Pseudo-haptic Feedback on Softness Induced by Grasping Motion

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Abstract. In most of the research on pseudo-haptic feedback, subjects' hands are on the desk and the visual image is provided from a monitor placed in front of them. The setup easily induces sensory conflicts for pseudo-haptic feedback between visual and haptic perception. However, subjects rarely see simultaneously their hand in motion and in a visual display. We report here our preliminary study on pseudo-haptic feedback related to tactile perception of softness. In the study, subjects hold a hand-held display with pressure sensors. A virtual object shown on the display screen changes shape according to pressures from the subject's squeezing of the device. In this configuration, subjects are able to see their hand and the visual display at same time. We also describe the preliminary experimental results confirming the feasibility of our system and its applicability in investigating haptic pseudo-haptic.

Keywords: Pseudo-haptic feedback, softness, hand squeeze.

1 Introduction

Much research has been undertaken in the field of pseudo-haptic feedback. In most of this research, a visual display is placed in front of a subject while his/her hand is on a desk. This setup easily induces sensory conflicts for pseudo-haptic feedback. However, as current smartphones and similar devices show, displays have become small and light enough to be hold in the hand. Moreover, to equip these devices with multiple sensors as well as to interact with these sensors, such as touch sensors, has become easier. Such displays should have potential in pseudo-haptic technology.

Squeezing an object is one way to gauge its malleability, *i.e.* hardness-softness. In this situation, humans perceive softness by comparing the object's distortions and resistance perceived when squeezing. If the distortion is not so great, that information is mainly perceived by visual appearance. As a hypothesis, a haptic illusion of "softness" should then be sensed if one were given visual feedback with a virtual object in hand, that changes shape artificially according to squeezing pressure.

For our study, we introduced a new method that produces pseudo-haptic feedback from the hand by using a hand-held display equipped with pressure sensors. In the

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system, a virtual object viewed on the display changes its shape according to squeezing force as sensed by the device's sensors. In this configuration, subjects are able to see their hand and the visual display simultaneously.

2 Related Work

Lecuyer *et al*. have conducted experiments to investigate hardness/softness under pseudo-haptic feedback on [1, 2]. In their research, subjects were asked to push against a piston mounted on an experimental input device. The piston is connected to a ball-like object that is also fixed to the device. A virtual ball displayed on a monitor changed its shape according to the applied force between the piston and the ball. By using the device, they were able to generate pseudo-haptic feedback in response to hard or soft pushing on the virtual ball. In addition, the sense of softness had changed according to the ratio between input force and amount of deformation. However, subjects had to fix their eyes on the monitor rather than their hands when handling the physical input device.

Hirano *et al*. investigated the same phenomenon by using Mixed Reality Technology [3]. Subjects in this study were given visual feedback while seeing their hand moving. They used blocks of urethane foam equipped with a bend sensor. Then visual image is superimposed on the block by using a video-see-through head mounted display. The visual image changes its shape according to the force applied to the urethane foam. By changing the ratio between the amount of distortion and the applied force, the study succeeded in enabling subjects to feel the variation in hardness in this illusory set-up. This study had overlapping features with our own where we induce pseudo-haptic feedback while seeing the hand in motion. However, pseudo-haptic feedback related to squeezing motion remained to date uninvestigated.

3 Prototype Device

In this section, we describe a prototype device used in our study on softness induced by pseudo-haptic feedback. As shown in Fig. 1, the prototype device consists of a conventional smartphone (Samsung Nexus S) and film-type force sensors. Two force sensors (Interlink Electronics Inc. FSR-400) are mounted on each side of the screen. These sensors are used to measure the forces when subjects hold the screen in their hand. Measurements are transmitted to a microcomputer (Arduino RT-ADK) and used to generate a visual image. As shown in Fig. 2, a blue rectangle is generated and displayed on the screen. The resolution of the displayed area on the screen is 800 × 480 [pixels]. The width of the rectangle changes according to the measured forces in squeezing. Force compliance can be changed by altering its value (C in equation (1)). If subjects apply no force, the rectangle returns to its initial state.

$$\textit{[actual width]=[initial width]-C*[sum of pressure value]} \quad (1)$$

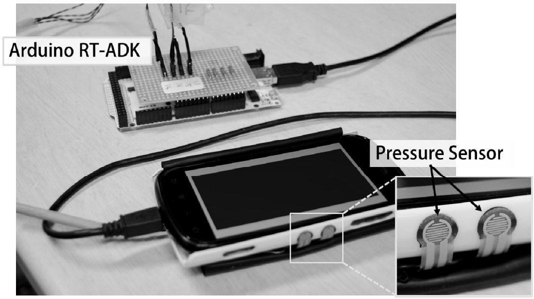

Fig. 1. Prototype Device

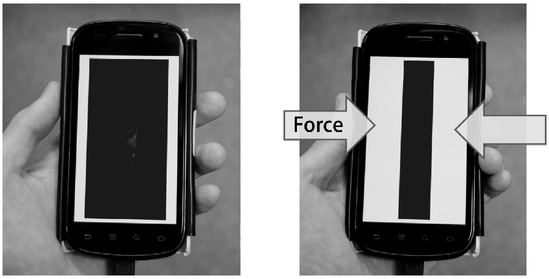

Fig. 2. Resizing of rectangle by squeezing

4 Experiment

In this section, we report on results from a questionnaire that we gave subjects so that we could confirm the pseudo-haptic feedback on softness based on the proposed method.

4.1 Procedure

We asked six subjects to squeeze the developed device and afterwards take a questionnaire. The experiment was conducted as follows:

1. Three values for the pressure resistivity coefficient, C_0(C=0), C_{small} and C_{large} (C_{small} =1/50, C_{large} =1/5) had prepared. The ratio between the grasping force and the width of the rectangular displayed on the device changes according to the coefficient. When C_{large} is selected, less grasping force is required for subjects to change the width than the case of selecting C_{small} . This means, subjects should feel softer when C_{large} is selected. When C_0 is selected, the width never changes.
2. Two of these coefficient settings (e.g., the pair C_{large} and C_0) are selected in one trial. First, specific coefficient had selected and a subject required to squeeze the device for 10 seconds. Then the coefficient had been changed and the subject also required squeezing it again. After each trial, the subjects was asked to compare the two for relative softness. The six patterns including orderings have been examined.

4.2 Result

The responses from the questionnaire showed Table 1. Combination of (C_0, C_{large}) and (C_{small}, C_{large}), all subjects responded that C_{large} settings produced a softer sense than the C_0 or C_{small} setting. Furthermore, in combination of (C_0, C_{small}), five subjects also responded that the C_{small} setting feels softer than for C_0 , and one does not feel neither of them. From these results, changes in shape according to hand pressure do produce difference in tactile sense through pseudo-haptic feedback. Furthermore, changes in the coefficient associated with pressure compliance also produce an illusory variation in softness.

Table 1. Result of Experiment

coefficient patterns		Which is softer ?
First	Second	
C_0	C_{large}	C_{large} (all subjects)
C_0	C_{small}	C_{small} (5 subjects), Neither (1 subject)
C_{large}	C_0	C_{large} (all subjects)
C_{large}	C_{small}	C_{large} (all subjects)
C_{small}	C_0	C_{small} (5 subjects), Neither (1 subject)
C_{small}	C_{large}	C_{large} (all subjects)

5 Conclusion and Future Work

In this paper, we proposed a new method to produce pseudo-haptic feedback related to softness that occurs in the hand. Analysis of questionnaire responses confirmed the feasibility of the proposed method using the prototype device. These results show that our device, consisting of a smartphone and pressure sensors, can generate an illusory sense of softness. Furthermore, by changing compliance values relating the squeezing forces and the width of the displayed rectangle, variation in the degree of softness can be achieved under pseudo-haptic feedback.

In future work, we will investigate more detail on the sense of softness from the pseudo-haptic feedback with the prototype device. Moreover, we will be using this technology as an interface for games and training of gripping power.

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