Control of Ridge by Using Visuotactile Cross-Modal Phenomenon

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Abstract
Currently, touch panels are used in many devices, and there have been many proposals to add tactile sensation to touch panels, which require additional electro-mechanical components. In this paper, we propose a simple method of adding a tactile sensation of a ridge, using just a thin sheet. The sheet has ridges that are haptically imperceptible, but once a visual cue such as a line is presented, visuotactile cross-modal response induces a haptic ridge. We tested the effects of the visual cue and height of the ridge. The result showed that the visual cue definitely enhances feeling of a ridge.

Author Keywords
Cross-modal; Interface; Ridge sensation; Tactile illusion; Visuotactile

ACM Classification Keywords
H.5.2. [Information interfaces and presentation]: User Interfaces - Haptic I/O;

General Terms
Human Factors

Introduction

In recent years, touch panels have become pervasive on for many devices. They display visual information and respond to touch input, but lack sufficient tactile capability, that constrains device operations. One example of this tactile deficiency is "bumps" for buttons and keys.

To solve this problem, there have been many proposals to add tactile sensation to touch panels. Bau et al. proposed TeslaTouch, which can change surface friction by controlling the electrostatic force on touch panels [1]. Jansen et al. proposed MudPad which can present tactile sensation by controlling the viscosity of a magnetic fluid in electromagnets [2]. Saga et al. presented virtual bumps by pulling a user's finger laterally using SPIDAR system [3]. Tactus Technology, Inc. proposed a method to form real ridges on the touch panel by controlling a micro fluid [4]. However, it is still not easy to mount these devices on mobile terminals because they require additional electro-mechanical components such as motors or electromagnets.

In this study, we propose to simply put a thin sheet with ridges for keys on the touch panel. Of course, normal ridges will interfere with operations when they are not necessary. However, we discovered that visual cues added to the ridge will dramatically increase the perception of the ridge, and consequently, we can switch between a "ridge" and "no ridge" status by just changing visual information.

For this paper, we measured a basic property of this cross-modal phenomenon and verified the validity of our proposal.

Method

We preliminary observed the following phenomenon; the ridge of a few μm is just below the perception threshold, and normally cannot be perceived when we trace the ridge with a finger (Figure 1, left panel). However, when a visual cue such as a line is added over the ridge, the ridge suddenly becomes perceivable (Figure 1, right panel). This phenomenon is considered to be one of the visual-tactile cross-modal phenomena.

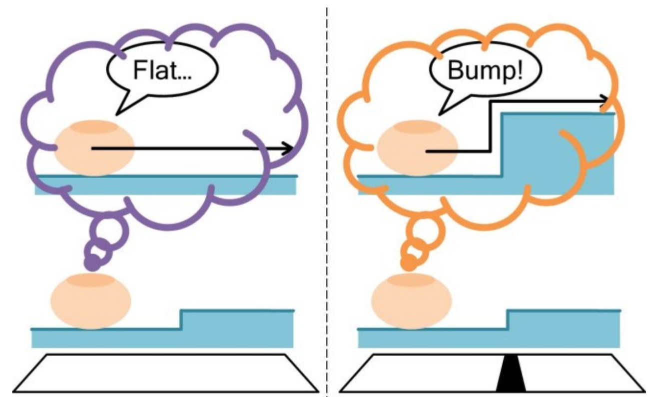

Figure 1 Proposed method. (Left) without visual cue, a user feels a flat surface; (Right) with visual cue, a user feels a tactile ridge.

Our idea is to apply this phenomenon to add ridges to the touch panel. Our scenario is as follows; we put a thin transparent sheet with ridges below the perception threshold, forming keyboard or buttons. When the user needs keyboard, an image of the keyboard is displayed, and the ridges is perceived. In other words, the subjective ridge height is controlled by visual modality.

There have been many studies on the cross-modal relationship between visual and tactile stimuli and its

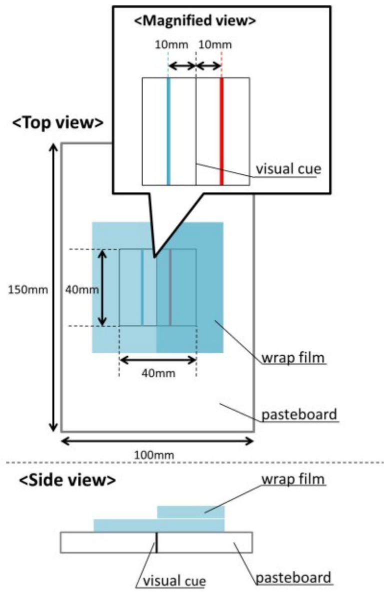

Figure 2 Experimental setup

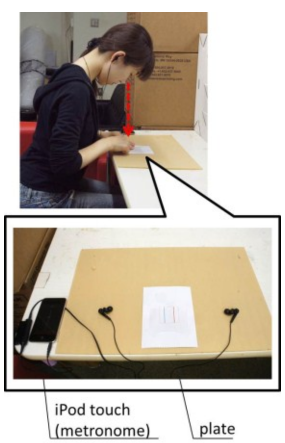

Figure 3 Environment of the experiment (This picture was taken under lighting)

effect on perception threshold. Taylor et al. reported that if the tactile stimulation site is visually observed by the participant, the discrimination threshold is decreased [5]. Kennett et al. reported that even if a visual cue that was unrelated to the tactile stimuli was added to the body surface at the tactile stimulation site, the two-point discrimination threshold was improved [6].

However, these studies cannot substantiate our proposal, because in our situation, users gaze at the tactile stimulation site and the visual cue is hidden by the user's finger (a visual cue is presented under the user's finger). Therefore, we conducted an experiment to establish the validity of our proposal.

EXPERIMENT

We examined the relationship of the subjective ridge height and visual cue.

Experiment setup

We made a transparent plate with a ridge using a wrap film (Asahi Kasei Home Products Corporation, Saranwrap20m) and a pasteboard (Figure 2). A plate is made with a ridge, created from the texture of the wrap film, running down the center. We prepared ridges of various thickness (of 0, 1, 2 wrap film thicknesses). A 40 mm square was drawn on the square plate, and a blue and a red line (line width 1.0 mm) were printed at a spacing of 20 mm on each side of the step. Participants move a finger between these two lines at a designated velocity.

There were two visual conditions; with and without visual cue. The visual cue is a 0.1 mm-wide black line, which was printed midway between the two lines just under the step (Figure 2 Side view). In total, we prepared six types of plates (3 different ridge heights, 2 different visual cues). Actual ridge heights were measured using a micrometer (Mitutoyo Corporation, M320-25AA, Range: 0.000-25.000 mm, Accuracy: 0.001 mm), and the three thickness conditions were 0.000, 0.014±0.001, and 0.021±0.002 mm.

Procedure

Figure 3 shows the environment of the experiment. Because ridges were visible under normal lighting conditions, the illumination of the room was set down to 2.3 Lux. Before the experiment, participants confirmed whether they could see the visual cues. They were asked to trace the plate from the blue line to the red line with their right index fingers. To control speed, we asked participants to move their fingers according to the beats of a metronome (iPod touch software) so that sounds were only heard when the fingers were on blue or red lines. By this means, the duration in moving the finger from the blue line to the red line was 0.75 sec, giving a speed of 26.7 mm/s.

Participants traced two plates (plate1 and plate2) and were asked which ridge was higher with three alternative responses ("plate1", "plate2", or "same"). We paired the six types of plates, giving 36 randomized trials in total for each participant. Participants were 5 laboratory members composed of 3 males and 2 females, aged between 22and 24 yeas, right handed, with 4/20-20/20 eyesight.

Result and Discussion

Figure 4 shows a partial result. It compares the same ridge height with or without visual cue. The horizontal axis is the physical ridge height from 0.000 to 0.021

mm, and the vertical axis is the answer rate. For example, when the ridge was 0.000 mm, 90 % of the participants answered that two specimens (with or without visual cue) has the same height, while 10 % answered that a specimen with visual cue was higher.

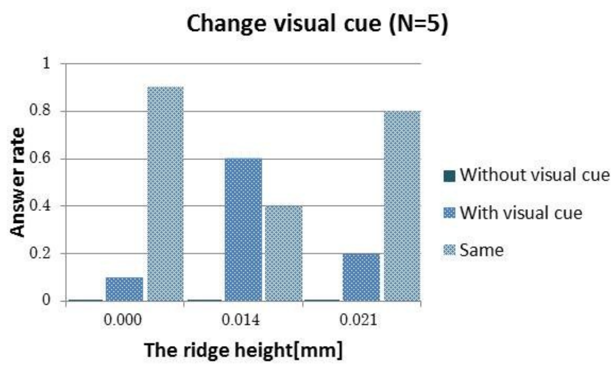

Figure 4 Average answer rate when changing visual cues.

When the ridge height was 0.000 and 0.021 mm, the subjective ridge height was not affected by the visual cue (i.e. most participants answered that two specimens had the same height). However, when the ridge height was 0.014 mm, the subjective ridge height was affected by visual cue.

This result clearly indicates that the subjective ridge height became higher by adding a visual cue. However, because the participants could perceive the lowest in ridges (0.014 mm) we had prepared, the result did not fully validate our proposal; when a visual cue is added, the ridge which normally cannot be perceived can become perceivable. Therefore, as a next step, we will use lower ridges that are normally unperceivable.

CONCLUSION

In this paper, to add a tactile sensation of ridges to touch panels with a simple set up, we proposed to control the subjective ridge height using a visualtactile cross-modal phenomenon, and partially confirmed the validity of our proposal.

Our next step is the sophistication of the experiment using ridges below a certain threshold height. In the future, we will prepare design guidelines that state optimum parameters such as ridge height, visual line width and luminance.

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