion to two-point discrimination threshold¹ of the part of body. Two-point discrimination threshold of the thenar of foot is as same as that of the palm, which is 10 mm. Thus, we applied the conditions

¹ The shortest distance to discern that two nearby objects touching the skin are truly two distinct points, not one

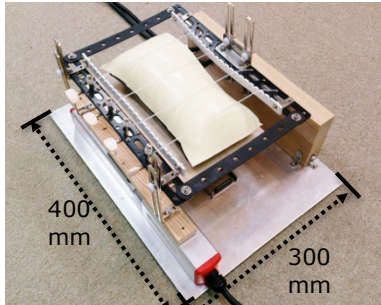


Figure 5: VHI generation device for foot

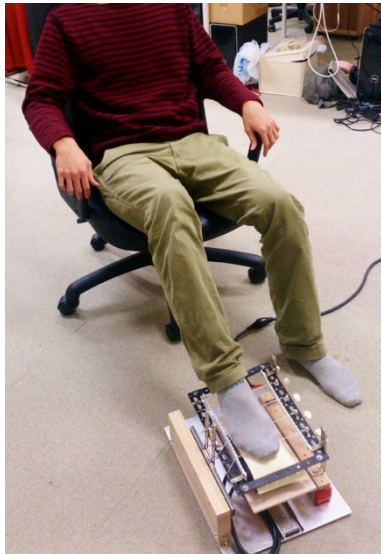


Figure 6: Experiment of VHI on foot

of the palm (1.5 mm of wire diameter, 5.0 mm of wire distance, 100 mm/s of speed [4]) to the foot. From a preliminary trial of VHI on foot, it was found that this palm's condition generated VHI to the sole of foot. Then we developed a VHI generation device for foot as shown in Figure 5.

We used a linear actuator (ES4, THK) and a driver controller (TSC, THK) to move the wire equipment with straight-line motion. From this, we are able to feel VHI by putting one foot on the device. We also prepared a silicone sheet (5 mm of thick) and a rubber water bag (120 mm of width and 230 mm of depth) to fit to the sole of foot. Owing to the relation between the force of repulsion and generation of VHI, we controlled the quantity of water in rubber bag to change force of repulsion against foot. The repulsion reaches the foot equally by using water known as Pascal's principle. Then, we covered the rubber bag with a silicone sheet to feel like human skin.

Procedure

8 subjects (5 male, 3 female, mean age 22.8) participated the experiment. Before the experiment, each subject rubbed the wire equipment by hands to learn the VHI feeling. Then, as shown in Figure 6, we asked them sit down a chair in a comfortable position and to put their foot with socks on the device. All subject's dominant foot were right. We also asked them to wear an eye mask to make them focus on generated sensation on sole of foot. The device reciprocated at 1Hz of speed and generated repeated stimulus on their foot. They tested 3 conditions of quantity of water (100cl, 70cl, 40cl), and did 10 trials in each condition. After 30 seconds of each trial, we asked if it felt the VHI feeling.

Results

Generation probability of VHI feeling on the sole of foot was shown in Figure 7.

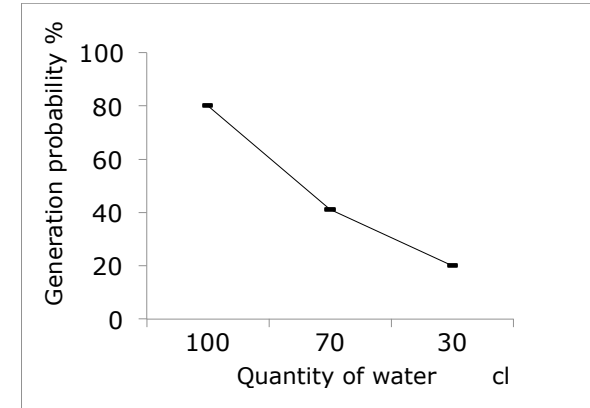


Figure 7: Mean VHI probability on foot by device

Significant difference was observed in quantity of water by one way analysis of variance ($F=44.10$, $p<0.01$). We also found that 100 cl of quantity of water was the best condition to generate VHI feeling. It is caused that the volume of protruding silicone between adjacent wires increases force of repulsion against foot, and VHI feeling became stronger. All subjects replied that they felt strong VHI feeling with foot rather than with palm. As for VHI with palm, their consciousness focuses on touching the experimental device. However we rarely touch the object with a foot consciously, so they did not care for the device and it may improve perceptual action. They also said that the strength of VHI feeling was changed by foot force. It must be caused by centralizing the weight to the foot. Thus it is necessary to verify the relation between a subject's weight on the device and the generation probability of VHI.

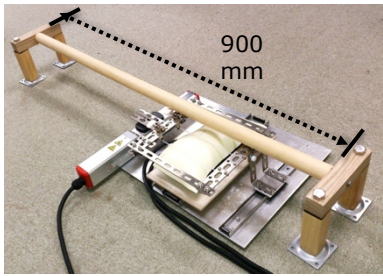


Figure 8: VHI generation device for heel

Reflexology effect by VHI

We also evaluated about the reflexology effect by VHI. In preliminary test of VMI, most subjects replied that VHI feeling of a heel is stronger than a tiptoe's. The stimulus of a part of heel has influence on buttocks. And the skin temperature rises if massage has an effect on the part of body. Thus, we improved VHI generation device to give stimulus to the heel as shown in figure 8, and verified the reflexology effect with skin temperature of buttocks. 4 male subjects (mean age 23.25) participated the experiment. Before the experiment we measured skin temperature of buttocks with a thermography. We asked them to sit down a chair in a comfortable position and to put their feet on the stand and device. Then the device repeated VHI stimulus on their heel. After 20 minutes of trial, we also measured skin temperature of buttocks. The quantity of water was 100 cl, which was the best condition of VHI.

Figure 9 shows one of the cases of temperature distributions of buttocks before and after the experiment.

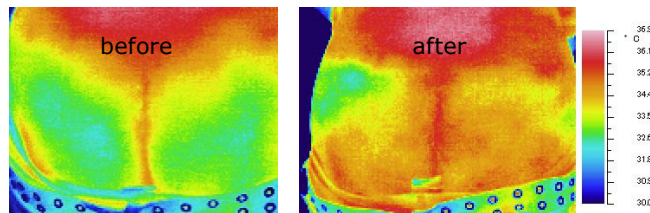


Figure 9: Temperature distributions of buttocks

There were no significant differences between the temperatures before and after the experiment. However mean temperatures of after the experiment were higher than before. This may conclude reflexology

effect is expected more by the improvement of the device.

Conclusion and Future works

In this paper, we made a VHI generation device to foot and verified the conditions to generate VHI of sole of foot in order to propose a massage system applied VHI. As our device was able to generate VHI automatically on sole of foot, this suggests the possibility that VHI is applied to tactile displays, which generate smooth feeling for massage such a reflexology. However, it was observed ambiguous result that some subjects became to feel less VHI by repeating trials during experiment and others became to feel strong VHI by repeating trials. As subjects say, it is assumed that feeling of VHI is influenced by changing subject's weight against the device for long duration of the experiment. Thus we are going to conduct an experiment to weigh a foot force during each trial. It is also necessary to verify if controlling quantity of water or temperature of water could influence feeling of VHI.

We also verified the reflexology effect on buttocks by stimulating a heel. It was observed that VMI might have an effect. However, the device was still imperfect and had subject restrict their foot motion. We will need to improve the device to realize reflexology with velvety massage interface.

As a future work, we hope VMI to become an interactive system connected to plural devices in order to communicate with friends, family, and colleagues by touch of sense like inTouch [2]. Massaging each other with VHI feeling may influence the relationship of them. We hope this system will give massage and relationship to the people.

References

- [1] Botvinick, M., and Cohen, J. Rubber hands 'feel' touch that eyes see. *Nature* 391 (1998), 756.
- [2] Brave, S., Dahley, A. inTouch: a medium for haptic interpersonal communication. In *proc. CHI 1997*, ACM Press (1997), 363-364.
- [3] Chami, A., Ohka, M., Kawabe, Y., and Yussof, H. B. Response of SAI afferents may play a role in the perception of velvet hand illusion. *Journal of Computer Science* 6, 8 (2010), 934-939.
- [4] Doi, K., Sutoh, T., Fujimoto, H. Empirical study for velvet tactile illusion emerged by passive touch. *Biomechanisms* 20 (2010), 125-134.
- [5] Hayward, V. A brief taxonomy of tactile illusions and demonstration that can be done in a hardware store. *Brain Res. Bull*, 75 (2008), 742-752.
- [6] Machi, Y., Liu, C., and Fujita, M. Physiological measurements for reflexology foot massage. *ISLIS* 3, 2 (2000). 502-510.
- [7] Miyaoka, T. Measurements of velvet hand illusion by magnitude estimation and paired comparison. In *Proc. ISP 2012*, 268-273.
- [8] Mochiyama, H., Sano, A., Takesue ,N., Kikuue ,R., Fujita, K., Fukuda, S., Marui, K., and Fujimoto, H. Haptic Illusion Induced by Moving Line Stimulus. In *Proc. WHC 2005*, 645-648.
- [9] Nader, R., Kawabe, Y., Ohka, M., Miyaoka, T. Investigation of conditions generating velvet hand illusion toward tactile displays. In *Proc. MHS 2011*, 523-528.
- [10] Nissei Seitai. http://www.seitaijp.org/seit_ryo/sei_refrex.html.
- [11] Ohka, M., Kawabe, Y., Chami, A., Nader, R., Yussof, H. B., and Miyaoka, T. Investigation on velvet hand illusion using psychophysics and FEM analysis. *S2IS* 3, 3 (2010), 488-503.
- [12] Nordahl, R., Berrezag, A., Dimitrov, S., Turchet, L., Hayward, V., Serafin, S. Preliminary Experiment Combining Virtual Reality Haptic Shoes and Audio Synthesis, *Haptics: Generating and Perceiving Tangible Sensations Lecture Notes in Computer Science* 6192, (2010), 123-129.
- [13] Satomi, M., Perner-Wilson, H., Massage me. <http://www.massage-me.at/>
- [14] Schmidt, H., Hesse, S., Bernhardt, R., Kruger, J. Hapticwalker: a novel haptic foot device. In *proc. TAP*, ACM Press 2, 2 (2005), 166-180.
- [15] Vaucelle, C., Abbas, Y. Touch: sensitive apparel. In *Proc. CHI 2007*, ACM Press (2007), 2723-2728.
- [16] Visell, Y., Law, A., Cooperstock, J.R. Touch is everywhere: Floor surfaces as ambient haptic interfaces. *IEEE Transactions on Haptics* 2 (2009), 148-159.