Feeling Softness on a Hard Touch Panel Using an Electrostatic Tactile Texture Display

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Abstract—This paper presents a method to deliver soft tactile textures on a hard touch panel, using an electrostatic tactile feedback display, which produces high-frequency frictional textures with extremely low-frequency friction stimuli. Through experiments involving several participants, we found that low frequency signals are effective at transmitting soft sensations. Although the underlying mechanism requires further study, this new perceptual effect may provide the touch panel industry with an attractive haptic advancement.

I. INTRODUCTION

The presentation of tactile feedback by a touch panel would lead to an improvement in the operability of the touch panel and the appearance of new content. The demand for the implementation of a tactile feedback mechanism is increasing and various principles are being studied. The presentation of softness on a hard touch panel extends the tactile feedback capabilities of tactile display; however, it is highly challenging to present softness on a hard touch panel because of its inherent hardness. Until now, some researches have been conducted to present softness by using vibratory mechanical stimuli. There have been studies that present softness to the finger by using low-frequency vibrotactile stimuli [1], [2] and one that presents softness of virtual objects while holding the objects [3]. However, no study has been conducted to present the softness of virtual texture when the finger slides on the touch panel. Hence, we aimed at presenting the softness of virtual texture on a touch panel based on the concept of low-frequency frictional stimulus related to the movement of the finger and the increase of friction when the finger slides on the soft material.

The objective of this paper is to present fine textures and softness simultaneously using an electrostatic tactile display which presents natural tactile feedback when the finger slides on the touch panel. This paper is the first on an electrostatic tactile display to present soft textures.

II. ELECTROSTATIC TACTILE DISPLAY

Fig. 1(a) shows the mechanism of an electrostatic tactile display. It manipulates the friction between the finger pad and touch panel by controlling the attractive electrostatic force which is induced by the applied voltage between the finger pad and the conductor. A change in the friction force influences the tangential deformation of the skin as the finger pad slides along the panel. Fig. 1(b) shows our experimental setup [4]. The frictional stimuli were produced by electrostatic forces induced by a voltage (V_e) between the conductive rubber pad and an Indium Tin Oxide panel. The Indium Tin Oxide plate was covered with an 8 μm an insulator (kimotect PA8X, KIMOTO
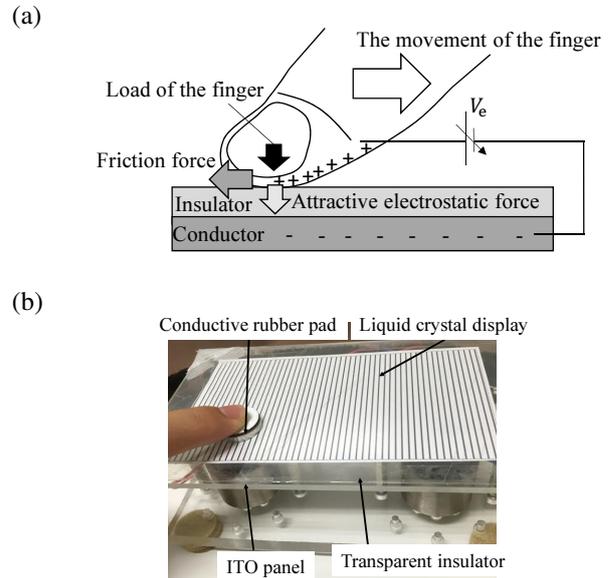

Fig. 1. Structure of the electrostatic friction display. (a) Principle of electrostatic tactile display. (b) Photo of the tactile texture display.

Co. Ltd., Japan). The voltage V_e was driven by a high-voltage amplifier (HJOPS-1B20, Matsusada Precision Inc., Japan). The conductive rubber pad was used for regulating the frictional condition of the panel. Otherwise, the friction operating between the finger and the panel would be adversely affected by individual finger properties, such as the moisture content of the finger pad.

A load cell (FS2050-0000-1500-G, TE Connectivity, Switzerland) was affixed beneath each corner. The center of the force on the panel was calculated at a 1 kHz sampling frequency using the four load cells for tracking the finger position.

Our display delivered frictional tactile stimuli, based upon the position and velocity of the finger through the pad. Without finger movement, the display does not yield any tactile stimuli.

III. EXPERIMENT

The participants in the experiment compared two types of fine texture stimuli presented by the touch panel. One was combined with low frequency variation of friction, and the other was without. Using a forced-choice experimental option, the participants were asked to choose the softer stimulus.
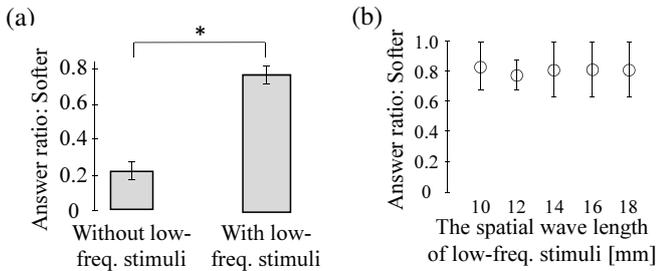
(a)   (b)

Fig. 2. Answer ratios of "feeling softer". (a) Mean and Standard Deviation values of answer ratios at which the stimulus was felt softer than the other. $*$ indicates $p < 0.05$. (b) By each low-frequency component.

A. Stimuli

Based on previous research that reported on the perception of softness as being related to low-frequency mechanical stimulus [2], [3], the presented stimuli were determined by the equation as follows:

$$V_{\mathrm{e}}(t) = A \sin 2\pi \frac{x(t)}{2\lambda_{\mathrm{h}}} + B \sin 2\pi \frac{x(t)}{2\lambda_{\mathrm{l}}} \qquad (1)$$

where A and B were maximum values of each voltage and $x(t)$ was the position of the finger on the panel. λ_{h} and λ_{l} are the spatial wave length of fine textures and long spatial wave length for presentation of softness, respectively. They were selected randomly from determined ranges. λ_{h} was a range of 0.2–1.0 mm by 0.2 mm, and λ_{l} was a range of 10–18 mm by 2.0 mm. We prepared five parameters for λ_h and λ_l. The first part of (1) is related to fine texture, and the second is related to the low-frequency stimulus for the perception of softness. The frictional force applied to the pad was determined by the following equation:

$$F_{\mathrm{e}}(t) = \mu \left\{ W + kV_{\mathrm{e}}^2(t) \right\} \qquad (2)$$

where μ, W, and k are the coefficients of friction, the load of the finger, and the electrostatic force constant, respectively.

B. Alternative forced-choice task

Participants experienced two kinds of texture stimuli: those combined with low-frequency variations of friction ($A = 110$ V, $B = 0$ V) and those without ($A = 25 - 100$ V, $B = 200$ V). Because the magnitude of the perceived friction (related to A and B) while sliding the finger pad could affect the participant's responses, we tuned the gains of A and B such that the magnitude of the stimuli were felt close to each other. They chose the stimulus that felt softer, and the one that felt rougher. The task of choosing the rougher texture constituted, which was a fake task. Each participant compared 20 pairs of stimuli. They were instructed to move the pad at a comfortable speed (about 15 cm/s). They could freely switch between the two types of stimuli as frequently as they wanted.

C. Participants

Five volunteers (non experts, average age 23.4) participated in this experiment. They were not informed of the research objective.

D. Results

The experimental results are shown in Fig. 2; (a) shows the answer ratio of softness and (b) shows the answer ratio per low frequency applied to each λ_l. Fig. 2(a) shows that the stimuli including the low-frequency frictional change by λ_l were judged as softer by the participants (t-test, $p < 0.05$). These results indicate that low-frequency stimuli influenced the perception of softness. Fig. 2(b) shows that the values of λ_l did not affect the answer ratios since there were no significant differences in the answer ratios among the spatial wave lengths of low-frequency stimuli.

IV. Discussion

Our experimental results showed that the virtual texture was perceived softer by adding the stimulus of spatial wave length of 10–18 mm when the display presented the fine texture of spatial wave length of 0.2–1.0 mm. Because there were no significant differences among the values of low-frequency spatial wave lengths, softness was perceived when the low-frequency wave length was sufficiently longer than that of the fine texture stimulus. The causes of this perception demand more research, but, our hypothesis is as follows. The increase of friction from the softness would be related to this experiment. The adhesion and hysteresis friction is negative power of the Young's modulus of objects [5]: the softer the material, the larger the friction. Additionally, the friction depends on the load and the velocity of the finger. Normally, the movement of the finger is low frequency. Hence, the frictional force from the softness is also low frequency. The low-frequency friction might have led the participants to imagine the softness of material.

V. Conclusion

With this research, we experimentally presented soft-feeling textures on a hard touch panel with an electrostatic tactile display by adding low-frequency frictional stimuli. Thus far, such results have not been formally reported. This approach would extend the possibilities of software-driven tactile displays.

Acknowledgment

References

[1] Takahiro Yamauchi, Shogo Okamoto, Masashi Konyo, and Satoshi Tadokoro. Real-time remote transmission of multiple tactile properties through master-slave robot system. *Proceedings of IEEE International Conference onRobotics and Automation*, pages 1753–1760, 2010.

[2] Lope Ben Porquis, Masashi Konyo, and Satoshi Tadokoro. Representation of softness sensation using vibrotactile stimuli under amplitude control. *Proceedings of the IEEE International Conference on Robotics and Automation*, pages 1380–1385, 2011.

[3] Atsutoshi Ikeda, Takahiro Suzuki, Jun Takamatsu, and Tsukasa Ogasawara. Producing method of softness sensation by device vibration. *Proceedings of IEEE International Conference on Systems, Man, and Cybernetics*, pages 3384 – 3389, 2013.

[4] Ken Ito, Shogo Okamoto, Hatem Elfekey, and Yoji Yamada. High-quality texture displays: The use of vibrotactile and variable friction stimuli in conjunction. *Haptic Interaction: Science, Engineering and Design, Lecture Notes in Electrical Engineering*, 432:125–130, 2016.

[5] Michael J Adams, Brian J Briscoe, and Simon A. Johnson. Friction and lubrication of human skin. *Tribology Letters*, 26:239 – 253, 2007.