Exploring Swiping with Thumb Input on Flexible Tablets

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ABSTRACT

Research in flexible displays has currently focused on bend interaction techniques, yet little work has been done to support touch input, the most common input for rigid handheld displays. In this paper, we explore swipe interaction using the thumb of the holding hand. Our result suggests that user performance and preference for swipe interaction using thumb input does not vary between a flexible and a rigid tablet, indicating that we could port some of the current swipe actions to flexible tablets. We also found that users like to hold the device on the side or on the corner while performing swipe interaction on flexible tablets using the thumb of the holding hand.

Keywords: Flexible tablet, swipe, touch, thumb, bend

Index Terms: H.5.2 [INFORMATION INTERFACES AND PRESENTATION]: User Interfaces - Interaction styles

1 INTRODUCTION

While rigid tablets can take the full advantage of touch input, flexible displays currently provide limited support for touch interaction, mainly because they may not always provide adequate normal force to support touch input [2]. However, the holding hand provides the structural support required for pointing and dragging tasks using the other hand [2].

Extending Dijkstra's observations, we noticed that the holding hand may also provide sufficient normal force to support touch in the adjacent region of that hold. As several studies revealed user preference for touch input using the thumb of the holding hand on rigid devices [3,7], we were interested in testing the ability of thumb input in a flexible device context. In addition to providing standalone thumb input, we believe it would be particularly useful when combined with bend interactions [1,4,5]. To bend a tablet-sized display, users typically use both hands, one to hold the device and the other to bend it. By using thumb input, the holding hand can add an additional dimension to bend gestures, bringing in the advantages of bimanual interactions to flexible displays [7].

Riyadh [6] studied thumb input for tapping interaction on a flexible tablet and found that flexibility does not impact user performance for tapping. In this paper, we investigated the feasibility of thumb input for swiping, on flexible tablets. We compared user performance and preference for swiping between a flexible and a rigid tablet prototype. We evaluated each interaction for both hands, and for three hold positions: bottom center, bottom corner, and side center. We present our results and discuss the implications for design.

2 RELATED WORKS

Karlson et al. [5] evaluated four types of swipe (vertical, horizontal, diagonal and radial) with thumb input for handheld devices (Figure 1(i)). Users were more comfortable performing horizontal, vertical and radial swipes while they struggled to perform the diagonal ones. A few studies on flexible displays [1,4] evaluate the combination of bend and touch on flexible devices, and found that users prefered using the thumb for touch than the index finger while using bend and touch together. Riyadh [6] found that users had comparable performance for tapping with thumb input between a flexible and a rigid tablet. He also found that users preferred to hold the device on the side or the corner.

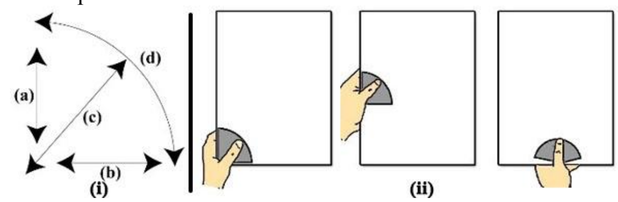

Figure 1: (i) Type of Swipes (a) Vertical (b) Horizontal (c) Diagonal (d) Radial; (ii) Three common holds;

3 EVALUATION

We explored the potential of swipe interaction using thumb input on flexible displays. We selected Karlson et al.'s [3] four swipes and investigated their compatibility on a flexible tablet prototype using Riyadh's [6] three hold positions (Figure 1(ii)).

3.1 Task and Design

Our factors were: flexibility (rigid, flexible), hand (dominant, non-dominant), hold positions (bottom center, bottom corner, side center), and type of swipe (horizontal, vertical, diagonal, radial). Two factors, flexibility and hand, were counter-balanced and the other two were randomized.

After training, participants were required to perform the swipes for a minimum length of 2.38 mm within the appropriate region. This threshold was set after few design iterations. There were no additional requirements for angle or direction, to help us gain insight about the participant's preferred direction for each swipe.

In the beginning, tapping once on the adjacent hold area displayed a swipe arrow in the middle of the screen, and users were required to perform the swipe. A new swipe arrow then appeared. Each type of swipe appeared three times in each direction, in a random order, for each hold position. This was repeated for three holds. Participants filled out questionnaires on the difficulty level for performing each swipe in each hold position using the 5 point Likert scale (1= Easy, 5 = Difficult). The experiment lasted 20 minutes. We measured the duration of each swipe (time between when participants touch the appropriate region to start swipe and when they lift off their thumb).

3.2 Participant

21 participants (8 females, M: 24.5yo) were all right handed but two (one left handed and one ambidextrous). Two participants had prior experience with a flexible display prototype. Participants received $10 gift card as compensation.

3.3 Prototype

Our prototype was composed of 6 layers, with a total thickness of 3.25 mm, and an extra layer of Plexi Glass (2 mm) for the rigid condition (Figure 2). We used a 10.06" x 7.17" flexible and transparent Zytronic touch sensor. A paper was placed under the transparent sensor to indicate the touch regions. The grey areas

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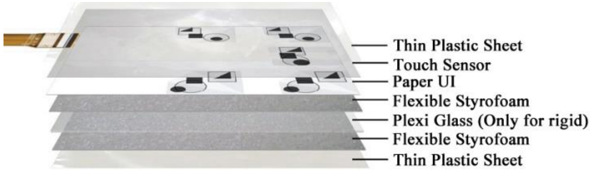

Figure 2: Exploded view of Prototype

represent the touch region for each hold where swipes should take place. The black and outlined shapes were used in the prior work with this prototype [6]. None of the participants indicated the presence of printed tapping regions as an issue. We used a pico-projector to create a dynamic display.

3.4 Result

We performed a repeated measures ANOVA, using the factors: flexibility (2), hand (2), hold (3), and type of swipe (4) on the duration data. We found statistical significance on swipe duration for hold ($F_{2,40} = 27.276$, $p < 0.001$), and hand ($F_{1,20} = 5.163$, $p < 0.05$). Users took significantly longer time to swipe in the bottom center (M: 220.04ms) than the side center (M: 161.69ms) and the bottom corner (M: 159.59ms). A pairwise comparison using Bonferroni correction ($p < 0.001$) confirmed this variation. We found that the users were significantly faster with their dominant hand (M: 170.38ms) than the other hand (M: 190.49ms).

We analyzed our Likert scale data for the same factors using the Friedman test. The significant factors were: type of swipe ($\chi^2 = 74.996$, $p < 0.001$), hold position ($\chi^2 = 93.071$, $p < 0.001$), and hand ($\chi^2 = 39.7$, $p < 0.001$). The horizontal swipe (M: 1.60, SD: 0.92) were the most preferred ones, followed by the vertical (M: 1.76, SD: 1.09), radial (M: 1.83, SD: 1.16) and diagonal swipe (M: 2.30, SD: 1.40), consecutively. Participants preferred swiping in the side center (M: 1.69, SD: 1.07) and bottom corner (M: 1.66, SD: 1.03) over the bottom center hold (M: 2.27, SD: 1.33). Participant preference was higher for the dominant hand (M: 1.71, SD: 1.05) than the non-dominant hand (M: 2.04, SD: 1.28).

In both analyses, flexibility remained a non-significant factor.

Figure 3 illustrates the point cloud and regression lines generated from the touch points of all four swipes for flexible prototype and dominant hand, a representative set. We noticed that for all swipes but the vertical ones, the regression line of the side holds is less angled in reference to the x-axis compared to bottom center. We believe it implies that users have a more comfortable range of thumb movement in the vertical direction in the other two holds, which is in line with the prior work [1]. We also find the horizontal swipes not to be fully horizontal in the two side holds. The vertical swipes are, however, close to being perfectly vertical.

4 Discussion

Flexibility: Participants had comparable performance and preference for swiping with thumb for both rigidities. Point cloud maps also did not show any noticeable visual distinction of the swipes for different flexibility. Five participants, who preferred using the rigid device, stated that it provided them with better control to hold the device. Interestingly, five other participants, preferring the flexible prototype, mentioned similar reasons to opt for the flexible version. Two of them stated that the flexible device fits into the hand a bit better, increasing the range of thumb. We believe this preference to be further improved when touch will be used in parallel with bend, as combining these two improves user experience in flexible displays [4]. We suggest that using thumb for swiping can contribute in bringing the advantages of touch input on flexible tablets.

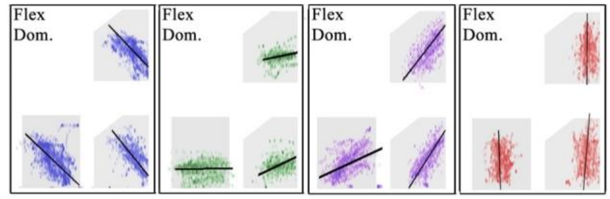

Figure 3: Point cloud maps (diagonal, horizontal, radial, vertical)

Holds: Participants took the longest time to swipe in the bottom center. Their preference for hold was also similar to their performance, which is coherent with prior works [6,7]. With our current results, we discourage the use of this hold for swipe.

Type of Swipe: Swipe duration did not vary significantly among four types of swipe, although we did observe that the diagonal and radial swipes were systematically taking longer time than their counterparts. However, participant preference significantly varied across different swipes. The diagonal swipe was much less appreciated by the participants than the other three types, supporting the prior work [3]. We recommend avoiding the diagonal swipe for all three holds. Use of both horizontal and radial swipe in bottom center should be proceed with caution as these two swipes almost overlapped in that hold.

Hand Dominance: User performance and preference for swipe were better with their dominant hand than the other hand. We believe this indicates that users are more efficient and comfortable with their dominant hand than their non-dominant hand, but they can still utilize both hands for swipe interaction when required. Using both hands can also contribute in improving user experience by lessening the fatigue on one hand. In addition, holding the device with one hand will allow users to perform other operations with the other hand.

5 Conclusion and Future Work

In this study, we explored the feasibility of thumb input for swipe interaction on flexible tablets. Based on our findings and prior work [6], we conclude that thumb input can bring some of the benefits of touch input in flexible displays. We believe our design guidelines produced to be particularly helpful for integrating swipe interaction using thumb input on flexible handheld devices and to be useful for evaluating bimanual interactions on flexible displays by using thumb input and bend gestures simultaneously.

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