One-Handed Behind-the-Display Cursor Input on Mobile Devices

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Abstract

Behind-the-display interaction has gained popularity for interactions on handheld devices as researchers have demonstrated the viability of such interactions on small devices. However, most designs have investigated the use of direct input behind the screen. We demonstrate that behind-the-display interaction with cursor input is promising and can be a useful augmentation to handheld devices. We developed a prototypical system on a PDA to which we affixed a wireless mouse. The mouse is mounted on the rear of the PDA with the optical sensor facing outwards. The system is designed to be used with one hand, and prevents occlusion and finger-reach. Through several applications we propose the benefits associated with behind-the-display cursor interaction. A preliminary user evaluation indicates that users can benefit from such an interaction when operating a handheld using one hand.

Keywords

Behind-the-display interaction, relative positioning.

ACM Classification Keywords

H5.2 [Information interfaces and presentation]: User Interfaces I Input devices, Interaction styles.

Introduction

Handheld devices are ubiquitous and considered by some as a natural extension to our cognitive resources.

Studies show that one-handed use is the preferred method for operating a handheld device [8]. In this mode, the user grips onto the device and interacts using the thumb or other auxiliary fingers. While this works well for interacting with buttons on a cell-phone for example, it is not convenient for touch-input on the display for several reasons. Usually, the distance covered by the thumb is not sufficient to manipulate objects in the extreme and opposite corners of the device. Furthermore, the "foot-print" of a thumb is significantly larger than other fingers, resulting in a large amount of occlusion [12]. Studies have also reported the inaccuracy in selecting targets with a finger on a touch-display, specifically when the targets are in proximity to one another or small [11]. Finally, trajectory-based interactions such as scrolling a long document or highlighting a line of a sentence are difficult to operate using only the thumb with one hand.

To resolve some of the problems with direct-touch input on handheld devices researchers have proposed a number of techniques. Behind-the-surface interaction [12, 10], resolves some of the complexities associated with finger occlusion. To resolve inaccurate object selection techniques such as Shift [11] allow large finger footprints for selecting objects in corners or even small targets. However most of the previously proposed techniques require both hands for operating the device or additional timeouts for invoking visual filters for selecting enlarged targets. Furthermore most techniques for behind-the-screen interaction employ direct input.

We hypothesize that cursor interaction with relative positioning can be helpful for solving some of the intricate problems associated with single-handed interactions on a handheld device. A pixel-size cursor tip provides users with an easy and precise mechanism for pointing and selection and avoids occlusion. We developed a prototype system, to validate our hypothesis. The system is similar to HybridTouch [10]. However, instead of a touchpad, it embeds the core of a mouse onto its rear surface, which allows the user to interact with the PDA with a cursor with the fingers free from gripping the device with one hand. Furthermore, the use of optical sensor facilitates a large number of mouse interactions, by allowing the user to simply glide the PDA onto a flat surface, just as you would a mouse. Thereby, a large number of mouse-based interactions that were previously not possible on the PDA can be made available to the user.

Related work

A variety of developments are related to our work. Most of them are aimed at addressing the issues concerning finger and single-handed input. To improve the accuracy of finger selection, Albinsson and Zhai proposed to use widgets to facilitate pixel-accurate selections [1]. Olwal and Feiner's [9] rubbing motion technique enlarges the targets using a fisheye view. Benko et al. [3] suggested using two-hand input to achieve precise selection.

To address the occlusion problem, Shift [11] displays a copy of the occluded screen area in a "shifted" view near the touch point. The latest Escape [14] technique facilitates selection using the direction information of the targets. Lucid-Touch [12] addresses the problem by having the user interact on the back of a mobile device. Fluid DTMouse [4] displays the cursor in the middle of two touch points of fingers to avoid occlusion.

These techniques provide solutions to many of the issues we address. Note that the majority of touch screens are used on handheld devices. In the case of mobile computing, many of these technologies require the user to use both hands. However, single-handed operation is favored among many handheld device users [8, 13]. As a result the thumb is normally the only finger that is in front of the display and thus can be used to perform operations.

The AppLens and LaunchTile [7] were designed for one-handed thumb interactions for handhelds. The interfaces utilize different zooming technologies to facilitate selections. The controllers are large enough for finger input, and are placed within the region that is reachable by the thumb. ThumbSpace [6] allows the user to use the thumb to select small and/or out-of-reach targets with high level of accuracy. Unlike the thumb, the other fingers of the hand have a larger reach and are better suited for handling complex kinesthetic tasks. In many situations, however, they are used only for holding the device. LucidTouch's novel design allows users to interact with mobile devices using all the fingers. However, its back-mounted camera significantly reduces the mobility of the device.

A variety of other techniques have been proposed to support behind-the-display interaction for mobile computing. ScrollPad [5], for example, has an optical sensor mounted on the back of the device. However, the sensor is only used to detect the motions of the device. Therefore it supports very limited types of interactions. HybridTouch [10] is a two-handed interface, which supports scrolling and zooming. The prototype consists of a USB touchpad, which is mounted on the back of a PPC. The touchpad is used as a secondary input device that assists the direct touch screen input. A mouse cursor is provided but is only used to enhance awareness of the finger motions panning on the touchpad. Unfortunately, none of these works investigates the possibility of using relative cursor input on mobile devices in facilitating one-handed operation of daily tasks such as pointing, group selection, and tunneling. In this paper we extend prior studies and investigate the benefits of relative cursor input behind the display for one-handed interaction.

Hardware configuration

The prototype system consists of a Pocket PC (PPC) and an optical sensor, which is mounted on the back of the PPC (see Figure 1). Direct finger or stylus input can be made through the touch screen. Mouse input is made through the optical sensor, which senses the movements of the user's fingertip. Cursor position was mapped in relative mode. An arrow-style cursor is displayed and Cursor movements can be controlled by moving the index fingertip over the optical sensor or by gliding the device on a flat surface.

The system consists of a Dell AXIM PocketPC (PPC) augmented by the core mechanics of a Stowaway bluetooth mouse. The Stowaway mouse can be used on PPCs using a bluetooth connection. A regular arrow-style cursor is available on the handheld device. We remove the casing of the mouse so that the resulting surface is flat. We taped the rest of the mouse, which includes an optical sensor, a main board, and two batteries, on a base plastic card (see Figure 1) and mounted the entire set on the back of the PPC using velcro hooks. The optic sensors are facing in the opposite direction of the handheld screen. We placed the mouse as close as possible to the top of the PPC to make it conformable for the users to manipulate the cursor with the index finger.

Figure 1. Left: Prototype of our device.

With an indirect input mechanism it is necessary to develop a method to facilitate button clicks and selection. We provide some flexibility with three options, to trigger the left-mouse button click. The first option provides access to selection if the user presses one of the hardware buttons located on the left side of the PDA. The second option gives access to the "Enter" key, which is located at the center of the jog-dial on the PDA. The third access to selection is to take advantage of the original left-button mouse click. Since the mouse is inverted on the rear of the PDA, the buttons of the mouse are directly touching the casing of the PDA. To make the button clickable we filled up the space between the button and the PDA case using a piece of plastic. The plastic is flexible so that it is easy for right handed users to trigger a button click by pressing on the corner of the mouse, using the base of the index finger. In contrast to the first two options, in this mode the user can perform pointing and selection using one finger, which makes the interaction smoother and faster. With all three methods, we expected participants to find the most suitable way for clicking in different tasks. As described in our results, users indeed used different mechanisms based on the task.

Test applications

We developed three test applications all of which are commonly require the use of both hands; the non-dominant hand to hold the device and the dominant hand for interaction. We wanted to assess the benefit of using cursor input with respect to one-handed interaction, and therefore asked our test participants to only use one hand for the evaluation. We performed an informal evaluation and report our results after describing each of the three tasks. Five participants, all right-handed users volunteered for our evaluation. We are carrying out formal evaluations for these tasks as part of our future work.

Pointing and Selection: Pointing and selection are common tasks that require access to the entire screen. The task is very difficult to accomplish with one hand since the thumb cannot reach the entire screen area (see Figure 2). Furthermore such a task typically requires precise selection. We designed a simple Fitts' Law task which required participants to point and select at targets either 4.5mm or 2mm wide that were randomly dispersed on the screen.

Figure 2. It is common that targets to be selected are located in places that are difficult to reach by the thumb (right).

Map Browsing: the map browsing task required users to perform a panning operation. To start panning, the user can click anywhere on the screen. It is possible to pan by using one hand as long as the user keeps the operation within the region that is reachable by the thumb. Users may have difficulties to perform diagonal thumb movements in the North-West/South-East directions (for right handed users, and the reverse directions for left-handed users) [8]. As a consequence, the performance of thumb panning can be poor. We asked the participants to use the prototype to pan a map freely in all directions.

The back mounted optical sensor allows the user to operate the device by gliding it onto a flat surface, like a mouse. We asked the participants to repeat the previous tasks by sliding the device over a table and a wall, just as they would with a mouse. Various mappings are possible for cursor placement. We selected the following: the cursor moved in the direction opposite of the device movement. For example, if the user glided the device to the left the cursor moved to the right. This task was particularly different from the other two, as it allows users to operate the PPC as mouse, thus facilitating a number of different types of interaction including those with a flavor of peephole displays.

Group selection: Selecting a group of targets is a common task bearing characteristics of pointing and/or dragging. Like pointing and selection, group selection is challenging with single-handed operation due to far reaching corners and occlusion. The test application displayed 4 target objects in pre-defined locations on the reachable and unreachable portions of the display. When operating on the front of the display, the participants were asked to select the group by tapping on each target. The size of the targets was small enough to be occluded by the thumb so that the participants needed to use the Shift [11] technique for precise selection. When operating on the back of the display, the participants were asked to select the group using the common ‘rubber’ banding technique.

Results

All participants were able to successfully complete the tasks. This suggests that cursor input behind-the-display can become a suitable augmentation for one-handed interactions. Interestingly, we observed that for different tasks, participants chose the most suitable way to trigger clicking for that task. In the pointing and selection task, the participants mainly used the original mouse button for clicking. In the map browsing and group selection task, the participants mainly used the side buttons for clicking. The "Enter" key was rarely used in all of the three tasks. This suggests that future work needs to determine the most appropriate selection mechanisms for cursor input behind the screen.

For the group selection task, it took the participants an average of 5425ms to select a group of 4 targets by using tapping with Shift. This is not significantly different from the selection time (5437ms) of using the elastic band behind the display. The participants perform the task with tapping slightly faster than with behind-the-display cursor interaction. One possible explanation for this is the number of targets being tested was too small. We expect that with an increase in the size of the group, requiring larger movements, behind-the-display cursor interaction could outperform tapping. Additionally, for symmetric groups of objects, cursor input with relative position mapping would be beneficial particularly for regions that are not reachable with the thumb. Overall, the results of the preliminary (informal) studies show that for certain tasks, there could be a potentially significant advantage for behind-the-display cursor input. Such form of interaction may prove to be particularly useful for situations where one-handed interaction is preferred. We believe a formal study will help us gain a better understanding of this form of augmentation.

Conclusion and future work

We demonstrated that behind-the-display cursor interaction can be a helpful augmentation to mobile devices. The benefits of cursor input lie in not only the fact that it facilitates one-handed usage of mobile devices but also the fact that with a cursor many of the cursor-based interaction techniques can be used on mobile devices. For future work, we will refine our prototypical device to make it easier to operate. A possible design can be similar to [10] by mounting a touch-pad on the back of a PPC. We will also conduct a formal study to gain a better understanding of the benefits of behind-the-screen cursor input in mobile computing. We believe both direct finger and indirect cursor inputs have their advantages. Part of our future work will delineate cases where one method is more suitable than the other in the settings presented in this paper.

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