# Advanced Natural and Tangible Interfaces for Spatial Information

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**Abstract**
Since 6000 years humans have used maps to navigate through space and solve other spatial tasks. Nearly all of time maps were drawn or printed on a piece of paper (or on material like stone or papyrus) of a certain size. Thus the two most common interaction methods were: (i) Holding the map in both hands (ii) or putting the map on a tabletop and perform specific tasks. Nowadays maps can be displayed on a wide range of electronic devices, starting from small screen mobile devices or highly interactive large multi-touch screen and of course the "old interaction schemas" cannot be applied anymore. In my PhD thesis I investigate new natural and tangible interfaces that allow intuitive interaction with digital spatial information transferring and/or preserving the "old interaction schemas". All different sizes of devices are considered, starting from mobile augmented reality interfaces, mobile projection interfaces, or even large scale interactive multi-touch surfaces.

**Author Keywords**
Location based service, virtual globes, digital maps, tangible and natural user interfaces, maps

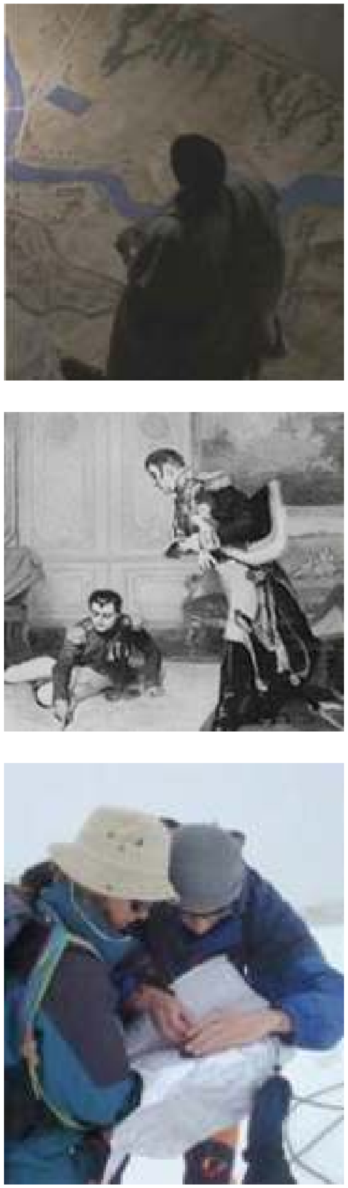

**Figure 1:** Interaction methods with paper maps. (i) Caesar inspecting a map from above (ii) Napoleon analyzing the battle of Waterloo (iii) Mountaineers using a paper map. The interaction schema nearly stays constant for nearly 6000 years (pictures from flickr.com).

## Introduction

*"This geospatial stuff is going to get bigger, faster than anybody thinks."*

*Kevin Kelly, former WIRED editor*

*"Maps become a user interface to many things [...] Geography is another way, a different way, to organize information."*

*Financial Times 21.5.2008*

Both quotes illustrate the growing importance of digital available spatial information for our daily lives. Of course these quotes are not underlayed with scientific facts, but good for capturing the spirit of a certain topic in the society.

Humans have used maps, as abstract representations of space, more than 6000 years to facilitate orientation and navigation in different scenarios [11]. These abstractions and "mappings" of real environments into new abstract spaces still involve lots of human interaction and human intelligence [7]. Still today map design is a complex task. Robinson, an American cartographer, stated that a map not properly designed "will be a cartographic failure". He also claimed, when considering all aspects of cartography, that "map design is perhaps the most complex" [14][15][24]. In addition Robinson stated that the mapmaker's understanding that a map must be designed foremost with consideration to the audience and its needs.

Nowadays maps are turning from static information products printed on paper to dynamic digital representations of space displayed on various kinds of interactive electronic devices (like mobile devices or large scale interactive displays). As envisioned by Weiser the first wave of ubiquitous computing begins with three different sizes of computing devices: The first size are wall-sized interactive surfaces. The second size are so called "notepads", envisioned not as a personal computer but as analogous to scrap paper to be grabbed and used easily, with many in use by a person at once. The third size are tiny computers ("Pads"), with the main goal to simulate PostIts.

In combination with digital available spatial information these device classes offers a lot of new potential for the users (e.g. it is dynamic and can be personalized), but of course different challenges arise e.g. displaying maps on small and low-resolution mobile devices with low input modalities (in contrast today paper maps are still superior in some categories to their digital counterparts; they provide high resolution with zero power consumption).

The theses will have three main contributions:

(i) We want to investigate how users consume digital available spatial information and how this new digital spatial information is combined with traditional spatial information (e.g. maps). This is done with empirical studies. These studies are needed to understand how people interaction with traditional spatial information and how technology change that.

**Figure 2:** Multi-touch Interaction with the first (Wikear) EESD Layer on a large multi-touch surface [19].

(ii) On this basis we want to design and implemented new forms of natural and tangible interfaces that allow interaction with digital spatial information with the main goal to transfer and/or preserving the “old interaction schemas” but enriching the interfaces with dynamic, personalized, digital spatial information. We deployed various forms of new interfaces to cover the whole range of electronic displays available today (from mobile devices to large interactive multi-touch surfaces) and will present two different interfaces later in this paper.

(iii) In addition some of these interfaces are evaluated in user test to understand some usability issues of these new interfaces in more detail.

This thesis follows the method of deployment-based research. Deployment based research serves to gain user insight as well as technical insight. The approach involves a tight cycle where theoretical issues and understanding, developed through reflection on empirical observations, are used to design deployed systems that test and explore the theories. These deployed systems then create a new context for observation of user behavior and thus lead to fresh insights, discoveries and refinement of theoretical understanding. The deployed systems take a role on a continuum between technology probes [6][10] and traditional field prototypes (i.e. working prototypes evaluated in the field or in-situ) and support a single main functionality and use logging as a main method to generate data.

While the related work is reaching across various fields and communities, such as cartographic visualization, HCI or Ubicomp, related work is discussed when needed when describing the interfaces developed in this thesis. In the following the contributions of this thesis (i-ii) are described in more detail and we will highlight some examples.

*(i) How technology change the usage of spatial information*

To investigate this question two user studies were conducted. The first study investigates the usage of virtual globes and maps [19], the second study was conducted how geocachers are using digital spatial information in combination with classical media (maps, notes on paper). The second paper will be published in a upcoming paper. The results of both studies were used in the design process of the new tangible or natural interfaces.

*(ii) Different natural of tangible interfaces to improve interaction through digital spatial information.*

In the following we describe how the results of the empirical studies can be used to design new interfaces to access digital spatial information. We will start how the results of the first study reflect in our work on a new virtual globe application.

Virtual globes have progressed from little-known technology to broadly popular software in a mere few years. We investigated this phenomenon through a survey and discovered that, while virtual globes are en vogue, their use is restricted to a small set of tasks so simple that they do not involve any spatial thinking. Spatial thinking requires that users ask “what is where” and “why”; the most common virtual globe tasks only include the “what”. Based on the results of this survey, we have developed a multi-touch virtual globe derived from an adapted virtual globe paradigm designed to

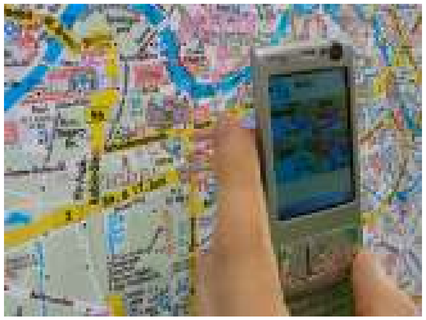

**Figure 3:** The Wikeye (mobile map interaction) application (i) and the Maptorchlight application (ii).

widen the potential uses of the technology by helping its users to inquire about both the “what is where” and “why” of spatial distribution. We do not seek to provide users with full GIS (geographic information system) functionality, but rather we aim to facilitate the asking and answering of simple “why” questions about general topics that appeal to a wide virtual globe user base. Our prototype (see figure 2) enables this facilitation by demonstrating enhancements in two key areas: data type and interface. We introduce a new simple spatial thinking-oriented virtual globe data type called Explicitly Explanatory Spatial Data (EESD), which contains both a standard spatial layer and a new explicitly explanatory layer designed specifically to answer “why” questions. Two test case data sets are presented. The first is based on our previous WikEar [20] and Minotour [8] projects, which use Wikipedia to generate narratives between geotagged Wikipedia articles. The second uses a prototype of GeoSR [9], a new semantic relatedness-based system that is backed by a Wikipedia-based knowledge repository. The semantic relatedness literature originates in computational linguistics and seeks to define a single number to “quantity the degree to which [any] two concepts are related” ([1] p. 1). More detailed information about the new interface can be found in [19].

The new interfaces that reflect the results of the second study are still work in progress. There the combination of digital spatial information and paper-based media is the focus of the research.

While the presented interface was deployed on a large multi-touch surface we want to highlight a second example of a new interface for mobile devices. At the beginning of this PhD in investigated the combination of mobile devices with traditional paper maps [18]. The mobile device was used as a magic lens to explore additional dynamic information on the map (see figure 3 (i)). In previous tests, we found that users tend to keep visual attention on the device display and take less benefit from the large-scale background map than they could otherwise. This disadvantage is especially severe when the task requires the acquisition of overview knowledge [16]. Camera projector units have the potential to overcome this switching cost, because they integrate static content from the paper map with dynamic content from the projector on a single display. Initial research on mobile projection interfaces was conducted by Raskar et al. [13] followed up by Beardsley et al. [2] and Cao et al. [5]. Blasko et al. [4] explored the interaction with a wrist-worn projection display by simulating the mobile projector with a steerable projector in a lab. The recent work of Hang et al. [7] investigates the advantages and disadvantages of interacting with map applications using mobile projection. Beyond previous work, we present a lightweight combination of a mobile camera device with a mobile projector. Using the camera to determine the position of the mobile camera projection unit with respect to the background, we enable a pixel precise augmentation of the background content, such as a paper map, with additional information. No additional tracking infrastructure is needed, such as a fixed camera based tracking system (Vicon) in [5]. We try to combine the properties of the systems presented above and developed a lightweight, small, wireless prototype that can be used in a mobile scenario. In contrast to the few mobile devices with built in projectors, our projector and camera are mounted in such as way that the camera field of view is overlapping the projected

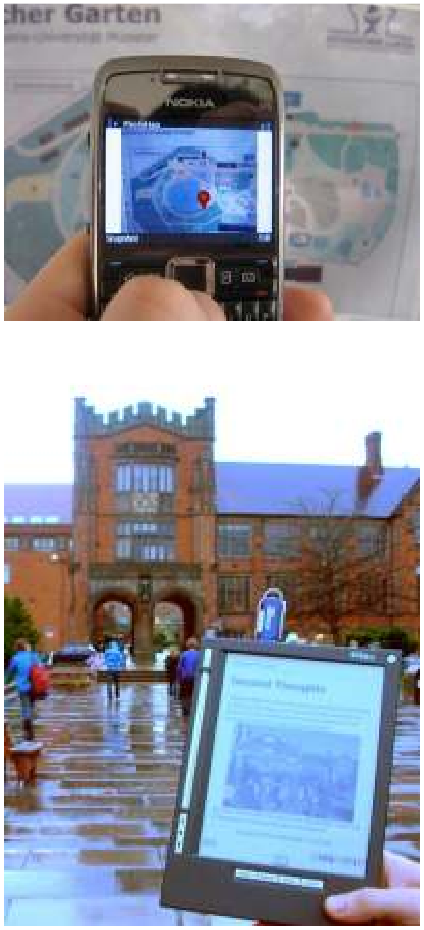

**Figure 4:** The PhotoMap application (i) and the iBookmark (ii) system.

area. Figure 3 (ii) shows our prototype in use using the tracking system presented in [17]. The main advances of a mobile projection system also show up in our Map Torchlight system: The projection area is larger and the mobile projection can overcome the switching cost of magic lens interfaces. The basic interaction pattern is similar to magic lens interfaces. Sweeping the camera projector unit over the map, the projector will, for instance, highlight different points of interest (POI) on the map. Because the projection is significantly larger than the device display (around 4 times in our setup) more dynamic information can be directly presented on the map (as can be seen in figure 3 (ii)). It also provides a higher resolution compared to a standard mobile device display, if the projector is controlled independently from the device display. As shown in figure 3 (ii), larger objects can be highlighted compared to a traditional magic lens interfaces. The projector can also be used to collaboratively interact with a map by using the map as a used as a shared screen. For instance, one user can tell another a route through the city by moving a projected crosshair over the map. Again, in all of these examples, there are no switching costs for the users. A downside of projection is that the real-world view cannot completely be blocked out, as is possible with (video see-through) magic lens interfaces. The virtual globe application and the mobile camera projector unit are just two examples of various new interfaces developed in my thesis. The PhotoMap application [23], or the iBookmark [22] systems are additional examples (see figure 4 (i, ii)).

## Conclusion and Long Term Vision

This thesis explores the design, and evaluation of new tangible and natural interfaces for spatial information. This thesis tries to make contributions in following areas: Invent novel interaction techniques, invent new hardware, invent new evaluation methods altogether, develop detailed models which factors influence usage of digital spatial information. Apply laboratory studies to investigate the detailed impact of different factors on the interaction. With the study of such new interfaces to access and interact with spatial information, we hope to discover how traditional interaction patterns transform over time with the impact of technology. In addition we believe that the digital available spatial information will have a big impact on many decision with make in our daily lives. I hope to get feedback from the DC committee to complete my thesis with some additional studies in the next 1-1 ½ years.

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## References

[1] S. Banerjee and T. Pedersen. Extended Gloss Overlaps as a Measure of Semantic Relatedness. In Proc. of IJCAI-03, (2003), 805–810.

[2] Beardsley, P., Van Baar, J., Raskar, R., Forlines, C. Interaction Using a Handheld Projector. IEEE Computer Graphics and Applications (2005), vol. 25, no. 1, 39-43.

[3] Bier, E. A., Stone, M. C., Pier, K., Buxton, W. and DeRose, T. Toolglass and magic lenses: the see-through interface. In Proc. of SIGGRAPH '93, ACM Press, (1993), 73-80.

[4] Blaskó, G., Coriand, F., Feiner, S. Exploring interaction with a simulated wrist-worn projection display. In Proc. of IEEE International Symposium on Wearable Computers, (2005).

[5] Cao, X., Forlines, C., and Balakrishnan, R. 2007. Multi-user interaction using handheld projectors. In Proc. of UIST 2007, ACM Press (2007), 43-54.

[6] Graham, C., Rouncefeld, M., Gibbs, M. Vetere, F.,Cheverst, K. How probes work. In Proc. of OZCHI '07: 29- 37, New York, NY, USA, (2007).

[7] Hang, A., Rukzio, E. and Greaves, A. Projector Phone: A Study of Using Mobile Phones with Integrated Projector for Interaction with Maps. In Proc. of Mobile HCI 2008, ACM Press (2008), 207-216.

[8] B. Hecht, N. Starosielski, and D. Dara-Abrams. Generating Educational Tourism Narratives from Millozzi. In Proc. Wikipedia. In Proc. of AAAI 2007 Fall Symposium on Intelligent Narrative Technologies, (2007).

[9] B. Hecht. Using Wikipedia as a Spatiotemporal Knowledge Repository (2007). Masters Thesis. University of California, Santa Barbara.

[10] H. Hutchinson, W. Mackay, B. Westerlund, B. Bederson, A. Druin, C. Plaisant, Beaudouin M. Lafon, S. Conversy, H. Evans, H. Hansen, N. Roussel, B. Eiderbck, S. Lindquist, and Y. Sundblad. Technology probes: inspiring design for and with families, 2003.

[11] MacEachren, A.M. (1995). How Maps Work. New York: The Guilford Press. ISBN.

[12] Pickles, J.. A History of Spaces: Cartographic Reason, Mapping, and the Geo-Coded World. Taylor & Francis, (2003)

[13] Raskar, R., van Baar, J., Beardsley, P., Willwacher, T., Rao, S. and Forlines, C. iLamps: geometrically aware and self-configuring projectors. In Proc. of the International Conference on Computer Graphics and Interactive Techniques, ACM Press, (2005).

[14] Robinson, A.H. Elements of Cartography. New York: John Wiley & Sons. ISBN, (1953).

[15] Robinson, A.H. Early Thematic Mapping: In the History of Cartography. Chicago: The University of Chicago Press. ISBN, (1982).

[16] Rohs, M., Schöning, J., Raubal, M., Essl, Georg and Krüger, A. Map Navigation with Mobile Devices: Virtual versus Physical Movement with and without Visual Context. In Proc. of ICMI 2007, ACM Press, (2007), 146-153.

[17] Rohs, M., Schöning, J., Krüger, A. and Hecht, B. Towards Real-Time Markerless Tracking of Magic Lenses on Paper Maps. In adjunct Proc. of Pervasive, (2007).

[18] Schöning, J., Krüger, A. and Müller, H.J. Interaction of Mobile Camera Devices with Maps. In adjunct Proc. of Pervasive, (2006).

[19] Schöning, J., Hecht, B. Raubal, M., Krüger, A., Marsh, M., Rohs, M. Improving Interaction with Virtual Globes through Spatial Thinking: Helping users Ask „Why?". IUI 2008: Proceedings of the International Conference on Intelligent User Interfaces, (2008)

[20] Schöning, J., Hecht, B., Starosielski, N. Evaluating Automatically Generated Location-Based Stories for Tourists. CHI 2008: Adjunct Proc. of CHI 2008, (2008)

[21] Schöning, J., Rohs, M., Kratz, S., Löchtefeld, M., Krüger, A. Map Torchlight: A Mobile Augmented Reality Camera Projector Unit. CHI 2009: Adjunct Proceedings of the 27th International Conference on Human Factors in Computing Systems, (2009)

[22] Schöning, J., Bartindale, T., Olivier, P., Jackson, D. Krüger, A., Kitson, J.: iBookmark: Locative Texts and Place-based Authoring. CHI 2009: Adjunct Proceedings of the 27th International Conference on Human Factors in Computing Systems, (2009)

[23] Schöning, J., Cheverst, K., Löchtefeld, M., Krüger, A., Rohs, M., Taher, F.: Photomap: Using Spontaneously taken Images of Public Maps for Pedestrian Navigation Tasks on Mobile Devices. In Prof. of Mobile HCI 2009, (2009)

[24] Wikipedia, Cartography - Wikipedia, The Free Encyclopedia, online accessed 25.06.2009, (2009).