

Tactile Representation of Image in a Plane Actuator

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Abstract

Our study investigated the effect of vibration elements on the recognition of texture in a planar type actuator. A planar type actuator is highly advantageous in naturally conveying the texture of a graphic object on a large-sized touch screen display to a user, which can considerably improve the user's experience when interacting with such screens. In order to investigate the effect of frequency and amplitude elements of vibration on texture representation, we analyzed the texture image quantitatively and conducted a user experiment to find the vibration elements that best matched a texture. Experimental results show that controlling frequency is more effective in expressing texture than controlling amplitude, but in a certain frequency band, different texture can be represented by changing the amplitude only.

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI)**; HCI design and evaluation methods; Haptic devices;

1. Introduction

The touch screen, which is familiar to users through the use of smart phones, is being applied to various smart devices, due to its natural and convenient usage. As the touch screen is applied to other electronic products such as auto-mobile, refrigerator or wall screen, the size of the touch screen has been enlarged and a lot of studies are being conducted to improve the usability of the touch screen. In particular, the tactile feedback technique that has been useful for confirming user input on a touch screen is evolving into a means of providing a texture of various graphic objects on the screen. In case of using tactile feedback in a large touchscreen, it is more advantageous for the touchscreen itself to operate as an actuator than to use a small actuator embedded in the touchscreen. Because if the touchscreen is as small as he/she is holding the device, tactile feedback can be transferred mainly to the holding hand rather than the touching fingertips. However in a large touchscreen such as wall screen, it needs to be transferred to the touching fingertip. When the texture of the graphical object on the screen is directly transmitted to the finger touching the screen, the user experience can be enhanced by providing a sense of reality and immersion to the user [BPIH10] [LJ15].

However, in order to effectively express various textures by using the vibration of a planar type actuator, which is essentially a glass plate, the range of the vibration must be identified, and the relationship between the image texture and the vibration elements should be analyzed. In this paper, we report the results of user experiments conducted to investigate the correlation between vibration elements and perception of image texture.

2. Experimental setup

2.1. Haptic Touchscreen & Subject characteristics

We fabricated a haptic touchscreen by stacking an IR touch sensor on an electrostatic parallel plate actuator (280x350x1mm). The working principle of the actuator is to operate by vertical movement of the upper plate by electro-static force between the two plates, and the vibration is transmitted to the user's fingertip in contact with the upper plate [LJ15].

Twelve subjects (4 females, 8 males, aged 23-40) who had experienced various haptic feedback from smartphones participated the experiment. However, since they were experiencing a large-sized haptic touchscreen for the first time, there was no information about the tactile vibration occurring in the plane actuator. Therefore, the subjects participated in the experiment only after experiencing the vibration characteristics of the haptic touch screen sufficiently.

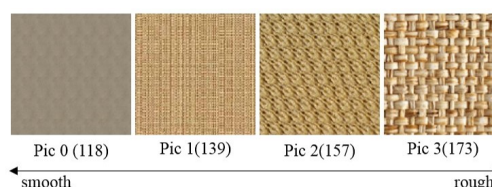


Figure 1: Test images and texture analysis results

2.2. Test Images & Stimuli Design

Four images (Pics 0-3) were selected for their range from smooth texture to rough texture, based on the results of a user survey on roughness [Figure 1]. We quantitatively analyzed the texture of the images, using the algorithm of [KLSO*15]. Kim's algorithm classifies the texture according to the edge density included in the image, and the classification result by the algorithm and the user survey result were generally similar. Experimental stimuli were designed to find out which property of vibration (waveform, frequency, and amplitude) is beneficial in expressing roughness. In the experiment, five frequencies (30, 60, 90, 120, and 150 Hz) were selected in the sensitive region of the Meissner's corpuscle. Based on the absolute threshold experiment, five amplitudes (0.64, 1.11, 1.58, 2.05, and 2.52 Kvpp) were selected at equal intervals.

2.3. Test Procedure

For the image on the touch screen, a vibration is presented in random order when a user rubbed the image. The subjects then evaluated degree of matching with a 5-point Likert scale on how well the vibration matched the test image. The experiments were carried out in two ways to investigate the effect of frequency and amplitude, respectively. In Experiment 1 and 2, we presented five vibrations with different frequencies (30, 60, 90, 120, and 150 Hz) at fixed amplitudes (1.1, and 2.52kV). Experiments 3, 4, and 5 set the frequencies at 30, 90, and 150 Hz, and presented the vibrations of five different amplitudes in an arbitrary order. Five experiments were performed twice per subject, and the order of experiment, image and vibration was presented in random order.

3. Discussion

3.1. Experiments 1 & 2

In experiment 1, for each test image, low frequency vibrations were evaluated to be more suited to rough texture images. On the other hand, high-frequency vibrations were evaluated to be more suited to smooth textures (one-way ANOVA, $\alpha = 0.05$, $p = 0.000$, 0.000 , 0.000 , 0.003). The results of experiment 2 are similar to those of experiment 1, except with Pic 2 (one-way ANOVA, $\alpha = 0.05$, $p = 0.000$, 0.000 , 0.179 , 0.003). In these experiments, the effect of changing the amplitude did not show a significant difference in degree of matching [Figure 2].

3.2. Experiments 3, 4 & 5

For three types of frequencies (30, 90, and 150 Hz) that can be fully perceived frequency differences, we measured the degree of matching only by the amplitude change after fixing at one of the frequencies [Figure 3].

- **30Hz:** In all images, it was shown that the amplitude property has an influence on the evaluation of vibration coupling. Smooth texture images (Pic 0, Pic 1) are well-matched vibration with small amplitudes while rough texture images (Pic 2, Pic 3) are well-matched with large amplitude vibrations (one-way ANOVA, $\alpha = 0.05$, $p = 0.000$, 0.02 , 0.000 , 0.000).

- **90Hz:** The larger the amplitude in all images, except for the smooth texture image (Pic 0), image and vibration were evaluated to be well-matched (one-way ANOVA, $\alpha = 0.05$, $p = 0.08$, 0.002 , 0.000 , 0.000).
- **150Hz:** We evaluated the degree of matching of images with the smooth texture (Pic 0, Pic 1) more positively than the images with rough texture (Pic 2, Pic 3) for all amplitudes (one-way ANOVA, $\alpha = 0.05$, $p = 0.07$, 0.01 , 0.012 , 0.246).

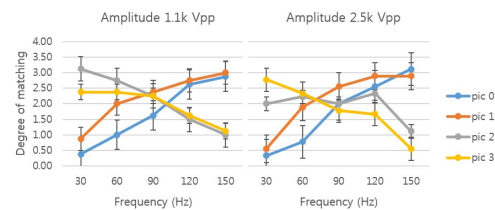


Figure 2: Degree of matching - frequency change

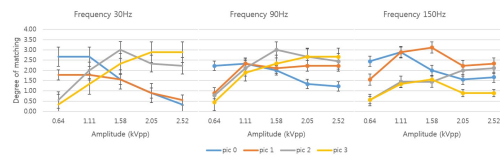


Figure 3: Degree of matching - amplitude change

4. Conclusions

In this paper, we investigate how amplitude and frequency affect the texture representation of plate actuator vibration. Experimental results showed that frequency is more effective for texture representation than amplitude. At fixed amplitude vibration, a high frequency is advantageous for expressing smooth texture, and a low frequency is advantageous for expressing rough texture. In the case of amplitude, the effect of texture representation is weaker than that of frequency. However, in a certain frequency band (low frequency band), it is possible to express smooth texture and rough texture depending on amplitude.

5. Acknowledgements

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References

- [BPIH10] BAU O., POUPYREV I., ISRAR A., HARRISON C.: Tesla Touch: electrovibration for touch surfaces. In *Proc. UIST2010* pp.283 - 292. 1
- [KLSO*15] KIM M. LIM J. SHIN H. OH C. JEONG H.: Estimating the number of clusters with database for texture segmentation using Gabor filter. In *Proc. ICVS2015* pp.435 - 444. 2
- [LJ15] LIM J., JEONG H.: Force and Displacement Analysis of a Haptic Touchscreen. In *Proc. ICCE2015* pp589 - 591. 1