Interaction with Stereoscopic Data on and above Multi-touch Surfaces

Florian Daiber
German Research Institute for Artificial Intelligence (DFKI)
Campus D3_2, Stuhlsatzenhausweg 3
66123 Saarbrücken, Germany
florian.daiber@dfki.de

ABSTRACT
With the increasing distribution of multi-touch capable devices multi-touch interaction becomes more and more ubiquitous. Especially the interaction with complex data (e.g. medical or geographical data), which until today mostly rely on mice and keyboard input or intense instrumentation, can benefit from this development. Multi-touch interaction offers new ways to deal with 3D interaction allowing a high degree of freedom (DOF) without instrumenting the user. This research will evaluate multi-touch and gestural 3D interaction on and above interactive surfaces and explore the design space of interaction with stereoscopic data.

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

General terms: Design, Human Factors

Keywords: Multi-touch Interaction, 3D Interaction, Spatial Data

INTRODUCTION

Multi-touch technology has received considerable attention in the last years, especially for 2D user interfaces. But multi-touch has also great potential for exploring complex content in an easy and natural manner, e.g. three dimensional data. However, while multi-touch has shown its usefulness for 2D interaction by providing more natural and intuitive techniques such as 2D translation, scaling and rotation, it has rarely been considered if and how these concepts can be extended to 3D multi-touch interfaces. In recent years, the interaction with 3D data has become more and more popular. Current 3D user interfaces, as they are for example provided by virtual reality (VR) systems consist of stereoscopic projection and tracked input devices. But these are often expert systems with complex user interfaces and high instrumentation. On the other hand using stereoscopic displays allow users to perceive 3D data in an intuitive and natural way. On stereoscopic displays objects might be displayed with different parallax paradigms resulting in different stereoscopic effects. Objects may appear behind (positive parallax), on top (zero parallax), or in front (negative parallax) of the screen. Interaction with objects that are displayed with different parallaxes is still a challenging task even in VR-based environments [20]. Multi-touch technology can be used in order to overcome this limitation because it allows a rich set of interactions without using high instrumentation. However, the benefits and limitations of using multi-touch in combination with stereoscopic display have not yet been examined in-depth and are not well understood [20].

Figure 1: Interaction with stereoscopic projected geographic data on a multi-touch wall with anaglyph display.

In this work I address the challenge how users may interact with stereoscopically displayed 3D data when the interaction is restricted to a two-dimensional multi-touch surface. More specifically it investigates novel ways to interact with multi-touch surfaces with a particular consideration of interaction context as an additional modality besides simply touching the interactive surface. Furthermore, this work is motivated to understand the adaption of the user interface based on early prediction of the user's intention derived from interaction context.

RELATED WORK

Today mice and keyboards are still used to navigate, explore and interact with complex systems (e.g. Geoinformation Systems and Desktop VR Systems) even though they are not optimal devices for this purposes [3]. Nowadays several hardware solutions exist that allow multi-touch input on surfaces of different sizes [18, 7, 17, 10, 15, 13, 14]. Additionally, emerging commercially available multi-touch products (e.g. Apple iPhone[1] or Microsoft Surface[2]) have brought up a variety of novel gesture-based interaction techniques. Much work has been carried out on the definition of frameworks and taxonomies for such gesture-based multi-touch input. Wu et al. defined the principle of Gesture Registration, Relaxation and Reuse [26]. Wobbrock et al. investigated user defined gestures and developed a taxonomy of gestures for surface computing [25]. Daiber et al. [6] proposed a framework for multi-touch and foot interaction with geospatial data.

But only few researchers have addressed the problem of 3D interaction on a 2D multi-touch surface so far. To allow interactions in the 3D space Benko et al. [1] introduced the *Balloon Selection*. Following that direction Grossman and Wigdor [8] proposed a taxonomy for 3D interaction on interactive tabletops. Schöning et al. have considered some of the challenges of multi-touch interaction with stereoscopically rendered projections [19]. One limitation of these approaches is the constraint of the interaction and visualization to almost zero parallax because the plane of the interactive surface limits the interaction space more or less to the 2D surface. Valkov et al. investigated how far a user perceives direct touching objects displayed with different parallax as if they are on zero-parallax [22].

Hilliges et al. [12] tried to overcome this limitation by adding further depth to interactive tabletops. Through the tracking of gestures on and above the surface, interactions in the air have been made possible. *Z-touch* [21] is a system that allows – to a certain extend – the tracking of gestures above the surface by using horizontal layers of laser mounted on the surface. On the *Immersive Multitouch Workspace* [2] the touch surface and projection surface are separated and thus solve the occlusion problem for objects projected with negative parallax.

Wilson et al. suggest to include physics in surface interaction [24] and on that basis Wilson simulates grasping behavior on interactive surfaces [23]. Some distinct interaction methods have been discussed that allow 6DOF multi-touch interaction with 3D data. Reisman et al. proposed interactions for direct manipulation of 3D objects through rotation, scale and translation [16] and Hancock introduced force-based 3D interactions for multi-touch tabletops [11]. Hachet presented a widget-based approach for 3D navigation through 2D input for different (touch-enabled) devices [9] whereas Cohé et al. used widgets to provide 3D transformations on touch screens [5]. Coffey et al. proposed "Slice WIM", a multi-touch application for overview+detail exploration of volume datasets in virtual reality [4].

There is a need for further investigations on how to interact with complex three dimensional data in particular stereoscopic rendered data. I will therefore investigate interaction with 3D data using gestural input on and above interactive surfaces. The focus of this work lies on gestural interaction techniques allowing users to interact in a direct manner without further instrumentation.

RESEARCH DIRECTIONS

The research agenda of this work is structured as follows. First the interaction with stereoscopic data is discussed from the perspective of different device classes (mobile devices and tabletop-/wall-sized multi-touch displays). Depending on the form factor additional modalities might play a role for the interaction (e.g. accelerometer and orientation sensors on mobile devices). Secondly the introduction of grasp postures as context information for stereoscopic multi-touch interaction might improve the very by integrating short term interaction history as context for multi-touch input.

Interaction with Stereoscopic Data on Multi-touch Devices

In this part of the thesis different navigation, selection and manipulation techniques to interact with stereoscopic data are investigated. It aims to analyze interaction techniques that use direct touch, but avoid occlusions that might destroy 3D perception.

Multi-touch refers to a set of interaction paradigms, which allow to control applications with several simultaneously performed touches. But multi-touch input does not directly map to 6DOF-input like classic 3D input technologies (e.g. data gloves). So the question arises how users interact with stereoscopically displayed 3D data when the interaction is restricted to a two-dimensional multi-touch surface. Therefore different interaction techniques with stereoscopic data are investigated. These techniques aim a seamless touch interaction with 3D objects that are displayed with different parallax.

Nowadays smartphones are equipped with various sensors (touch, gyroscope, accelerometer etc.) and powerful enough to process complex tasks like graphics or image processing. Most recently the release of handheld devices equipped with an autostereoscopic display fosters the development of 3D applications for mobile devices. Bringing stereoscopic 3D to mobile devices will facilitate a more realistic perception of augmented and virtual reality and offer new ways to interact with mobile devices. Mobile 3D interaction techniques are investigated that rely on sensor-based input to track how the user is holding, moving and touching the device. These techniques allow the navigation in the scene as well as the manipulation of objects.

Towards Grasp as Interaction Context for Multi-touch 3D Interaction

In addition, the thesis aims to enhance the interaction that is restricted to a two-dimensional multi-touch surface with additional context information. It is motivated by the assumption that the user interface can be adapted based on predictions what the user is planning to do next. This context information allows the adaption of the touch-based user interface

[1]http://www.apple.com/iphone/
[2]http://www.microsoft.com/surface/

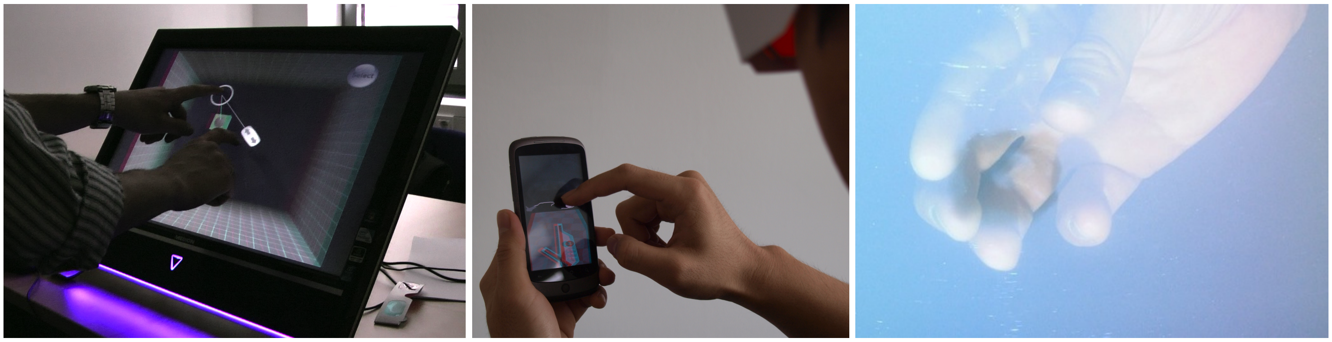

Figure 2: Current Research: Multi-touch widget-based 3D selection (left); Sensor-based interaction with stereoscopically displayed data on a mobile device (middle); Grasping a virtual knob on an interactive surface captured from behind the (nearly) transparent projection screen (right).

right before the user reaches the interactive surface.

CURRENT RESULTS

The doctoral thesis has been carried for almost two years. In this section a brief overview on the current state of the research is provided.

Interaction with Stereoscopic Data on Multi-touch Devices

Various interaction techniques for stereoscopic touch tabletop- and wall-sized displays but also mobile devices are investigated. In the first place two interaction methods for 3D selection on stereoscopic multi-touch surfaces were developed and evaluated: (1) the *Balloon/ Fishnet Selection* (see Figure 2 (left)) and (2) the *Corkscrew Selection*. The Balloon/ Fishnet Selection technique is an extended version of the "Balloon Selection". In contrast to the original work that uses a head mounted display (HMD) with objects displayed with positive parallax above a multi-touch surface the proposed version offers two selection modes for positive (Balloon) and negative (Fishnet) parallax. The corkscrew metaphor is based on a widget that allows drilling down or up a selection tool by a rotation gesture and moving the tool by a slide gesture (DOF separation).

Another section of the thesis contains the developement of interaction concepts for mobile 3D interaction that rely on sensor-based input. These techniques will be evaluated in a prototypical game application (see Figure 2 (middle)). Besides general usability findings, one main challenge of this approach is the question on how to transform the generalized interaction styles into a game design and vice versa.

Analyzing Grasp as Interaction Context

In an initial study I already investigated how hand postures can improve multi-touch 3D interaction taking grasp postures as interaction context into consideration. The knowledge of the grasp posture shortly before touching the multi-touch surface – referred to as "short term interaction history" – can be used to adapt the parallax in a way that the user can interact with the most probable object directly on the surface (with zero parallax). In this study the subjects had to grab user interface elements (buttons, knobs etc.) on an interactive surface (see Figure 2 (right)). I primarily observed the subject's hand shape and posture while interacting with these UI elements. The study shows first evidence that multi-touch gestures can be detected right before the user is reaching the surface and starting to explicitly interact (via multi-touch).

CONCLUSION

This work will present a set of novel interaction techniques that incorporate different interaction modalities on and above multi-touch devices. The research will evaluate these techniques and explore the design space of gestural interaction with stereoscopic data on multi-touch surfaces.

ACKNOWLEDGEMENTS

This research project is partially supported by the Deutsche Forschungsgemeinschaft (DFG KR3319/5-1).

REFERENCES

1. Hrvoje Benko and Steven K. Feiner. Balloon Selection: A Multi-Finger Technique for Accurate Low-Fatigue 3D Selectio. In *IEEE Symposium on 3D User Interfaces*. IEEE Computer Society, 2007.

2. Benoît Bossavit, J.-B. De La Rivière, Toni Da Luz, Mathieu Courtois, Cédric Kervegant, and Martin Hachet. An Immersive Multitouch Workspace. In *Siggraph 2011 Emerging Technologies*, 2011.

3. Doug A. Bowman, Ernst Kruijff, Joseph J. LaViola, and Ivan Poupyrev. *3D User Interfaces: Theory and Practice*. Addison Wesley Longman Publishing Co., 2004.

4. Dane Coffey, Nicholas Malbraaten, Trung Le, Iman Borazjani, Fotis Sotiropoulos, and Daniel F. Keefe. Slice WIM: a multi-surface, multi-touch interface for overview+detail exploration of volume datasets in virtual reality. In *I3D '11: Symposium on Interactive 3D Graphics and Games*, pages 191–198. ACM, 2011.

5. Aurélie Cohé, Fabrice Dècle, and Martin Hachet. tBox: A 3D Transformation Widget designed for Touch-screens. In *CHI '11: Proceedings of the 2011 annual conference on Human factors in computing systems*, pages 3005–3008. ACM, 2011.

6. Florian Daiber, Johannes Schöning, and Antonio Krüger. Whole Body Interaction with Geospatial Data.

In *SG '09: Proceedings of the 10th International Symposium on Smart Graphics*, pages 81–92. Springer, 2009.

7. Paul H. Dietz and Darren Leigh. DiamondTouch: a multi-user touch technology. In *UIST '01: Proceedings of the 14th annual ACM symposium on User interface software and technology*, pages 219–226. ACM, 2001.

8. Tovi Grossman and Daniel Wigdor. Going deeper: a taxonomy of 3d on the tabletop. In *TABLETOP '07: Proceedings of theSecond Annual IEEE International Workshop on Horizontal Interactive Human-Computer Systems*, pages 137–144. IEEE Computer Society, 2007.

9. Martin Hachet, Fabrice Decle, Sebastian Knödel, and Pascal Guitton. Navidget for Easy 3D Camera Positioning from 2D Inputs. In *3DUI '08: Proceedings of the 2008 IEEE Symposium on 3D User Interfaces*, pages 83–89. IEEE Computer Society, 2008.

10. Jefferson Y. Han. Low-cost multi-touch sensing through frustrated total internal reflection. In *UIST '05: Proceedings of the 18th annual ACM symposium on User interface software and technology*, pages 115–118. ACM, 2005.

11. Mark Hancock, Thomas ten Cate, and Sheelagh Carpendale. Sticky tools: full 6DOF force-based interaction for multi-touch tables. In *ITS '09: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, pages 133–140. ACM, 2009.

12. Otmar Hilliges, Shahram Izadi, Andrew D. Wilson, Steve Hodges, Armando Garcia-Mendoza, and Andreas Butz. Interactions in the air: adding further depth to interactive tabletops. In *UIST '09: Proceedings of the 22nd annual ACM symposium on User interface software and technology*, pages 139–148. ACM, 2009.

13. Steve Hodges, Shahram Izadi, Alex Butler, Alban Rrustemi, and Bill Buxton. Thinsight: versatile multi-touch sensing for thin form-factor displays. In *UIST '07: Proceedings of the 20th annual ACM symposium on User interface software and technology*, pages 259–268. ACM, 2007.

14. Daniel Jackson, Tom Bartindale, and Patrick Olivier. Fiberboard: compact multi-touch display using channeled light. In *ITS '09: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, pages 25–28. ACM, 2009.

15. Sergi Jordà, Martin Kaltenbrunner, Günter Geiger, and Marcos Alonso. The reacTable: a tangible tabletop musical instrument and collaborative workbench. In *SIGGRAPH '06: ACM SIGGRAPH 2006 Sketches*, page 91. ACM, 2006.

16. Jason L. Reisman, Philip L. Davidson, and Jefferson Y. Han. A screen-space formulation for 2D and 3D direct manipulation. In *UIST '09: Proceedings of the 22nd annual ACM symposium on User interface software and technology*, pages 69–78. ACM, 2009.

17. Jun Rekimoto. SmartSkin: an infrastructure for freehand manipulation on interactive surfaces. In *CHI '02: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 113–120. ACM, 2002.

18. Jun Rekimoto and Nobuyuki Matsushita. Perceptual Surfaces: Towards a Human and Object Sensitive Interactive Display. In *PUI'97: Workshop on Perceptural User Interfaces*, 1997.

19. Johannes Schöning, Frank Steinicke, Dimitar Valkov, Antonio Krüger, and Klaus H. Hinrichs. Bimanual Interaction with Interscopic Multi-Touch Surfaces. In *INTERACT '09: Proceedings of 12th IFIP TC13 Conference in Human-Computer Interaction*, Lecture Notes in Computer Science (LNCS). Springer, 2009.

20. Frank Steinicke, Klaus H. Hinrichs, Johannes Schöning, and Antonio Krüger. Multi-Touching 3D Data: Towards Direct Interaction in Stereoscopic Display Environments coupled with Mobile Devices. In *AVI '08: Workshop on designing multi-touch interaction techniques for coupled private and public displays*, pages 46–49, 2008.

21. Yoshiki Takeoka, Takashi Miyaki, and Jun Rekimoto. Z-touch: a multi-touch system for detecting spatial gestures near the tabletop. In *SIGGRAPH '10: ACM SIGGRAPH 2010 Talks*, pages 1–1, New York, NY, USA, 2010. ACM.

22. Dimitar Valkov, Frank Steinicke, Gerd Bruder, and Klaus Hinrichs. 2D Touching of 3D Stereoscopic Objects. In *CHI '11: Proceedings of the 2011 annual conference on Human factors in computing systems*, pages 1353–1362. ACM, 2011.

23. Andrew D. Wilson. Simulating grasping behavior on an imaging interactive surface. In *ITS '09: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, pages 125–132. ACM, 2009.

24. Andrew D. Wilson, Shahram Izadi, Otmar Hilliges, Armando Garcia-Mendoza, and David Kirk. Bringing physics to the surface. In *UIST '08: Proceedings of the 21st annual ACM symposium on User interface software and technology*, pages 67–76. ACM, 2008.

25. Jacob O. Wobbrock, Meredith Ringel Morris, and Andrew D. Wilson. User-defined gestures for surface computing. In *CHI '09: Proceedings of the 27th international conference on Human factors in computing systems*, pages 1083–1092. ACM, 2009.

26. Mike Wu, Chia Shen, Kathy Ryall, Clifton Forlines, and Ravin Balakrishnan. Gesture Registration, Relaxation, and Reuse for Multi-Point Direct-Touch Surfaces. In *TABLETOP '06: Proceedings of the First IEEE International Workshop on Horizontal Interactive Human-Computer Systems*, pages 185–192. IEEE Computer Society, 2006.