World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:4, No:5, 2010

Enhancing Human-Computer Interaction and Feedback in Touchscreen Icon

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Abstract**—**In order to enhance the usability of the human computer interface (HCI) on the touchscreen, this study explored the optimal tactile depth and effect of visual cues on the user's tendency to touch the touchscreen icons. The experimental program was designed on the touchscreen in this study. Results indicated that the ratio of the icon size to the tactile depth was 1:0.106. There were significant effects of experienced users and novices on the tactile feedback depth ($p < 0.01$). In addition, the results proved that the visual cues provided a feedback that helped to guide the user's touch icons accurately and increased the capture efficiency for a tactile recognition field. This tactile recognition field was 18.6 mm in length. There was consistency between the experienced users and novices under the visual cue effects. Finally, the study developed an applied design with touch feedback for touchscreen icons.

Keywords**—**HCI; Touchscreen icon; Touch feedback; Optimal tactile depth; Visual cues.

I. INTRODUCTION

TOUCHSCREENS have enabled the development of many applications [15]. Touchscreens are not only used in public information systems such as information kiosks and ticketing machines but also in personal consumer products such as iPhones. Additionally, touchscreens are replacing conventional buttons because of their intuitive operations, software flexibility, and space and cost savings [6]. Therefore, the applications of touchscreens have now become popular in electronic products.

The technology of a touchscreen interface has many additional advantages , including a direct control interface and no extra input control device or space. It may also reduce some problems of the human computer interface (HCI), such as compatibility between hard devices and functions. However, the interface of a touchscreen causes new HCI problems such as usability or feedback on the touchscreen.

In particular, Levin [6] indicated that the interface on the touchscreen strongly requires tactile feedback effects because the lack of tactile feedback has caused serious impediments to the conversion from mechanical switches to digital controls. Therefore, in order to improve the technology of touchscreen devices, the most important issue is to investigate the user's interaction on touch interfaces.

In general, the touch pen offers a choice to touch the objects on the touchscreen. Many studies have investigated the related ergonomic issue in the case of the touch pen [7]. However, the touch pen may tire the user's arms and their hands could obscure a part of the screen. In addition, the pen is very fragile for use in public access environments [19]. Instead, the finger is the most direct control tool. Shneiderman [18] has pointed out that users can make direct control touch on the touchscreen using a finger. The ability to direct-control touch and manipulate the data on the screen without using any intermediate devices has appealed strongly to the users [1]. Therefore, using fingers to touch or control the interface on the touchscreen is the best choice. On the other hand, the touchscreen icon is an object that can be touched most directly during the process of interaction on touchscreen. Good feedback for a touchscreen icon can avoid users can not feel it press down and enable users to know the system has already captured their touching.

Some relevant researches have provided some suggestions such as the target size (touched objects), key size (tactual recognition field), accuracy of touch, and performance of touchscreen keyboards. For example, Parhi et al. [11] have found that a target size of 9.2–9.6 mm should be sufficiently large for the touch task to be used on small touchscreen devices. Colle and Hiszem [3] have indicated that users prefer a key size of 20 mm2 (key size is the size of the tactual recognition field and not the size of the visually displayed key) in public information kiosks. In order to increase the precision on the touchscreen, Albinsson and Zhai [2003] have proposed two techniques (Precision-Handle and Cross-Keys), which complement the existing techniques for touchscreen interaction. Sears et al. [17] have investigated the effect of the keyboard size on the touchscreen typing speed. The results indicated that very small touchscreen keyboards are used for limited data entry. Besides, there was the difference between novices and experienced users on typing performance. Novices can type approximately 10 words per minute (WPM) on the smallest keyboard and 20 WPM on the largest. Experienced users have speeds of 21 and 32 WPM on the smallest and largest keyboards, respectively. Sears [15] compared with touchscreen keyboard, mouse, and normal keyboard on typing performances. The results indicate that users can type approximately 25 WPM using the touchscreen keyboard while they can type 17 WPM using the mouse, and 58 WPM using the keyboard. To summarize above studies, they have proposed

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basic interface frames for touchscreen. However, a few recent studies deeply investigated how to improve user's feedback in touchscreen.

For touchscreens, special care has to be taken to give the user clear feedback and a clear indication of the effect of their input. In addition, Lansdale and Ormerod [5] have indicated that the efficient use of feedback in an interface must attract the user's attention and reinforce the user's behavior. However, these suggestions for obtaining interface feedback on the touchscreen are usually conceptual statements and do not help in effectively designing a system for obtaining discernible feedback.

Based on the above descriptions, it is necessary to pay attention to the usability and feedback in the face of more applications on touchscreen. Regarding the touchscreen interface, the first challenge is how to reinforce the user's control behaviors and improve tactile feedback. In addition to solving the main problem of lack of confirmation, tactile feedback helps in avoiding errors and the disappointment of the users [6]. Therefore, this study investigated the user's preference for feedback, including the optimal tactile feedback depth and the effect of visual cues for touch behaviors on touchscreen icons by the experimental design of psychophysics. The purpose of this study was to improve touch feedback and increase the usability of touchscreen icons. The findings could serve as a guide to design a touch feedback system appropriate for touchscreen icons and improve the usability of the HCI on the touchscreen.

II. METHODS

A method of adjustment was executed in this study. In psychophysics, the method of adjustment required the subjects to control the level of stimulus by instructing them to adjust it until it was just detectable and at an optimal level [Scharf et al., 1975; Laming, 1997]. The experiment was divided into two phases. After adjusting the level to the optimal tactile feedback depth of touchscreen icons, the subjects performed a visual cue test on the touchscreen. User's coordinate values of touch location were collected by computer program.

A. *Subjects*

A total of 15 females and 15 males (paid volunteers) participated in this experiment. Their age was between 22 and 32 years (mean = 25.5., SD = 2.66). These subjects included 15 novices and 15 experienced users (familiar with touchscreens). All the subjects were right-handed.

B. *Materials & Stimuli*

The stimuli in this experiment consisted of an adjustable depth for icons and a visual cue (blue region) on touchscreen icons. In addition to the subject's experience and gender, the main independent variables included depth level of touchscreen icon and type of visual cue. There were three levels in the type of visual cue, including no cue (control group), the top left part of the cue on the touchscreen icon (center coordinates of the blue region (XTL: 501, YTL: 371)), and the bottom right part of the cue (XBR: 528, YBR: 391). Fig. 1 shows the location of the visual cue on the touchscreen icons used in experiments. The optimal tactile depth and the preferable location on the visual cue effect were the dependent variables.

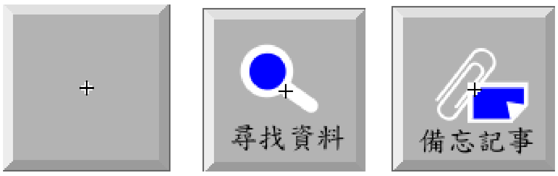


Fig. 1 Design of visual cues (blue region) on touchscreen icons. (a) No cues, control group; (b) TL, the Chinese characters mean "Search"; and (c) BR, the Chinese characters mean "Memo"

All touchscreen icons used had a size of 100 × 100 pixels and were set at a resolution of 1024 × 768 pixels. The icons were disposed on the center of the touchscreen. Because the experimental program was designed using Visual Basic, the coordinate system was the same as the graphics coordinates system (i.e., the original coordinates on left top was (0, 0) and center coordinates were (512, 384)). Fig. 2 shows the related coordinates of touchscreen icons in the experiment layout. All the materials were presented on a 3M touchscreen system (LCD/MD17-5MS). The other specifications were as follows: LCD display size of 337.92 mm × 270.34 mm, contrast ratio of 450:1, brightness of 260 cd/m2, and response time of 16 ms.

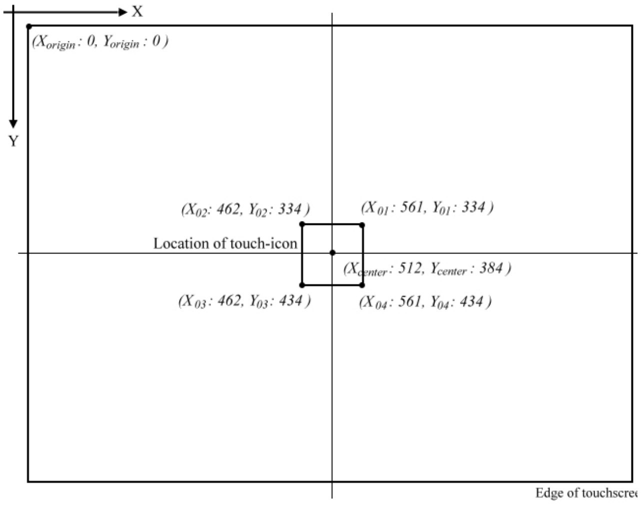


Fig. 2 Related coordinates of icon in the experiment layout

C. *Procedures*

Prior to this experiment, the subjects were briefed on the rules and purpose of the experiment and were asked to provide their personal details. The experiment was divided into two test phases. First, the subjects adjusted the tactile feedback depth of the touchscreen icons by using the up/down buttons on the keyboard. The touchscreen icons were adjusted from flatness statement (i.e., depth value = 0 pixel) and were increased/decreased by 1 pixel with each click on the "up/down" button. In this process of adjustment, the subjects could touch the icon and feel its feedback until they found out the tactile feedback was significant. In the second test, the subjects touched different locations of the visual cue on the touchscreen icons. The depth value and touch location were recorded by a program automatically. This experiment was performed in the ergonomic lab at the university. All the subjects were tested under the same conditions with an average luminance of 700 Lx. Each subject completed the experiment in approximately 3 min. Figure 3 shows the experimental conditions

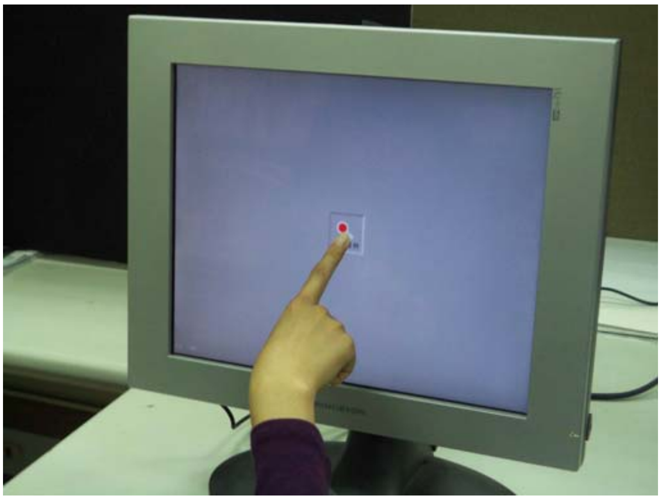


Fig. 3 Experimental conditions in this study

D. Data analysis

The main statistical analyses in this study were frequency statistics, analyses of variance (ANOVAs), and the Duncan test. All the calculations were made using the SPSS software.

III. RESULTS

A. Difference in tactile depth

The results of descriptive statistics show that the mean tactile feedback depth of 30 subjects was 8.83 pixels (SD = 3.73). However, the subjects' experiences showed significant differences in the tactile depth (F (1, 28) = 8.44, p < 0.01). The boxplot shows the depth performances of the subjects with different experiences (Fig. 4). The mean depth of the experienced users and novices were 7.07 pixels (SD = 2.22) and 10.6 pixels (SD = 4.15), respectively. Fig. 5 shows the difference between the tactile depth of the experienced users and novices on the tactile depth of touchscreen icons.

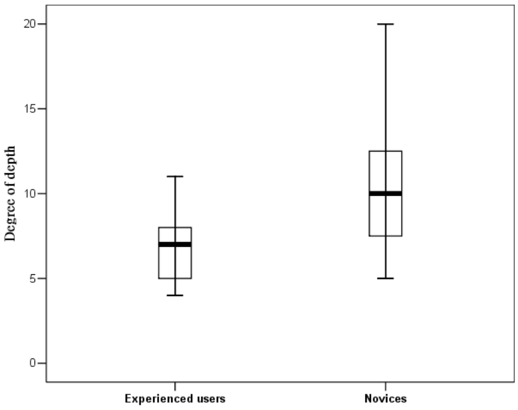
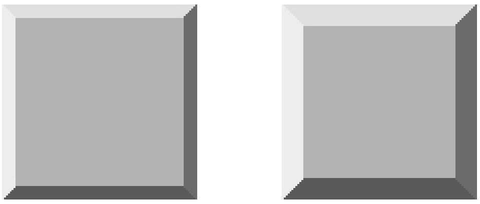


Fig. 4 Depth performance of subjects with different experiences

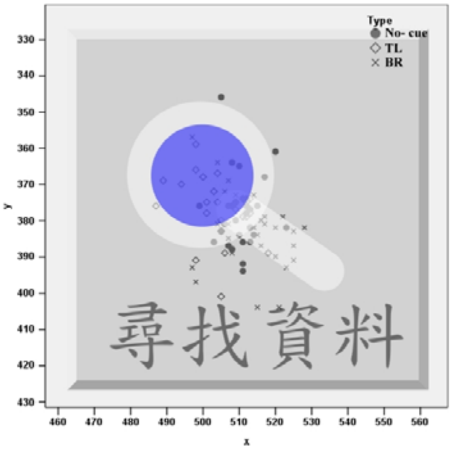


(a) (b)

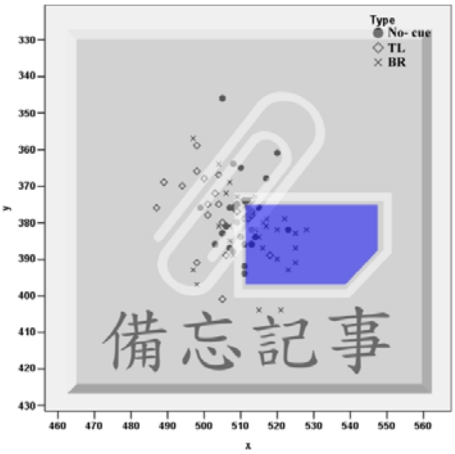
Fig. 5 Differences in tactile depth. (a) Experienced users. (b) Novices

B. Distribution of touched locations

In the case of no visual cue, the mean coordinates of all the subjects were (510.5, 386.0). These coordinates were almost the same as those of the center of the touchscreen icons. Fig. 6 shows the effect of different visual cues on the distribution of the subject's touch (coordinate location of subject's finger on the touchscreen icon). In the case of the TL cue, the mean coordinates of the subjects were (504.7, 384.2). The distributions of the subjects' touch deflect to the top left. These touch marks are shown in Fig. 6a. On the other hand, in the case of the BR cue, the mean coordinates of the subjects were (513.3, 391.0). These touch marks deflect to the bottom right (Fig 6b). All the subjects do not touch the region of the ideogram (guide of words on touchscreen icons).



(a)



(b)

Fig. 6 Touch marks of subjects on different locations of the visual cue

C. *Effects of visual cue*

The results of ANOVA analysis presented three types of visual cues that have significant effects on the mean coordinates (x-coordinate: F (2, 58) = 13.29, $p < 0.01$; y-coordinate: F (2, 58) = 4.88, $p <= 0.01$)). This result showed that the visual cue influenced the location touched by the subject, i.e., the subjects attempt to touch the blue region on the touchscreen icon. The x and y coordinates of different visual cues were further analyzed using Duncan's multiple comparison tests (Table 1). The results of the Duncan test showed that these cues are different on the x-coordinates ((BR, No cue) > TL) and y-coordinates (BR> (No cue, TL)). Moreover, the touch of most subjects tended to move toward the center when there were no cues on the touchscreen icon. This field of touch had sizes of 53 × 53 pixels.

TABLE I RESULTS OF DUNCAN TESTS ON THE COORDINATES OF VISUAL CUE UNDER EACH VARIABLE

Coordinates	Type of visual cue (***n*** = 90)		
	No cue	**TL**	**BR**
x	510.5 (-1.5)	504.7 (-7.3)	513.3 (+1.3)
Duncan grouping		▬	
	▬		▬
y	386.0 (+2.0)	384.2 (+0.2)	391.0 (+7.0)
Duncan grouping			▬
	▬	▬	

D. *Preference of touch with subjects' experiences*

For the design of the visual cues on the touchscreen icons, there were no significant differences in the touched location between the experienced users and the novices on the touched location [No cue (x: F (1, 28) = 1.09, $p > 0.01$; y: F (1, 28) = 0.27, $p > 0.01$). TL (x: F (1, 28) = 0.38, $p > 0.01$; y: F (1, 28) = 0.09, $p > 0.01$). BR (x: F (1, 28) = 4.16, $p > 0.05$; y: F (1, 28) = 0.83, $p > 0.01$)]. This result showed that there was consistency between the two types of experiences, i.e., all subjects will touch toward region of visual cue. Fig. 7 shows the change in the touched location on the three types of cues for subjects with different experience levels.

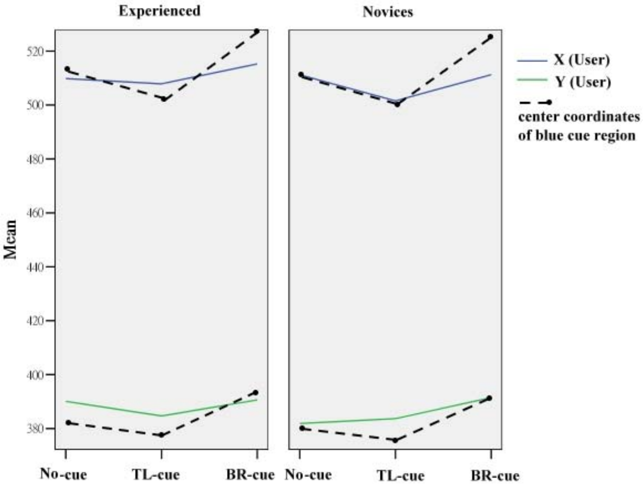


Fig.7 Comparison between experienced and novice subjects with regard to change in x and y coordinates

IV. DISCUSSION

In the direct control interface, the visual presentation of the objects should provide a convenient feedback environment for showing changes explicitly [19]. In this study, all the subjects considered that the touchscreen icon provided depth was better than the flatness on the presentation of tactile feedback. Moreover, the novices prefer deep and significant tactile feedback; however, the experienced users prefer less depth. Due to novices were so unfamiliar with touchscreen that they need more strong feedback to prompt present condition. Relatively, the experienced users knew the characteristics of the touchscreen and have even used a PDA in their lives. Hence, they accepted fewer changes in the feedback.

In the case of the subjects' experiences, some studies have indicated that the users' experiences were usually affected by a difference in the operational behaviors of the computer interface [2; 8; 17]. In particular, Sears et al. [17] have indicated that the experienced user's typing performance is better than that of a novice on various size levels of touchscreen keyboards. They have also suggested the importance of the experience of using touchscreen keyboards. Therefore, the difference in the levels of experience was a key in developing the human-computer interface.

On the other hand, this phenomenon also showed that novices needed stronger tactile feedback in order to satisfy their expectancy in touch icons. Shneiderman and Plaisant [19] have indicated that the user's expectations played an important role in the interface design. In order to avoid situations in which users may become frustrated and make mistakes or discontinue working, some details of the interface must be in accordance with the user's expectations. Similarly, touchscreen icon should provide satisfied expectations for tactile depth when user touched it.

In the tactile depth feedback phase, the novice's results offered a wider and safer range for tactile depth value. Sanders and McCormick [1993] have indicated that designing for a maximum population value is the appropriate strategy if the given maximum value of a design feature should accommodate all the people. Thus, this study chose the design for maximum individuals on the practical touchscreen icon design. The depth value of the novices was the optimal tactile depth that could satisfy the needs of different experienced users (novices and experienced users). It is also considered that a main characteristic of touchscreens was used in the public environment. According to the results of the experiments, the rate of the tactile depth was 1:0.106 (100:10.6 pixels) on the touched icon. For example, an interface designer should design the tactile depth of 7.95 pixels if the total size of the touchscreen icon is 75 × 75 pixels.

Marcus [9] has indicated that computer icons should be receptive to a click. However, when icons are ignored or cannot accurately capture the user's touch, their usability decreases. At the same time, users feel frustrated, which interrupts the feedback. Additionally, Levin [6] has pointed out that when using a device with tactile feedback is used, the apposite cue helps the users to touch correctly and alerts them for ones they did not intend. Here, the visual cues are designed on the touchscreen icon that guided the users to touch and reinforce their interface behaviors. Evidently, this function of guide is demonstrated in this study. Under the condition of the visual cue, we find that most users' touch marks of field became more converge at blue cue region. Therefore, we could correct some defects where the users touch haphazardly or do not touch the appropriate location by visual cue design. Some studies indicate that larger key sizes are better [10; Wilson et al. 1995]. The key size with a size of the tactile recognition field and not the size of the visually displayed key [3]. However, by visual cue design, the key size could become smaller and more accurate, thereby increasing the touch efficiency. Therefore, the key size of touchscreen icon consists not in large, but in sensitive, detectable, efficient and usable, such as sweet spot (The term originally referred to various parts of sporting equipment, particularly tennis. Tennis racket's sweet spot is the most optimum hitting area). In order to avoid touching near the icons imprudently, the location of the cue should not be far away from the icon center. The optimal design lets users to touch the center location of icons efficiently and not its corner.

Additionally, most subjects' touch mark of distribution field is 53 × 53 pixels in the experiment. Under the standard resolution of the screen (72 dpi), we convert 53 × 53 pixels into a value in millimeters and obtain 18.6 mm. This value coincides with that suggested by Colle and Hiszem [3]. They consider that 10 mm, 15 mm, or smaller key sizes would not be recommended. A key size of 17–20 mm is an appropriate tactile recognition field on touchscreens.

In summary, this study was concluded to design touchscreen icons with feedback. Figure 8 shows an example of an icon with an optimal tactile depth and location of visual cues.

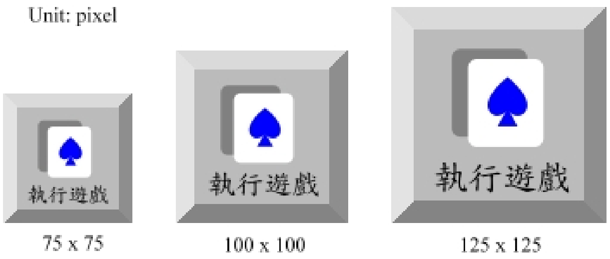


Fig. 8 Various proportions of touchscreen icon with feedback design (the Chinese characters from the English word "Game")

V. CONCLUSIONS

Appropriate feedback could improve the usability of an interface. However, the related issues generally illustrated the feedback concepts that have no guidelines of practical values, particularly in the touchscreen. This study established some guidelines for touchscreen icon design. These results could help in investigating the feedback issues of touchscreens and reduce the indefinite concepts of feedback. A study was also conducted on more user's tactile recognition behaviors on touchscreens.

ACKNOWLEDGMENT

This study was partially supported by the National Science Council of Taiwan, R.O.C. under Grant no 98-2218-E-218 -003 NSC.

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