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Developing a Multi-Touch Map Application for a Large Screen in a Nature Centre

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Abstract. *The paper describes the development of a research prototype of a multi-touch map application for multi-use on a large multi-touch screen intended for a nature centre. The presented system and the development steps provide insight into what can be expected when similar systems are designed. A number of new considerations regarding multi-touch interaction, map browsing, and user needs for multi-use have been taken into account during the challenging ongoing development. These considerations include making a simple user interface used with intuitive, continuous and simultaneous gestures for map browsing, and taking different kinds of users and their needs to interact with each other into account. Since multi-user map applications in multi-touch environments are still rare, the given considerations may be helpful for the future development of similar map applications intended for public spaces.*

1 Introduction

Touch screen interaction has become a major form of user interface technology over the last couple of years. The development of touch screens is a result of the desire to build user interfaces (UI) that feel more natural to users: natural user interfaces (NUIs). Even though touch-screen technology has been available for several decades, it has only recently become popular in consumer electronics, especially on handheld devices with the introduction of the Apple iPhone in 2007. Smart phones have introduced touch screen technology to smaller devices, but there have also been considerable developments in order to bring touch screen technology to desktop devices (Microsoft Surface, 2011) or even to very large multi-touch walls, as in CityWall (Peltonen et al., 2008). Both approaches are interesting in terms of presenting and interacting with a map. In this paper we concentrate on the map interface design issues of large multi-touch screens in public spaces. Our approach is general, although our case study focuses on using large multi-touch screens for hiking map applications in public spaces like the visitor centres of national parks.

1.1 Background

The motivation for the ‘Multi-Publishing in Supporting Leisure Outdoor Activities’ (MenoMaps) and ‘Map Services for Outdoor Leisure Activities

Supported by Social Networks' (MenoMaps II) projects, some of the results of which are described in this paper, is to provide better map-based services to support outdoor leisure activities, such as hiking. Maps have always played a pivotal role in planning a hike and in ensuring that you are on the right trail. In our MenoMaps projects we have applied a multi-channel approach in which users may access the same (geospatial) information from different devices and media types at different phases of their hike. A mobile map application (Kovanen et al., 2009) or a printed map (Kettunen et al., 2011) are best suited to hiking, whereas a web map application (Oksanen et al., 2011) is best suited to planning a hike at home, and also for reminiscing about the trips later. Public spaces, such as the visitor centres of national parks, are often furnished with large wall maps, and today also with computer displays that can be used to access maps, photographs and other related information. Our interest is to study how large multi-touch screens could be used in that kind of environment, especially when a multi-user map application is the key element in user interaction.

1.2 Structure of the paper and the goal of the research

The purpose of this study is to provide insight into what kind of challenges can be expected when similar systems are designed. Furthermore, the development of a map application when multi-touch interaction and user needs are regarded is a demanding approach. We present the ongoing development of a map application for a large public multi-touch screen called MenoMaps Tassu ('Tassu' means a paw in English). The study also lists considerations that were gathered while developing the map application and revised after the application was user-tested during an exhibition in July 2012 (Rönneberg et al., 2013). The considerations can be helpful when using multi-touch as a platform for map applications in public spaces.

After a review of previous research on multi-touch based map applications and other related research for the topic in Section 1, we present the MenoMaps Tassu map application in Section 2. First, we introduce the system setup of Tassu, after which we describe the user interface. We describe our experiences developing the map application in Section 3. In Section 4, considerations that arose during the development and after the user test are listed. In Section 5, the considerations are discussed based on previously described research. Finally, future work is briefly described in Section 6.

1.3 Multi-touch and multi-touch map applications

In the geosciences, applications related to maps on large multi-touch screens are still rare. Most of the reported research relates to studying the interaction as such on a touch screen, with maps being displayed from other map applications rather than an interactive map application being developed specifically for a large multi-touch screen to be used by multiple users.

Han (2005) described a simple, inexpensive and scalable technique for enabling high-resolution multi-touch sensing on rear-projected interactive surfaces based on frustrated total internal reflection (FTIR) that brought attention to optical multi-touch systems. An example of using a large multi-touch system in a public space is presented by Peltonen et al. (2008). They present CityWall, a large multi-touch display which is installed in a central location in Helsinki, Finland. Photos tagged with the keyword 'Helsinki' from Flickr were presented along a timeline. Sorting photos is an often-used application example in multi-touch systems – an example of this is shown on our own multi-touch wall setup in Figure 1. Photos can be moved around, scaled and rotated freely by multiple users at the same time. The study introduced two interaction paradigms. The first one involved direct manipulation, meaning that users can grab objects displayed on the display. Non-modality, the second paradigm, means that all the modes of functionality are available to the user all the time. Modal user interfaces, on the other hand, rely on menus to change interaction modes, which are difficult to handle in multi-user and multi-touch environments. The findings of the study demonstrate that multi-touch supported participants in coordinating, communicating and acting out different roles. Also, it was found that users were able to learn about ways of interacting from other users. Peltonen et al. observed that multi-user interaction was the primary type of interaction, in which base types, parallel use and teamwork were reported.

The same collaboration and communication between visitors was frequently observed by von Zadow et al. (2012) as. von Zadow et al. presented the GeoLenses application that shows the same map segment as the underlying base map and superimposes different data layers on it. GeoLenses can be dragged and resized using the pinching gesture. von Zadow et al. observed that most people were actually able to access the content after a short period of exploration. On the other hand, Nacenta et al. (2012) found that their multi-user table was not interacted simultaneously by multiple users. Instead, users took turns even when they were aware of the possibility of multi-user interaction. Hofstra (2008), who presented a multi-touch table system for disaster management, found that the system was highly appropriate for a broad group of non-technical users, offering a simple and intuitive user interface that was easy to learn.

In most map applications only one user able to effectively change the map view at a time. This is the case in The Cube, Rittenbruch et al. (2013), a facility that combines 48 large multi-touch screens and very large-scale projection surfaces to form one of the world's largest interactive learning and engagement spaces. One part of The Cube includes a web based map application running on a web-browser called the Community science wall that allows users to interact with maps and user-contributed informational layers. One of the key features was dividing and merging the map between multiple screens to accommodate for single- and multi-user situations. Forlines et al. (2006) explain another way to resolve the issue of multiple users, by making only one person the "driver". Other touches referenced items or annotated rather than changed the map view. The "driver" status could also be passed around users. Bowers (2001) lists different kinds of user types for public multi-user interfaces, such as 'hands on', 'overseeing', 'passing by', and 'in the distance, yet taking an interest'. Bowers considers it important how these multiple ways of interaction can be designed into the installation. Bowers also

Figure 1. *Sorting images is one of the most used examples of applications shown on multi-touch screens. This example is from our own older multi-touch wall setup.*

emphasises the understanding of practical contexts in which the installation is encountered by the users.

Cooper & Reinman (2003) list principles for public touch-based applications, such as touchable objects that should be easy to manipulate, making accidental selection difficult. An on-screen keyboard, drag and drop functionality and scrolling should be avoided. Kin et al. (2011) built a multi-touch set construction application capable of creating virtual environments used in computer-animated films. Multi-touch was used as input for 3D object manipulation. They found that the gestures created were easy to learn and remember, but precision and occlusion were an issue though. Further, Kin et al. have summarized lessons of which the most relevant are: justify simultaneous interactions, balance gestures across both hands and design fluid transitions between gestures.

Schöning et al. (2009) demonstrated how multi-touch hand gestures in combination with foot gestures can be used to perform navigation tasks in interactive systems. The multi-touch wall was based on the FTIR technique, displaying an application based on NASA's World Wind Java SDK. A Nintendo Wii Balance Board was used for gathering the users' foot gestures. They provided a way of categorizing multi-touch hand and foot gestures for interacting with spatial data on a large-scale interactive wall.

To explore alternatives and variations of the multi-touch mode of interaction, Artinger et al. (2010) defined five alternative sets of gestures for the tasks of modifying the map view and selecting map objects in an emergency management scenario. In a video, they presented a demo that shows an interactive map on a multi-touch table, which provides an overview in an emergency situation. Whenever hands were laid on the screen, a visual clue was given to represent the number of fingers detected. Two fingers were used to move the map. Zooming in was implemented by dragging a rectangle with one finger. Zooming out was done by double tapping the screen with one finger. Selecting was done by holding three fingers on the screen and creating a pattern around the objects included in the selection. Alternate selecting of objects was done by touching each object while holding an object with another finger. Holding one finger on the map while moving a finger from the other hand around it produced a rotation. A help menu was introduced where the user laid a hand with all five fingers on the screen. For another set of gestures, a spiral pattern was drawn on top of the map when one finger was touching the screen. Visual clues were given with a plus '+' and minus '-' sign. Zooming in and out was performed by tracing the spiral either in or out with a finger. A widget with familiar buttons for panning, zooming and rotating operations was also presented.

The goal of a project presented by White (2009) was to provide insight into the potential impact of multi-touch interfaces in the fields of cartography and GIS. Using the FTIR technique, White constructed a multi-touch table as a usability testing platform. His findings showed that common navigation techniques such as panning require additional consideration in terms of cartographic design and physical limitations when exposing the interface to a general audience. White also introduced a time-based replacement for the hover state that is commonly used in desktop applications.

2 The Multi-Touch Channel of the MenoMaps Service

We have developed the MenoMaps Tassu map application for hikers on a large multi-touch screen as an example of a service that can be used in a public space for example a nature centre. The system will be set up indoors as a permanent installation and used in an exhibition hall in a nature centre close to outdoor leisure services. In this section we present the planned system setup and provide insight into the changes made to it during the development cycle.

2.1 MenoMaps Tassu system setup

Display and hardware – The setup for the multi-touch map application was planned to have three separate multi-touch LCD displays, which will be integrated to create a single large display surface. The Multi-Touch Cell Advanced displays are provided by Multi-Touch Ltd (Multi-Touch, 2011). The single, 46-inch LCD display cell has a resolution of 1920 × 1080 pixels and physical dimensions of 105.2 by 60.6 centimetres. The active display area of a cell is 101.8 by 57.3 centimetres, while the cell is 29 centimetres thick. The touch technology is based on Computer Vision Through Screen (CVTS) technology, which recognises finger tips, fingers, hands and objects through the LCD display and touch surface. Unlike some other multi-touch technologies, with CVTS there is no limit to the number of touch points it recognises. The technology is based on infrared cameras and infrared light diffused through the LCD display, where the tracking speed is up to 100 Hz.

In the planned setup, the cells are aligned horizontally and placed side by side, thereby creating a display surface of 1.81 × 1.05 metres with a display

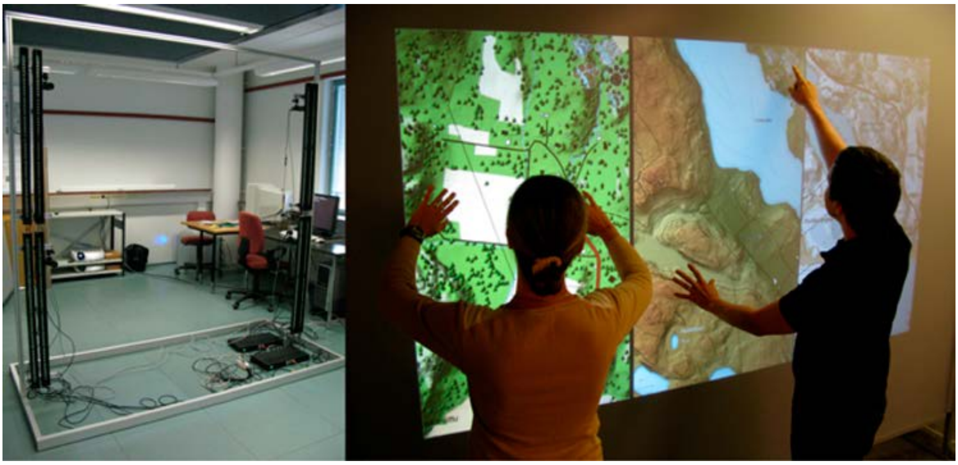

***Figure 2.** Our original rear projection setup for the multi-touch system, with a projector, computer, IR cameras and IR lights at the back (on the left) and a large canvas on the front displaying the map application (on the right).*

resolution of 3150 × 1920 pixels. It is intended that a set of steps or a platform will be situated in front of the display so that users of all heights will have the opportunity to interact with it. The C++ map application has been developed using the Cornerstone Software Development Kit (MultiTouch Cornerstone, 2011). Ubuntu version 10.04 is used as the operating system.

Originally, Tassu was developed and tested using a rear projection setup as shown in Figure 2, in which a large screen was used as a display. The rear projection approach was discarded for three reasons. First, the cell displays take up significantly less space than the rear projection setup. Second, the cells offer a higher display resolution in a smaller area. Finally, maintaining the rear projection setup in a public space is time consuming and challenging, whereas the cell setup requires almost no maintenance.

Data – The map application uses a number of data sources, which include map data, additional information related to different geospatial objects, such as descriptions of the routes, and data originating from social media. The map data, developed specifically for our multi-touch map application, consists of raster layers with five different themes that have been named as: a ‘Topographic Map’, a ‘Relief Map’, a ‘Forest Map’, an ‘Orthophoto Map’ and a ‘Winter Map’ (Oksanen et al., 2011). Each map theme is stored in an image pyramid with up to eight generalized scale levels. Currently, the 14.7 GB of map data is located on the local hard drive, but it could also be obtained online on the fly. The additional information includes descriptions as webpages with images related to specific places on the map such as a fire pit close to a lake. The images are currently stored locally, but they could also be obtained online. The data from social media consists of Facebook comments that are attached to specific objects on the map such as comments about a campsite. The comments are accessed using Facebook Graph API (Facebook Developers, 2011).

2.2 MenoMaps Tassu Interface

The map application interface, shown in Figure 3, is based on multiple widgets with different functions. A widget is defined here as an interactive user interface element that can be controlled with gestures. The widgets are divided into core and support widgets, of which core widgets do most of the visible work and support widgets are used behind the scenes. There are currently three core widgets being developed: a *map*, an *object* and an *activity* widget, which we describe briefly in Table 1.

Map widget – The *map* widget, shown in more detail in Figure 4, is used to browse the MenoMaps maps and data related to different objects. The *map* widget fills the background of the entire display area of a single cell. The *map* widget is

Figure 3. *A single Multi-touch Cell Advanced display showing our MenoMaps Tassu map application. The 'Topographic Map' on the left and the 'Forest Map' on the right.*

Table 1. *Core and support widgets of the map application.*

Widget	Functionality	Support widgets
Map	Used for browsing the maps and opening object widgets	*Layer switcher*, *Thematic map layer*
Object	Displays information gathered from social media along with basic information and pictures of the geospatial object.	*Image gallery*, *Social*
Activity	Aids visitors in finding interesting activities around the area.	

controlled with two gestures for panning and zooming. Panning is performed by grabbing the widget either with a combination of finger or with both hands and moving the map into the desired direction. Zooming can be performed either by using a pinching gesture with several fingers or by grabbing the widget with both hands and moving the hands apart to zoom in or closer together to zoom out. Zooming in and out is seamless due to the on the fly image processing of map tiles from the image pyramid, and the quality of cartographic generalization of different scale levels of the map data. On the fly image processing scales the tiles when needed. Threading is used to obtain the new map tiles in order to ensure overall performance of the interface.

The *map* widget itself is fixed to the cell and thus cannot be moved. Rotating the map data is also disabled. Each *map* widget has one support widget called a *layer switcher*, which allows the user to change the theme of the background map to any of the five alternative map themes. The *layer switcher* is currently located in the top right-hand corner of the map and is represented as ‘paws’, shown in Figure 4.

Object widget – The *object* widgets are generated from the *map* widget by touching the symbols of points of interest on the *thematic map layer*. The *thematic map layer* overlays the map data layer and consists of geospatial objects like popular hiking routes and fire pits. Once a symbol is touched, an *object* widget is created next to the touch point. Then the *object* widget can be moved around independently while browsing the map. The *object* widget displays information about the selected object and its Facebook comments if available, shown in Figure 5. The user can scroll the *object widget* up and down using the wipe gesture, if necessary. Rotating the object widget is disabled, but it can be resized within certain boundaries. The *object* widget can be closed by dragging it outside the display boundaries. When the *object* widget is left untouched for a while, it slowly begins to shrink and finally closes itself. The user can stop the shrinking at any point by touching the widget. The *object* widgets are not cell dependent, so they can be shared with other cells simply by moving them from one cell to the other.

Figure 4. *Zooming out of the 'Orthophoto Map' using the MenoMaps Tassu map widget (on the left). The map theme can be changed using the layer switcher widget, represented by paws (on the right).*

Figure 5. *The object widgets display information about the points of interest by touching the symbols on the map.*

Activity widget – The *activity* widget is designed to be used as a shortcut for users who want to find available outdoor activities in a specific area. Such activities might include swimming or popular places like beaches or camping places. The *activity* widget can be moved around freely on the screen by touching the centre of the widget. Activities are generated from buttons around the widget and displayed as *object* widgets. The *activity* widget is still being developed.

3 Experiences Gained During the Development of the Multi-Touch Map Application

During the development of MenoMaps Tassu, we have learned a lot about geospatial applications in a multi-touch environment and about the development of user interfaces in general. The map application has gone through several changes based on the decisions made collectively by our group. The Cornerstone SDK has also been updated several times. This has partly added to the difficulty in developing the map application, but most of the challenges have, however, been related to the multi-touch aspect of the interaction. When designing the user interface in particular, creating functioning prototypes of the map application has proved to be a useful way of approving the design steps. In many cases it has been beneficial to touch and feel the new user interface components in order to evaluate them properly. At the beginning of development, decisions regarding the map application were based on informal heuristic evaluation by our development group. During the project, the different versions have been presented to our project steering group, which has involved a research partner and thirteen organizations and companies along side our institute. Besides that we have been invited to present the ongoing development in several public seminars and fair events. Through these opportunities we have gathered a lot of feedback and suggestions for improvement.

When developing a multi-user and multi-touch interface, we cannot make as many assumptions about users as with other systems, because it is difficult to associate a single touch point to a specific user. In addition, the lack of precision afforded by the finger compared to a computer mouse has to be considered when users interact with the UI elements. The simultaneous usage of UI elements also presents a number of challenges. Many details must be thought about from a new perspective, while keeping in mind the basic principles of user interface design (Shneiderman and Plaisant, 2010).

One of the first major decisions concerned the *map* widget. Because of the nature of map browsing, *map* widgets are designed to have just one user interacting with them at a time. This involved a choice between two possible development options. One was to fill the whole screen with one large unmovable *background index map* widget of the target area and to have users generate *floating map* widgets from it, as shown in Figure 6. The other was to fill each cell with one *fixed map* widget as in Figure 2. The *floating map* widget approach allows more users to interact with the system, whereas with the cell map approach the number of users interacting with the *fixed map* widgets is limited by the number of cells installed. The *floating map* widgets required sufficiently large borders, from which they can be moved and scaled. Due to the widget depth logic in Cornerstone SDK, multiple *floating map* widgets can overlap. This can result in unintended interactions with other users' *floating map* widgets, especially when the screen is crowded. This is avoided in the *fixed map* widget approach, because the user is relieved from the need to scale and move the map widget itself. The *background index map* method also requires a larger display in comparison.

The *layer switcher* in the map widget has undergone significant changes, mostly because of the design aspects. Some questions still remain unresolved, such as the size, amount and location of the widgets. Details that we need to consider here include the height of the users, as children and adults must be able to reach the all the widgets, and space used by the widget. One more consideration involves the movement of the widget itself. Currently, the layer switcher is fixed in a certain position, but it could be allowed to move around the display freely or within a confined space. Forms of *layer switcher*s other than the paws have also been considered, such as a slider, where sliding a symbol through steps would change the map theme. Another possibility is to have the user rotate a wheel to change the map theme. The widget could also be reduced to a sleep state when it is idle, hiding most of its components. Touching the widget in the sleep state, would return it to full size and show all of its components. The *layer switcher* paws with images of the given map were chosen to entice users to touch them.

We have tested different kinds of shapes and sizes for the *object widget*. The *object* widgets can be moved freely across the whole display so that users can share them with each other. Due to size restrictions, scrolling is used to reveal more information on the object. The scrolling could also be replaced with a support widget, which could be flipped around to reveal new information instead of the having the user scroll the widget.

One other important aspect of the freely moving *object* widgets that needs to be considered is the possibility that the user might be unaware of where the geospatial object of the *object* widget is located on the map. We have considered numerous solutions. One way is to fix the position and scale of the *object* widgets in relation to the map, but this prevents the widget from being shared with other users. Another possible solution is a *minimap* widget, which shows the object with less or restricted functionality than the *map* widget. The *object* widget could have a locate button that would move the *map* widget in the background to the location of the object, although this functionality may cause distraction when an *object* widget is shared among users. The locate button could also move the *object widget* it self to its origin on the map. In addition to the previously mentioned options, we plan to add a feature which allows the object widget to be closed with a button because users are already familiar with it from other user interfaces. There is still the problem that users often press buttons accidentally, so a short closing delay needs to be added to the button to compensate for this.

We decided not to use widget rotation because of the upright position of the display. It was considered useless or even distracting to the users. On the other

Figure 6. *An early functioning version of the freely movable floating map widgets on top of the fixed background index map widget. Floating map widgets are generated from the index map.*

hand, in tabletop systems it is usually necessary to rotate the widgets towards the user. We also included the option of resizing the widgets within certain boundaries because users have a varying ability to read small text. We set the boundaries to such an extent that the user cannot make the widget too small to touch or too large to interfere with other users. We also plan to implement a loading indicator for situations in which things take longer than expected in order to provide the user with a visual on-screen clue that something is happening.

4 Considerations When Developing Map-Based Multi-Touch User Interfaces

Interacting with maps on a large public multi-touch screen presents challenges for developing the user interface. These considerations are based on our early findings during the development of the MenoMaps Tassu map application. These considerations were revised and confirmed after the application was user tested during an exhibition in July 2012 (Rönneberg et al., 2013).

Interaction

- Buttons are not always needed – buttons are not always the best way of doing things. For example, it might be easier and quicker to close a widget just by throwing it away rather than by pressing a button.

- Visual feedback – it is important to always give visual feedback on actions taken by the user. When pushing a button, there should be some sort of indication that the user actually hit the button.
- Invite and guide the user on how to touch – UI elements should guide the user in how to touch them by giving visual clues before hand, as well as during and after the operation; this might include when, for example, to push, slide or turn. This makes the UI elements more inviting to touch.
- Avoid complex gestures – combining simple gestures, like swiping, pinching and rotating, to create a single action may be confusing for the user or even difficult for users to accomplish.
- Encourage the user to use both hands – it is multi-touch, so why not give the user the opportunity to use both hands?

Map browsing

- What is possible might not be useful – If rotating the map is useless or even distracting, do not make it an aspect of map browsing.
- Allow things to be done in multiple ways – Common actions like panning and zooming should not be limited so that they can only be done in just one way. Panning should be possible with one and multiple fingers.
- Strive for intuitive solutions – Using opposing gestures for opposing actions leads to an intuitive interface. Zooming in by tapping one finger twice does not necessarily lead one to believe that zooming out is performed by tapping two fingers once. If a user is able to zoom in by moving their hands apart, then it is only natural that the user should be able to zoom out by reversing the gesture.
- Keep actions ongoing – There is no need for the user to have to stop constantly. Zooming in and out and panning across the map can be done simultaneously.
- Make the map large enough – The map browser should be large enough to display a relatively large or small area in enough detail if the map browser is the primary tool for familiarising the user with the area. This could also mean having other UI elements revert to a sleep state, thus taking up less space on the display.

Users

- Keep it simple – A good public multi-touch interface is easy to learn and easy to use. Not much can be assumed about the users or how many of them there will be. Keeping things simple usually requires a lot of work and user-oriented thinking.
- Personal map browsing – The functionality of a map browser allows only one user to interact with it fully, since actions like panning and zooming can only be carried out effectively alone.
- Democracy of a large screen – The user should not be able to affect the user experience of all other users on the screen by, for example, blocking

all other interaction with one enlarged widget; thus, widgets should have size limitations.

- Support interaction between users – The user should not be denied the possibility to interact with others on the screen. Users might want to share widgets, for example.
- All users are different – Make sure everyone can reach the interface, since users might be children or adults. Make the UI elements large enough so that users can actually hit them, as fingers come in different sizes.

5 Discussion

Multi-touch based map applications require special attention regarding interaction and users, as Peltonen et al. (2008) show. Map browsing is still new in multi-touch, but basic interface design principles still apply, as listed by Cooper & Reinman (2003). Keeping the interface and interaction simple includes giving visual clues as to when something is happening and avoiding complex gestures. Those principles as listed by Cooper & Reinman (2003) should be followed, but scrolling, for example, cannot always be totally avoided. Many means of zooming and panning are presented by Artinger et al. (2010). It is intended that map browsing can be performed with intuitive, continuous and simultaneous gestures, as Peltonen et al. (2008) describe, using direct manipulation and non-modality. It should be possible to pan across the map with just one or with multiple fingers, giving the user multiple options. This makes it easier for the user to learn how to use the UI. The user should be able to zoom in and out without having to stop. The user should also be able to do it with more than one gesture, as with panning. Zooming in and out by reversing the gesture is considered intuitive. Since panning and zooming are used so often in map applications, their simultaneous use should be possible. The map view should also be large enough so the user can concentrate on small details or get a good over all view. Due to the nature of map browsing, only one active user can browse a map at a given time. Having multiple users means having multiple map browsers. With the displays in an upright position, it is not usually necessary to be able to rotate content, especially a map. Having the users interact with each other should be conducted in such a manner that one user cannot, for example, take control of the whole screen, which occurred with the CityWall as described by Peltonen et al. (2008). In addition, physical aspects like the user's height and the size of their fingers should be considered when developing for public use.

6 Future Work

We have presented a map application for a large multi-touch screen that is to be used in a public space. Our study is part of an ongoing research project that is currently a research prototype exhibited to the visitors of Haltia the Finnish Nature Centre, opened in May 2013. The development will continue by improving the multi-touch map application. During the development stages, a list of considerations has been made regarding the map application itself, user needs and user interaction with the map application. During the exhibition a thorough user testing will be carried out with the actual visitors in the exhibition space to further expand or revise our considerations presented above. Additionally, we will consider the required improvements in the further development of our multi-touch map application.

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References

Artinger E, Schanzenbach M, Echtler F (2010) Alternative Multitouch Gestures for Map Interaction. Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces, November 7–10, 2010, Saarbrücken, Germany. Online: `http://www.dfki.de/its2010/papers/de113.html` (15/01/14).

Bowers, J, TONETABLE: A Multi-User, Mixed Media, Interactive Installation (2001) In Proc. COST G-6 Conference on Digital Audio Effects (DAFX-01).

Cooper A, Reinman R (2003) About Face 2.0 The Essentials of Interaction Design. Indianapolis, IN: Wiley Publishing, Inc. 498–499.

Facebook Developers (2013) Facebook Graph API. Online: https://developers.facebook.com/docs/reference/api/ (15/01/14).

Han JY (2005) Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. ACM Press, New York, pp 115–118.

Hofstra H, Shcholten H, Zlatanova S, Scotta A (2008) Multi-user tangible interfaces for effective decision-making in disaster management. In: Nayak S, Zlatanova S, editors. Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters. Berlin: Springer. pp. 243–266.

Kettunen, P., Sarjakoski, L. T., Ylirisku, S. and T. Sarjakoski, 2012. Web Map Design for a Multipublishing Environment Based on Open APIs. In: Cartwright, W., Gartner, G., Meng, L. and M. P. Peterson, (eds.), Online Maps with APIs and WebServices, Lecture Notes in Geoinformation and Cartography, Part 3, pp. 177–193, Springer. Online: http://dx.doi.org/10.1007/978-3-642-27485-5_12.

Kovanen J, Sarjakoski L. T., Sarjakoski T (2009) Studying iPhone as a Media for Context-Aware Map-Based Mobile Services. Proceedings of the 6th International Symposium on LBS & TeleCartography, Sep 2–4, 2009, CGS, University of Nottingham, UK.

Microsoft Surface (2011) Welcome to Surface. Online: http://www.microsoft.com/surface (15/01/14).

MultiTouch (2011) MultiTouch Ltd. is a leading developer of interactive display systems, based on proprietary software and hardware designs. Online: http://www.multitaction.com/ (15/01/14).

MultiTouch Cornerstone (2011) Developing with Cornerstone SDK. Online: http://cornerstone.multitouch.fi/ (15/01/14).

Nacenta M, Jakobsen M, Dautriche R, Hinrichs U, Dörk M, Haber J, Carpendale S (2012). The LunchTable: a multi-user, multi-display system for information sharing in casual group interactions. In Proceedings of the 2012 International Symposium on Pervasive Displays (PerDis '12). ACM, New York, NY, USA, Article 18, DOI=10.1145/2307798.2307816 http://doi.acm.org/10.1145/2307798.2307816.

Oksanen J, Schwarzbach F, Sarjakoski L. T. and Sarjakoski T (2011) Map Design for a Multi-Publishing Framework – Case MenoMaps in Nuuksio National Park. The Cartographic Journal, 48(2):116–123. Online: http://dx.doi.org/10.1179/1743277411Y.0000000007 (30/06/11).

Peltonen P, Kurvinen E, Salovaara A, Jacucci G, Ilmonen T, Evans J, Oulasvirta A, Saarikko P (2008) "It's Mine, Don't Touch!": Interactions at a Large Multi-Touch Display in a City Centre. CHI 2008, April 5–10, 2008, Florence, Italy.

Rittenbruch M, Sorensen A, Donovan J, Polson D, Docherty M, Jones J (2013) The cube: a very large-scale interactive engagement space. In Proceedings of the 2013 ACM international conference on Interactive tabletops and surfaces (ITS '13). ACM, New York, NY, USA, 1–10. DOI=10.1145/2512349.2512814 http://doi.acm.org/10.1145/2512349.2512814.

Rönneberg M., Halkosaari H.-M., Sarjakoski T. and L.T. Sarjakoski, 2013, Hands-on Maps: a Multi-touch Map Application in a Public Space, Kartographische Nachrichten, (4/2013):210–215.

Sarjakoski LT, Sarjakoski T (2008) User Interfaces and Adaptive Maps. In: Shekhar S, Xiong H (ed) Encyclopedia of GIS, pp 1205–1212 Springer.

Schöning J, Daiber F, Rohs M, Krüger A (2009) Using hands and feet to navigate and manipulate spatial data. In: CHI 2009 extended abstracts on Human factors in computing systems, ACM Press, New York, pp 4663–4668.

Schöning, J (2008) Using both hands and feet to interact with World Wind 2008, YouTube video, Online: http://youtu.be/riFw0kKoinU (15/01/14).

Shneiderman B, Plaisant C (2010) Designing the User Interface, Strategies for Effective Human-computer Interaction. 5th ed., Upper Saddle River: Addison-Wesley.

von Zadow U, Daiber F, Schöning J, Krüger A (2012) GeoLens: Multi-user Interaction with Rich Geographic Information, In Proceedings of Workshop Data Exploration on Interactive Surfaces (Dexis 11), research report RR-0421, INRIA, May 2012, pp. 16–19.

White J (2009) Multi-touch interfaces and map navigation. Master of Science Thesis, Department of Geography, University of Wisconsin-Madison.