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QuantiScale: A Study in Redesigning Interactions for Multi-Touch

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Abstract

We investigate the performance of QuantiScale, a new multi-touch interaction technique for the quantification of distances in medical images and discuss the benefits and prospects of redesigning interactions with multi-touch devices. Taking advantage of the multi-touch capabilities, QuantiScale behaves like a tape measure, but automatically adjusts the view onto the measured object to improve precision and speed. The technique has been studied in a real-world scenario measuring the diameter of structures for the diagnostic reading of medical images and provides hints for the replacement of traditional mouse-based interaction with gestural interaction. Results of the quantitative evaluation indicate a high measurement precision particularly for small objects. Participants experienced QuantiScale as being more fun, natural, and intuitive in comparison to mouse-based interaction even though the subjective preference for speed and precision was still in favor of the mouse.

Categories and Subject Descriptors: H.5.2 User Interfaces: Benchmarking, Input devices and strategies

1. Introduction

With increasing popularity of mobile devices and mobile apps, the use of gestural interaction style is becoming daily routine. Multi-touch gestures are arguably more natural or compelling. However, redesigning existing interactive tools for professional users must be handled with great care. One concern often expressed by these users is a reduction in productivity. We especially noticed this reaction while exploring the suitability of touch interaction for the diagnostic reading (inspection) of medical images. During the presentation of a multi-touch-operated image reading system at RSNA (the largest annual conference on radiology), the most asked question was: *How does multi-touch interaction compare to mouse interaction in terms of precision and speed?* This question should come at no surprise given that most users are well trained in using a mouse to control a computer but not necessarily in using a multi-touch device for the same purpose. Yet that question could not be answered precisely due to a pending quantitative study and the non-conventional interaction design of our image reading system.

The workflow-oriented design of our MR-image reading system wirelessly links a mobile touch-device, such as Apple’s iPad, with dedicated diagnostic monitors and adapts the behavior and the presented content on the mobile device depending on the location and access permission level of the user. Having access to patient information on the move and being able to answer patient specific questions regardless of the current location is a major advantage in clinical routine. However, the available screen space of mobile devices is very limited. Image comparisons, such as current-prior comparison of patient images or the comparison of different MR sequences, are essential for diagnostic reading and require sufficient screen space. Mobile software that has FDA 510(k) clearance and that can be used for diagnosis is therefore restricted to situations in which no other workstation with calibrated, larger screens is available [FDA11]. Our system design tries to overcome this limitation by linking the mobile device with dedicated monitors if image reading is required. All diagnostically relevant image data will be presented on large, calibrated screens. The mobile device displays secondary information, such as anamnesis, patient history, genetic predisposition and even controls the patient selection but is never used to display patient images for diagnostics. Interaction with the data, however, is controlled entirely via multi-touch gestures on the multi-touch tablet. Thus using our approach, diagnostic reading differs in interaction style and the use of interaction devices —a multi-touch device vs. a conventional mouse.

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Figure 1: *Pairing a mobile device with a workstation or a large screen for diagnostic reading*

A meaningful study of the effects that multi-touch gesture control has on the entire image reading system would be difficult to conduct since the information architecture and the interaction design have been tailored to touch-control. Instead, we chose to investigate the performance of users for a very common task in image reading that requires high precision, the quantification of distances between structures and diameters of objects in images. The precise interaction of marking two reference points is usually accompanied by zooming and panning in order to reveal and clearly recognize the borders of the structures to be measured. Taking advantage of multi-touch capabilities, a new multi-touch interaction technique, called QuantiScale, has been designed to support the user's measurements by combining the interactions of marking reference points and view control. The technique has been studied in the context of reading medical images displayed on a conventional display with the user interacting on a touchpad device. Sitting and standing use are compared to mouse interaction for reference. We included standing use to account for a usage scenario in which the physician stands in front of a wall mounted monitor holding the mobile device with one hand (see Figure 1).

2. The interaction technique QuantiScale

While reading images for diagnostics, radiologists often use distance quantification tools, for instance to compare the size of a lesion before and after treatment. It is crucial to offer a tool that allows precise results and that is effective, efficient, and easy to use.

For quantification, the user usually places start and end point of a measurement line. This is a well-known interaction technique commonly performed using a mouse to sequentially mark the reference points. It is so simple that an adaptation for multi-touch seems unnecessary and possible gains very small. Yet an optimization of the interaction offers several opportunities for improvement but also for degradation. A redesign of this functionality for multi-touch must consider the following aspects:

- The precision that is required in image space:
  - While this seems obvious it is also very crucial: The user must be able to see the structures she wants to measure by *adjusting the view*. Hence this is part of the quantification process.
  - The user must be able to *precisely mark two reference points* in the image.
- The *speed* with which users typically perform this function:
  - Using multi-touch, the reference points can be marked in parallel. Attention of the user, however, might not work in parallel.
  - A parallel adjustment of the reference point positions allows for a more stable, focused view on the object

With QuantiScale the user places the two control points with thumb and index finger of the same hand (also called pinching). QuantiScale is a unimanual, multi-touch interaction technique.

While gesture interaction often feels more natural, it is not without drawbacks. QuantiScale works around the common issue of low precision selection with fingers on small targets [SW13] and the need for executing multiple gestures. It anticipates the desired size (by observing the finger movements) and zooms the image automatically to enable a precise measurement even of very small structures (see Figure 2). The gesture does not require periodic panning adjustments as it coordinates panning and zooming simultaneously, using the center between the first and second finger as the focus point. Furthermore, while users pan and zoom, spanning the fingers also lengthens or shortens the measurement line, which is shown on the external screen overlaying the image, to set the endpoints for measuring the distance.

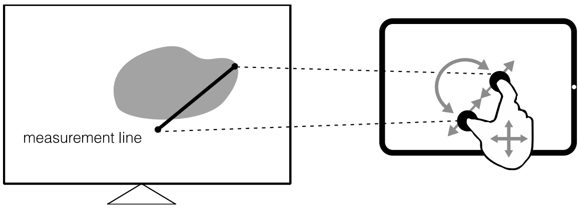

Figure 2: *The two-finger interaction technique enables spanning, rotation, and target selection of the measurement line and its endpoints and simultaneously pans and zooms the image. (Left: Large viewing screen. Right: Mobile touch-device.)*

Moving the fingers closer together zooms into the image and visually lengthens the line, while moving them further apart zooms out and shortens the line. The zooming factor is calculated based on the length of the measuring line. If the distance between the two fingers falls below a certain value, the application automatically starts to zoom into the image as the user continues to pinch. Zooming out works with the same principle. If the distance between the two fingers exceeds a certain value, the application automatically zooms out (see Figure 3).

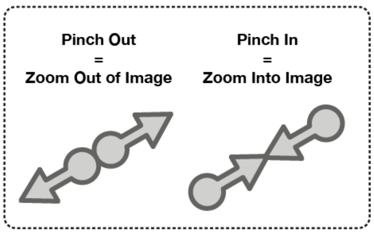

Figure 3: *Pinch gesture in QuantiScale.*

3. Related work

There is a large body of previous work in the field of human-computer interaction studying touch-based input and interaction while comparing it to input techniques with devices such as mouse, keyboard, or stylus ([BWB06], [CAG12], [FWS*07], [MSB91], [MGF09], [SS91], [SW13]). As our work aims at using touch devices for indirect interaction with images represented on an additional screen, disadvantages such as fingers or arms occluding the screen [AZ03] are insignificant. However, other challenges such as arm fatigue can still wield influence on the users' performance [Yee09].

3.1. Precision & Speed of Touch vs. Mouse

Several works concluded finger accuracy to be a disadvantage of touch interaction with small targets despite often being faster than mouse interaction. Forlines et al. [FWS*07] suggests touch for bimanual input and mouse for interactions requiring a selection point. Lee & Zhai [LZ09] and Sasangohar et al. [SMS09] found finger accuracy in touch interaction to be worse. Cockburn et al. [CAG12] investigated the performance of touch selections comparing finger, stylus and mouse for tapping, dragging, and radial pointing and confirmed prior results, showing finger pointing to be faster than stylus or mouse but more inaccurate, particularly with small targets. Dragging tasks with finger input were also slower than mouse and stylus, though dragging errors were low in all conditions.

3.2. Zooming & Panning

Guiard and Beaudouin-Lafon [GB04] showed that more complex tasks, such as multiscale pointing, conform to Fitts' Law. Bourgeois and Guiard [BG02] found the performance of multiscale pointing to strongly depend on the degree of pan-zoom parallelism. Malacria et al. [MLG10] introduced *CycloZoom+,* a technique that integrates simultaneous 2D panning and zooming. During the zooming-in it allows the user to continuously adjust the location of the expansion focus without lifting their finger from the screen. To overcome the fat-finger problem, Negulescu et al. [NRL11] introduced a 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.

3.3. Direct vs. Indirect Interaction

Schmidt et al. [SBG09] compared direct and indirect multi-touch input on large surfaces and found a higher cognitive load in indirect conditions. In the indirect condition the study found more negative impact on completion time for pointing than for dragging.

4. Evaluation / Experiment

The objective of this study was to evaluate the precision and speed for measuring the diameter (defined as the maximum distance between any two points) of an object in an image. We compared the finger touch gesture

QuantiScale executed on an mobile touch-device to the traditional single-point mouse interaction.

20 participants (8 women and 12 men, 80% being right-handed) between 17 and 39 years old (μ = 29.3, σ = 5.84), volunteered for the experiment. All were experienced computer users (ø 8,3h/day) but did not have significant experience using smartphones or tablets with touch screens.

The experiment was conducted on an Apple Macbook Pro running OS X and an iPad used as the multi-touch interaction device. The external screen, on which the images were shown, had a resolution of 2560 x 1140 pixels. The images were 512 x 512 pixels wide simulating real breast MRI image data as acquired for breast cancer screening. A pixel represented an area of 0.664 x 0.664mm of the imaged object. Each image contained one synthetic object (representing a lesion) of which all geometric properties are known. The objects diameters were in a range of 8mm to 54.7mm (μ=27.47mm, σ=12.64mm). To assess the effect of the object size itself, we distinguish between small (≤3cm) and large (>3cm) objects.

4.1. Task & Procedure

The experiment consisted of one task, the measurement of distances in three conditions. One conditions was sitting and using the mouse for measuring (see Figure 4), the second was sitting while using the mobile touch-device, and the third was standing and using the mobile-touch device.

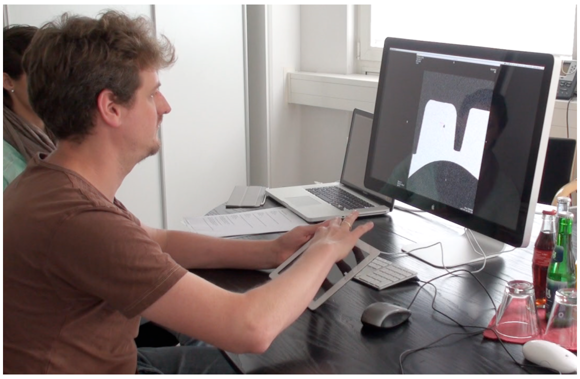

Figure 4: *The participant measures the object using the mobile touch-device while he is sitting.*

The participants were asked to follow the instructions given by the prototype. Before starting each experiment, all participants were led through a training session of 10 cases for each condition to get familiar with the gesture and the setup. The prototype randomly chose in which condition to start the training session as well as the evaluations session. For signaling a started and finished case, participants had to press the space bar on the keyboard. Only then the time counter started and stopped. Between consecutive cases, the participants were allowed to take as much time as they needed. After the training session, participants conducted 15 repetitions of the measurement task for each condition (15x sitting/mouse, 15x sitting/mobile touch-device, 15x standing/mobile touch-device) while being asked to measure each case as precise and fast as possible.

Sitting, using the mouse. The participants sat in front of a large screen on which the image data was represented and used the mouse to measure the diameter of an object in the image. Zooming of the image was controlled using the mouse wheel while pressing and holding the wheel could move the image. The participants were asked to hit the space bar with the same hand they operated the mouse with. This way they could not lay their other hand ready on the space bar.

Sitting, using the mobile touch-device. The participants sat in front of a large screen on which the image data was represented and used the iPad to measure the diameter of an object in the image. They could choose whether to hold the iPad in their hands or lay it on the table. Participants were asked to hit the space bar with the same hand they used for gesture input.

Standing, using the mobile touch-device. The participants stood in front of a large screen on which the image data was represented and used the iPad. They could tilt the large screen and hold the iPad as they preferred. Participants were again asked to hit the space bar with the same hand they used for gesture input.

4.2. Measures & Statistical Tests

There were two sources of objective data. In order to assess precision, the deviation of the measured diameter (MD) from the ground truth as well as the shortest distance of each of both endpoints of the measurement line from the closest border of the object was calculated. Distances were recorded in millimeters with screen pixel precision for the placement of the endpoints. Since the displayed image could be zoomed-in, measurements could be more precise than one pixel of the original image. All three values were combined (added) to form the precision error (PE) value. If compared, a smaller PE value represents a more precise measurement. Second, the task completion time (TCT) was measured. In addition, a pre- and post-questionnaire was used to evaluate the participants' opinion regarding the

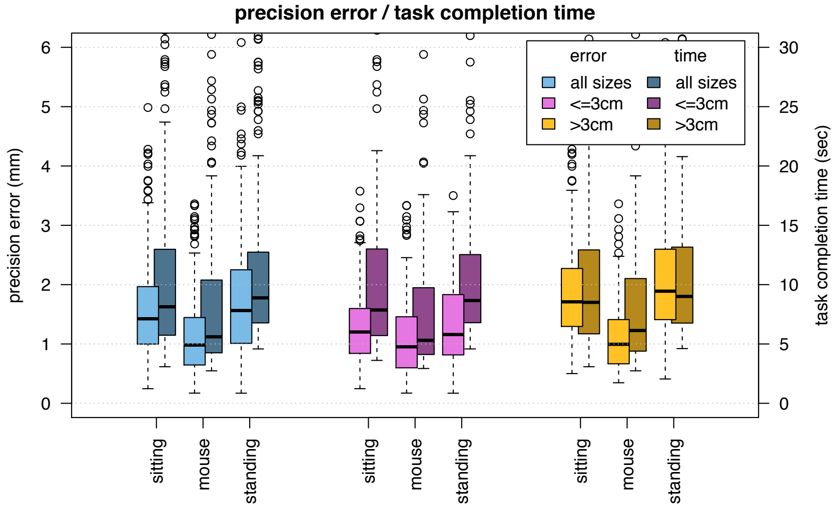

Figure 5: *The precision error for different object sizes (all, ≤3cm, >3cm); a smaller value is better*

anticipated interaction performance with the different techniques before as well as the joy of use, intuitiveness, and effort after executing the tasks. We used 4-point Likert scales and combined subjective ratings into two categories: 'agree' and 'not agree' for further analysis. While the inclusion of a neutral answer might seem favorable, we did not force participants in either direction. An interviewer who also filled the questionnaires asked the questions. All objective data were analyzed using an analysis of variances (ANOVA) test with repeated measures and the within-subjects factor *interaction technique*, post-hoc analysis was performed using Tukey's HSD.

5. Results

5.1. Precision

For the precision, as defined in the previous section, we found a significant effect of the used interaction technique, $F(2, 38)=28.4$, $p<0.001$. Post-hoc tests (Tukey HSD) revealed a significant difference between mouse interaction (μ=1.13mm, σ=0.65mm) and sitting (μ=1.59mm, σ=0.83mm) as well as the standing (μ=1.74mm, σ=0.96mm) use of QuantiScale. No significant difference between sitting and standing use of QuantiScale was found. Further investigation using a 2x3 mixed ANOVA for *object sizes* and interaction techniques showed a significantly more precise measurement for small objects (MD<=3cm, μ=17.05mm, σ=6.12mm) than for large objects (MD>3cm, μ=37.9mm, σ=8.04mm) with $p<0.001$.

The percentage of participants who perceived the mouse input as being more precise was in line with our measurements (80%).

Although the difference in precision error between mouse interaction and gestural input is statistically significant, the difference is very small. The deviation of the measured distance from the ground truth for mouse input was on average 0.77mm. For sitting gestural input, the deviation was 1.13mm on average. In our test case, the medical images had a pixel size of 0.664 x 0.664mm. Hence the difference between mouse and sitting gestural interaction is less than the size of one image pixel. The integrated zooming diminishes this difference for small objects even further (see Figure 5). This is very important since precise interaction with small objects is often one of the known drawbacks of multi-touch gestures.

The importance of the precision error depends on the use case. For our medical case, the difference between mouse and gestural input bears no practical relevance. A mean difference between both techniques of less than the size of one image pixel is within the range of the precision of the image acquisition unit (or image acquisition process).

5.2. Speed

The interaction technique had a significant effect on the TCT as well, $F(2, 38)=9.67$, $p<0.001$. Again, the mouse interaction (μ=9.62s, σ=10.82s) was significantly faster than the sitting (μ=11.52s, σ=9.57s) or standing use of QuantiScale (μ=11.8s, σ=8.41s) (see Figure 5). Both uses of the multi-touch gesture revealed no significant difference. No significant effect was found for the object size.

80% of the participants also perceived the mouse input as being faster than the gesture interaction.

Although precision often carries a much higher weight, if measuring distances is a frequent task in an application, the speed differences between mouse and multi-touch gesture interaction of approximately 20% might have a relevant effect on the overall performance.

6. Discussion

Many participants criticized the limited zooming in our test application. Ensuring the whole object can always be seen in its entirety, it did not allow for enough precision. This was especially the case for larger objects. While measuring, the distance between two fingers does not fall below the value that activates the zooming or it reaches the set limit too soon. This led us to compare object size and precision. The results show that for large objects the user cannot define the edges of the object to set the endpoints as precisely as one can do for small objects. In further work, we plan to improve QuantiScale so that there is no set limit to the zoom activation level. We believe that with this adjustment and familiarization with touch interaction the performance of QuantiScale can be improved.

Indirect interaction, as in our setup, might result in a higher cognitive load of users. Our results show that the performance of the gestural interaction is slightly worse than mouse interaction. However, for the application of diagnostic reading, indirect interaction is often the only way of using these mobile technologies due to regulatory restrictions [FDA11].

6.1. The User Experience

Before conducting the training session and going through the evaluation cases, all participants were asked which interaction technique they expect to perform better. 80% anticipated the mouse being faster and more precise. Based on their experience during the evaluation we asked them again after finishing the evaluation, which also resulted in 80% of the participants voting in favor of the mouse. However, 50% thought QuantiScale to be more pleasant to use and 80% perceived QuantiScale to be more fun. 90% valued QuantiScale as being intuitive while some users also experienced the gestures also as tiring (45%, this includes standing use).

The results show that most participants enjoyed using QuantiScale. While discussing the prototype they described QuantiScale as being more natural. Some also imagined QuantiScale being more precise and especially faster when using the gesture regularly and thought QuantiScale being disadvantaged due to their permanent and long-time use of the mouse. We believe that joy of use is an important aspect for using software regardless of the application area.

7. Conclusion

We investigated precision and speed for multi-touch input in a real-world professional scenario that traditionally relies on mouse-based interaction. Since the task of measuring the distance between two points in an image naturally requires the user to select two separate points, we developed QuantiScale—a unimanual multi-touch technique. Based loosely on the interaction metaphor of a measuring tape, the technique automatically adjusts the view onto the object or distance one is about measure. The technique has been compared in sitting and standing conditions against traditional mouse interaction. While mouse control is faster and more precise than gestural input, the differences are very small. Depending on the actual use case, the difference might not bear any practical significance. For our usage scenario, the diagnostic reading of medical images, the precision of QuantiScale is acceptable. Above all, the positive feedback of the participants concerning the user experience while using the multi-touch gesture confirmed the approach of investigating the use of touch-input for application areas where precision and interaction speed is vital.

References

[AZ03] Albinsson, P.A., Zhai, S. (2003). High Precision Touch Screen Interaction. In *Proc. CHI 2003*, ACM Press, 105-112.

[BWB06] Benko, H., Wilson, A.D., & Baudisch, P. (2006). Precise selection techniques for multi-touch screens. In *Proc. CHI 2006*, ACM Press, 1263-1272.

[BG02] Bourgeois, F, and Guiard, Y. (2002). Multiscale Pointing: Facilitating Pan-Zoom Coordination. In *Proc. CHI EA 2002*, ACM Press, 758-759.

[CAG12] Cockburn, A., Ahlström, D., and Gutwin, C. (2012). Understanding performance in touch selections: Tap, drag and radial pointing drag with finger, stylus and mouse. In *International Journal of Human-Computer Studies*, Volume 70 Issue 3, 218-233.

[FDA11] FDA (2011). Mobile Medical Applications: Draft Guidance for Industry and Food and Drug Administration Staff. July 21, 2011.

[FWS*07] Forlines, C., Wigdor, D., Shen, C., and Balakrishnan, R. (2007). Direct-touch vs. mouse input for tabletop display. In *Proc. CHI 2007*, ACM Press, 647-656.

[GB04] Guiard, Y. and Beaudouin-Lafon, M. (2004). Target Acquisition in Multiscale Electronic Worlds. In *International Journal of Human-Computer Studies 2004*, Volume 61 Issue 6, 875-905.

[LZ09] Lee, S. and Zhai, S. (2009). The performance of touch screen soft buttons. In *Proc. CHI 2009,* ACM Press, 309-318.

[MSB91] MacKenzie, S. Sellen, A., and Buxton, W. (1991). A Comparison of Input Devices in Elemental Pointing and Dragging Tasks. In *Proc. CHI 1991*, ACM Press, 161-166.

[MLG10] Malacria, S., Lecolinet, E. and Guiard, Y. (2010). Clutch-Free Panning and Integrated Pan-Zoom Control on Touch-Sensitive Surfaces: The CycloStar Approach. In *Proc. CHI 2010,* ACM Press, 2615-2624.

[MGF09] Matejka, J., Grossmann, T., and Fitzmaurice, G. (2009). The Design and Evaluation of Multi-Finger Mouse Emulation Techniques. In *Proc. CHI 2009*, ACM Press, 1073-1082.

[NRL11] Negulescu, M., Ruiz, J. and Lank, E. (2011). ZoomPointing Revisited: Supporting Mixed-resolution Gesturing on Interactive Surfaces. In *Proc. ITS 2011,* ACM Press, 150-153.

[SW13] Sambrooks, L. and Wilkinson, B. (2013). Comparison of gestural, touch, and mouse interaction with Fitts' law. In *Proc. CHI 2013*, ACM Press, 119-122.

[SMS09] Sasangohar, F., MacKenzie, S., and Scott, S.D. (2009). Evaluation of Mouse and Touch Input for a Tabletop Display Using Fitts' Reciprocal Tapping Task. In *Proc. of the 53rd Annual Meeting of Human Factors and Ergonomics Society*, 839-843.

[SBG09] Schmidt, D., Block, F., and Gellersen, H. (2009). A Comparison of Direct and Indirect Multi-touch Input for Large Surfaces. In *Proc. INTERACT 2009*, Springer-Verlag, 582-594.

[SS91] Sears, A., and Shneiderman, B. (1991). High precision touchscreens: design strategies and comparisons with a mouse. In *Journal of Man-Machine Studies 1991*, Volume 34 Issue 4, 593-613.

[Yee09] Yee, W. (2009) Potential Limitations of Multi-touch Gesture Vocabulary: Differentiation, Adoption, Fatigue. In: *Proc. 13th Int'l Conf. on Human-Computer Interaction (HCI'09)*, 291-300.