Evaluation of Effects of Textures Attached to Mobile Devices on Pointing Accuracy

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Abstract. When a user holds a mobile device that has a touch screen, his/her fingers and palm touch the back of the device. For this reason, we think that input accuracy can be improved by attaching textures on the back of the device. We selected ways to attach textures and then evaluated pointing accuracy with each texture. In the results, the texture attached to the center of the device achieved the best results of accuracy.

Keywords: eyes-free interaction, single-handed interaction, touch screen.

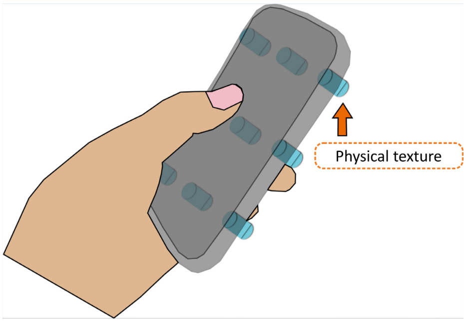

Fig. 1. Mobile device with physical texture attached on the back

1 Introduction

Many mobile devices have touch screens for input. However, poor tactile feedback from those touch screens requires user's visual attention when touching GUI elements [1]. Therefore, eyes-free input on touch screens is difficult.

Despite this difficulty, there are some situations where users do want to use their mobile devices in eyes-free [2]. For example, users must reply to messages they receive while talking with others, whereas such overtly use of mobile devices is socially inappropriate.

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In this research, our aim is to improve eyes-free and single-handed input accuracy on mobile devices. We focus on single-handed input because the vast majority of users want single-handed interaction with mobile devices [3,4].

To this end, our idea is to attach textures to the back of the devices. These are touched by users' fingers and palm (Figure 1), thus giving tactile feedback to users. Therefore, input accuracy could be improved in the same way as raised dots or bars on home position keys of ASCII keyboards. Moreover, since a texture can be implemented as a phone case, the implementation would be very simple and low cost.

To explore how the pointing accuracy is improved by the textures attached to the back of mobile devices, we first prepared mobile devices with no texture and three kinds of textures. Then, we evaluated pointing accuracy by a user study.

The findings of this research is that on the mobile device with touch screens used in this study, which is generally used, if one bead is attached to the center of the mobile device's back, users can point the screen accurately in eyes-free under the condition where the screen is divided into a 3 $\times$ 3 grid.

2 Related Work

Our research builds on the following two areas of prior work: tactile feedback on touch screens of mobile devices and eyes-free input in a mobile environment.

2.1 Tactile Feedback on Touch Screens of Mobile Devices

Some researchers have tried to add tactile feedback to touch screens of mobile devices. Active Click [5] attached actuators to mobile devices to provide click-feeling to users. Similarly, TouchEngine [6] and Ambient Touch [7] attached actuators that can change the frequency of vibration. Therefore, they can provide various types of click-feeling to users. Fukumoto [8] attached transparent urethane soft-gel films to touch screen's surface to provide button-pushing feeling to users. Yu et al. [9] attached buttons made of conductive rubber to the edges of touch screens to provide button-pushing feeling to users and to reduce finger occlusion.

These researches attached physical textures to mobile devices to provide the feeling of operation to users. In contrast, we attached physical textures to mobile devices to improve users' input accuracy.

2.2 Eyes-Free Input in a Mobile Environment

Some researchers have proposed eyes-free input systems in a mobile environment. PocketTouch [10] enables eyes-free multi-touch input with a capacitive touchscreen on the back of a smartphone detecting finger-strokes through fabric, allowing users to input without taking the device out of their pocket. However, PocketTouch requires auxiliary hardware. Imaginary Phone [11] enables users to operate mobile devices in eyes-free by gesturing on their palm in the same way as gesture on the mobile devices. By leveraging spatial memory of their mobile devices, users can operate mobile devices even in eyes-free. In this system, users can utilize existing input methods they normally use. However, Imaginary Phone also requires auxiliary hardware. Jain et al. [12] proposed a bezel-based text input system with high accuracy in eyes-free. However, users must learn a new input method.

In contrast, our approach is only to attach textures to the back of the devices. Therefore, it does not cost much and is widely applicable to existing input methods.

3 Evaluation

We conducted a user study to evaluate pointing accuracy using mobile devices in four cases with different textures.

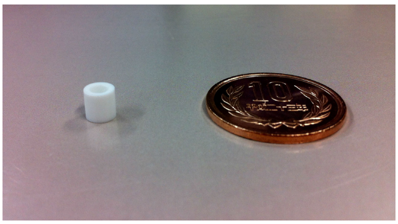

Fig. 2. White cylindrical bead

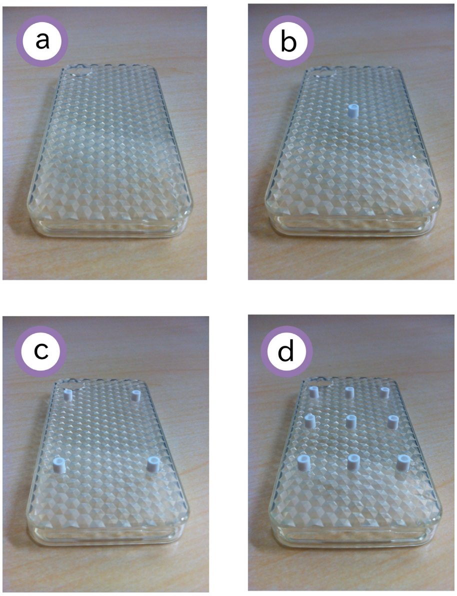

Fig. 3. Texture conditions: a) non-texture, b) center texture, c) corners texture, and d) latticed texture

3.1 Participants

12 participants (11 male and 1 female) ranging in age from 21 to 24 ($mean = 22.3$, $SD = 0.94$) took part in the experiment as a volunteer. They had used mobile

devices with touch screens from 0 to 36 months ($mean = 17.8$, $SD = 11.6$). All participants were right-handed.

3.2 Apparatus

We attached white cylindrical beads shown in Figure 2 (5 mm in diameter and 5 mm in height) to mobile device case (Apple iPhone 4S, which a 3.5-inch screen). We prepared the following four kinds of mobile device's cases, each of which has a different texture condition:

Non-texture (Figure 3a)
We attached nothing to the mobile device case.

Center texture (Figure 3b)
We attached one bead to the center of the mobile device case.

Corners texture (Figure 3c)
We attached four beads to the corners of the mobile device case.

Latticed texture (Figure 3d)
We attached nine beads to the mobile device case in a latticed pattern.

3.3 Procedure

We located a laptop computer on a desk (Apple MacBook Pro, which has a 13-inch screen). We asked the participants to sit down on a chair and hold a mobile device with single hand (Figure 4). We also asked the participants to place the hand holding the mobile device under the desk so as not to look at the mobile device's screen and to look at the laptop's screen.

The mobile device's screen which is split into a 2×2, 3×3, 4×4, or 5×5 grid (split conditions) was mirrored on the laptop's screen (Figure 5), and a gray rectangle (hereafter target) was shown in one of the grids. We asked the participants to point (i.e., tap) the corresponding position on the mobile device's screen as accurately as possible.

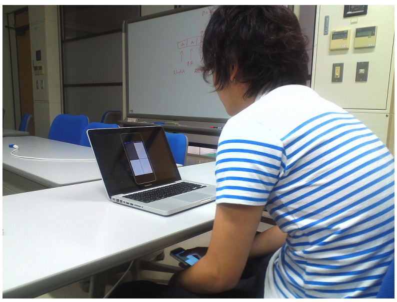

Fig. 4. Experiment environment

Fig. 5. Example of target shown on laptop

Figure 6 shows the relationship between split conditions and texture conditions. In this figure, shows a texture of center texture condition, shows textures of corners texture condition, and shows latticed texture condition. Under the split condition and texture condition, the participants carried out the task in accordance to the following procedure:

1. The participant taps any position of the mobile device's screen, a task starts, and a target is shown on the laptop by mirroring as shown in Figure 5.
2. The participant points the corresponding position on the mobile device's screen.
3. Regardless of the success or failure of the pointing, a beep is played to promote the participant to perform the next trial, and the next target is shown. (Split condition and target position were changed in a randomized order.)
4. The participant takes a break after 100 trials (25 trials $\times$ 4 split condition $=$ 100 trials).

Each participant carried out this task four times in each texture condition (presentation order of the four texture conditions was counterbalanced) and completed all four tasks in approximately 30 minutes.

After completing the task, each participant answered a questionnaire about his/her impressions of the four texture conditions.

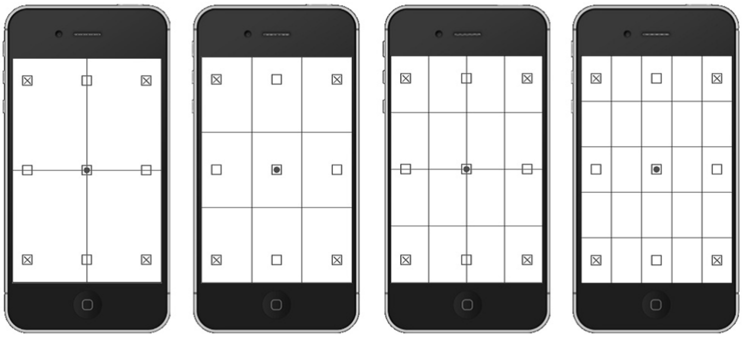

Fig. 6. Relationship between split conditions and texture conditions

3.4 Questionnaire

Participants said which of the four texture conditions were easiest and hardest to input and gave a reason for both choices.

4 Results

4.1 Results of Measurement

Figure 7 shows pointing accuracy per texture condition. One-way repeated measures ANOVA shows no significant difference among texture conditions. Post-hoc analysis with Bonferroni correction shows marginally significant difference between non-texture condition and center texture condition (p = .089).

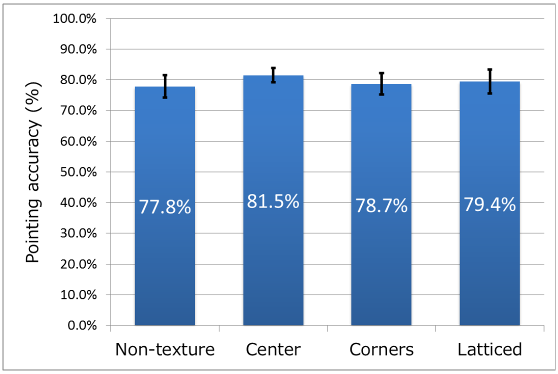

Fig. 7. Pointing accuracy per texture condition

Figure 8 shows pointing accuracy per texture condition in each split condition. In each split condition, we conducted a one-way repeated measures ANOVA. In the 3 × 3 split condition, there was significant difference among texture conditions ($F_{3,33}$ = 4.964 p = .006 < .05). In contrast, there was no significant difference in other three split conditions. To analyze these further, we conducted a post-hoc analysis with Bonferroni correction in each split condition. In pairwise comparisons, in the 3 × 3 split condition, accuracy in center texture condition was significantly higher than those in the other three conditions (p < .05). In the 4 × 4 split condition, accuracy in latticed texture condition was marginally significantly higher than that in non-texture condition (p = .050).

4.2 Results of Questionnaire

As shown in Table 1, center texture condition received the most votes for "easiest to input" (5 participants). Non-texture condition received the most votes for "hardest to input" (7 participants). Latticed texture condition was the only one to receive votes for both "easiest to input" (3 participants) and "hardest to input" (5 participants).

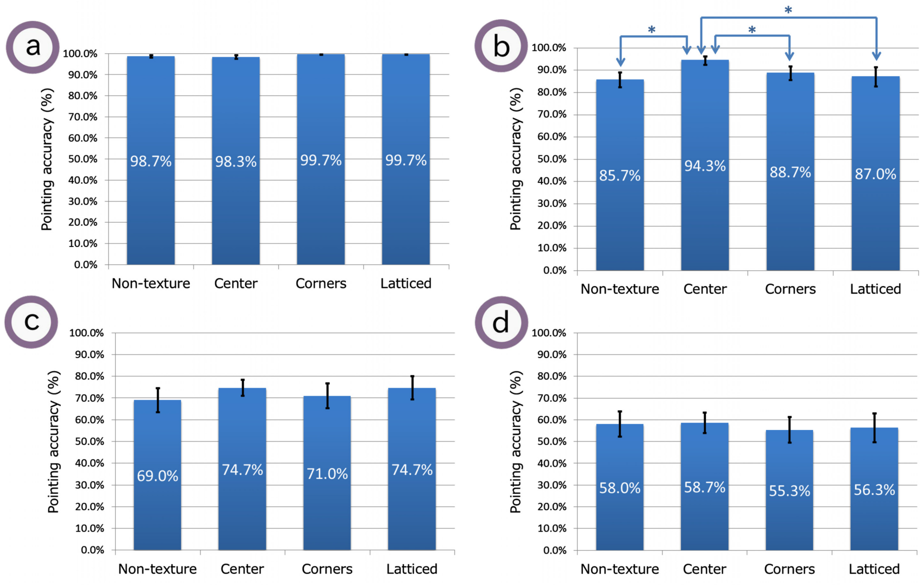

Fig. 8. Pointing accuracy per texture condition: split condition is a) 2 × 2, b) 3 × 3, c) 4 × 4, d) 5 × 5

Table 1. Results of questionnaire [participants]

	Texture condition			
	Non-texture	Center texture	Corners texture	Latticed texture
Easiest to input	0	5	4	3
Hardest to input	7	0	0	5

5 Discussion

In this experiment, the best results of accuracy in three split conditions (3 × 3, 4 × 4, 5 × 5) were achieved in center texture condition. In addition, in the questionnaire, center texture condition received the most votes for "easiest to input" (5 participants).

In the 2 × 2 split condition, pointing accuracy was above 98% in every texture condition. This suggests that even in eyes-free users can accurately touch buttons whose layout is like that in the 2 × 2 split condition.

In the 3 × 3 split condition, pointing accuracy was 94.3% in center texture condition. In addition, accuracy in center texture condition was significantly higher than those in the other three texture conditions. This suggests that even in eyes-free users can accurately touch buttons whose layout is like that in the 3 × 3 split condition by using a texture attached to the center of device as a clue.

In the questionnaire, there were the following comments about latticed condition, which we had assumed would be the most accurate before this experiment:

- "I was confused and did not know which texture to touch as a clue because there were too many textures." (2 participants)
- "I felt uncomfortable when touching textures." (2 participants)
- "I could not touch all textures." (1 participant)

This suggests that too many textures can confuse users and stop accuracy improving.

On the other hand, there were the following positive comments about latticed condition:

- "It was easy to grip the mobile devices because I could hitch my fingers to textures." (1 participant)
- "I think I could touch intended positions by touching the texture with one finger and touching the target with another finger." (1 participant)

As shown these comments, some participants felt that they could utilize latticed textures well. In the questionnaire, 3 participants voted latticed condition as "easiest to input". On the other hand, 5 participants voted latticed condition as "hardest to input".

There were the following comments about the size and hardness of the texture in the questionnaire:

- "I would like to try a softer texture." (1 participant)
- "I am curious about the results in using textures of various hardnesses." (1 participant)
- "The texture was too large to use normally" (1 participant)

In this experiment, we used large and hard textures to emphasize the influence of the textures. We need to reconsider the form, size, and hardness of texture in accordance with the comments.

6 Conclusion and Future Work

We evaluated eyes-free and single-handed pointing accuracy by using mobile devices that had different textures attached. Specifically, we prepared four kinds of mobile device cases that had different texture conditions (non-texture, center texture, corners texture, and latticed texture). By using the mobile devices with the four kinds of cases, we evaluated eyes-free and single-handed pointing accuracy under four kinds of split conditions (2×2, 3×3, 4×4, and 5×5). As a result, we found that in the 2×2 split condition, pointing accuracy was above 98% in every texture condition. This suggests that even in eyes-free users can accurately touch buttons whose layout is like that in the 2×2 split condition. In addition, we found that in the 3×3 split condition, the texture attached to the center of the device resulted in 94.3% pointing accuracy, which is significantly higher than those for the other three kinds of textures. This suggests that even in eyes-free users can accurately touch buttons whose layout is like that in the 3×3 split condition by using the texture attached to the center of the device.

On the other hand, in a questionnaire, some participants said that they were confused when there were too many textures. This might decrease accuracy.

For the future, we plan to evaluate textures of various forms, sizes, and hardnesses. Specifically, we plan to evaluate some softer textures. In addition, we plan to evaluate the learning effects of textures.

References

1. Yatani, K., Truong, K.N.: Semfeel: a user interface with semantic tactile feedback for mobile touch-screen devices. In: Proceedings of the 22nd Annual ACM Symposium on User Interface Software and Technology, UIST 2009, pp. 111–120. ACM, New York (2009)
2. Yi, B., Cao, X., Fjeld, M., Zhao, S.: Exploring user motivations for eyes-free interaction on mobile devices. In: Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems, CHI 2012, pp. 2789–2792. ACM, New York (2012)
3. Karlson, A.K., Bederson, B.B.: Understanding single-handed mobile device interaction. Technical report, Department of Computer Science, University of Maryland (2006)
4. Parhi, P., Karlson, A.K., Bederson, B.B.: Target size study for one-handed thumb use on small touchscreen devices. In: Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services, MobileHCI 2006, pp. 203–210. ACM, New York (2006)
5. Fukumoto, M., Sugimura, T.: Active click: tactile feedback for touch panels. In: CHI 2001 Extended Abstracts on Human Factors in Computing Systems, CHI EA 2001, pp. 121–122. ACM, New York (2001)
6. Poupyrev, I., Rekimoto, J., Maruyama, S.: Touchengine: a tactile display for handheld devices. In: CHI 2002 Extended Abstracts on Human Factors in Computing Systems, CHI EA 2002, pp. 644–645. ACM, New York (2002)
7. Poupyrev, I., Maruyama, S., Rekimoto, J.: Ambient touch: designing tactile interfaces for handheld devices. In: Proceedings of the 15th Annual ACM Symposium on User Interface Software and Technology, UIST 2002, pp. 51–60. ACM, New York (2002)
8. Fukumoto, M.: Puyosheet and puyodots: simple techniques for adding "button-push" feeling to touch panels. In: CHI 2009 Extended Abstracts on Human Factors in Computing Systems, CHI EA 2009, pp. 3925–3930. ACM, New York (2009)
9. Yu, N.H., Tsai, S.S., Hsiao, I.C., Tsai, D.J., Lee, M.H., Chen, M.Y., Hung, Y.P.: Clip-on gadgets: expanding multi-touch interaction area with unpowered tactile controls. In: Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, UIST 2011, pp. 367–372. ACM, New York (2011)
10. Saponas, T.S., Harrison, C., Benko, H.: Pockettouch: through-fabric capacitive touch input. In: Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, UIST 2011, pp. 303–308. ACM, New York (2011)
11. Gustafson, S., Holz, C., Baudisch, P.: Imaginary phone: learning imaginary interfaces by transferring spatial memory from a familiar device. In: Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, UIST 2011, pp. 283–292. ACM, New York (2011)
12. Jain, M., Balakrishnan, R.: User learning and performance with bezel menus. In: Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems, CHI 2012, pp. 2221–2230. ACM, New York (2012)