Sticky Widgets: Pseudo-haptic Widget Enhancements for Multi-Monitor Displays

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ABSTRACT

People use multiple monitors to increase their display surface and to facilitate multitasking. However, if windows are maximized to fill one screen, users may have difficulties accessing widgets and tools on the borders of the displays, accidentally crossing over to the other display. To assist users of multi monitor displays, we developed a pseudo-haptic approach to enhance boundary widgets. We compared our sticky widget to a standard widget for two multi monitor display configurations: two identical side-by-side monitors, and two separated monitors of different sizes. Our enhancement improved performance by significantly reducing errors for accessing a boundary widget, reducing the number of accidental crossovers to the wrong display and consequently decreasing selection time.

Author Keywords

Multiple monitors, pseudo-haptic, sticky widgets, interaction technique, user interface.

ACM Classification Keywords

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

INTRODUCTION

Multi monitor use is increasing and researchers have been exploring appropriate interaction styles for this larger display surface [1, 6]. Multiple monitors enable people to increase their display surface and employ multi-tasking behaviours [2]. Previous studies have examined use patterns for multi monitors [2] and mouse movements between the two display surfaces [1, 6]. When using multiple monitors, users often maximize application windows to fill one of the monitors, however, there are difficulties with this practice when accessing widgets on the borders between the displays, such as scrollbars and the 'close window' icon.

Our research presents a software enhancement for multi monitor displays, to allow for easier acquisition of widgets on the boundaries between monitors. For certain software widgets, we created a disparity between the visual feedback on the display and the kinesthetic feedback from moving the mouse, which produces an illusion of force feedback, making the widget 'sticky'. We evaluated our technique with two aiming tasks, in two multi monitor configurations, and show that our sticky widget improves performance.

Pseudo-haptics

Pseudo-haptics is a software technique that creates the illusion of haptic properties such as stiffness and friction by combining the use of a passive input device with visual feedback [5]. The disparity between the visual feedback (i.e. slowing down of cursor on screen) and the increasing reaction force applied to the input device to compensate, provides an illusion of force feedback, without expensive technology. Other research has also manipulated the visual motion of the pointer for improved targeting [3]. Although not implemented, Swaminathan and Sato [7] introduced the concept of sticky controls for improved targeting on large displays. With sticky controls, the mouse would move fast through empty space and slow down in the vicinity of controls, creating the illusion of stickiness.

Multi-monitor displays

Researchers have investigated how multi-monitor displays impact user performance, and developed solutions to assist with target selection across displays. Tan and Czerwinski [8] examined the effects of visual separation and physical discontinuities, introduced by bezels or depth disparities, when distributing information across displays. They found that physical discontinuities had no effect on performance, but found a detrimental effect from separating information within the visual field, when also separated by depth.

Baudisch et al. [1] created mouse ether to allow the mouse to exist in gaps between multiple monitors. Mouse ether improved performance and user satisfaction. Mackinlay and Heer [6] described an approach to creating seam-aware applications for multi-monitor displays.

SOFTWARE IMPLEMENTATION

The sticky widget technique we developed was applied to a scrollbar for evaluation, however, the technique could easily be applied to other boundary widgets. Our sticky scrollbar detected when the mouse cursor was located over

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the scrollbar, and when the mouse cursor left the scrollbar in either a right or left direction. To make our scrollbar sticky, we reset the pointer's horizontal position on attempts to move to the right of the scrollbar (and toward the 2nd monitor), up to a threshold. The cursor was repositioned to the right-most boundary of the scrollbar to avoid any visual "jumping" of the cursor. Although mouse speed can be manipulated to give the feeling of slope [5], our approach factored in mouse speed differently. When mouse speed was high, our algorithm was satisfied quickly and let the mouse pass to the second monitor. However, if mouse movement was slow, the mouse cursor was repositioned to the boundary of the scrollbar for a longer period. Increasing the count of times that we repositioned the cursor increased the 'stickiness' of the scrollbar.

EVALUATION

To evaluate our sticky widget, we compared target selection requiring scrolling in two multi monitor configurations (identical-adjacent, different-separated) with three levels of stickiness (none, mild, heavy).

Participants and Setting

Twelve right-handed university students (9 male, 3 female) who passed a colour-blindness test participated. All 12 participants used computers every day and 7 had previously used multiple monitors: 3 use them almost always, 1 uses them 75% of the time, and 3 rarely use them.

Hardware Setup

Participants completed trials in two multi monitor display configurations: two identical monitors placed side-by-side; and two different monitors, placed with a slight gap (45mm) between them. In both configurations, participants sat in the centre of the displays, with the primary display on their left (Figure 1). The primary display in both conditions was a 20 inch LCD monitor with a resolution of 1024x768. The secondary monitor in the different monitor condition was a 15 inch LCD monitor with a resolution of 1024x768.

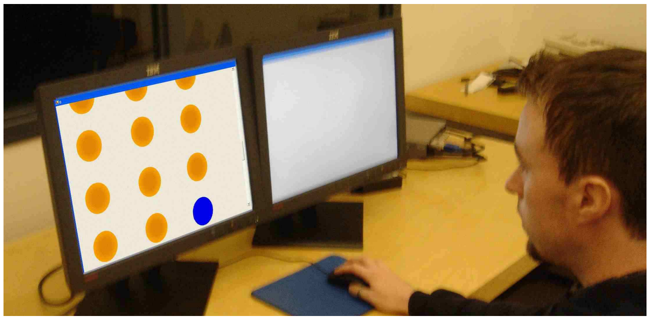

Figure 1: Setup (two identical monitors) and test application.

Task

Participants performed two tasks in both display configurations, with all 3 levels of scrollbar stickiness: a target selection task, and a serial tapping task. The target selection task was designed to mimic pointing in an application window maximized in the primary monitor. This task presented users with a grid of coloured target circles (3 across by 6 down). Targets were 50mm in diameter and were orange with the exception of one blue circle. Users scrolled through the grid of targets and selected the blue one using a mouse (Figure 1). Each participant completed 60 trials for each level of scrollbar stickiness, in each display condition for a total of 360 randomized trials. In each set of 60 trials, 5 trials were completed for each of the lower 9 targets (which required scrolling). The remaining 15 trials were randomly selected from the upper 9 targets (no scrolling).

The 60 trials for each level of scrollbar stickiness were completed in 3 blocks. After each block, participants were presented with the serial tapping task designed to examine how difficult it was for users to cross over between the two monitors. In this task users selected a blue target square that alternated between the displays 11 times. The squares appeared in the centre of each display and were 40mm wide. For both tasks, participants were instructed to select the targets as quickly and as accurately as possible.

Procedure

Participants completed a colour-blindness test and a background questionnaire. The order of display condition was balanced, and the ordering of stickiness was fully crossed. After completing all target selection trials, and the tapping task for one scrollbar stickiness in one display configuration, participants completed a post-condition questionnaire, based on the device assessment questionnaire from the ISO 9241, Part 9 standard [2]. After resting, the participants completed another set of trials, followed by the same post-condition questionnaire, for each of the remaining levels of stickiness and display configuration.

Data Analyses

Computer logs were used to determine target selection time (ST), target selection errors, and the number of times that the cursor crossed over to the secondary monitor during the target selection task. All analyses were performed using only the lower 9 targets, which required scrolling. Logs were also used to find serial tapping task movement times (MT) for the primary and secondary monitor. ANOVAs were performed on the data and Huynh-Feldt corrections were used if the sphericity assumption was violated.

ST was calculated from when the grid of targets appeared, to when the target was selected. The median of ST data for the five repeated trials for each combination of scrollbar stickiness and display was computed. Outliers, (trials whose time exceeded 3 SD above the mean), were computed, however, there were no outliers in this task.

Target and Crossover errors were determined from mouse coordinates and mouse clicks, and ANOVAs were performed on the error counts. Trials with target selection errors were removed from the ST, (61 trials, 1.4% of total trials) and MT (23 trials, 0.5% of total trials) analyses but trials with crossover errors were included.

Table 1: Crossover Errors Analyses

	Different – Separated			Identical - Adjacent		
Stickiness	Mean (SE)	F	p	Mean (SE)	F	p
None (1)	2.40 (.41)	21.79*	**.000**	1.51 (.23)	20.90*	**.000**
Mild (2)	.68 (.13)			.45 (.05)		
Heavy (3)	.61 (.09)			.46 (.06)		
1 vs 2		22.61	**.001**		23.78	**.000**
1 vs 3		22.04	**.001**		19.93	**.001**
2 vs 3		.80	.390		.02	.885
Direction						
Down	.85 (.22)	25.86$^+$	**.000**	.49 (.09)	19.71$^+$	**.001**
Up	1.61 (.16)			1.12 (.14)		
Stick x Dir		.08*	.925		.08*	.920

*df=2,22; $^+$df=1,11

MTs for the serial tapping task were calculated as the mean selection time for the square on the main monitor, and the mean selection time for the square on the secondary monitor. All trials taking longer than 3 SD above the mean were removed as outliers (16 trials, 0.37% of total trials).

RESULTS

Our results were analyzed based on three key assessments. First, the number of times a user's cursor accidentally crossed over to the secondary monitor for each level of scrollbar stickiness. Second, the impact these crossover errors had on selection time and user satisfaction. Third, the impact that scrollbar stickiness had on tasks that required movement between the two monitors.

Crossover Errors

We expected that our sticky scrollbar would decrease cursor crossovers to the secondary monitor during a primary monitor task. Participants made 434 crossover errors (10% of total trials: 348 no, 48 mild, and 38 heavy stickiness). A 2[direction: scroll up, down] x 2[display] x 3[stickiness] repeated measures ANOVA was run on the number of crossover errors. A significant interaction effect of display condition by stickiness was found, ($F_{2,22}$=5.745, p=.01), so each display was analyzed separately (see Table 1).

For both display conditions, significant main effects were found for stickiness. Both levels of stickiness significantly reduced the number of crossover errors compared to no stickiness, but the level of stickiness itself had no effect on the number of crossover errors. Significant main effects were also found for the direction of scrolling with fewer crossover errors being made when scrolling down to the target than when scrolling back up to begin the next trial.

Although the crossover error results were similar for the two display conditions, there were more crossovers with different-separated displays than with identical-adjacent displays. This difference was significant with no stickiness (p=.009), marginally significant with mild stickiness (p=.049), but not significant with heavy stickiness (p=.171).

Impact of Crossover Errors

Target Selection Times

We compared the target selection time (ST) with crossover errors to the STs of the remaining trials (matching the combination of target, display, stickiness, and participant), and a paired-samples t-test revealed that STs were significantly higher when a crossover error occurred, (t_{199}=-9.47, p<.001). On average, this caused a ST increase of 30% and in 14 instances, the STs more than doubled.

Table 2: MT Analyses for Serial Tapping Task

	Left Movement			Right Movement		
Stickiness	Mean (SE)	F	p	Mean (SE)	F	p
None (1)	789 (27)	5.09*	**.017**	845 (32)	38.75*	**.000**
Mild (2)	826 (27)			1053 (63)		
Heavy (3)	879 (25)			1330 (71)		
1 vs 2		2.11	.174		28.25	**.000**
1 vs 3		9.99	**.009**		54.41	**.000**
2 vs 3		2.95	.114		23.17	**.001**
Display						
diff-sep	863 (27)	9.55$^+$	**.010**	1144 (69)	5.978$^+$	**.033**
ident-adj	800 (27)			1008 (38)		
Stick x Dis		.41*	.661		.50*	.530

We hypothesized that scrollbar stickiness would assist in scrollbar acquisition and improve overall target selection time. Although participants took longer, on average, to select targets without scrollbar stickiness (none=2120ms, mild=2003ms, heavy=2002ms), this difference was not significant ($F_{2,22}$=1.760, p=.195). This is likely due to the fact that crossover errors occurred in only 10% of the trials.

Participant Perceptions

Crossover errors also impacted participants' perceptions. All participants indicated that they noticed the cursor crossing over to the other display. Ten of the 12 participants also indicated that it bothered them. One participant commented: "Sometimes I moved the mouse too far to the right and missed the scrollbar. When the mouse entered the other screen it took me some time to locate it again."

In the post-condition questionnaires participants reported that that it was easier to accidentally cross over to the secondary monitor without stickiness than with mild stickiness, (p=.017), and that they accessed the scrollbar more accurately with mild stickiness than with no stickiness (p=.007). No significant differences were found between no stickiness and heavy stickiness or between levels of stickiness for accidental crossovers or perceived accuracy.

Impact of Stickiness on Movements Between Monitors

Our serial tapping task was designed to see if scrollbar stickiness would impact the time to cross between displays. Cursor movements were only impeded when crossing from the primary monitor to the secondary monitor (moving right). As a result, there was a significant main effect of direction on tapping time ($F_{1,11}$=75.9, p=.000), where users were faster moving left than moving right.

A significant interaction effect was found for direction and level of stickiness ($F_{2,22}$=51.30, p=.000), so each direction was analyzed separately (see Table 2). For movements to the right (sticky), a significant main effect was found for stickiness, with each level of stickiness significantly increasing the average tapping time. For movements to the left (not sticky), surprisingly, a significant main effect was also found for stickiness. The average tapping time increased with each level of stickiness, but only significantly from no stickiness to heavy stickiness.

Display configuration also impacted tapping times in both directions. Participants were faster tapping between identical-adjacent than different-separated displays (see Table 2).

DISCUSSION

Beyond the error and timing results, our study also provides insight into why issues with multiple monitors may be more prominent for different, disjoint, display configurations.

The crossover errors showed an interaction between display and stickiness. This implies that users carried out the tasks differently with identical-adjacent displays than with different-separated displays. Different mental models may have impacted users' interactions. When two identical monitors are placed side-by-side, it suggests a contiguous display. A maximized window on the left monitor may appear to be similar to a non-maximized window on a single computer monitor. As a result, users would use a targeting task to acquire the scrollbar, slowing down, to not overshoot. When two different monitors are placed with a small gap between them, the associated mental model may be more like two separate displays. In this case, a window that is maximized on the left monitor may appear similar to a window maximized on a single monitor. As a result, users may be less careful when acquiring the scrollbar, using the 'edge of the screen' to stop the cursor. Our results supported this hypothesis, revealing more crossover errors with different-separated monitors.

Another important result from this study came from the analysis of the post-task scrolling. After selecting the target, users were required to scroll back up to the top of the page and click on the 'Next Trial' button. Participants were told that their performance was only being timed during the target selection task and that they could rest if they wanted during this 'reset' phase, leaving participants free to scroll up in a natural manner. Despite not being timed, significantly more crossover errors occurred during up-scrolling. Two possible explanations for this result include: that acquiring the scrollbar for an up-scroll is more difficult than for a down-scroll and therefore more crossover errors were made; or that users felt less constrained to perform the task well and exhibited sloppier behaviour resulting in more crossover errors. This sloppier behaviour may also be indicative of how users normally perform scrolling actions.

CONCLUSIONS & FUTURE WORK

The results of this research clearly demonstrate that a pseudo-haptic technique can be used to create sticky widgets at the edge of a monitor. In our evaluation, participants were more accurate using a 'sticky' scrollbar. The benefits of reduced crossover errors included faster movement times, increased perceived accuracy and ease of use, and less frustration. One user commented that he found it "noticeably harder to pick the scrollbar [without stickiness] after using the stickiness for a while". However, it is also important to recognize the disadvantages of sticky widgets. The serial tapping times in our study did increase with stickiness of the scrollbar. In addition, stickiness creates a jerky movement across displays, which was commented on by several of the participants: "Moving to the second screen was not smooth enough; the jerks cause a delay in repositioning to the correct spot." Our further research will explore ways to minimize these disadvantages when the user needs to move between displays.

This study examined two levels of stickiness (mild and heavy). Our results showed very few differences between the two levels of stickiness. Future research will seek to determine the optimal level of stickiness for boundary widgets in different multi monitor configurations.

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