Audiotactile Feedback for Touch Screens

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Introduction

Touch sensitive displays and touch surfaces are more and more replacing physical buttons. If a physical button is pressed, audio and tactile feedback confirms the successful operation. The loss of audiotactile feedback in touch sensitive interfaces might create higher input error rates and user dissatisfaction. Therefore the design and evaluation of suitable signals is necessary. Different papers discuss implementation and evaluation of audio and tactile feedback for mobile applications using small vibration actuators and primarily high-frequency vibrations, e.g. [1, 2, 3, 4, 5, 6]. However in ticket machines or automated teller machines the size of the actuator is not a limiting factor. Thus vibratory stimuli with lower frequencies and bigger amplidudes can be generated by moving the whole touch sensitive display.

Experiment

In a pilot study with six subjects the usability of tactile feedback is investigated. Different synthetic signals are developed and compared with each other. In a dialing task the objective performance of the subjects (effectiveness, error rate) is measured. The perceptual quality of the designed signals is evaluated using a questionnaire.

Setup

Different patents and papers describe possibilities for reproduction of tactile feedback for touch screens [7, 8, 9, 10, 11, 12]. In this paper a touch sensitive system is presented that reproduces event triggered audio tactile feedback. The tactile component is generated using an electro-dynamic exciter, which is mounted behind a touch screen. The surface of the panel is divided into 6 virtual buttons. The layout is shown in Figure 1. The audio signal is played back via headphones. However, this paper primarily focuses on the effect of tactile feedback.

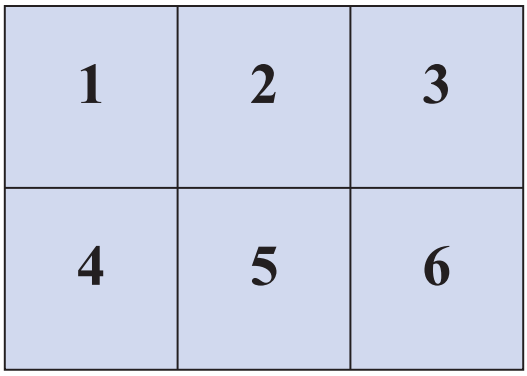

Figure 1: Interface printed on the touch screen.

Stimuli

The goal of this pilot experiment is to investigate the perceptual difference between several stimuli for tactile feedback to the finger, while pressing a virtual button on a panel. Five different stimuli, which can be seen in Figure 2 are selected (duration = 0.05 s each): sin, triangle, square, sawtooth and $\sin^2$. The stimuli amplitude corresponds to the perpendicular displacement of the surface. Positive amplitude means movement towards the subject.

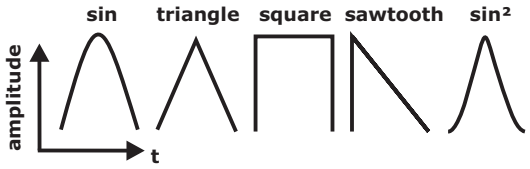

Figure 2: Five different stimuli evaluated in this study. Length each = 0.05 s.

Subjects

Six university students (3 male, 3 female; average age: 22.8 ± 1.8) voluntarily participated in this pilot study.

Design

The experiment is divided into two parts. In the first part, each of the five virtual buttons is linked to one stimuli, leaving one button with no tactile feedback. After a short explanation of the panel, the participants are asked to test the buttons in a training phase. The first task was to identify how many kinds of feedback are provided by the panel and which virtual buttons feel the same for them. This comparing task is repeated 6 times for each participant to balance the way of matching the signals with virtual buttons. The order of the stimuli is also balanced between different participants.

In the second part, a dialing-numbers task is used. The participants are asked to dial 16 numbers displayed on an extra screen as fast and accurately as they can. The execution time and the errors during the task were measured. For each participant, the task is repeated six times. During each task the tactile feedback (five stimuli used in the first experiment and one without any feedback) is the same for all six virtual buttons, but varies between different tasks.

After each task the participants were asked to evaluate the overall quality of the feedback, the suitability for confirmation and the comfort on a quasi continuous scale from “-5 (bad)” to “5 (good)”. It was also possible to write down comments. The order of the stimuli was balanced between different participants.

Results

All the participant had to compare the six buttons six times during the first part of the experiment. The result of the comparing task is shown in Table 1. It was defined that two tactile stimuli have little difference if they are rated the same more than three times. It can be seen that most participants consider sin, triangle and $\sin^2$ feedback to have little difference. The square and sawtooth stimulus are also rated as similar.

Table 1: Number of participants that feel little difference between different tactile feedbacks.

	sin	triangle	square	saw	$\sin^2$	none
sin		5	0	0	4	0
triangle			0	1	5	0
square				4	0	0
saw					1	0
$\sin^2$						0

To analyze the data of the second part of the experiment(dialing-numbers task) ANOVA repeated measures were used. The results for the subjective valuation are shown in Table 2. Difference between different feedback stimuli and none-feedback is significant for overall quality and suitability for confirmation and almost significant for comfort of feedback.

Pairwise comparisons shows that:

- The overall quality of none-feedback is significantly worse than that of the other five kinds of feedback, while they have no significant difference between themselves (Figure 3).

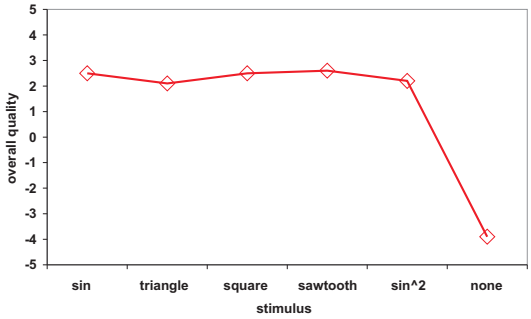

Figure 3: Overall quality of none-feedback is significantly worse than that of the other five kinds of feedback.

- The suitability for confirmation rating of none-feedback is significantly worse than that of the other five kinds of feedback. The suitability for confirmation of square feedback is rated better than that of sawtooth and $\sin^2$ feedback (Figure 4).

The performance of the subjects in terms of completion time and error rate of the dialing-numbers task is shown in Table 3. The difference between different feedback

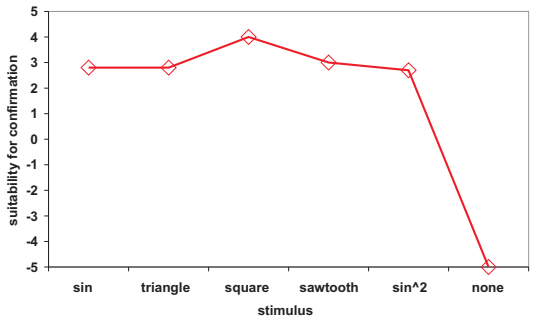

Figure 4: Suitability for confirmation of none-feedback is significantly worse than that of the other five kinds of feedback.

stimuli and none-feedback is significant for the number of errors and not significant in completion time. The number of errors of none-feedback is significantly larger than that of the other five kinds of feedback except $\sin^2$ feedback. The number of errors of sin feedback is significantly larger than that of sawtooth feedback (Figure 5).

Figure 5: Number of errors.

Discussion and Outlook

The first part of the experiment investigates the perceived similarity or dissimilarity for different tactile feedback. The results indicate, that only two kinds of tactile feedback can be perceived from the five stimuli: the sharp feedback including square and sawtooth stimulus and the softer kind including sin, triangle and $\sin^2$.

The results of the second part of the experiment show the advantage of tactile feedback in both perceptual quality and performance for a number-dialing task. Event triggered single movement stimuli, like in this study, are suitable to confirm that a button is pressed. Further experiments will show if high-frequency vibration stimuli might be the better choice to report an error.

The results indicate that completion time alone may not be a very good way to measure performance. Further studies are necessary to investigate this hypothesis, because of the small number of participants in this pilot experiment. The effect of inverted movement direction, vibration amplitude and the influence of audio feedback will be investigated.

Table 2: Perceptual quality ratings for different tactile feedbacks showing mean values and standard deviations.

	sin	triangle	square	saw	$\sin^2$	none	F	p	η
overall quality	2.5 ± 1.5	2.2 ± 1.5	2.5 ± 2.4	2.7 ± 2.3	2.3 ± 1.6	-3.3 ± 1.4	14.08	0.000	0.738
suitability for confirmation	2.5 ± 1.6	2.5 ± 1.6	4.0 ± 1.6	2.8 ± 1.6	2.2 ± 1.8	-4.7 ± 0.5	31.32	0.000	0.862
comfort of feedback	3.2 ± 1.7	2.5 ± 1.1	3.0 ± 2.5	3.8 ± 1.0	2.2 ± 1.3	-1.3 ± 3.7	4.38	0.051	0.467

Table 3: Performance for different tactile feedbacks showing mean values and standard deviations.

	sin	triangle	square	saw	$\sin^2$	none	F	p	η
time to complete the dialing task in s	42.2 ± 4.9	46.0 ± 3.8	49.8 ± 12.4	47.0 ± 15.5	50.5 ± 14.1	44.5 ± 9.5	0.60	0.702	0.107
number of errors	1.0 ± 1.1	1.3 ± 1.5	0.7 ± 0.8	0.2 ± 0.4	1.3 ± 1.8	4.5 ± 2.6	8.03	0.000	0.616

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