Touch the map!
Designing Interactive Maps for Visually Impaired People

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Abstract

Visually impaired people face important challenges related to orientation and mobility. Accessible geographic maps are helpful for travel preparation. Historically, raised-line paper maps have been used, but these maps possess significant limitations. However, recent technological advances have enabled the design of accessible interactive maps that overcome these limitations. This paper presents the development of an accessible interactive map prototype based on the cycle of participatory design. Development steps are presented for each phase in the cycle: the analysis of context and users' needs, generation of design ideas, prototyping and the evaluation of the prototype with visually impaired users. Our studies confirm a high usability and, thus, importance of these map types to the visually impaired.

Introduction

Orientation and mobility are among the biggest challenges for the visually impaired population. Exploring an unknown environment is stressful and sometimes dangerous for visually impaired people (Gaunet & Briffault, 2005). Exploration of geographic maps at home for travel preparation may provide valuable assistance. Raised-line maps, i.e. static tactile paper maps, have long been used to present spatial information to visually impaired people (Jacobson, 1996). These maps allow for the localization of spatial objects such as streets, buildings or parks, the estimation of distances and directions, as well as finding itineraries between points on the map (Hatwell & Martinez-Sarrochi, 2003). Yet, despite their common usage by visually impaired people, tactile maps have important limitations. First, tactile maps include a large amount of information which often results in perceptual overload for readers (Jacobson, 1996). Second, once raised-line maps are printed, they cannot be updated and therefore quickly become outdated (Yatani, Banovic, & Truong, 2012). Finally, the use of Braille in tactile maps is problematic, as it requires a lot of space. Therefore, raised-line maps tend to be cluttered and difficult to read (Tatham, 1991). Most importantly, many visually impaired people do not read Braille: fewer than 10 percent of the legally blind in the United States are Braille literate (National Federation of the Blind, 2009). The development of innovative technologies (such as multi-touch devices) has opened up possibilities for designing accessible interactive maps.

We have designed and prototyped interactive maps for visually impaired people that make use of a multi-touch screen, a tactile paper map overlay and audio output. This paper presents the different contributions of my Ph.D. to the design of accessible interactive maps. Figure 1 shows how the work conducted during my Ph.D. integrates into the cycle of participatory design as proposed by Mackay (2003). These contributions are explained in detail in the following paragraphs.

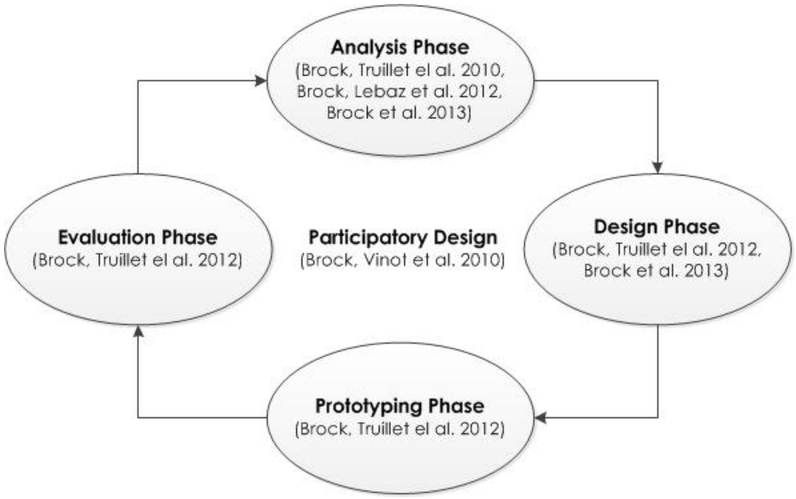

Figure 1: Designing an interactive map for visually impaired people. The diagram shows how the contributions of my Ph.D. integrate into the Participatory Design Cycle (Mackay, 2003).

Designing accessible maps based on a participatory design cycle

To ensure that users' needs were met, we adopted a participatory design cycle for the development of the interactive map prototype. We based our work on the description of the participatory design cycle by Mackay (2003) which proposes four design phases: analysis / observation, design / generation of ideas, prototyping and evaluation. By doing so we observed that the participatory design methods themselves were often based on the use of the visual sense and thus not accessible for visually impaired people. We therefore proposed adaptations for making the design process itself accessible (Brock, Vinot, et al., 2010).

Analysis phase

A first step in the participatory design process was devoted to the analysis of existing solutions, the context of use as well as the technical environment.

The literature on accessible interactive maps has shown that several research projects have been devoted to making interactive maps accessible for visually impaired people within the last 25 last years. All of these projects involved interactive geographic maps, most of them representing streets and buildings. Within this corpus, the underlying concepts for map design differ in various aspects. In Brock et al. (2013) we proposed a classification of different interactive map prototypes. This classification was based on the use of different input and output modalities and the possibility of using the device in motion (immobile versus mobile).

The context of use included aspects such as the characteristics and needs of blind users, their specificities regarding spatial cognition, their interaction with technology, and the influence of haptic exploration strategies on spatial cognition. So far, little is known on the latter question. Yet, a better understanding of haptic exploration strategies would be crucial to design interaction techniques for visually impaired users to more fully satisfy their needs. In order to facilitate the observation and analysis of haptic exploration strategies, we developed Kin'touch (Brock, Lebaz, et al., 2012). This prototype tracks finger movements by integrating data from the Microsoft Kinect camera and a multi-touch table and can thus be used for the analysis of haptic exploration strategies.

The technical context included aspects such as the production of raised-line maps and the choice of hardware and software environments. In Brock, Truillet, et al. (2010) we explained the analysis of different multi-touch technologies for their use in interactive map prototypes.

Design phase

The different types of interactive maps that we identified during the analysis phase show both advantages and disadvantages. We decided to design an interactive map prototype based on a raised-line paper map overlay, a multi-touch screen and audio output for the reasons explained in detail in Brock et al. (2013) and Brock, Truillet, Oriola, Picard, & Jouffrais (2012).

For generating further ideas during the design phase, we conducted brainstorming sessions with visually impaired users as well as orientation and mobility instructors. These sessions focused on mobility and orientation without sight. Interesting ideas that emerged from these sessions concerned the type of geographic information that would be presented (such as public transportation or tourist attractions) as well as the different levels of information accessible on a single map. For instance users proposed a first level of information indicating the name of a geographic element, e.g. "museum", and a second level giving practical information concerning this geographic element, e.g. opening hours.

Prototyping phase

Successive versions of interactive map prototypes have been developed based upon the previous analysis and design phases.

The first prototyping step was a low-fidelity "Wizard of Oz" prototype. This method usually involves visual representations, but can be adapted to visually impaired people (Miao, Köhlmann, Schiewe, & Weber, 2009). Concretely, we used raised-line maps and simulated speech output. Based on the pre-tests with the low-fidelity prototype, we confirmed the users' appreciation for the interactive map concept.

A first interactive map is described in Brock, Truillet, Oriola, & Jouffrais (2010). The final prototype which served as an experimental platform to study the usability of interactive maps is described in Brock, Truillet, et al., (2012). Briefly, it consisted of a raised-line map placed as an overlay over a multi-touch screen. We implemented a double tap as input interaction to obtain speech output on different map elements. Output interaction was thus both tactile (through the raised lines of the map) and auditory (through the text-to-speech associated with touch events).

Evaluation phase

To verify if users' needs have been met, it was essential to evaluate the prototype with the target group, in our case, visually impaired users. The usability of a prototype can be evaluated by measuring efficiency, effectiveness and user satisfaction during interaction with the prototype (ISO - International Organization for Standardization, 2010).

The user satisfaction for our prototype was assessed in a first study (Brock, Truillet, et al., 2012). Interestingly, we observed a high level of user satisfaction regardless of chronological age, previous visual experience or Braille reading experience. One person had serious difficulties with a classic raised-line map because of the Braille text, but was capable of reading the interactive map without problems.

A second study (to be published) will present a comparison of two different map types. We created an interactive map (multimodal tactile and audio map) and a non-interactive map (tactile map with Braille text) and compared them for satisfaction, efficiency and effectiveness. We observed significantly shorter learning time, i.e. higher efficiency, and higher satisfaction with the interactive map than with the raised-line map. These findings allow us to pursue the development of interactive maps for visually impaired people with confidence.

Conclusions and perspectives for future work

This paper presents the design of interactive map prototypes for visually impaired people based on the different phases of the participatory design cycle.

As participatory design is an iterative process (ISO - International Organization for Standardization, 2010) we are continuously improving our prototype. As mentioned above, users stated an interest in accessing different levels of information (e.g. the name of a point of interest, its opening hours, accessibility relevant information, etc.). We are currently working on providing increased functionality by using different gestural interaction techniques for each level of information. This will be based on prior work on gestural interaction for visually impaired people (Kane, Wobbrock, & Ladner, 2011; Kane, Ringel Morris, et al., 2011; McGookin, Brewster, & Jiang, 2008).

In the future, we expect that new touch screen technologies will provide enhanced design possibilities. Several projects are currently emerging on touch devices with haptic feedback or deformable surfaces (Bau & Poupyrev, 2012; Casiez, Roussel, Vanbelleghem, & Giraud, 2011; Weiss, Wacharamanotham, Voelker, & Borchers, 2011). These devices will enable the design of accessible maps without the need for a tactile map overlay.

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