5-2014

Medical imaging specialists and 3D: A domain perspective on mobile 3D interactions

Teddy SEYED

Frank MAURER

Francisco Marinho RODRIGUES

Anthony TANG
Singapore Management University, tonyt@smu.edu.sg

Citation

SEYED, Teddy; MAURER, Frank; RODRIGUES, Francisco Marinho; and TANG, Anthony. Medical imaging specialists and 3D: A domain perspective on mobile 3D interactions. (2014). *CHI EA '14: CHI '14 Extended Abstracts on Human Factors in Computing Systems, Toronto, Canada, 2014 April 26 - May 1*. 2341-2346.
Available at: https://ink.library.smu.edu.sg/sis_research/7993

Check for updates

Medical Imaging Specialists and 3D: A Domain Perspective on Mobile 3D Interactions

Teddy Seyed
Department of Computer Science
University of Calgary
2500 University Dr. NW
Calgary, Alberta, T2N 1N4
teddy.seyed@ucalgary.ca

Francisco Marinho Rodrigues
Department of Computer Science
University of Calgary
2500 University Dr. NW
Calgary, Alberta, T2N 1N4
fm.rodrigues@ucalgary.ca

Frank Maurer
Department of Computer Science
University of Calgary
2500 University Dr. NW
Calgary, Alberta, T2N 1N4
frank.maurer@ucalgary.ca

Anthony Tang
Department of Computer Science
University of Calgary
2500 University Dr. NW
Calgary, Alberta, T2N 1N4
tonyt@ucalgary.ca

CHI 2014, April 26–May 1, 2014, Toronto, Ontario, Canada.
ACM 978-1-4503-2474-8/14/04.
http://dx.doi.org/10.1145/2559206.2581301

Figure 1. A medical imaging specialist exploring a 3D volumetric image of a human chest using a tablet.

Abstract
3D volumetric medical images, such as MRIs, are commonly explored and interacted with by medical imaging experts using systems that require keyboard and mouse-based techniques. These techniques have presented challenges for medical imaging specialists: 3D spatial navigation is difficult, in addition to the detailed selection and analysis of 3D medical images being difficult due to depth perception and occlusion issues. In this work, we explore a potential solution to these challenges by using tangible interaction techniques with a mobile device to simplify 3D

interactions for medical imaging specialists. We discuss preliminary observations from our design sessions with medical imaging specialists and argue that tangible 3D interactions using mobile devices are viable solution for the medical imaging domain, as well as highlight that domain plays an important role in 3D interaction techniques.

Author Keywords
Mobile devices, medical imaging, 3D navigation, volumetric imaging.

ACM Classification Keywords
H.5. 2 [Information interfaces and presentation]: User Interfaces— Input Devices and Strategies; Interaction Styles.

Introduction

Magnetic Resonance imaging (MRI) and computed tomography (CT) are standard imaging techniques used by medical imaging specialists when conducting medical investigations that lead to important decisions about the healthcare of a patient (e.g. choice of treatments or surgery options). These imaging techniques produce volumetric slices of scanned tissue (i.e. multiple 2D cross-sections) and are examined in "abstract 2D" by medical imaging specialists [1]. These 2D cross-sections are considered individually, before medical imaging specialists mentally reconstruct them to fit a scanned organ or other anatomical structure [2].

Historically, 2D visualization approaches utilizing keyboard and mouse based interaction techniques have been employed in the medical imaging domain for 3D volumetric medical images instead of 3D interaction techniques. This is because medical imaging specialists consider 3D interaction techniques with keyboard and mouse based interfaces to be less practical than 2D, due to issues such as 3D images being hard to interpret on flat, 2D screens [2]. As a result, medical imaging specialists still face numerous challenges that are directly related to the interaction of 3D volumetric imaging data in a 2D manner. For example, an essential task for a medical imaging specialist is a detailed analysis of specific parts of scanned tissue, looking for irregularities that span multiple 2D cross-sections. This requires an efficient means of navigation and selection in 3D, but due to issues such as the lack of depth perception and occlusion, traditional keyboard and mouse interaction techniques makes this difficult.

The goal of our work is to improve interaction with 3D volumetric medical images for medical imaging specialists. Our approach is to leverage tangible objects as an interaction mechanism, taking advantage of existing spatial and physical reasoning skills [3]. As shown in Figure 1, we apply these concepts to the medical imaging domain, where a free-moving digital tablet displays reconstituted 2D slices of the volumetric 3D dataset (i.e. these slices are composed of multiple CT or MRI scan slices). In this paper, we discuss our explorations of tangible 3D interactions with mobile devices in the medical imaging domain and present our preliminary results from design sessions with medical imaging specialists. Our explorations present new requirements 3D interaction techniques with mobile devices for 3D volumetric medical images.

Related Work

Medical imaging specialists present a challenge in interaction design because of the variation in how 3D volumetric images are used. For example, when looking

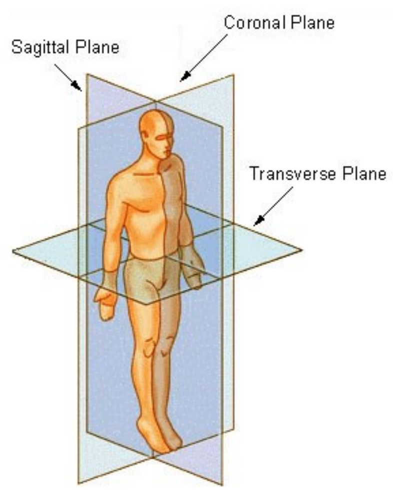

Figure 2. Orthogonal views in 3D imaging. (a) Sagittal plane represents the left/right view (b) Coronal plane represents the front/back view (c) Traverse plane represents the top/down view [9].

for anomalies in structures or tissues, medical imaging specialists look at images in 2D ("slice by slice") before examining the full volumetric 3D model. This means that 3D volumetric images are rotated, moved and cut, with guidance from their intuition and insights about the data they are able to read, as well as input from other collaborating specialists or physicians [3].

When software tools are used for viewing 3D medical images and performing tasks, medical imaging specialists typically explore a single anatomical structure. Keyboard and mouse-based inputs are mapped to navigate a "camera" around the anatomical structure, as well as to perform selection and manipulation. In the context of 3D interaction research, this is a common task [4] and illustrates the *view-based* technique, in which different simultaneous orthogonal views (See Figure 1) are manipulated in 2D interface. While this technique is common for 3D software tools in the medical domain, they do not consider the challenges that exist if a medical imaging specialist wants to examine a 3D volumetric image along non-orthogonal planes. For example, if they were to examine a non-orthogonal cut of a tissue or organ, or follow a specific path within a 3D medical dataset, these techniques may be cumbersome.

Interaction techniques in the research literature to address the challenges of non-orthogonal planes have been explored in the context of the medical domain, but they have been found to be obtrusive (e.g. virtual reality and its associated hardware) or require additional training to be properly utilized [5]. More recently, tangible techniques using mobile devices [6] have been explored for 3D interactions and have highlighted how leveraging intuitive spatial and physical relationships of users can be beneficial. Two common methods of mapping input devices to output are *position control*, which strictly maps input to a position (e.g. a mouse), and *rate-control*, where the input force and resistance is mapped to an output velocity that is used as a means of manipulation (e.g. airplane joystick). Prior research has shown that *position-control* mappings are generally more usable than *rate-control* mappings for most users [7]. These types of 3D interaction techniques and mappings have been applied to tablets previously [8], but as we show in this paper, the medical imaging domain introduces new challenges and considerations.

Mobile 3D Interactions

Working with a local medical imaging company, we developed two implementations based on the *position-based* and *rate-based* techniques (see Figure 3 and 4). In both implementations, the interactions specifically manipulate the view around a fixed center point of a 3D volume and a user-selected orthogonal plane. Touch-based input (e.g. pinch-to-zoom and panning) manipulates the scale of the 3D volume and gyroscopic and accelerometer from the iPad provide the necessary information for non-orthogonal slicing of the 3D volume.

Early Design Sessions

To explore some of the challenges the medical imaging domain introduces to 3D interactions, we utilized a design session approach, allowing for an early examination of different 3D interaction types, in addition to providing a means of stimulating discussions with medical imaging specialists. Our design sessions primarily focused on qualitative feedback with three medical imaging specialists, who each performed

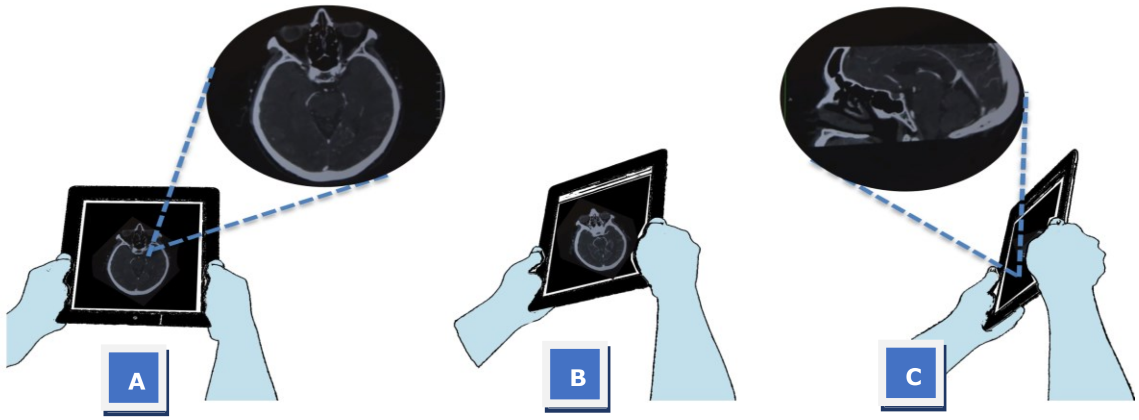

Figure 3. The *position-based* implementation. To navigate through a 3D volumetric medical dataset, a user tilts an iPad in the direction in which they choose to navigate. As the navigation is done by position, the movements are discrete. In this example, the iPad is initially in a top down (a) orientation of a human skull in 3D space and as the device is tilted to the right (b), the skull appears but from a view on the left side in 3D space (c).

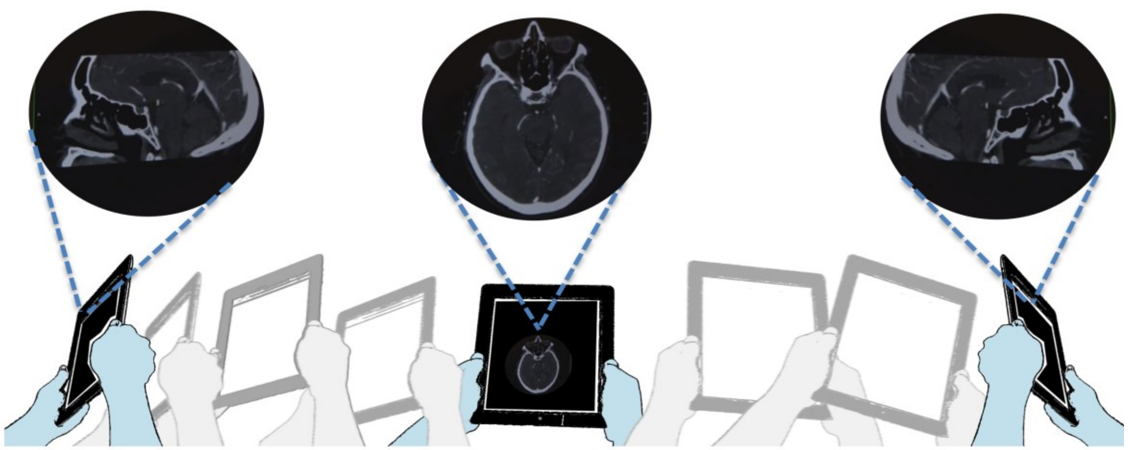

Figure 4. The *rate-based* implementation. To navigate through a 3D volumetric medical dataset, a user tilts an iPad in the direction in which they choose to navigate. As the navigation is controlled by rate, the movements are continuous, much like an airplane joystick. In this example, as the device begins tilted to the left in 3D space, a human skull appears from a left view before eventually appearing in the right-view.

simple navigation tasks with both implementions, on varying sizes of 3D volumetric medical images.

Observations and Feedback

From our design sessions, we clearly observed medical imaging specialists having less difficulty and easier navigation with the *position-based* implementation when compared to the *rate-based* implementation, confirming prior work by Zhai [7]. As one of the goals of the design session at this stage of the research was to gather feedback and inspiration on the usage of mobile 3D interactions for the medical domain, we synthesized the feedback from our discussions with the medical imaging specialists into four general themes.

Preference. As a whole, both implementations received positive feedback and all medical imaging specialists repeatedly stated "these interactions are definitely far more feasible than using a keyboard and mouse". Despite these comments, there was an immediate response when they were asked which implementation they preferred to use or found most feasible. Universally, they chose *position-based* over the *rate-based*, indicating that it was "easier to use." One of the medical imaging specialists noted: "…I preferred the [*position-based*] method because I feel I have more control and its more usable…it's hard to look at structures precisely [in *rate-based*]…." This sentiment was also echoed by the other medical imaging specialists, indicating that for tangible 3D interaction techniques, having control is important for tasks such as "finding important structures during information exploring or diagnosis" or "for decisions made that determine if another imaging procedure is needed."

Learnability. Two of the medical imaging specialists preferred the *position-based* over *rate-based*, for usability reasons, and because they felt it was easier to learn. One medical imaging specialist noted: "…it would take time to get used to [*rate-based*] because it's not common in how we use or navigate medical images now". All medical imaging specialists stated, regardless of implementation or preference, that these types of interactions would take time to learn, but the amount of time to learn them would not be a hindrance if future adoption of such techniques were to occur.

Alternatives. Despite the universal preference for *position-based*, the medical imaging specialists surprisingly found more value in the *rate-based* implementation for tasks that weren't a part of the study but a part of their domain. For instance, one medical imaging specialist noted: "…The [*rate-based*] one would be ideal for giving presentations that are more interactive or for teaching students and novice doctors and specialists about structures…[*position-based]* just wouldn't work there in that kind of setting, which needs to be dynamic…". Another medical imaging specialist noted that: "…In fact, having both might actually work better. The [*rate-based*] can be used to quickly and roughly find an area and the [*position-based*] can then be used to refine the navigation and search…]". This was also echoed by the other medical imaging specialists, highlighting that in the medical imaging domain, not all 3D interactions are necessarily equal and their value is dependent on the different tasks that need to be performed. Also indicated is a possibility for hybrid interactions utilizing both *rate-based* and *position-based* techniques.

Future Interactions. An interesting discrepancy in feedback occurred when the medical imaging specialists were asked about future interaction techniques. One noted "…I can definitely see this being used within 5 years and I myself would definitely use it at my desk right now". In contrast, another medical imaging specialist provided significantly different feedback, stating: "…I still see keyboard and mouse being used, despite this being better. Even 10-15 years from now, a tablet won't be used but might be properly discussed by then. By introducing these types of [techniques], you're not just changing how imaging-specialists work, you're also changing the entire imaging chain, from image retrieval, to hardware, to software, to even how images are thought of. We still use keyboard and mouse because that's how we think."

Discussion

In our preliminary design sessions, we confirmed prior work by Zhai [7] but we also revealed several insights into mobile 3D interactions for the medical imaging domain that haven't been discussed in prior research literature. Firstly, we saw that *rate-based* interactions can provide value, and as suggested by medical imaging specialists, hybrid techniques that utilize a combination of *rate-based* and *position-based* can provide value for tasks involving quick exploration, followed by detailed exploration. Secondly, we saw that medical imaging specialists performed 3D navigation tasks in discrete steps, which may arise from familiarity with 2D interaction techniques and interfaces. Maintaining some familiarity to these techniques may also impact the learnability of future mobile 3D interaction techniques and interfaces. This differs from the significant amount of research creating new 3D interactions, as the medical domain implies that 2D interactions need to still be taken into account. Lastly, one interesting backdrop provided by our discussions with the imaging specialists, is design implications for the medical imaging domain. A majority of interactions, techniques or prototypes for medical imaging in the research literature haven't fully considered the effects on the entire chain. For example, some work (such as our own) focuses solely on discrete medical disciplines without consideration for others disciplines. Having a disconnected chain when researching and developing 3D interaction techniques can hinder their adoption, not only in the medical imaging domain, but also other domains that require 3D interactions.

Conclusion and Future Work

In this paper, we discussed the challenges that imaging specialists currently face with 3D volumetric images, providing a backdrop for the introduction of tangible techniques for exploration of volumetric medical images in the medical domain. We implemented two different mobile 3D interaction techniques, *position-based* and *rate-based* and through our initial design sessions with medical imaging specialists, we saw that value is provided with both techniques, which differs from prior work in 3D interactions. We also saw that other aspects from the domain, such as familiarity with 2D inputs and techniques still need to be considered. This paper presents an initial starting point for research and design for mobile 3D interactions in the medical imaging domain, and moving forward, we to further explore the , in addition to further exploring hybrid interaction techniques.

References

[1] H. Cline, W. Lorensen, S. Souza, R. Kikinis, G. Gerig and T. Kennedy, "3D surface rendered MR images of the brain and its vasculature.," Computer Assisted Tomography, vol. 15, no. 2, pp. 344-351, 1991.

[2] L. Gallo, A. Minutolo and G. De Pietro, "A user interface for VR-ready 3D medical imaging by off-the-shelf input devices," Computers in Biology and Medicine, vol. 40, no. 3, pp. 350-358, 2010.

[3] J. J. Robert, "Reality-based interaction: a framework for post-WIMP interfaces," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'08), Florence, Italy, 2008.

[4] J. Jankowski and M. Hachet, "A Survey of Interaction Techniques for Interactive 3D Environments," in Eurographics 2013 - State of the Art Reports (STAR), Girona, Spain, 2012.

[5] K. Montgomery, M. Stephanides, S. Schendel and M. Ross, "User interface paradigms for patient-specific surgical planning: lessons learned over a decade of research." Computerized Medical Imaging and Graphics, vol. 29, no. 3, pp. 203-222, 2005.

[6] M. Spindler, M. Martsch and R. Dachselt, "Going beyond the surface: studying multi-layer interaction above the tabletop," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'12), Austin, Texas, USA, 2012.

[7] S. Zhai, "User performance in relation to 3D input device design," ACM SIGGRAPH Computer Graphics, vol. 32, no. 4, pp. 50-54, November 1998.

[8] B. Jones, R. Sodhi, D. Forsyth, B. Bailey and G. Maciocci, "Around device interaction for multiscale navigation," in Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services (MobileHCI '12), San Francisco, California, USA, 2012.

[9] Image extracted from: http://en.wikipedia.org/wiki/File:BodyPlanes.jpg on January 4, 2014.