Experiment and study of tactile characteristics resulting from vibration of a touch panel

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ABSTRACT

The recent popularity of touch interfaces equipped in smart phones, tablet PCs, and the like has dramatically increased the opportunities for performing finger operations directly on a touchscreen. In this study, the authors report on experiments in which an actuator is used to perform an operation on a touchscreen surface to express surface unevenness and roughness in order to determine the range of differences in stimuli, reproduced on the surface of a touchscreen, that can be distinguished by a test subject.

Three types of waveforms (triangle wave, square wave, and sine wave) for presenting surface roughness were achieved, and the perceptions resulting from those waveforms were investigated at that time. The results showed that differences existed according to the waveform shape, even when the magnitude of the sensation is the same. This magnitude was found to be perceived as successively larger when using waveform shapes in the order of triangle wave < square wave < sine wave.

Keywords: Surface roughness, Touchscreen, Vibration I-INCE Classification of Subjects Number(s): 49.2

1. INTRODUCTION

The recent popularity of touch interfaces equipped in smart phones, tablet PCs, and the like has dramatically increased the opportunities for performing finger operations directly on a touchscreen. In particular, the sensations of an uneven surface or roughness are tactile sensations directly linked to input operations via button clicks or the like on a touchscreen, and research is actively underway in this area [1, 2]. Furthermore, with the ability to reproduce and present a surface roughness, the interface is widely applicable for use in shape recognition and for realizing a virtual reality over a network. In this study, the authors report on experiments in which an actuator is used to perform an operation on a touchscreen surface to express surface unevenness and roughness in order to determine the range of differences in stimuli, reproduced on the surface of a touchscreen, that can be distinguished by a test subject.

2. EXPERIMENT

2.1 Experimental system

A touchscreen developed by Immersion Corporation was used as the experimental system. The system in this experiment was configured such that pressing the touchscreen with a finger causes the touchscreen to return a tactile sensation in response to that stimulus. Fig. 1 shows a schematic of the system for providing tactile sensations.

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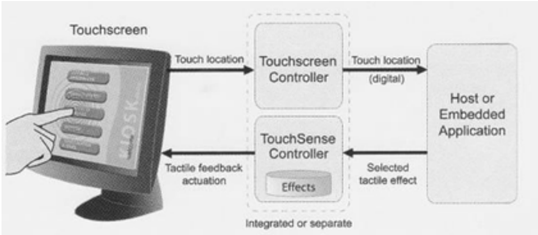

Figure.1 System schematic

2.2 Experimental method

Measurements were made using the method of constant stimuli. The test subject was presented with both a tactile sensation (standard stimulus) as a reference for comparison and a different tactile sensation (comparative stimulus) for comparison, and the test subject compared the strength of both tactile sensations. The comparison scale consisted of three categories, and the test subject selected from among: "weaker than the standard stimulus," "same as the standard stimulus," and "stronger than the standard stimulus." Additionally, a probability model was introduced for analysis of the experimental data, and parameters for the data were analyzed using the maximum likelihood method.

2.3 Experiment[3]

From preparatory experiments, a discrimination threshold on the order of 1000 was found to be distinguishable subjectively. The experimental apparatus was set to this numeric value, and changes in the surface unevenness were measured separately. Table 1 shows the measurement examples. The standard stimulus applied to this experiment was the S5 (5000) amplitude stimulus, and nine types of comparative tactile stimuli were presented, from S1 = 1000 to S10 = 10000 in steps of 1000.

A preliminary experiment was carried out based on the preparatory experiment [3]. Ten people participated as test subjects, with ages ranging from 18 to 21 years. Moreover, the stimuli were presented randomly so that the test subjects would not be able to anticipate each stimulus.

Table 1 Results of the tactile sense discrimination threshold experiment

μ	σ	c	JND(0.75)	μ+JND(0.75)	μ-JND(0.75)
5004.3	1574.8	1047.8	1062.2	6066.4	3942.1

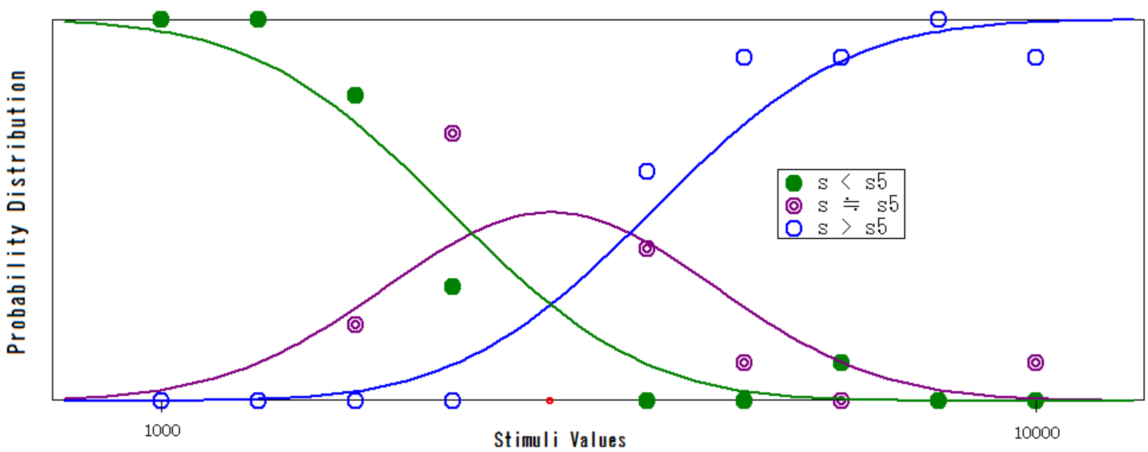

Figure. 2 Distribution of tactile sense in the discrimination threshold experiment

The displacement of the panel surface in the experimental apparatus is controlled based on the input value by the system that uses the actuator. The displacement is a value between 1 and 10000 and is the magnitude of the displacement, but is not equal to the measured value of the displacement from the surface. In this experiment, the value of input displacement is used as the amplitude, and the relationship between this value and actual measurements was also obtained to determine the correspondence; however, the difference between those values could not be sufficiently clarified in the preliminary experiment with an Mg value of 4000 or less.

The horizontal axis indicates the presented stimulus values and the vertical axis indicates the determination probability. Data values are represented with small circles: a filled circle is a determination of “weaker than the standard stimulus” ($s<s10$), a double circle is a determination of “same as the standard stimulus” ($s \approx s10$), and a hollow circle is a determination of “stronger than the standard stimulus” ($s>s10$). The curves show determination probabilities based on parameter values obtained from experimental data.

From the preliminary experiment [3], if the standard stimulus has an amplitude of 5000, the point of subjective equality is 5004. There is little error between the standard stimulus and the point of subjective equality. Moreover, the amplitude threshold for which a test subject can perceive differences in tactile sensation is said to be within the range of 3942 to 6066. However, since the change in amplitude was large, there was sufficient width to distinguish the stimuli.

This experiment, however, was implemented with smaller changes in amplitude. Table 2 shows the ranges of amplitude used. The standard stimulus used for comparison had an intermediate value within each amplitude range, and equaled 3000 in experiments (1) and (2), 5000 in experiment (3), and 7000 in experiment (4).

The test subjects consisted of 56 people, 53 men and 3 women ranging in age from 19 to 20 years old. Because fingertip tactile sensitivity is known to be highest in the range of several tens to one-hundred hertz [4], the following parameters were set for the measurement data: (1) Waveform: triangle wave; (2) period: 10 [ms]; (3) vibration frequency: once; (4) standard Mg: 3000 (three types of Mg regions: (a) 2000 to 4000, (b) 4000 to 6000, and (c) 6000 to 8000), and (5) Mg interval: 250 and 200.

Moreover, the stimuli were presented randomly so that the test subjects would not be able to anticipate each stimulus. Fig. 3 shows the results of experiment (1).

The result of obtaining the discrimination threshold in experiments (1) to (4) was a discrimination threshold value of $Z0.75 = 250$ to 265 in experiments (1) to (3), and a value of $Z0.75 = 395$ in experiment (4).

These values are specified by the manufacturer and do not represent the actual measured values of the amount of change in surface unevenness. However, based on values provided by the manufacturer, they do function as the discriminating criterion for humans. The correspondence between manufacturer-specified values and surface unevenness has previously been reported [3]. In the report at that time, there was insufficient correspondence between manufacturer-specified values and actual measured values of Mg 4000 or less. Furthermore, when Mg is 4000 or greater, the change in amplitude is sufficiently large and, as shown in Figs. 3(a) to 3(c), differences in tactile sensation can be determined when the change in amplitude is in the range of about 250 to 350, and values that indicate a large change in surface unevenness sufficiently allow for distinguishing of the stimuli.

Table 2 Change in amplitude interval

Experiment	Amplitude range	Amplitude interval
(1)	2000～4000	250
(2)	2000～4000	200
(3)	4000～6000	250
(4)	6000～8000	250

2.4 Waveform shape experiment that presents roughness

2.4.1 Change in tactile sense due to roughness waveform

In this system, the shape of the tablet surface was changed. By changing the roughness waveform to the three varieties of a triangle wave, square wave, and sine wave, experiments were carried out on the tactile sensation of the hardness of the surface and the like. The test subjects consisted of 26 men ranging in age from 18 to 22 years old. The magnitude of the stimulus for comparison had a specified Mg value of 2650, and the same magnitude of stimulus was used with all three waveform varieties. With the same magnitude stimulus as a standard, the test subjects were tasked with determining which waveform felt the largest. The following three combinations were used: (1) square wave and triangle wave, (2) square wave and sine wave, and (3) triangle wave and sine wave.

The result found differences, according to the shape of the waveform to be reproduced, in the test subjects' tactile perception. Table 3 shows the results.

Table 3 Difference in sensation intensity from the presented waveform

		X ＞ Y	X ＝ Y	X ＜ Y
①	A : B	22	3	1
②	A : C	1	5	20
③	B : C	1	1	24

A : sine wave B : triangle wave
C : square wave
X : right Y : left

The square wave reproduced the hardest tactile sensation. The sine wave reproduced an elastic sensation. The test subjects' responses to a questionnaire indicated that the square wave felt like pressing down on the shape of a "hard button." The sine wave was reported to have felt "squishy" or like "bubble wrap."

2.4.2 Correspondence between Mg value and amplitude of surface unevenness

On the basis of the shapes generated in the above experiments, the correspondence between the Mg value and the amplitude change of a square wave and a triangle wave was measured. The measuring device was an SV3000 (Mitutoyo Corporation), which has a resolution of 0.02 µm.

Measurements were made in the Mg value range of 2000 to 4000, which is assumed to be the range used when surface roughness is reproduced. Although this range has a low discrimination threshold for surface roughness, the difference was found to be distinguishable in the experiments. To that end, the rough nesses of these ranges were confirmed. At values 4000 and above, the surface roughness becomes large, the differences in sensation intensity for making a determination increase, and it becomes easier to estimate the discrimination threshold. In the preliminary experiment [4] as well, it had been difficult to clarify results for values of 4000 or less.

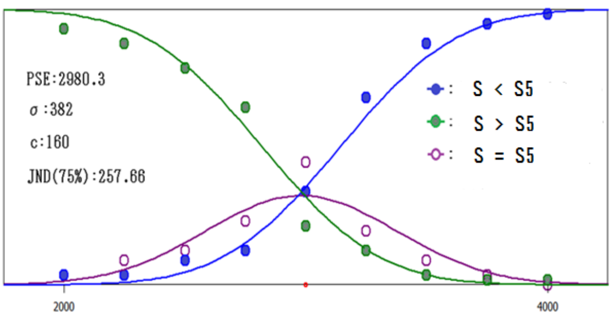

Figure. 3(a) Distribution of tactile sense in the discrimination threshold experiment (2000–4000 range)

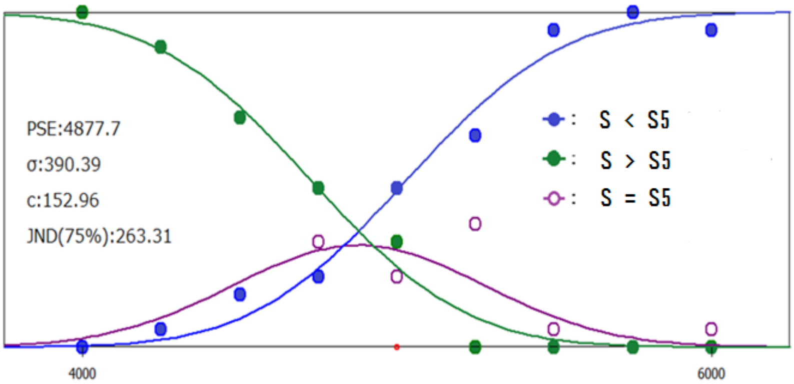

Figure. 3(b) Distribution of tactile sense in the discrimination threshold experiment (4000–6000 range)

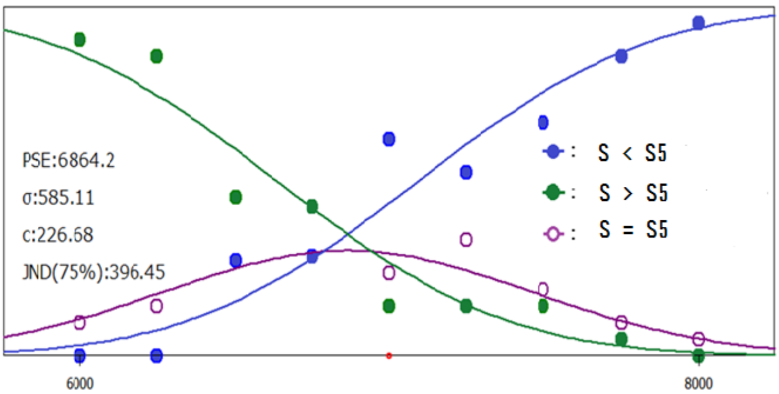

Figure. 3(c) Distribution of tactile sense in the discrimination threshold experiment (6000–8000 range)

From the roughness created by vibrations in the experiment, we measured the correspondence between specified values of 4000 or less and the roughness. In addition, we also measured the roughness caused by the difference in waveform shapes of triangle and square waves. Fig. 4 shows the results.

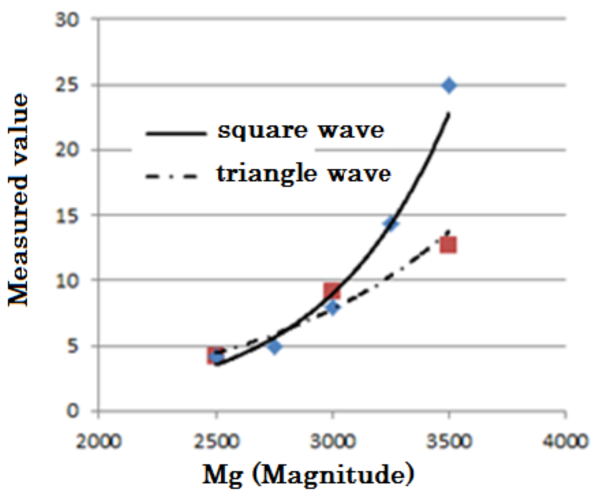

Figure. 4 Correspondence between Mg value and value of surface change

From the figure, it can be seen that for specified values of up to about 3000, there is not much difference between the roughness of the triangle wave and of the square wave, but for values above 3000, the difference in amplitude of the roughness becomes conspicuous.

3. CONCLUSIONS

Targeting the range of high fingertip tactile sensitivity, an uneven surface was generated on a touch panel surface and the tactile sensation of roughness was confirmed. For surface unevenness of about 5 [μm] or greater, a discrimination threshold of about 1 [μm] was confirmed. Moreover, by changing the waveform, different perceptions of the shape of the roughness were reported in response to a “pressing” action performed by the test subjects. With this method, we found that it is possible to create the perception of a “pushdown” type surface on a panel surface or the like.

Three types of waveforms (triangle wave, square wave, and sine wave) for presenting surface roughness were achieved, and the perceptions resulting from those waveforms were investigated at that time. The results showed that differences existed according to the waveform shape, even when the magnitude of the sensation is the same. This magnitude was found to be perceived as successively larger when using waveform shapes in the order of triangle wave < square wave < sine wave.

In the future, we would like to clarify the relationship between the expression and shape of roughness.

ACKNOWLEDGEMENTS

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