International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2014)
T. Nojima, D. Reiners, and O. Staadt (Editors)

The Effect of Visually-Induced Pseudo-Haptic on Softness

Shin-ichirou Yabe, Takashi Kimura, Hiroaki Kishino and Takuya Nojima

Graduate School of Information Systems, University of Electro-Communications, Japan

Abstract

The visually-induced pseudo-haptic is a type of haptic illusion induced by a visual stimulus. This phenomenon is considered to be helpful in formation of a haptic (force) display without using actuators. It is believed that this will contribute to the future popularization of such displays. However, most methods used to induce this phenomenon use a desktop size monitor and a mouse, which is a relatively large setup. In contrast, our previous work in the effects of pseudo-haptic on softness showed that a sensor-integrated smartphone is capable of inducing this phenomenon without using a mouse. In this paper, we will describe the smartphone-based system in detail, along with the results of experiments that we conducted to evaluate the effects of this phenomenon.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O

1. Introduction

Considerable research has been undertaken in the pseudo-haptic feedback field. In most of this research, a visual display is placed in front of a subject while his/her hand is resting on a desk [Lec09]. This setup easily induces sensory conflicts for pseudo-haptic feedback. However, as current smartphones and similar devices have demonstrated, the distance between the display and the hand is shorter than the distance to the desktop; the hand and the display are therefore in sight at the same time, and this was considered to be a disadvantage for pseudo-haptic. We proposed a new pseudo-haptic method where the hand and the display are in sight at the same time [KN12]. In this paper, we will describe the smartphone-based system in detail, along with the results of experiments that we conducted to evaluate the effects of this phenomenon.

2. Related Works

Lecuyer et al. conducted experiments to investigate hardness and softness under pseudo-haptic feedback [LCKRC00]. In their research, the subjects were asked to push against a piston mounted on an experimental input device. This piston was connected to a ball-like object that was also fixed to the device. A virtual ball displayed on a monitor changed its shape relative to the applied force between piston and ball. By using this device, the researchers were able to generate pseudo-haptic feedback in response to hard or soft pushing on the virtual ball. In addition, the sense of softness changed based on the ratio between the input force and the level of deformation. However, the subjects had to fix their eyes on the monitor rather than on their hands when handling the physical input device.

Kokubun et al. proposed a pseudo-haptic of stiffness with a mobile device [KBNTH13]. Their system involved placing a force sensor between two identical mobile devices. The subjects in this study pushed the back body of the system with a finger, and the visual image on the display was warped relative to the applied pushing power. However, the subjects could not see their own fingers on the mobile devices.

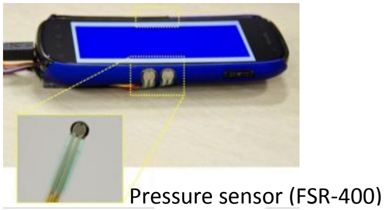

Figure 1: *Prototype pseudo-haptic feedback device.*

3. Prototype Device

In this section, we describe the prototype device used in our study of illusions of softness induced by pseudo-haptic feedback. As shown in Figure 1, the prototype device consists of a conventional smartphone (Samsung Electronics Co., Ltd., Nexus S) and film-type force sensors. Two sensors (Interlink Electronics Inc., FSR-400) are mounted on each side of the screen. These sensors are used to measure the forces when the subjects hold the screen in their hand. The measurement results are transmitted to a microcomputer (Arduino RT-ADK) and are used to generate a visual image. As shown in Figure 2, a blue rectangle is generated and displayed on the screen. The resolution of the displayed areas on the screen is 800×480 pixels. The width of the rectangle changes relative to the measured squeezing

DOI: 10.2312/ve.20141368

forces. The deformation rate is determined using equation (1). In the equation, k is the spring constant, w_i is the initial width of the rectangle, w_a is the width of the rectangle when squeezed, and f denotes the applied force.

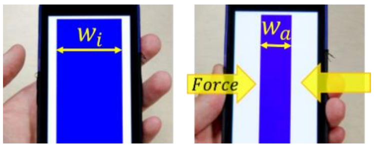

Figure 2: *Difference in the width of the visual stimulus (Left: not squeezing; Right: squeezing).*

$$w_a = w_i - \frac{f}{k} \quad (1)$$

4. Experiment

In this section, we describe our experiments to evaluate the effects of pseudo-haptic on softness in detail. In this experiment, participants are asked to squeeze the developed smartphone-based system, which has a specific k value. Then, the participants are asked to squeeze real spring-based comparison objects with different spring constants (Figure 3). Finally, the participants are asked to determine the comparison object with the softness that is closest to the feeling that the participant experienced when squeezing the prototype device. The sizes of the comparison objects were the same as that of the smartphone that we used in this experiment (width: 65 mm; height: 120 mm). We prepared four comparison objects. The spring constants of these objects were as follows: 0.471 (CO_d), 0.853 (CO_s), 1.197 (CO_m), and 1.521 (CO_h) [N/mm]. "CO_{**}" denotes "Comparison Object Dummy/Soft/Medium/Hard". In addition, we designed three visual stimuli with different k values. These visual stimuli were named Hard, Medium and Soft according to the size of their k values. Table 1 shows the relationship between the k values and the actual comparison objects. The CO_d was assumed to be a dummy object, for which the softness does not match any of the visual stimuli. The number of participants was three. They were all in their early twenties, male and right-handed.

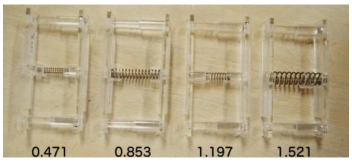

Figure 3: *Comparison objects with different spring constants.*

Table 1: *Visual stimuli and spring constants of the related comparison objects.*

Visual stimulus	Spring constant of comparison object [N/mm]
Hard	CO_h 1.521
Medium	CO_m 1.197
Soft	CO_s 0.853
	CO_d 0.471

5. Results

The results of the experiment are shown in Figure 4. The vertical axis shows the counts for the number of answers where a specific comparison object is selected. The lower horizontal axis shows the names of the comparison objects. The upper horizontal axis indicates the visual stimulus that is shown to the participants. The softness of the smartphone itself never changes. Therefore, if there is no pseudo-haptic effect, then all participants would always select CO_h, regardless of the experimental conditions. However, as shown by the results, all participants seemed to be affected by the visual stimuli. The oblique lines are used to indicate a match between the computer graphic (CG) spring constant and that of the object. On the other hand, if all participants selected Hard / Medium / Soft comparison object when they see Hard / Medium / Soft visual stimuli, that means this method has great pseudo-haptic effect. However, subject C selected Object (Hard) for CG (Medium), and subject B selected Object (Medium) for CG (Soft). In contrast, all subjects selected Object (Hard) for CG (Hard). It is believed that one of the reasons for this is that the prototype device has a plastic case, and the subjects feel that the case is harder than the CG spring rate. Therefore, there is a possibility that the pseudo-haptic phenomenon has a connection with the material.

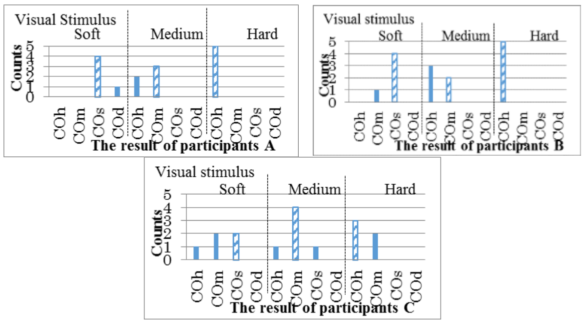

Figure 4: *Experimental results.*

6. Conclusions and future work

In this paper, we describe a novel method that can be used to induce pseudo-haptic effects on softness. In addition, we confirmed the effect of this phenomenon through preliminary experiments. This method will contribute to the development of a novel haptic (force) interface that does not require any actuators. In our future work, we will conduct further investigations of this phenomenon, including the effect of the appearance of the visual stimulus and the effect of the materials used for the comparison objects.

Acknowledgement

This research has been supported by the Kayamori Foundation of Informational Science Advancement.

References

[HKST11] Hirano, Y., Kimura, A., Shibata, F. and Tamura, H. Psychophysical influence of mixed-reality visual stimulation on sense of hardness, proceedings of IEEE VR, (2011), 51-54.

[KN12] Kimura, T. and Nojima, T. Pseudo-haptic Feedback on Softness Induced by Grasping Motion, proceedings of EuroHaptics, vol.2, (2012), 202-205.

[KBNTH13] Kokubun, A., Ban, Y., Narumi, T., Tanikawa, T. and Hirose, M. ARAtouch: Visuo-haptic Interaction with Mobile Rear Touch Interface, proceedings of ACM SIGGRAPH Asia 2013, (2013), 19-22.

[Lec09] Lecuyer, A., Simulating Haptic Feedback Using Vision: A Survey of Research and Applications of Pseudo-Haptic Feedback, PRESENCE, Vol.18, No.1,(2009), 39-53.

[LCKRC00] Lecuyer, A., Coquillart, S., Kheddar, A., Richard, P. Coiffet, P. Pseudo-Haptic Feed-back: Can Isometric Input Devices Simulate Force Feedback?, Procs of IEEE VR, (2000), 83-90.