ZoomPointing Revisited: Supporting Mixed-resolution Gesturing on Interactive Surfaces

Matei Negulescu
University of Waterloo
mnegles@uwaterloo.ca

Jaime Ruiz
University of Waterloo
jgruiz@uwaterloo.ca

Edward Lank
University of Waterloo
lank@cs.uwaterloo.ca

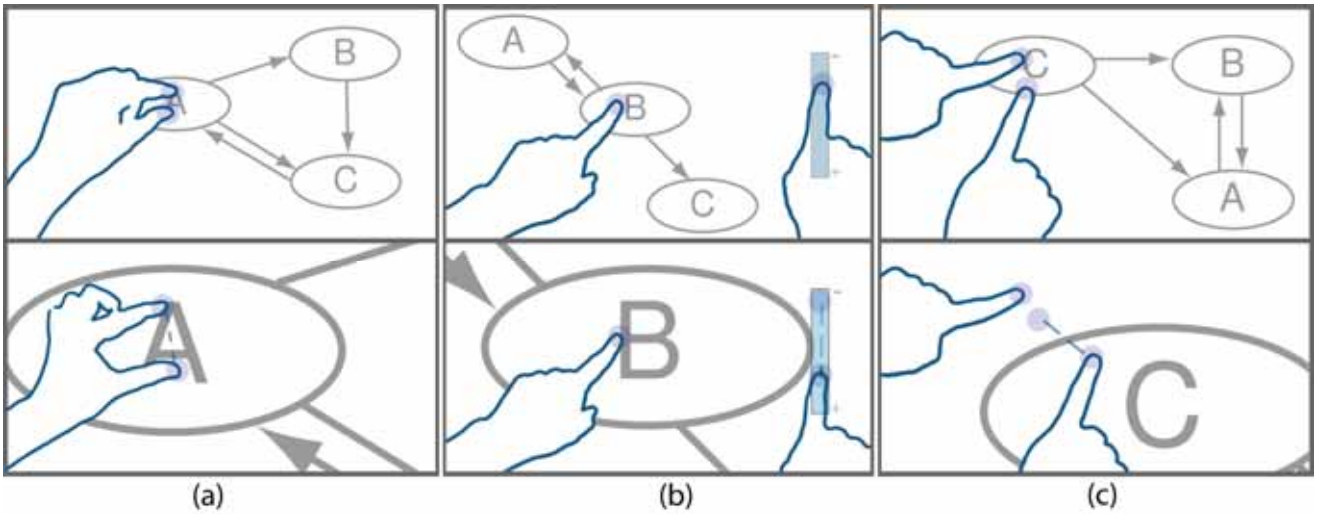

Figure 1. Three methods of supporting mixed-resolution gesturing on interactive surfaces: (a) Pinch-based zoom; (b) Widget – a bimanual technique where one hand is used to select the target and the other is used to zoom through a widget; and Offset (c), a hybrid technique where one hand is used to set the target while the other locally specifies the zoom magnitude; the zoom target is placed away from the direction of motion to enable simultaneous zoom-and-pan

ABSTRACT
In this work, we explore the design of multi-resolution input on multi-touch devices. We devised a refined zooming technique named Offset, where the target is set at a location offset from the non-dominant hand while the dominant hand controls the direction and magnitude of the expansion. Additionally, we explored the use of non-persistent transformations of the view in our design. A think-aloud study that compared our design to a bimanual widget interaction and the classic pinch-based interaction with a freeform drawing task suggests that Offset offers benefits in terms of performance and degree of control. As well, for the drawing tasks, the transient nature of view transformations appears to impact not only performance, but workflow, focus of interaction, and subjective quality of results by providing a constant overview of the user's task.

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

General terms: Human Factors

Keywords: Offset, mixed-resolution gesturing, tablet interaction

ITS 2011, November 13-16, Kobe, Japan.

INTRODUCTION
An affordance of multi-touch tablet computers and interactive surfaces, such as the Apple iPad and Microsoft Surface, is the ability to allow for free form 2D input. However, gesture-based input tasks on multi-touch tablets can be challenging if the gesture must be carefully positioned on the display [1]. For example, imagine drawing the node-link diagram shown in Figure 1a free-hand with a finger. The circular nodes and connecting links elements can be easily sketched at a coarse level of detail. However, drawing the strokes that define the node labels (i.e. sketching the text free-hand with a finger) introduces occlusion and inaccuracy as a result of the *fat finger problem* [8].

Addressing the fat finger problem involves improving accuracy by gesturing at multiple resolutions. Past solutions have supported scaling and translating content through gestures formed by two finger pinch-like interaction (e.g. [4]), or single finger gesturing (e.g. [5,6]).

In this work we present two designs to address the fat finger problem by efficiently supporting mixed-resolution gesturing through bimanual motor interaction [3]. Previous

research has demonstrated that bimanual interaction techniques on tablet computers result in quicker task completion times and are less error prone [7]. The first bimanual interaction method we consider is a *widget* based approach where zooming is activated through a traditional sidebar paradigm (Figure 1b) with an optional finger used to specify focal point of the zoom action. The second bimanual interaction technique we designed is a transient zooming technique (as opposed to persistent zooming) we call *Offset.* Offset uses the non-dominant hand to specify the target location of the zoom gesture. The dominant hand's motion is mapped onto a simultaneous zoom-and-translate operation (Figure 1c) due to an automatic offset applied to the user's target of zoom. Transformations to the view are reset when there are no fingers active on the screen.

We present an evaluation of the two techniques compared to the common two finger *pinch* paradigm (Figure 1a) using a think-aloud protocol. Our qualitative results suggest that Offset provides improved control and accuracy making it better suited for sketching tasks. Lastly, we discuss the effects of transient versus persistent transformations of the view on sketching behavior.

INTERACTION DESIGN

Our design of interaction techniques for mixed-resolution gesturing capitalizes on using multi-touch input to enable bimanual interaction for zooming and panning while drawing new strokes. In this section we describe each of the interactions considered for our study.

Pinch-based Interaction

Pinch interaction allows translation and zooming using two fingers. Zooming is done by pulling two fingers apart or together, where the midpoint between the fingers is taken as the target of the expansion (Figure 1a). Dragging two fingers on the canvas (while maintaining a constant mutual distance) corresponds to a translation (i.e. pan).

Widget-based Interaction

The *Widget* design allows users to zoom by brushing a finger on a toolbar on the right side of the canvas (shown in Figure 1b) and mimics the toolbar paradigm found on desktop paint applications. Moreover, we use Guiard's classification of bimanual motor interaction to support serial assembly [3]. Specifically, a finger on the canvas sets the frame of reference while the dominant hand can scroll up or down on the toolbar to modify the zooming factor (Figure 1b). Ruiz et al. have shown that setting the frame of reference with the non-dominant hand provides benefits in terms of performance and number of errors [7]. Considering this past work and the bias towards right handedness, our toolbar widget is located on the right. Additionally, the user can enter a pan mode through a separate mode on the toolbar. Lastly, the user can interact with content (e.g. drawing a stroke on the canvas) using one-finger input.

Offset

Offset is a modification of Albinsson and Zhai's Zoom-Pointing [1] and Benko et al.'s Dual Finger Stretch [2]. Similar to the Dual Finger Stretch, a single (most likely non-dominant) finger sets the target, or anchor, of the zoom operation. The second (likely dominant) finger specifies the magnitude of the expansion (Figure 2a-b). However, in our Offset technique, the target of the zoom is not directly underneath the non-dominant finger as in past techniques (e.g. [2,6]). Instead, the target of zoom is offset away from the trajectory of the dominant finger. As the dominant finger moves to zoom, the first 10px of motion is used to determine its trajectory. This trajectory is used to offset the target of zoom away from the anchor so that it is directly opposite to the direction of motion (Figure 2c). The remainder of the motion is used to specify the magnitude of the expansion. The placement of our offset effectively means that content beneath the anchor (i.e. non-dominant finger) is at the same time expanded and translated in the direction of motion (Figure 2d). Using this automatic offset provides additional control over where and how content is expanded.

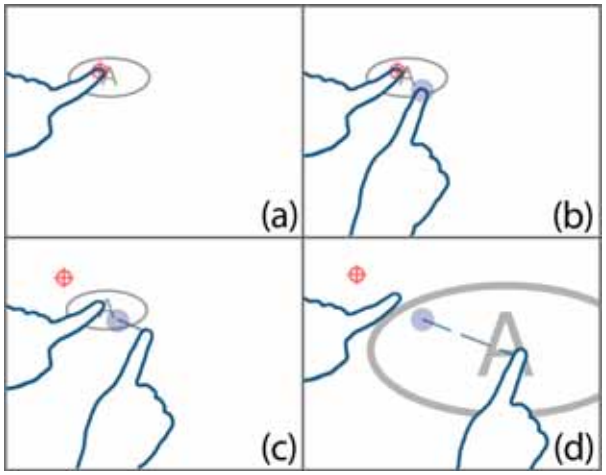

Figure 2: Offset interaction: (a) the target of zoom (in red) is initially set by the non-dominant finger; (b) the user places their dominant finger on the screen; (c) dragging the dominant finger 10px offsets the target of zoom opposed to the motion; (d) subsequent dragging of the dominant finger zooms and translates content due to the offset target of zoom.

Additionally, Offset offers two differences to the previous techniques. First the technique provides an implicit panning mode: moving the anchor finger while in a zoomed in state translates the view. Secondly, the technique provides transient transformations. Once the user performs a zoom operation (requiring two fingers) the system implicitly switches to a content interaction mode (e.g. inking in a drawing application). As long as at least one finger remains on the zoom surface, the scaling and translation operations persist. Once the user releases all fingers from the surface, the view resets to its default zoom level and translation. In other words, transformations to the view are enabled while a finger is engaged on the screen, making them transient as opposed to the persistent paradigm of Pinch and Widget.

The purpose for introducing transient transformations to the view, as opposed to persistent transformations, is two-fold:

first, we noted through informal observations that charcoal sketch artists lean in close to add detail and periodically pull away from the canvas to get an overview of the piece; second, we wanted to minimize the cost of errors in zooming and panning operations by implementing a quick reset.

Pilot Study

Our Offset design went through several iterations as a result of feedback from a pilot study with 4 people. Most importantly, our participants suggested difficulties with expanding content targeted by the non-dominant finger.

In our initial design, users set the set the target of expansion (i.e. zoom) with their non-dominant finger while their dominant hand controlled the magnitude. Our participants noted that after the expansion, the targeted content remains underneath and, therefore, obstructed by the non-dominant finger. As a result, participants learned to offset the placement of their non-dominant finger so that the desired content expands away from the occluding finger.

We experimented with applying an automatic offset to the target of the zoom operation in order to mitigate our users' need to compensate for the occlusion problem. Since this offset also scales with the zoom operation, the content effectively moves away from the non-dominant finger as magnification increases. Our final Offset design applies a constant automatic offset to the locus of zoom determined empirically from our pilot study.

STUDY

We evaluate mixed-resolution interaction using our three techniques (Pinch, Widget and Offset) through a think-aloud study with 7 participants (ages 24-33, all right handed). All participants were technically savvy early adopters, though not all were experienced with multi-touch tablets (P1 and P3 had no experience). Trials were performed on a Motorola Xoom tablet running Android 3.0 in landscape mode at a resolution of 1280x800.

Participants performed two freehand drawing tasks for each of the three techniques. The first consisted of highlighting spelling errors in three excerpts from a children's fairytale by circling the errors. Excerpts were long enough to fill a single landscape page and spelling mistakes were evenly distributed on the page. The goal of this task was to provide a scenario where the user is forced to get context (i.e. read a passage) but require accuracy to interact.

The second task asked participants to reproduce three entity-relationship (ER) diagrams – one for each technique – freehand at 1:1 scale (i.e. the entire sketch should fit on one screen at default scale). This task simulates a realistic scenario of two-dimensional interaction (e.g. sketching) requiring input at both coarse and fine scales. The order in which the techniques were presented was counterbalanced. Throughout, participants were asked to think aloud and each condition was followed by an unstructured interview focusing on the usability of the technique. A final interview was given to compare and contrast the interaction methods.

Results

Overall, 4 out of 7 participants preferred Offset over Pinch or Widget for freehand sketching tasks. One participant was undecided between the efficiency of Offset and the familiarity with Pinch for interacting with content.

"Offset is most efficient. It forces me to be precise. [...] I have more experience with Pinch though. I don't know. It's hard to say [which is better]." [P6]

Both P2 and P3 mainly disliked the transient nature of Offset and generally preferred Pinch. However, it is noteworthy that both of these participants were positive regarding the technique. P3, one of our two inexperienced users, mentioned that while Pinch is "*more intuitive,*" experienced users may be more positive towards Offset:

"Probably people who use tablets or smartphones, they might feel more comfortable using [Offset]." [P3]

Additionally, P2 was very positive about the afforded control of Offset and explained that an optional persistent mode should be added for freehand drawing tasks. The choice to switch between transient and persistent zooming would improve the overall efficiency for different tasks.

"For text [correction] you want an overview. […] In drawing you spend a lot of time in the zoomed level so you don't want to hold [the finger] all the time. […] If it's sticky (persistent) only on button click you just don't use it. In text [correction] it's much better if it goes back when you release it." [P2]

Three themes emerged from our interview and observation data: perceived performance, afforded control, as well as differences in behavior and perception of tools due to transient versus persistent transformations.

Performance

A common concern when comparing the interaction techniques was performance. Specifically, users frequently cited accuracy of interaction (e.g. the ability to predict and properly target the expansion and translation of content on the canvas), as well as the number of perceived actions as metrics for how much work is needed to perform a task.

In terms of predictability and accuracy of interaction, *Pinch* was ranked worst of the techniques by all but participants P3 and P5. Even users who rated Pinch very highly reported issues with the accuracy and efficiency of the interaction.

"[Pinch] is far less accurate, that's for sure; I found myself correcting almost every move I made. [...] I know how it works. I do a binary search on a page. Zoom into this top half then pan; […] 8 out of 10 times I would do some correction." [P6]

On the other hand, P1, P4 and P6 praised Offset for its accuracy in selecting a target for expansion (i.e. zoom)

"Seems like a nice way of zooming in on a targeted area. It's a lot better than the pull to expand that Apple uses. I haven't needed to pan yet, so that's a good sign." [P4]

Secondly, the transient nature of Offset resulted in fewer panning operations than either Widget or Pinch, as reported by a majority of the participants.

"There is no need for pan, because I knew where I wanted to zoom in." [P1]

Moreover, Offset succeeded in providing a low penalty for error in accuracy or control, therefore further limiting the number of operations performed. This low interaction penalty was a commonly suggested improvement for both Pinch and Widget.

"It would be nice to have a button to maximize zoom instantly." [P1]

Overall, participants perceived Offset to be most efficient due to accuracy of targeting, predictability of interaction, and number of actions required to complete a task.

Control

The issue of control afforded by each of the techniques was repeatedly referenced by our participants. Overall, participants enjoyed the ability to control the direction of expansion in Offset.

In addition, the ability to efficiently adjust the view by panning using the non-dominant hand was highly praised. P7 noted that using a hand to pan content while the other is used for input is similar to controlling a physical canvas.

"I felt I was more involved in the art piece; I was more hands on; I was moving the paper around, kind of how when you're drawing on a piece of paper, your non-dominant hand is on the paper, moving it around. This felt more like a metaphor of that."[P7]

However, participants noted that the ability to control the zoom by allowing users to "clutch" by continuously pinching is a useful feature in Pinch. This lack of sequential zoom in Offset (i.e. clutching) factored into P2 ranking the technique behind Pinch.

Transient versus Persistent Transformations

As previously presented, the choice between transient and persistent transformations has an impact on perceived performance. However, the two paradigms also offer important differences in users' workflows and their perception of the individual tools.

Participants spent more time inking new content while zoomed in when using the persistent Widget and Pinch. Participants effectively added content at the finest common scale needed for efficient input accuracy. As this behavior leads to fewer zoom operations and more panning, the focus of the interaction was shifted.

Since participants tended to heavily rely on the use of panning for the Pinch and Widget techniques, some of our participants viewed the techniques more equivalent than we expected, even though the same participants reported differences in accuracy and performance. For example, one participant stated:

"For drawing, Pinch and the sidebar (Widget) are pretty much the same because I only need to zoom in once." [P2]

This shift of focus, leads participants like P2 see the implementation of panning as more critical to get "right" in Pinch and Widget than the zooming interaction.

Additionally, working at a finer scale means that participants did not step back for an overview as often. We qualitatively rated the resulting ER diagrams and found that, when using persistent techniques (Pinch and Widget) our participants' sketches tended to have worse organization and did not fit on one screen as requested. This observation is in line with expectations of artists who do not step back from the canvas to get an overview as often.

CONCLUSIONS

In order to overcome the fat finger problem, we considered three designs for gesturing at multiple resolutions: pinch-based interaction, a widget-based interaction, and Offset – a hybrid technique where the user can target with one hand and perform pinch-like interaction with the other. Results from our think-aloud study demonstrate that users prefer Offset for freehand sketching tasks over the alternatives. Participants cited improved performance due to Offset's transient transformations of the canvas, as well as added control in panning and the ability to specify where content should be expanded. Lastly, we note that a non-persistent approach to view transformations has an impact on users' workflows, perception of tools, and the subjective quality of the results. Our initial evaluation demonstrates that Offset is a technique that efficiently supports mixed-resolution gesturing on interactive surfaces.

ACKNOWLEDGMENTS

Funding provided by the Natural Science and Engineering Research Council of Canada and the Networks of Centres of Excellence for Graphics, Animation and New Media.

REFERENCES

1. Albinsson, P.-A. and Zhai, S. High precision touch screen interaction. *Proc. of Human factors in computing systems - CHI '03*, (2003), 105.
2. Benko, H., Wilson, A.D., and Baudisch, P. Precise selection techniques for multi-touch screens. *Proc. of conference on Human Factors in computing systems*, 1263–1272.
3. Guiard, Y. Asymmetric Division of Labor in Human Skilled Bimanual Action: The Kinematic Chain as a Model. *Journal of Motor Behaviour 19*, 4 (1987), 486 – 517.
4. Hinckley, K., Czerwinski, M., and Sinclair, M. Interaction and modeling techniques for desktop two-handed input. *Proc. of User interface software and technology*, (1998), 49–58.
5. Malacria, S., Lecolinet, E., and Guiard, Y. Clutch-free panning and integrated pan-zoom control on touch-sensitive surfaces: the cyclostar approach. *Proc. of conference on Human factors in computing systems*, (2010), 2615–2624.
6. Olwal, A., Feiner, S., and Heyman, S. Rubbing and tapping for precise and rapid selection on touch-screen displays. *Proc. of Human factors in computing systems*, (2008), 295–304.
7. Ruiz, J., Bunt, A., and Lank, E. A model of non-preferred hand mode switching. *GI '08: Proc. of graphics interface 2008*, (2008), 49–56.
8. Siek, K.A., Rogers, Y., and Connelly, K.H. Fat Finger Worries: How Older and Younger Users Physically Interact with PDAs. In M.F. Costabile and F. Paternò, eds., *Human-Computer Interaction*, (2005), 267–280.