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ABSTRACT
In this paper we present *Touch-n-Go*, a novel software-based interaction technique for navigating information on a handheld computer, particularly when users are mobile. Touch-n-go provides navigation in any direction at variable speeds. Direction and speed are determined by display interaction relative to the center of the screen. We introduce and discuss our implementation, and present the results of a user study which demonstrated that the touch-n-go technique is superior to scrollbars in terms of performance and preference, and is also easier to use than tap-and-drag.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. – interaction styles.

General terms: Performance, Design, Human Factors, Experimentation.

Keywords: Mobile devices, PDA, input, scrolling, navigating, evaluation.

INTRODUCTION
Mobile devices are a growing market with the ability to augment nearly every facet of our lives. They provide convenient access to information whether we are stationary or mobile. However, these devices are limited by their very nature: they are small, input is restricted, and they are often used when mobile. Given the difficulty of displaying large amounts of information on a small display, users must often navigate an information space that is significantly larger than the screen.

There has been a great deal of research conducted on developing novel interaction and navigation techniques for mobile devices. These navigation approaches can be categorized as either software-based or hardware-based. Software-based navigation techniques are internal to the application and are often adapted from traditional desktop techniques, such as scrollbars and tap-and-drag. Hardware-based navigation approaches are generally external to the application, such as buttons and movement sensors.

A key benefit of hardware-based approaches is that they enable one-handed navigation and selection. However, two-handed interaction (one to hold the device and one to interact) is preferred for some tasks since they allow the device to be held more stable. In addition, software-based navigation techniques can be incorporated into applications more easily, without requiring specialized hardware. Currently, software-based techniques are the most common means for navigation on handhelds. Our research examines software-based navigation techniques for handheld computers, specifically designed for mobile usage.

Four main constraints that we wanted our mobile navigation interaction technique to satisfy were: 1) to enable simultaneous multi-directional navigation; 2) to provide variable speed control; 3) to be appropriate for use while mobile; and 4) to not take up valuable screen real-estate. It was with these considerations that we developed the *touch-n-go* navigation technique. Touch-n-go enables the user to navigate in any direction at variable speeds relative to the center of the mobile device screen.

In this paper, we present related work on interaction styles for mobile devices and introduce our implementation of touch-n-go. We also present the results of a user study that compared touch-n-go with scrollbars and tap-and drag. Finally, we discuss the results of the study and future work.

Related Work
The presentation of information on mobile devices is challenging given the limited size of the screen. It is often the case that an information space (i.e. a map, photograph or web-page) is larger than the screen space of the mobile device. To navigate the additional space, users need an efficient way to move the viewport around to view all parts of the information space.

A number of hardware-based interaction techniques have been developed for mobile devices. Hardware inputs such as quick buttons or jog wheels are included on many mobile devices, but in most current systems they provide limited functionality. Rekimoto [7] introduced the idea of tilt based navigation, using sensors that detect the rotation and angle of the mobile device itself. Tilt has since been researched extensively [1-3, 7] for navigation and selection on mobile devices. Other hardware-based approaches include Peephole displays [10], NaviPoint [5] and ScrollPad [9].

Hardware techniques are appealing for mobile environments as they often allow one-handed navigation and item selection [3, 5]. However, many of these implementations suffer from problems of glare and viewing angles (since the device needs to move to scroll [1-3]) and target overshoot-

(a) (b) (c)

Figure 1. *Touch-n-Go* in use; (a) touching the screen, and (b/c) navigating the subway map.

ing which has been shown to be a problem [2, 3].

Software-based navigation techniques provide direct input with the display, are native to the device, and may be familiar to users as they are often based on similar desktop paradigms. Scrollbars, although familiar, limit users to strict vertical and horizontal navigation. The small size of the screen can also make scrollbars difficult to use, particularly when trying to acquire the small, directional arrows or the scrollbar thumb.

Touch edge camera (edge navigation) [4] and push background (tap-and-drag) [4] are other common desktop models that have been transferred to small screen mobile devices. Johnson [4] compared edge navigation against tap-and-drag and found that users were faster and preferred tap-and-drag for navigation tasks. Tap-and-drag [4] allows for arbitrary movement, but is restricted because of the display size. The distance that can be moved in a single action is limited by the dimensions of the display. To move large distances requires multiple screen interactions.

Another technique, radial scrolling [8], extends radial lines from a central point that is then used to control horizontal or vertical movement within a document. The user moves the stylus in a circular motion around the central point advancing through the radial lines to control the scrolling and speed of advancing the document. Although this technique has been proposed for handheld computers, it only provides movement in one direction at a time

TOUCH-N-GO

Touch-n-go is a simple software-based interaction technique for mobile devices that allows for effective navigation of information spaces. The current implementation of touch-n-go relies on direct input with the screen, either using a finger or a stylus.

When a user wishes to navigate an information space using touch-n-go, they simply apply continuous pressure to the screen of the mobile device. The direction and speed of navigation is determined by the position of the user's touch on the screen (i.e. using a stylus) relative to the center of the screen (Figure 1). This 'touch' position determines what direction the viewport will move. The distance of the touch position from the center of the screen determines the speed of the navigation. Touches closer to the center will cause slower navigation, while touches farther from the center will cause faster navigation.

To differentiate between navigating and selecting targets, we use the dwell time of pressure on the screen; touch-and-release versus touch-and-hold. Touching the screen and releasing would indicate a selection action, not navigation. Touching and holding, maintaining continuous pressure on the screen would indicate a navigation action, not selection. Therefore, to select a target while navigating, the user simply lifts the stylus and clicks on the screen. This provides a nearly single stream operation with seamless transition between navigation and selection not seen with many interface widgets such as scrollbars.

Touch-n-go was designed to compensate for shortcomings of other software-based techniques on mobile devices. While scrollbars, edge navigation, and radial scroll can only move in one direction at a time, touch-n-go allows the user to go in any direction, at variable speeds. In addition, scrollbars require a visual widget on the screen, while touch-n-go is screen-based and does not require additional screen space. Tap-and-drag requires the user to navigate with a repetitive action of lifting and dragging the stylus across the screen until the target is located. Touch-n-go is one-touch navigation. The user simply places the stylus on the screen and then can move the stylus around the screen to adjust the direction and speed of movement.

Implementation

The two components of touch-n-go (direction and speed) are calculated by determining ‘the touch point’ (where the user has touched the screen) in relation to the center of the screen (Figure 2). The *origin* of the global space (i.e. a map or image) is the top left hand corner *Org(0, 0)* while the point $C(x_g , y_g)$ indicates the point in the global space that is positioned at the center of the local space (i.e. in the center of the viewport). $P_1(x_l, y_l)$ represents the center of the local space and $P_2(x_l, y_l)$ is the point of contact in the local space.

As the user navigates around the information space, the vector between points P_1 and P_2 is used to transform $C(x_g , y_g)$ in the global coordinate space:

$$C(x_{g\text{-}new}) = C(x_{g\text{-}old}) + (P_2(x_l) - P_1(x_l)) * S$$

$$C(y_{g\text{-}new}) = C(y_{g\text{-}old}) + (P_2(y_l) - P_1(y_l)) * S$$

The vector between P_1 and P_2 represents the direction in which the local space will pan. The magnitude of this vector represents the speed at which this movement will take place. When a user touches the display, P_1 and P_2 are recorded and Δx and Δy are calculated. A scaling factor (S) is then applied to Δx and Δy to select the rate at which the display will pan. These values are then added to $C(x_{g\text{-}old}, y_{g\text{-}old})$ and the center of the local space is set to be $C(x_{g\text{-}new} , y_{g\text{-}new})$. A timer records position $P_2(x_l, y_l)$ every 20th of a second and updates the display accordingly. $P_1(x_l, y_l)$ does not need to be continuously recalculated unless the display area is dynamically changing in size.

In order to provide a consistent, smooth visualization of the movement, it was important to adjust the speed of the navigation. Δx and Δy were multiplied by a scalar factor S. In our prototype S was set to 0.15 (i.e. the local space would pan 15% of the distance to P_2 every 20th of a second. This caused the display to pan more slowly under all conditions, but created a more natural appearance for larger changes.

USER STUDY

A within subjects field experiment was conducted to compare touch-n-go with two common software navigation approaches: scrollbars and tap-and-drag. These three navigation techniques were tested while participants were mobile (walking). Testing took place in the atrium of Dalhousie University’s Computer Science building. This informal meeting area has a coffee shop, microwaves, couches and table and chairs. This study was part of a larger study to examine the impact of different mobility levels on interaction techniques for mobile devices [6].

Eighteen, right-handed university students (14 male, 4 female) participated in the study using an iPAQ handheld device and stylus for all navigation techniques.

Using each navigation technique, participants were asked to navigate a large information space of hollow circles (800 x 1040 pixels) to find and select a solid black target circle (20 pixels in diameter). The size of the display area on the handheld was 240 x 320 pixels. In the centre of the screen

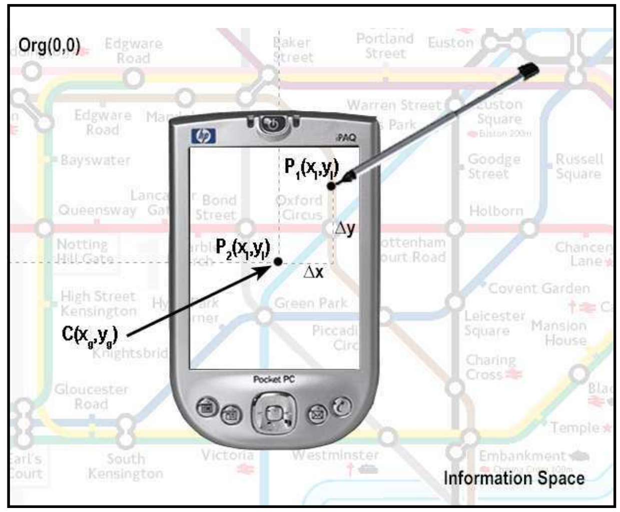

Figure 2. Implementation of the touch-n-go technique. The g subscript identifies coordinates in the global space while the l subscript identifies coordinates in the local space.

was a directional finder that pointed to the location of the target circle (Figure 3). The directional indicator was used to enable direct comparisons of navigation times across each navigation technique without selection time being confounded by the time to perform the visual search.

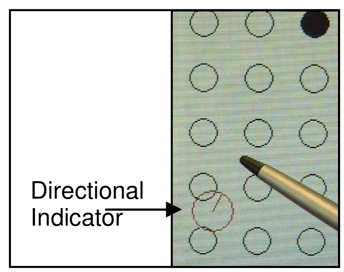

Figure 3. Icon to indicate the direction of the target circle.

Participants performed 40 navigation tasks per technique, selecting the same 20 solid black circles twice. At the beginning of each trial, participants were required to click on a start button and then navigate and select the target. Upon selection of the target, the screen would clear and reset to display only the start button. Once all trials (for all three techniques) had been performed, participants completed a post-condition and a post-experiment questionnaire.

Data logging was used to capture detailed timing data. Target selection times were used as a performance metric to determine navigation efficiency and were calculated from the time the participant selected the start button until they clicked on the target.

Background questionnaires collected handedness information and computer and handheld usage history. In the post-condition questionnaires, participants ranked each navigation technique in terms of ease of use and preference and also rated each navigation technique on a scale of 1-5 based on how easy they felt the technique was to use (1-*Strongly Disagree* that the technique was easy to use; to 5-*Agree Strongly* that the technique was easy to use).

Analysis and Results

All data were analyzed to compare the results for the touch-n-go technique against the scrollbar and tap-and-drag techniques. This data represents a subset (walking condition only) of the full data set from the larger mobility study [6]. Table 1 shows average target selection times; participants' rankings of the techniques based on ease of use and preference; and ease-of-use ratings assigned to each technique.

Table 1. For each navigation technique: mean and SD for target selection times; mean ranks for ease of use and preference; and mean ease-of-use ratings on a scale of 1-5 (1-Strongly Disagree to 5-Strongly Agree).

	Selection Time Mean (SD)	Ease of Use Mean Ranks	Preference Mean Ranks	Ease of Use Mean Ratings
Touch	3597 ms (557)	1.22	1.28	4.67
Scrollbar	4229 ms (470)	2.83	2.89	2.72
Drag	3504 ms (1223)	1.94	1.83	3.89

Target selection time data were analyzed using paired samples t-tests. All outliers (trials whose time exceeded 3 SD above the mean), were removed from the data set (approximately 1% of trials). The touch-n-go technique was significantly faster than the scrollbar technique, $t(17)=5.94$, $p=.000$, but no significant difference was found with the tap-and-drag technique, $t(17)=-0.45$, $p=.661$.

The questionnaire data were analyzed using Wilcoxon Signed Ranks Tests with a Bonferroni adjustment ($\alpha = .025$). Significantly more participants ranked the touch-n-go technique as being easier to use than the scrollbar technique ($z=-3.85$, $p=.000$) and the tap-and-drag technique ($z=-2.50$, $p=.012$). The ease-of-use ratings also supported this result with participants rating the touch-n-go technique significantly higher than both the scrollbar ($z=-3.37$, $p=.001$) and the tap-n-drag ($z=-2.37$, $p=.018$) technique. In terms of preference, significantly more participants preferred the touch-n-go technique over the scrollbar technique ($z=-3.83$, $p=.001$) but only a marginally significant preference was found over tap-and-drag ($z=-2.22$, $p=.027$).

Participants' qualitative feedback on the touch-n-go technique indicated that they felt this technique was fast and easy to use. The participants also appreciated that touch-n-go required less stylus usage. The main criticisms of the technique were that the speed was too fast at times and caused them to overshoot the target, and that the technique occasionally caused the user's hand to occlude information on the screen.

CONCLUSIONS AND FUTURE WORK

Overall, we found that for simple navigation tasks, the touch-n-go technique was faster than the traditional scrollbar technique and was superior in terms of ease of use and preference than both the scrollbar and tap-and-drag techniques. In terms of our original design constraints, the touch-n-go technique: 1) enables simultaneous multi-directional navigation; 2) provides variable speed control, 3) was shown to be superior to other software-based techniques when moving, and 4) does not take up additional screen real-estate.

In the future, we plan to compare the touch-n-go technique to hardware based approaches (in particular tilting). We also plan to investigate the touch-n-go technique with more complicated navigation tasks and observe longer-term, real usage of the technique.

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