Using Hands and Feet to Navigate and Manipulate Spatial Data

Johannes Schöning
Institute for Geoinformatics
University of Münster
Weseler Str. 253
48151 Münster, Germany
j.schoening@uni-muenster.de

Florian Daiber
Institute for Geoinformatics
University of Münster
Weseler Str. 253
4851 Münster, Germany
flowdie@uni-muenster.de

Antonio Krüger
Institute for Geoinformatics
University of Münster
Weseler Str. 253
4851 Münster, Germany
kruegera@uni-muenster.de

Michael Rohs
Deutsche Telekom Laboratories
Technische Universität Berlin
Ernst-Reuter-Platz 7
10587 Berlin, Germany
michael.rohs@telekom.de

CHI 2009, April 4 – 9, 2009, Boston, MA, USA
ACM 978-1-60558-247-4/09/04.

Abstract

We demonstrate how multi-touch hand gestures in combination with foot gestures can be used to perform navigation tasks in interactive systems. The geospatial domain is an interesting example to show the advantages of the combination of both modalities because the complex user interfaces of common Geographic Information System (GIS) requires a high degree of expertise from its users. Recent developments in interactive surfaces that enable the construction of low cost multi-touch displays and relatively cheap sensor technology to detect foot gestures allow the deep exploration of these input modalities for GIS users with medium or low expertise. In this paper, we provide a categorization of multi-touch hand and foot gestures for the interaction with spatial data on a large-scale interactive wall. In addition we show with an initial evaluation how these gestures can improve the overall interaction with spatial information.

Keywords

Multi-touch, Foot Interaction, Spatial Data, Tangible Interfaces, Geographic Information System (GIS), Large Screens

ACM Classification

H5.2. Information Interfaces and Presentation. User Interfaces: Evaluation/methodology, Input devices and strategies, Interaction styles.

Introduction & Motivation

Multi-touch has great potential for exploring complex content in an easy and natural manner. Some designers of these multi-touch applications make use of the geospatial domain to highlight the viability of their approaches. This domain provides a rich and interesting testbed for multi-touch applications because the command and control of geographic space (at different scales) as well as the selection, modification and annotation of geospatial data are complicated tasks and have a high potential to benefit from novel interaction paradigms [16]. Our hypothesis is that combining hand and foot gestures has several advantages over pure hand-based multi-touch systems. Hand gestures are good for precise input regarding point and area information. It is however difficult to input continuous data with one or two hands for a long period of time. For example, panning a map on a multi-touch wall is usually performed by a “wiping”-gesture. This can cause problems if the panning is required for larger distances, since the hand moves over the surface and when it reaches the physical border it has to be repositioned and then moved again. Foot interaction, however, can provide continuous input by just pushing the body weight over the respective foot. Since the feet are used to navigate in real life, such a foot gesture has the potential advantage of being more intuitive in the sense that it approximates a highly innate metaphor. One important observation of previous studies [12] with multi-touch GIS is that users initially preferred simple gestures, which are familiar from systems with mouse input using the WIMP desktop metaphor. After experiencing the potential of multi-touch, users tended towards more advanced physical gestures [17] to solve spatial tasks, but these gestures often were single hand gestures or gestures, in which the non-dominant hand just sets a frame of reference that determines the navigation mode, while the dominant hand specifies the amount of movement. For example the tilt operation was mostly performed by pressing the non-dominant hand flat on the screen and by moving the dominant hand up and down to adjust the tilt angle. Motivated by these observations, we developed a method by which users can perform actions on a large-scale multi-touch wall with both hands and with their feet by shifting their weight over their feet on a Wii Balance Board [9].

Figure 1: User is interacting with both hands and feet with a virtual globe using a large size multi-touch wall. User is standing on a Wii balance board (marked with yellow circle).

For example, tilting is performed just with the feet and two-handed gestures can be used for more appropriate tasks, such as zooming or region selection (see figure 1).

Related Work

Until today mice and keyboards are still used by most GIS users to navigate, explore and interact with a GIS even though they are not optimal devices for this purpose. Since 1999, several hardware solutions have existed that allow for the realization of GIS with multi-touch input on surfaces of different sizes. The webpage[1] of Bill Buxton gives a good overview on the actual technologies, as well as the history of multi-touch surfaces and interaction. With today's technology it is now possible to apply the basic advantages of bi-manual interaction [1], [4], [7], [17], [18] to the domain of spatial data interaction. Even though multi-touch interaction has received a lot of attention in the last few years, the interaction possibilities of the feet in combination with multi-touch for a large-scale display were not considered as much, not even in the geospatial domain.

What is still lacking is a better understanding of how multi-touch finger gestures can be used in combination with foot control in spatial applications. In [10] Pearson and Weiser identify appropriate topologies for foot movement and present several designs for realizing them. In an exploratory study [11] they assessed a foot-operated device against a mouse in a target-selection task. The study showed that novices could learn to select fairly small targets using a mole. We present a combined framework for multi-touch and foot interaction. In addition to our previous work [15] we initial evaluated the advantages of combing both modalities in the geospatial domain.

Multi-touch and foot input for GIS

As mentioned in the motivation, the combination of direct hand input and indirect foot input provide an interesting set of interaction possibilities for the geospatial domain. Hand gestures are well suited for rather precise input. Foot interactions have a couple of advantages over hand interactions on a surface: (a) they provide an intuitive means to input continuous data for navigation purposes, such as panning or tilting the viewpoint, (b) foot gestures can be more economic in the sense that pushing one’s weight over from one foot to another is less exhausting than using one or both hands to directly manipulate the application on the surface, e.g. when trying to pan a map over a longer distances, (c) they provide additional mappings for iconic gestures for single commands. Some basic interaction are explained in the following:

Panning can be performed by applying a single hand gesture (Pointing at a certain location on the map and dragging it to the desired location). Panning can also performed by leaning to one side on the balance board to perform continues panning into one direction (In the current implementation we can distinguish between 8 directions). Simply leaning forward to the map display with the feet performs tilting. Zooming can be performed by dragging two fingers or whole hands apart. In a combination of hand and foot input, a user can zoom to a certain location on the map by pointing at the location and controlling the zoom level by leaning towards or away the map display (see figure 1 and video). Furthermore gestures can be performed

---

[1] www.billbuxton.com/multitouchOverview.html

Figure 2: Foot waiting gesture. People waiting often standing on her sidefeets. This interaction can be used to return to the home screen.

with the feet (e.g. a "waiting gesture"; people waiting often standing on her sidefeet as can be seen in figure 2).

Initial Evaluation

We conducted an initial user study to compare multi-touch interaction against multi-touch interaction combined with foot input. The study was conducted with 18 participants, 10 female, 8 male, with a mean age of 25.3 years (ages 21-33).

The study was set up with a between-participants design. The task was the following: The subjects had to solve simple geospatial tasks to get information about certain places in the world. For example they had to navigate (with pan, zoom, rotate and tilt) to Washington, D.C., find the Washington Monument. Subsequently gather information about the monument ("When was it build?") the Lincoln Memorial and the Capitol. Another task was to measure distances on the globe (e.g. "How far is from Washington to Chicago?").

After the actual test, users were asked to rate the map navigation techniques by filling out a modified version of the "user interface evaluation questionnaire" of ISO 9241-9 with only a single Fatigue (seven-point rating; higher scores denote a better rating). The total time of the experiment was about 60 minutes for each participant.

The answers varied strongly between subjects, which is reflected in the large confidence intervals (see Figure 3). Just the differences in the categories comfort, smoothness and learnability are significant at the 5% level. In general, the tilting gestures caused problems for the users using the pure multi-touch system. Overall the users liked the extended foot input

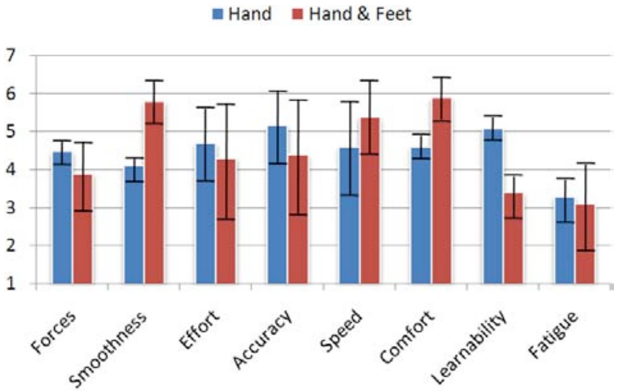

Figure 3: Results of the user interface evaluation questionnaire.

modality. They gave us comments like: "It is feels so natural: going up on my tiptoes and looking onto the world''. They tended to perform tasks faster, because they could perform actions (e.g. *panning* and *zooming*) simultaneously rather than in sequence as with a pure multi-touch system. In general the users had no problems performing the simple foot interaction on the balance board and liked the additional modality.

Implementation

We used a low-cost, large-scale (1.8 x 2.2 meter) multi-touch surface that utilizes the principles of FTIR (Frustrated Total Internal Reflection) [3], [13]. For image processing a Java multi-touch library, developed at the Deutsche Telekom Laboratories [5], was used. The application is based on NASA's World using the Java-based SDK [8]. The Wii Balance Board [9] is wirelessly connected via Bluetooth and GlovePie [2] was used to stream the sensor data from the Wii Balance Board to the application.

Conclusion and Further Work

In this paper, we have presented a mapping of multi-touch gestures with foot input from the Wii Balance Board to geospatial operations.

We have provided a first concept and implementation of the combination of multi-touch hand and foot interaction. For this purpose we have combined the advantages of both to overcome interaction problems with spatial data as one example for suitable domains. We are working on applying our framework to other domains to derive a general set of hand and foot interaction.

More generally, foot interaction provides an orthogonal horizontal interaction plane to the vertical multi-touch hand service and can be useful to improve the interaction with large-scale multi-touch surfaces. We still need to explore the combination of interaction in both planes for spatial tasks further, but believe that it has a huge potential for interaction with in spatial domain or even in any other visualization domain that uses a 3D space to organize data. In addition, the combination of the directness of hand input and the indirectness foot input provide an interesting research direction.

Interaction designers should to be aware to not degrade multi-touch to single touch, while using the non-dominant hand only for switching between different modes [14]. We show how additional modalities can overcome this problem and let users interact more intuitively and even faster. This has to be tested with further user studies.

Finally, we are investigating solutions that allow users to move freely in front of the multi-touch wall and still being able to perform foot gestures. This could be accomplished by using a larger sensor mat with multiple strain gauge force sensors that allow the measurement of weight more precisely at different positions in front of the multi-touch surface. This would also allow the interaction of multiple users, an extension that we believe would be very useful for the given domain.

References

[1] W. Buxton and B. Myers. A study in two-handed input. In Proc. of CHI 1986, ACM Press, (1986), 321–326.

[2] GloviPie. carl.kenner.googlepages.com/glovepie .

[3] J. Y. Han. Low-cost multi-touch sensing through frustrated total internal reflection. *In Proc. of UIST 2005,* ACM Press, (2005), 155-118.

[4] K. Hinckley, R. Pausch, D. Proffitt, and N. F. Kassell. Two-Handed Virtual Manipulation*. ACM Transactions on Computer-Human Interaction*, 5(3), (1998), 260-302.

[5] Java multi-touch library. http://code.google.com/p/multitouch .

[6] A. Maceachren and I. Brewer. Developing a conceptual framework for visually-enabled geocollaboration. *International Journal of Geographical Information Science*, 18(1), (2004), 1–34.

[7] T. Moscovich and J. F. Hughes. Indirect mappings of multi-touch input using one and two hands. *In Proc. of CHI 2008*, ACM Press, (2008), 1275–1284.

[8] Nasa World Wind Java SDK. http://worldwind.arc.nasa.gov/java/ .

[9] Nintendo Ltd. Wii Balance Board. e3nin.nintendo.com/wii_fit.html .

6. T. Pakkanen and R. Raisamo. Appropriateness of foot interaction for non-accurate spatial tasks. *In Proc. of CHI 2004*, ACM Press, (2004), 1123–1126.

[10] G. Pearson and M. Weiser. Of moles and men: the design of foot controls for workstations. *ACM SIGCHI Bulletin*, 17(4), (1986), 333–339.

[11] G. Pearson and M. Weiser. Exploratory evaluation of a planar foot-operated cursor-positioning device. *In Proc. of CHI 1988*, ACM Press, (1988) 13-18.

[12] J. Schöning, B. Hecht, M. Raubal, A. Krüger, M. Marsh, and M. Rohs. Improving Interaction with Virtual Globes through Spatial Thinking: Helping users Ask “Why?”. *In Proc. of IUI 2008, ACM Press*, (2008), 129-138.

[13] J. Schöning, P. Brandl, F. Daiber, F. Echtler, O. Hilliges, J. Hook, M. Löchtefeld, N. Motamedi, L. Muller, P. Olivier, T. Roth, and U. von Zadow. Multi-Touch Surfaces: A Technical Guide. *Technical Report TUM-I0833: Technical Reports of the Technical University of Munich*, (2008).

[14] J. Schöning, A. Krüger and P. Olivier Multi-Touch is Dead, Long live multi-touch. *CHI 2009: Workshop on Multi-touch and Surface Computing*, (2009)

[15] J. Schöning, A. Krüger. Multi-Modal Navigation through Spatial Information. In adjunct Proc. of GIScience 2008, (2008).

[16] UNIGIS. Guidelines for Best Practice in User Interface for GIS. ESPRIT/ESSI project no. 21580. (1998).

[17] A. Wilson, S. Izadi, O. Hilliges, A. Garcia-Mendoza, and D. Kirk. Bringing physics to the surface*. In Proc. of UIST 2008*, ACM Press, (2008), 67-76.

[18] M. Wu and R. Balakrishnan. Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays*. In Proc. of UIST 2003*, ACM Press, (2003) 193-202.