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Effect of control-to-display gain and movement direction of information spaces on the usability of navigation on small touch-screen interfaces using tap-n-drag

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ABSTRACT

Tap-n-drag is a popular navigation method for small touch-screen interfaces. When an information space is too large compared to the touch-screen size, navigating the information space using tap-n-drag requires too many drags, resulting in poor usability such as long navigation time or fatigue. In this study, the effect of control-to-display gain on the usability of tap-n-drag was experimentally investigated to determine whether increasing the control-to-display gain can resolve this problem. The effect of movement direction of the information space relative to the drag direction was also investigated (push background vs. push viewport). In experiments, increasing control-to-display gain seemed to increase the usability of tap-n-drag, but excessively large gain seemed to have the opposite effect on some measures such as task completion time, ease of use and overall preference; as a result these measures-vs.-GAIN curves were U-shaped or inverted-U-shaped. Overall, both task completion time and number of touches required to locate a target were lower when using push viewport than when using push background, except at GAIN = 1.

Relevance to industry: The results of this study can be used to enhance the usability of tap-n-drag and other navigation methods in small touch-screen devices when users navigate a large information space.

1. Introduction

1.1. Backgrounds

Facilitating completion of basic tasks in small touch-screen interfaces has been an important goal in Human-computer interface research. Navigation[1] is an important basic task on small screen devices because the size of the information space is frequently much larger than the screen size, so only a small portion of the entire information space is shown on the screen. For example, on a screen with a resolution of 320 × 240 pixel can present only about 1/11 and 1/17 of the total information when the sizes of the information space are 1024 × 768 pixel and 1280 × 1024 pixel, respectively (Gutwin and Fedak, 2004). In this case, navigating the entire information space is not an easy task. Zooming out the information space presents a larger portion of the information space and the navigation task requires less effort, but the size of the information such as text or image might become too small, thus causing problems in perceptibility or readability (Chung et al., 2011). Therefore, a variety of navigation methods on small touch-screen interfaces have been developed (Dearman et al., 2005; Jones et al., 2005; Burigat et al., 2007).

Two representative navigation methods used in commercialized mobile devices are ‘flick’ and ‘tap-n-drag’. Navigating an information space using flick on a mobile device is analogous to throwing a sheet of paper on a flat surface while only a part of the paper is seen through a small window. Researchers have proposed that flick is an intuitive and natural method for shifting content within a viewing window (Geiβler, 1998; Reetz et al., 2006) and a compelling interaction method for navigating information spaces (Aliakseyeu et al., 2008). However, as flicking speed increases, visual feedback from the screen becomes a smooth or blurred transition from one part of the information space to another (Aliakseyeu et al., 2008), which makes the users may not perceive that their target has appeared on the screen and may miss its location in the information space. To reduce the effect of smoothing or blurring, the information space can be zoomed out when scrolling speeds are high (Igarashi and Hinckley, 2000).

‘Tap-n-drag’ is similar to ‘flick’ except that tap-n-drag ‘drags’ the information space while flicking ‘throws’ the information space. The user taps the touch-screen first, and keeps his or her finger tip

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[1] In this study, the term ‘navigation’ is defined as moving information spaces to make the desired targets appear in a screen. Similar terms are ‘scrolling’ (especially in one-dimensional movements of information spaces) or panning.

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or stylus in contact with the screen. Next, if the user drags the finger tip or stylus on the touch-screen, the information space is dragged along the movement trajectory of the finger tip or stylus. This is a very intuitive method and is widely used for navigation, alone or in combination with flicking, in many commercially available mobile devices. In tap-n-drag, the movement trajectory of the information space is identical to that of the finger tip or stylus. Therefore, if the information space is too large compared to the touch-screen, as often occurs on mobile devices, the user must perform frequent and continuous drags, which are tedious and which reduce the usability of tap-n-drag (Mackey et al., 2005; Burigat et al., 2007).

1.2. Effects of control-to-display gain

We speculated that the need to perform frequent and continuous drags can be resolved by applying the concept of control-to-display gain (GAIN) to tap-n-drag. GAIN can be expressed as the ratio of the distance traveled by pointer (such as cursor) to the distance traveled by device (such as mouse) or as the ratio of the pointer velocity to the device velocity (McCormik, 1976). At lower GAIN the device movement needs to be longer for the same amount of pointer movement than when GAIN is high, and the area available for device movements may become scarce. In this case, to navigate long distances, the user may need to reposition the device frequently without affecting the position of pointers (Casiez et al., 2008). To solve this problem one may increase GAIN, to make the pointer travel farther for the same amount of device movement. However, if GAIN is too high, the pointer movement may be too sensitive to allow fine positional control; as a result, visual feedback may be poor.

Many studies have been conducted to explore the effect of GAIN on the usability (especially in task completion time) of pointing devices. However the effects of GAIN differ among studies. For joysticks, one study found that task completion time increased with GAIN in the range $0.15 \leq \text{GAIN} \leq 0.90$, (Gibbs, 1962) whereas another detected no effect of GAIN in the range $0.2 \leq \text{GAIN} \leq 2.0$ (Buck, 1980). For a mouse task, one study found that task completion time decreased with increased GAIN in the range $1 \leq \text{GAIN} \leq 3$ (Johnsgard, 1994), whereas another found that the curve for task completion time showed a U-shaped relationship to GAIN in the range $1 \leq \text{GAIN} \leq 32$, with the shortest completion time at $\text{GAIN} = 2$ (Jellinek and Card, 1990). U-shaped relationship was also observed for both a mouse and a head-controlled pointer with the shortest completion time at $1 \leq \text{GAIN} \leq 2$ and $0.3 \leq \text{GAIN} \leq 0.6$, respectively (Lin and Radwin, 1992). On a graphics tablet, the relationship of task completion time to GAIN in the range $1 \leq \text{GAIN} \leq 16$ was also observed to be U-shaped, with the shortest completion time at $2 \leq \text{GAIN} \leq 4$ (Accot and Zhai, 2001); the authors speculated that if GAIN is too large users cannot control their movements with sufficient precision, and that when GAIN is too small, the required movement may extend beyond the user's arm reach.

The concept of GAIN may easily be applied to tap-n-drag to resolve its requirement of numerous drags when users navigate large information spaces on small touch-screen devices. Device movement corresponds to the movement of a finger or stylus on the touch-screen surface and pointer movement corresponds to the movement of the information space. The GAIN of conventional tap-n-drag is set to 1 which means the information space moves exactly along the drag trajectory. If $\text{GAIN} > 1$, we expect that users can navigate large information spaces with shorter time. However, task completion time using tap-n-drag may increase if GAIN is too large, because the movement of the information space will be too sensitive due to the limits of human motor precision, and because the visual feedback may be significantly degraded due to the blurring or smoothing effects.

1.3. Push background and push viewport techniques

The usability of tap-n-drag varies according to the mechanism that determines the movement direction of the information space relative to the drag direction of a finger or stylus (DIRECTION) (Fig. 1). Two types of tap-n-drag are 'push background (PB)' and 'push viewport[2] (PV)'. In PB the information space moves in the same direction as the drag motion; this is analogous to dragging a sheet of paper on a flat desktop. In PV the information space moves in the direction opposite to the drag direction; this is analogous to moving a camera while seeing objects through the viewfinder. Johnson (1994) showed that PB was better than PV for both objective measures such as time and number of touches required to locate a target, and subjective preference. However, Johnson (1994) considered only horizontal movements, so this result does not guarantee that PB is better than PV for navigation on small touch-screen interfaces, in which users navigate in a variety of directions. In addition, Johnson (1994) considered $\text{GAIN} = 1$ only. In contrast Bury et al. (1982) showed that time and number of key-pressing required to locate a target using tap-n-drag were lower when using PV than when using PB. However, the input device was not a touch-screen interface but a keyboard. In this study, we experimentally investigate the effect of DIRECTION on the usability of tap-n-drag.

1.4. Objective of this study

In this study, the effects of GAIN and DIRECTION on the usability of tap-n-drag were experimentally investigated on small touch-screen devices. We mainly tested the following hypothesis: $\text{GAIN} > 1$ will improve the usability (mainly in terms of task completing time as was in the previous studies) of tap-n-drag. But, if GAIN is too large, the usability of tap-n-drag will decrease because of the limits to human motor precision. Overall, the usability curve of tap-n-drag according to increasing GAIN will be U-shaped.[3] In addition, overall usability of tap-n-drag will be better when using PB than when using PV.

2. Methods

2.1. Participants

Thirty right-handed undergraduate or graduate students (15 males and 15 females, mean age: 23.8 (s.d.: 2.0)) were recruited using an online bulletin board. No participants had previous experience of using tap-n-drag for navigation on small touch-screen devices. Participants were only accepted if their hand lengths and widths were within the 5th percentile to 95th percentile of Koreans in their 20s and 30s (SIZE KOREA, 2010) to avoid the unexpected effects of extreme hand sizes. No participants had problems reading text on the screen or had musculoskeletal disorders of their hands or arms. Each participant was paid $10 for participating.

2.2. Apparatus

The experiment was conducted on an iPAQ-hx2490b PDA that has a 3.5-inch touch-screen with a resolution of 320 × 240 pixels. The PDA is 119.4 mm (H) × 76.6 mm (W) × 16.3 mm (D) and weighs 164.4 g. A SONY SCR-SR 300 digital camcorder was used to record

[2] Johnson (1994) used the term 'push camera'. In this study, the term 'push viewport' was used instead to give readers a more generalized meaning.

[3] In this study, the term 'U-shaped' may be interpreted as 'inverted-U-shaped' according to the characteristics of usability measures.