VirtualThumb: One-Handed Multi-Touch Emulation Technique on Small Devices

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ABSTRACT
Recently, there has been growing interest in the design of multi-touch based mobile devices. However, multi-touch interactions with one hand on the mobile device are difficult in terms of usability. In spite of this, few have attempted to address a supportive approach for multi-touch operations with one hand. In this paper, we present VirtualThumb, a set of software-based conceptual techniques that enables a user to handle multi-touch operations under the limited physical resources available. This simple and novel technique allows users to comfortably handle multi-touch pinching gestures such as zooming, scaling, and rotating using only one finger. Hence, occlusions caused by two fingers are reduced by half, gestures are not restricted by the physical boundaries of the screen, and physical limitations of the user's fingers are reduced.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces - Graphical user interfaces.

General terms: Design, Human Factors, Algorithms

Keywords: multi-touch, interaction techniques

INTRODUCTION
Today, many companies try to extend the capabilities of the touch screen to support multi-point input, giving richer user interactions. However, multi-touch input methods on mobile devices carry a number of problems. A major problem being that the vast majority of users want to use one hand for interacting with mobile devices, but current interfaces, especially for touch screens, are not designed to support dedicated single handed use [2].

A problem with using a multi-touch device with one hand is that the user's movements are restricted because of the unnatural and uncomfortable grasp. In addition, using two fingers can result in double the occlusions, making it harder to see the valuable screen real estate. This problem becomes more serious as the device gets smaller.

Interfaces that accommodate single-handed interaction can offer a significant benefit by freeing one hand for the physical and intellectual demands of mobile tasks [4]. However, multi-touch input based devices typically don't offer such support. In this paper, we propose a novel set of software-based interaction techniques called VirtualThumb, which enables users to handle multi-touch operations with only a thumb.

RELATED WORK
There have been many attempts to reduce occlusion and to improve comfort. Solutions for such occlusion problems have been suggested in SideSight[1] and LucidTouch[5]. SideSight uses infrared proximity sensors to sense the user's fingers distances from the device and analyze pinching gestures. This approach has no occlusions but instead requires the device be rested on a flat surface and the user use both hands to gesture. LucidTouch also reduces occlusion by allowing the user to conduct multi-touch gestures by using the back of the device. Although this reduces occlusion and enables the user to use all ten fingers naturally, it requires the user to use both hands to conduct pinching gestures.

Rub-Pointing[3], a technique by A. Olwal et al, uses a diagonal rubbing gesture to point and zoom with one hand. However, this results in the target object juddering because the rubbing technique processes a gesture after it is completed, resulting in a series of rapid panning (from rubbing) followed by zooming in (recognition of gesture). Another technique introduced with Rub-Pointing is Zoom-Tapping, in which the user points with one hand and taps with the other, to zoom. A drawback of this method is that it needs both hands.

VIRTUALTHUMB INTERACTION WITH PHOTOBOARD
We tried VirtualThumb with Photoboard, a multi-touch photo browser. VirtualThumb worked as follows. In Normal Mode, a user can drag the photo as usual. When the user triggers an event, such as a double-tap or a long-tap, the mode changes to Virtual Mode and a VirtualThumb appears at an equal distance away from the pho-

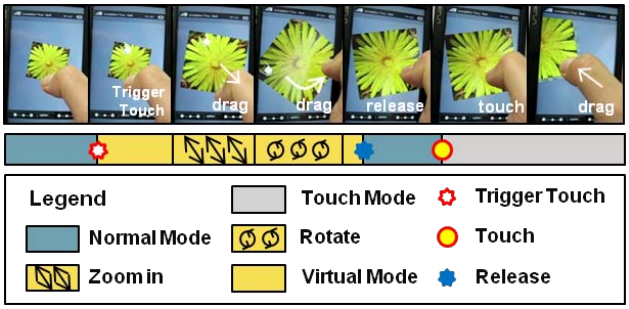

Figure 1: Sequence of multi-touch operations with VirtualThumb.

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to's center point as the user's finger. Under the Virtual Mode, the user can interact as if handling the photo with two fingers by recognizing the position of the virtual finger. After releasing and exiting Virtual Mode to Normal Mode, the user can immediately go back to Virtual Mode by touching the photo again before time *t* passes.

Figure 1 shows the sequence of conducting pinching gesture operations using one finger. This sequence shows the user entering virtual mode, zooming in, rotating the object counterclockwise and translating it to the left.

VIRTUALTHUMB INTERACTION WITH WEB BROWSER

VirtualThumb was designed differently for web browsing. First, when an event is triggered to enter Virtual Mode, the position of that event becomes the center point. This way, a user can zoom into an arbitrary point on the page, increasing the expressiveness. Second, because web pages are always vertical and do not need to be rotated, rotating gestures are, instead, used to go back and forth between web pages. Figure 2 shows how the expressiveness has increased in corners, because the VirtualThumb is not restricted to the physical limitations of the bezel. Without VirtualThumb, as shown on the left in Figure 2, a user has to repeat scaling gestures. Doing so in the opposite diagonal to increase the zoom magnitude would zoom in, but the center point would not be where the user intended, resulting in an extra panning gesture.

Figure 2: Comparison of pinching gestures in corners. The dot represents the zoom point, while the line represents the distance between two fingers, determining the magnification.

USABILITY TEST ON PROTOTYPE

Our VirtualThumb prototype was implemented in ActionScript2.0 on a smartphone (LG-KU2000) with a touch screen size of 320x480. For the usability test, we conducted a quick and simple test on 11 participants, of which 4 were women and 7 were men, with an average age of 26.6. All except one had experience with touch devices. In order to compare VirtualThumb with multi-touch, the participants were asked to use Photoboard and browse the web using both but limited to using one hand. To compare with single-touch, the participants were given a baseline technique, zoom bar and zoom buttons interface, for using Photoboard. They were then asked to fill in a questionnaire in which they ranked the various methods on a seven-point Likert scale, ranging from -3 to 3, with regard to learnability, ease of use, comfort, fun, speed.

The results, which are shown in Figure 3, show that VirtualThumb ranks high in all categories. It is interesting that the participants perceived VirtualThumb to be as fast as multi-touch. We believe this is because it was difficult for the participants to use multi-touch with one hand, resulting in a longer time than what would have taken with both hands. For the high comfort score, we had observed that VirtualThumb had no limitations in the degree of rotation, which used to be greatly restricted due to biomechanics. We also observed that when an object was partially located off the screen, the users continued their gestures naturally, aware of the VirtualThumb on the off-screen area. However, a limitation of VirtualThumb was that it was not possible to scale or rotate an object while dragging it, a feature possible in multi-touch.

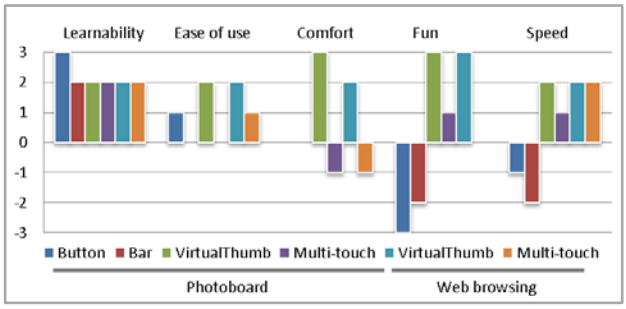

Figure 3: Median plot of the usability test

CONCLUSION AND FUTURE WORK

We proposed a new and simple interaction technique called VirtualThumb that enables users to handle multi-touch interactions with one finger, and thus decrease the occlusions by half and free a hand. In addition, this technique enables users to handle objects that are partially off the screen. Finally, user tests indicated that VirtualThumb had potential in supporting multi-touch in one-handed environments. For future work, we plan to extend our ideas to use more than one virtual finger and compare VirtualThumb with additional related work.

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