Felix Ritter, Jumana Al Issawi, Markus Harz, Simon Benten, Kathy J. Schilling

Combining Mobile Devices and Medical Workstations for Diagnostic Reading of Medical Images

Kombination von Mobilen Geräten und Medizinischen Workstations für die Diagnostische Betrachtung Medizinischer Bilder

Human-computer interaction_medicine_interaction design_iPad_healthcare_interface_touch interaction_multi-touch

Summary. We propose a new concept for the combination of mobile multi-touch devices and diagnostic reading workstations to provide a workstation-grade reading experience of medical images with mobile devices. The patient-centric, workflow-oriented design links a mobile touch-device with dedicated diagnostic monitors and adapts the behavior and the presented content of the mobile device depending on the location and access permission level of the user. The design is based on a breast MRI reading system, exploring the suitability of touch interaction for diagnostic reading of MRI patient cases. We discuss the benefits for radiologist as well as possible challenges. Furthermore, we will describe the results of an informal evaluation of the prototype and a formal evaluation of the speed and precision of the indirect multi-touch gesture for measuring objects in image data.

Zusammenfassung. Wir präsentieren ein neues Konzept für die Kombination mobiler multi-touch Geräte und medizinischer Workstations, um über mobile Geräte eine mit medizinischen Workstations vergleichbare Qualität für die Betrachtung medizinischer Bilddaten anzubieten. Das patientenzentrierte, workflow-orientierte Design verbindet hierbei ein mobiles Touch-Gerät mit medizinisch zugelassenen Monitoren und passt die Steuerung sowie die auf dem mobilen Gerät dargestellten Inhalte und Informationen dem Standort und den Zugangsrechten des Benutzers an. Das Konzept der Software basiert auf einem Diagnosesystem für die Befundung von Brust-MR-Daten und exploriert die Eignung von Touch-Interaktionen für das diagnostische Betrachten von MR Patientendaten. Wir diskutieren die Vorteile für Radiologen sowie mögliche Herausforderungen. Des weiteren werden die Ergebnisse einer informellen Evaluation des Prototypen sowie einer quantitative Studie zur Geschwindigkeit und Präzision einer neuen multi-touch Geste zur Vermessung von Objekten in medizinischen Bilddaten beschrieben.

1. Introduction

Mobile interaction with clinical data is becoming increasingly popular as mobile devices, such as smartphones or multi-touch tablets, evolve into personal information hubs. A high number of doctors already own such devices or intend to (Hirschorn 2011). Having access to patient information on the move and being able to answer patient specific questions regardless of one's current location is a major advantage and can be a big time-saver. Several software solutions for smartphones and multi-touch tablets, such as Apple's iPad, have been available recently. However, for diagnosis and viewing of image data, the available screen space of these devices is very limited. Image comparisons, such as current-prior comparison of patient images or the comparison of different MR sequences are not very meaningful if possible at all. Often, the use of mobile software that has FDA 510(k) clearance is therefore restricted to situations in which no other workstation with calibrated, larger screens is available (FDA 2011).

In this article we propose a combination of mobile multi-touch devices and workstation-grade screens or even conventional workstations to provide a workstation-grade reading experience with mobile devices (see Fig. 1). Contrasting to current mobile applications, a highly increased display space and processing power is paired with a more natural and direct interaction on image data, as well as a higher mobility and lo-

DOI 10.1524/icom.2013.0002

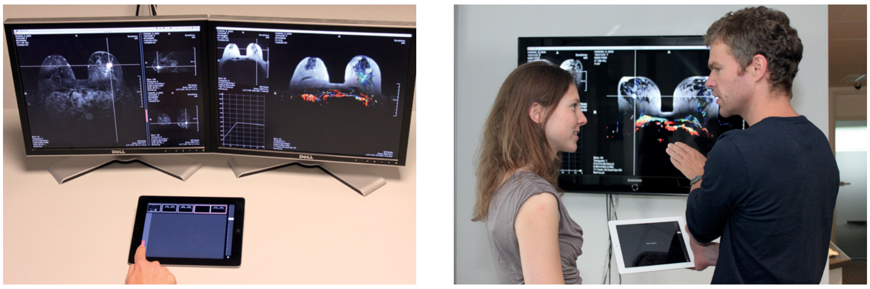

Figure 1: Pairing a mobile device with a workstation (left) or a large screen for diagnostic reading (right).

cation awareness when compared to current workstations.

All diagnostically relevant image data will be presented on large, calibrated screens. The mobile device may display secondary information, such as anamnesis, patient history, genetic predisposition and even control the patient selection but is never used to display patient images for diagnostics. Interaction with the data is controlled via multi-touch gestures on the multi-touch tablet or smartphone. We will show some new approaches that go beyond the limits of mouse and keyboard and demonstrate the potential for increased interaction performance. The concept is applied to diagnostic reading of breast MRI series, however, potential applications spread beyond. Possible use cases include but are not limited to:

- Location-independent image reading for diagnosis and therapy planning
- Support of tumor board discussions: physicians review patient cases with colleagues
- Patient-clinician communication: physicians show and discuss images and diagnosis with patients in either the patient's room or an examination room

2. Current state of the art

We note a high demand for reading software on mobile devices, reflected in a growing number of presentations at RSNA 2011, and also reflected by company efforts to support their respective clinical software platforms on mobile devices. Based on the current display quality of mobile devices, the FDA limits the diagnostic reading of patient images on mobile devices to high-contrast, low-resolution images (SPECT, PET, CT, and MRI), which excludes most X-ray and mammography images. However, research shows that the iPad (iPad 1 and 2) shows a similar performance in the detection of pulmonary nodules as LCDs. Thus, certain mobile devices can be used as secondary displays as they do not significantly change performance compared to an off-the-shelf LCD (Mc Entee et al. 2012).

The latest generation of mobile devices with high-resolution displays will accommodate much finer detail but still requires panning a mammography or computed radiography in order to inspect and perceive all details. Because most mobile devices adapt themselves to changes in lighting conditions, calibrating the display and maintaining a calibration is difficult. Currently, FDA-approved mobile applications may therefore only be used when there is no access to a workstation (FDA 2011). That said, only very few medical applications have been approved for diagnostic reading. To our knowledge, all these applications use the screen of the mobile device to display the image data directly. None of them integrates the mobile device into the reading process of the workstation.

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 (Forlines et al. 2007, Sears and Shneiderman 1991). 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 (Albinsson and Zhai 2003) are insignificant. However, other challenges such as arm fatigue can still have influence on the users' performance. Furthermore, finger accuracy can be a disadvantage of touch interaction for smaller targets while often being faster than interaction with the mouse (Cockburn 2012).

3. What issues do current workstations have?

Conventional workstations for image reading, such as breast MRI workstations in this case, support the viewing of patient images from fitting modalities, the navigation within the images, the marking, annotation, or quantification of findings and structures, as well as the generation of reports that summarize the reading results. Despite providing powerful image analysis methods for automatic quantification and computer-aided detection, the most important aspect is to display patient images efficiently.

Most workstations are sold as a combination of hard- and software for one specific purpose, such as the diagnostic reading of MRI breast images. Due to cost and space limitations, they are usually bound to a fixed location in the hospital and are not available at every place. „Mobile" access to the reading software could be accomplished by two very different approaches:

- Providing multi-purpose workstations with one or two big screens at many locations within the hospital – a whole software suite of applications would support a multitude of different diagnostic tasks at these workstations
- Providing each doctor with a mobile device that supports their very specific tasks

Having multi-purpose workstations present at many different places would indeed solve the accessibility issue. Still, specialized input devices, such as special keypads for mammography reading applications, would not be available automatically due to the same limitations. A highly customizable input device that configures itself to personal preferences could be very beneficial here. It could also collect and provide additional information, such as a history of cases recently viewed, regardless of a specific application. Such an input device would be mobile, personal, and connectable to a workstation wherever required.

A different challenge workstations pose to the user is the underlying interaction design and information visualization concept, which is often strongly affected by the engineering perspective of software design and overloaded with user interface elements providing random access tools. While doing a contextual inquiry at the Center for Breast Care of the Boca Raton Regional Hospital in Florida, we noticed that only very few tools of current workstations for Breast-MR-reading are being used. Despite providing more powerful analysis, functions or interface elements can either not be found because they are too small or hidden, their purpose is not understood, or they are redundant. By offloading secondary information or status indicators onto an interaction device with a display, the screen provides even more distraction free real estate for the patient images. Only the most important information has to be visible on the reading screens.

In other words, a multi-touch tablet device would be the perfect companion for these multi-purpose workstations.

4. What issues do current mobile applications have?

With our concept we want to avoid possible disadvantages of mobile applications as standalone reading devices. As described by Albinsson and Zhai (2003) one limitation while interacting with mobile devices is the user's fingers, hands, or arms blocking part of the screen and thus, in medical context, blocking part of diagnostically relevant information. This is particularly impractical when doctors discuss images with either their patients or colleagues. Users have to execute a gesture and then remove their hands to uncover the mobile devices' screen to be able to read the data correctly.

Beside the occlusion of the screen, high precision interaction with the human finger becomes an issue when users select targets that are smaller than their fingers (Albinsson & Zhai 2003). Various applications emulate mouse interaction. When a measurement is performed the users choose start and end point by tapping on each target. However, if the target is too small users have to zoom in first to be able to choose each point precisely. Instead, a variety of potential, more flexible finger gestures to reduce the number of required steps could be used.

Furthermore, while observing radiologists and their tasks in their working environment it became clear that mobile device screens are too small to accommodate multiple images or additional image data such as graphs (e.g. plotting the distribution of contrast agent over time). This results in the users not being able to view all relevant image data at a glance, but having to switch between different views to get an overview of all relevant data.

5. What's the benefit of using mobile devices in combination with stationary displays for reading medical images?

5.1 Overcoming the one-finger interaction

So far, the majority of first generation mobile applications for the inspection of medical images did not introduce interaction styles beyond basic gestures, such as the pinch gesture for magnification. However, using fingers to grab, to measure, to fold, or to annotate may be easier to operate despite our long-term training towards „masters of the mouse". A step towards a more natural interaction using more than one finger.

We spent a lot of effort in designing a concept for interacting with the system with multi-touch gestures. The aim was to develop gestures to easily access functions of high importance, and to ensure that actions cannot be triggered accidentally by a similar gesture. Avoiding ambiguities and identical gestures for controlling dissimilar actions in different contexts was another objective. We reflected on how radiologists used to work with film-based images before the digital age, which inspired our concept of interaction.

5.2 For viewing and interaction

In our setup the mobile device acts as a hybrid image display and interaction device, changing its role during the workflow. The fundamental principle is to not show images for clinical diagnosis on the device. This way, users do not block their view on diagnostically relevant images with their fingers, hands, or arms. Moreover, the concept of combining mobile device and stationary display still involves the use of high resolution displays to present the images, which goes with the FDA, demanding not to use mobile medical applications for primary diagnosis (FDA 2011).

Breast MRI diagnostic workstations usually offer a set of viewports showing different aspects of the data, arranged on one or more monitors. The user is free to define preferences for the layout (called hangings), and is able to zoom viewports to full screen, or interact with them in arbitrary sequence. This is not intended in a system as ours. Based on a workflow analysis we carried out in a community hospital breast care center in which an above-average number of MRI exams are being read, we defined a number of viewport arrangements. One viewport is shown in larger size (the master viewport) with which the user can interact directly. The other, smaller viewports support the reading by providing additional information (see Fig. 2). These hangings are then executed in sequence, following a predefined but customizable workflow. Furthermore, the diagnostic screen is freed from menus, buttons, and bars as the radiologist interacts only on the mobile device that offers the gestural interface.

With application-side interpretation and implementation of gestures, coherent interaction is guaranteed regardless of what mobile device is being used. Technically for the workflow, the device is only required to send one or multiple touch points, and all intended interaction is evaluated on the server computer.

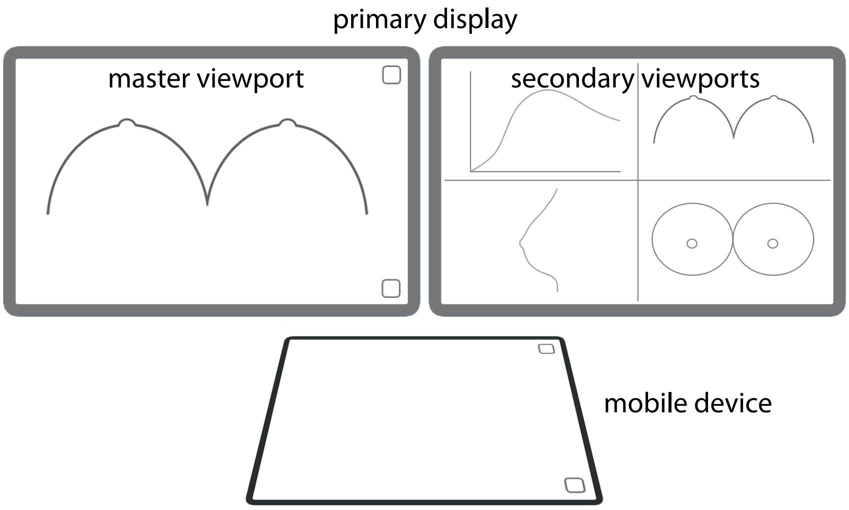

Figure 2: Master viewport (left), secondary viewports (right), mobile device (bottom).

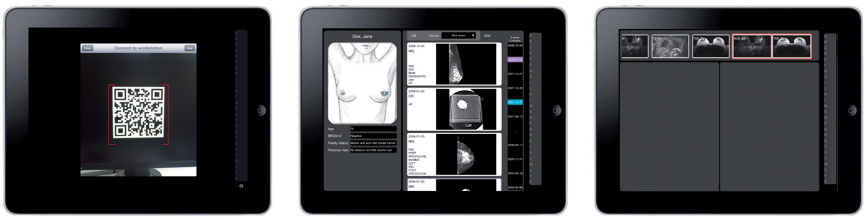

Figure 3: Mobile device screens: Reading the QR code (left), the patient browser interface (middle), and the mobile device user interface during reading (right). MR images are displayed on the primary display (see Fig. 2).

Patient selection

To ensure data protection, we chose to visualize the patient browser on the mobile device. People standing or passing by cannot see personal data such as patient name and date of birth, as they are not shown on the primary display. Also, the patient browser is supposed to be fully accessible outside the clinics IT system. After the primary diagnosis, doctors shall be able to view key images and reports anywhere and access these through the patient browser. In this way we ensure a consistent representation of information and data.

The intuitive patient browser shows the patient history with clinical events and cancer risk data (see Fig. 3, middle). Annotations are correlated between sketch (left), image series (middle), and time line (right) using distinctive colors. Thumbnails of image series displayed in the middle can be previewed in larger size on the diagnostic screens in combination with additional information.

Navigation in images

In each hanging, navigation is done solely using finger gestures on the mobile device, where all gestures always apply only to the master viewport on the primary display. Other viewports providing additional image data, derived data, orthogonal projections of the master view etc. might be present, and if they are, their display is continuously updated to match the image on the master viewport.

Measurement

Counting and measuring the quantification of structures in medical images is where computer support most obviously may be faster and more precise than humans. However, the detection and separation of different tissue types is difficult. Moreover, some measurements may be highly patient specific and therefore have to be done manually.

For size measurements, such as measuring the largest diameter of tumors, we designed an indirect multi-touch gesture that works around the issue of low precision selection with fingers on small targets and the need for executing multiple gestures. It anticipates the desired size and zooms the images automatically to enable a precise measurement even of very small structures (see Fig. 4). 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 a distance.

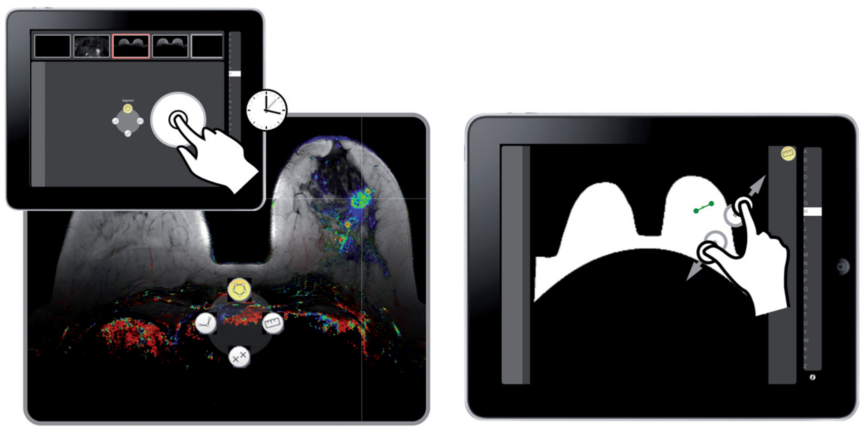

Figure 4: Tap and hold shows a radial menu around the finger on the touch display and on the primary screen (Lepinski et al. 2010). All options that apply to this location, e.g. measurement, are displayed. Measuring the size of a lesion is executed by moving two fingers away or towards each other.

Opposed to expectation, stretching the fingers zooms into the image and visually lengthens the line, while pinching zooms out and shortens the line. This goes with the metaphor of a tape measure that becomes longer the more it is stretched or a person measuring or grabbing a distance with her fingers.

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 zooms into the image. This results in a point at which the user cannot zoom-in further. Zooming out works with the same principle. If the distance between the two fingers exceeds a certain value, the application automatically zooms out.

Reporting
Traditional workstations demand the users to access information and read images at pre-defined locations. Our concept allows secured storage of selected key images and information on the mobile device. These key images contain annotations such as measurements and segmentations, out of which reports are automatically generated while reading MRI patient cases. The reports can be location-independently shared with other doctors, as they are stored on the mobile device. Doctors still need to use dedicated workstations for primary diagnosis, but can take the generated reports to any location to share and discuss the data and information with their patients or colleagues.

5.3 For safety and security

In our setup, we think of the mobile device as a personal item belonging to the radiologist. Users will log in to their device and authenticate towards it. To connect to a primary display, different mechanisms are conceivable. In our current implementation, the internal camera of the mobile device reads a QR code that is displayed on the primary display (see Fig. 3, left). By reading the QR code, the mobile device learns about the primary display, such as its location and capabilities. It configures itself so that the available tools are offered, and only the applicable patient data is shown to the radiologist. In practice, in a patient room only the data pertaining to the patient in that particular room is offered, and diagnostic tools, annotations, and reporting functionality is not provided. In a meeting room only the data of that day's tumor board meeting might be shown with annotation functionality; while in a diagnostic reading room, all functionality will be provided for all patients assigned to the doctor.

The mobile device does not store data locally but acts as a client. The data is provided by a server-based architecture with patient records residing only on the server. It can be accessed through a securely protected wireless network.

5.4 For location independence and personalization

We think of the mobile device and primary display communicating and interacting with each other, making it simple for the users to connect their personal devices to workstations, and workstations connecting to the users' personal devices. Devices are aware of their location to only allow relevant and authorized information to be accessed.

As described in the previous section, the mobile device acts as the doctor's personal key to patient data; history and other protected data stored in the hospital IT. It holds different access permissions to all IT systems so that the doctor is not in need of using dedicated reading rooms. At the same time, each workstation offers data, information and tools depending on the user accessing the workstation, as well the location and purpose of the workstation itself.

Furthermore, not being bound to workstations, doctors can use mobile devices to confirm courses of treatment and explain these to patients. Confirmed by radiologists we interviewed, we believe this could enhance the doctor patient relationship as doctors can spend more time with their patients while explaining treatment, not being in need of doing this at dedicated workstations.

6. Possible challenges

The concept of combining a stationary display and a mobile device offers a wide range of possibilities that can or should be considered in the development. The challenge is to develop a concept that maintains usability and understandability, whilst relevant functions are translated into appropriate processes and gestures.

6.1 How to interact with multiple viewers and not losing focus

We observed and interviewed four radiologists of the Boca Raton Regional Hospital in Florida and analyzed their tasks while they were using the system. Based on this, we developed a workflow for our combined system of screen device and mobile device, considering barriers that users might encounter with mobile tasks (Karlson 2010).

In the current system, the master viewport shows primary images. Additional images or curves to support reading and interpretation of data are represented in smaller, secondary viewports. The radiologist can interact with the image presented on the master viewport only. The secondary viewports are synchronized, showing and adjusting information depending on the image and the interaction on the master viewport. Direct interaction with secondary viewports is not possible.

However in rare cases, doctors may want to directly interact with images on a secondary viewport, for instance, to adjust the window level. Therefore, a gesture or functional element for choosing and activating one of these viewports had to be implemented. The required functional element or gesture has to be chosen in a way not to demand the user of looking down at the mobile device. Yet, while introducing additional gestures it has to be made sure not to overwhelm the user and maintain usability and understandability.

6.2 Carrying the mobile device around

Taking Apple's iPad as an example for a mobile multi-touch device, it is evident that it has not been designed to fit in a radiologist's white coat. Instead of walking around freely, the doctor has to carry the mobile device to meetings and patient visits and make sure not to forget or lose the device. However, as mentioned by Lewis Dolan "Mobile technology has made it possible to bring the patient's bedside to the physician's smartphone or tablet"(Lewis Dolan, 2012). Doctors can access the patient's medical information anywhere, consolidated on one device, and offer a faster treatment. Equally, the entire patient data such as lab results, EKG results or MRI images can be easily brought to the patient's bedside to establish a better patient-doctor relationship (Pfeifer et al. 2012). We think the advantages that occur in mobile devices increasingly being used for multiple functionality outweigh the disadvantage of carrying them around. This is substantiated by the fact that many doctors already own iPads (Hirschorn 2011). And a study revealed that 80 percent of doctors believe the iPad having a promising future in healthcare (Spyglass Consulting Group 2012). Now, with the release of the iPad Mini this problem might be solved. However, it still has to evaluated whether the smaller screen poses new challenges to our concept and the usability of the system.

7. Evaluation

7.1 Informal Evaluation

In discussions with the target group we found out that mobile devices are becoming more and more important and that there is an increased demand, especially from younger doctors. Initial presentation of the prototype to the public during RSNA 2011 was well received. We demoed the prototype system for five consecutive days to approximately 70 radiologists, discussing with them the pros and cons of the approach.

The general setup and paradigm – to pair a mobile device with a larger, dedicated display – was appreciated. Radiologists are well aware of the small display space of mobile devices but also like the convenience of a personal device that is readily available wherever they need it. Combining both seemed natural to most of them. Also, to use the device as a key to the diagnostic screen by scanning the QR code was liked, as was the use of the mobile device to present the patient browser. Presenting status information during reading on the mobile device, such as context dependent task support or additional data of minor importance, was highly rated, too. Radiologists feel that this lets them focus on the diagnostic images on the primary screen but does not hide additional information. Most critical remarks focused on the speed that can be achieved by using touch interaction instead of a mouse, demanding for experimental performance figures compared with special keypads and of course mouse and keyboard. In response to that, an evaluation of the indirect multi-touch gesture for measurement in comparison with mouse-based interaction has been conducted.

7.2 Formal evaluation of the indirect multi-touch gesture

A formal evaluation of the whole concept is lacking at this point of development. Instead we focused on the most critical remark first – to provide concrete numbers on the precision and performance of the gestural interaction.

Being an example of multi-finger interaction, the indirect multi-touch measurement gesture was evaluated with 20 participants in an experiment consisting of three tasks: Sitting and using the mouse for measuring diameters of lesions in medical images, sitting while using the mobile touch-device, and standing and using the mobile touch-device (see Fig. 5).

There were two sources of objective data. In order to assess precision, the deviation of the measured diameter from the known 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. All three values were added to form the precision error. Second, the task completion time was measured. All objective data were analyzed using an ANOVA analysis of variances test and Tukey HSD post-hoc test.

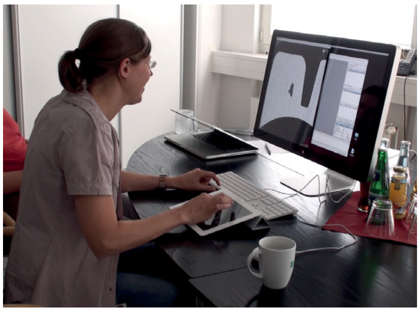

Figure 5: The participant measures a structure in an image using a mobile touch-device while she is sitting.

For the precision we found differences depending on the used interaction technique: The precision error was significantly smaller for mouse interaction than for the touch gestures (see Fig. 6). However, those differences did not bear significance for the application of reading MR images. Comparing the pixel size of the used medical images to the differences in the combined precision error values, we found that even the biggest difference between mouse interaction and standing use of the gesture is smaller than the size of one pixel. The integration of zooming diminishes this difference for small objects even further. This is very important since precise interaction with small objects is often one of the known drawbacks of multi-touch gestures.

The interaction technique had a significant effect on the task completion time as well. Using the mouse the participants were significantly faster than using the mobile touch-device while sitting or standing (see Fig. 6). The object size did not have an effect on the measuring speed. 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. However, for our scenario precision carries a much higher weight.

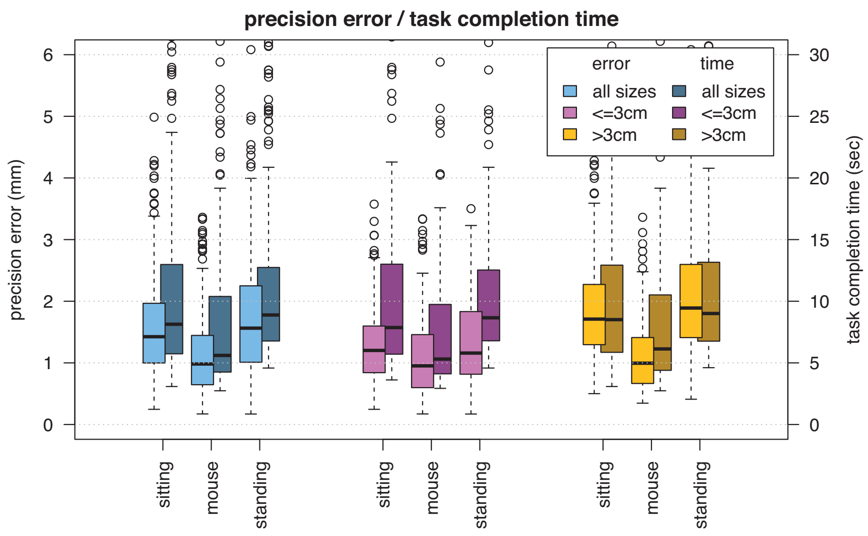

Figure 6: The precision error and task completion time for different interaction tasks and object sizes.

7.3 Discussion

The informal and formal evaluation showed that the target group enjoys the concept and using mobile-touch devices to interact with image data and measure objects. They experienced the multi-touch gesture as being more natural and intuitive for measuring, despite it performing slightly worse than measuring with the mouse. We believe that 'joy of use' is an important aspect for using software, also in a serious application such as reading medical images. While testing the multi-touch gesture some participants imagined it to be more precise and especially faster when using the gesture regularly and thought it to currently be disadvantaged due to their permanent and long-time use of the mouse.

8. Conclusion

We believe that our concept of combining mobile devices and medical workstations opens up new possibilities of presenting relevant medical information, such as magnetic resonance or computed tomographic images to clinical staff. Clinicians are not in need of being at a specific location anymore. The relevant data is always with the user, accessible at any location where a viewing screen can be found, for instance in the patient room. Moreover, it allows us to think the merging of clinical data further. Clinicians hope that at one point they do not need to collect essential data for patient treatment from different sources, locations and different media anymore. Relevant information should be location-independently accessible, customizable and user-friendly presented. Mobile technology opens up a new scope of communicating and delivering this information and bringing patient data and medical knowledge, and thereby patients and doctors together.

Furthermore, our work demonstrated that a multi-touch gesture is valuable for fast and precise measurement of objects in images with multi-touch devices. Despite most of the study participants thinking the mouse would perform better than the touch gesture, the results prove no practical significant disadvantage of our multi-touch interaction technique. They rather encourage improving the gesture and thinking its application further. Above all, the positive feedback of the participants concerning the user experience while using the multi-touch gesture confirmed our approach.

Acknowledgments

This work was partly done at Boca Raton Regional Hospital, Florida. We thank the staff for their support and for giving us insights into their clinical workflow. Many thanks are due to Johanna Kramme and Caroline von Dresky for their valuable feedback and to all our study participants.

References

Albinsson, P-A.; Zhai, S.: High Precision Touch Screen Interaction. Proc. of the SIGCHI Conference on Human Factors in Computing Systems, 105–112, 2003.

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

Forlines, C.; Wigdor, D.; Shen, C.; and Balakrishnan R.: Direct-touch vs. mouse input for tabletop display. Proc. of the SIGCHI Conference on Human Factors in Computing Systems, 647–656, 2007.

Hirschorn, D.: Radiology Informatics Series: Mobile Computing Devices. Chicago: RSNA 2011.

FDA: Mobile Medical Applications: Draft Guidance for Industry and Food and Drug Administration Staff. July 21, 2011.

Lepinski, G. J.; Grossman, T.; Fitzmaurice, G.: The design and evaluation of multitouch marking menus. Proc. of the SIGCHI Conference on Human Factors in Computing Systems, 1411–1420, 2010.

Lewis Dolan, P.: Everything in medicine is going mobile (HIMSS meeting). http://www.ama-assn.org/amednews/2012/03/26/bisa0326.htm (Last accessed 24/05/2012), 2012.

Karlson, A. K.; Iqbal, S. T.; Meyers, B.; Ramos, G.; Lee, K.; Tang, J. C.: Mobile taskflow in context: a screenshot study of smartphone usage. Proc. of the SIGCHI Conference on Human Factors in Computing Systems, 2009–2018, 2010.

Mc Entee, M.; Lowe, J.; Butler, M.-L.; Pietrzyk, M.; Evanoff, M.; Ryan, J.; Brennan, P.; Rainford, L.: iPads and LCDs show similar performance in the detection of pulmonary nodules. Proc. SPIE 8318, Medical Imaging 2012: Image Perception, Observer Performance, and Technology Assessment, 2012.

Pfeifer Vardoulakis, L.; Karlson, A.; Morris, D.; Smith, G.; Gatewood, J.; Tan, D.: Using mobile phones to present medical information to hospital patients. Proc. of the SIGCHI Conference on Human Factors in Computing Systems, 1411–1420, 2012.

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

Spyglass Consulting Group: Apple iPad is not ready to transform healthcare delivery today. http://www.spyglass-consulting.com/press_releases/SpyglassPR_POC_Comp_Physicians_2012.v1.2.pdf (Last accessed 24/05/2012), 2012.


1


2


3


4


5

1 Felix Ritter is head of visualization and human computer interaction at Fraunhofer MEVIS, Bremen, Germany. His research interests include medical visualization, perception, and user experience design for medical devices. Felix's current work is focused on the usability of medical workstations and the development of intra-operative user interfaces. He is a member of the steering committee of the Gesellschaft für Informatik e. V.'s Special Interest Group „Visual Computing in Medicine" and holds a Ph.D. in Computer Science from the University of Magdeburg.
E-Mail: felix.ritter@mevis.fraunhofer.de

2 Jumana Al Issawi is User Experience Designer & Consultant at Fraunhofer MEVIS, Bremen, Germany. Currently, her key subjects focus on supporting the clinical workflow with mobile technologies and enhancing the clinical patient experience. She received a master's degree in Interactive Media at the University of the Arts London and a bachelor's degree in Digital Media at the University of Applied Sciences Bremerhaven.
E-Mail: jumana.al-issawi@mevis.fraunhofer.de

3 Markus Harz is expert for breast image analysis with a focus on breast MRI. He has headed an international research project to advance multimodal breast diagnosis. Multi-modal and interdisciplinary breast care are Markus' two major research interests. He has worked in a specialized breast care center in Boca Raton, Florida, and collected many practical experiences. As a member of the German society of Senology, his focus is always on the clinical feasibility of technological developments.
E-Mail: markus.harz@mevis.fraunhofer.de

4 Simon Benten is studying Computer Science in the master's program of the University of Bremen and received a bachelor's degree in Media Informatics at the University of Applied Sciences Osnabrück. At Fraunhofer MEVIS he focuses on the development of medical applications for mobile devices.
E-Mail: simon.benten@mevis.fraunhofer.de

5 Kathy J. Schilling is Medical Director of the Christine E. Lynn Women's Health and Wellness Institute at the Boca Raton Regional Hospital. She has spent the last 22 years building the Center for Breast Care, which has become nationally and internationally known for excellence and innovation in breast care. Her particular interests include evaluating new technologies to improve breast cancer diagnosis in sub populations of patients so as to provide effective individualized care.
E-Mail: kschilling@brrh.com
http://www.mevis.fraunhofer.de
http://www.brrh.com