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Design and evaluation of interactive audio-tactile maps for visually impaired people

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Abstract

In order to overcome challenges related to orientation and mobility, visually impaired people need to know their environment. Tactile relief maps are generally used for exploring geographic information, but they retain significant limitations. Recent technological progress allows the development of interactive maps which overcome these limitations. We designed an accessible interactive map prototype composed by a multi-touch screen with tactile map overlay and speech output. It provided auditory information when tapping on map elements. We have demonstrated in an experiment that our prototype was more effective and satisfactory for visually impaired users than a simple raised-line map. We also explored and tested different types of advanced non-visual interaction (gestural, tangible and wearable) for exploring the map. Finally, we present how this work has been conducted using a participatory design process.

1 Introduction

Visually impaired people face important challenges related to orientation and mobility. Indeed, 56% of visually impaired people in France declared having problems concerning mobility and orientation (C2RP, 2005). These problems often mean that visually impaired people travel less, which influences their personal and professional life and can lead to exclusion from society (Passini & Proulx, 1988). Therefore this issue presents a social challenge as well as an important research area. Accessible geographic maps are helpful for acquiring knowledge of an urban environment. Traditionally, raised-line paper maps with braille text have been used. These maps have proved to be efficient for the acquisition of spatial knowledge by visually impaired people. Yet, these maps possess significant limitations (Tatham, 1991). For instance, due to the specificities of the tactile sense only a limited amount of information can be represented on the map. Also, it is difficult to represent specific information such as distances. Furthermore, only a small percentage of the visually impaired population can read braille.

Recent technological advances have enabled the design of interactive maps with the aim to overcome these limitations. Indeed, interactive maps have the potential to provide a broad spectrum of the population with spatial knowledge, irrespective of age, impairment, skill level, or other factors (Oviatt, 1997). To this regard, they might be an interesting means for providing visually impaired people with access to geospatial information. The literature reveals that numerous research projects have been devoted to the design of interactive maps for visually impaired people since 1988 (Brock, Oriola, Truillet, Jouffrais, & Picard, 2013). The design of these maps varied in different aspects, including content (city maps, country maps, weather maps, etc.), devices (touchscreen, haptic devices, mouse and keyboard) and interaction techniques (auditory, tactile).

[*] Created the first draft of this document

2 Design and evaluation of an audio-tactile map prototype

The current paper presents the research that has been conducted during this PhD thesis on designing and evaluating interactive audio-tactile maps for visually impaired people (Brock, 2013a).

2.1 Design of an audio-tactile map prototype

We developed an accessible interactive map prototype based on the observations from the literature and our own studies on observing visually impaired users during mobility and orientation (see 4). The interactive map prototype was composed of a raised-line map overlay placed over a multi-touch screen (see Figure 1), a computer connected to the screen and audio output through loudspeakers. Users could explore the raised-line map on top of the screen with both hands, i.e. ten fingers, exactly the same way that they would explore a tactile paper map. They could obtain the names of streets and buildings by double-tapping on the map elements. The development of this map prototype consisted in four steps: 1) drawing and printing the raised-line paper map, 2) choice of multi-touch technology, 3) designing and implementing non-visual interaction methods and 4) developing the software architecture. We have presented this prototype in (Brock, Truillet, Oriola, Picard, & Jouffrais, 2012).

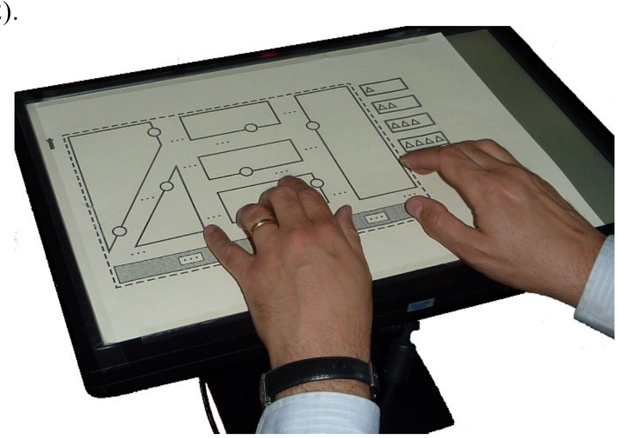

Figure 1: Interactive audio-tactile map prototype

2.2 Evaluating the usability of the audio-tactile map

Prior to this project, the usability of accessible interactive maps had never been compared to the usability of raised-line maps with braille text. Therefore, it has been unknown whether interactive maps were worse or better solutions than traditional embossed maps. To overcome this lack of knowledge, we conducted a systematic user study based on experimental psychology, comparing these two different map types for visually impaired people. Both maps were tested by 24 blind participants. The study showed that interactive maps had a higher efficiency and user satisfaction as classical tactile-Braille map. Improvement in spatial learning depended on users' expertise and characteristics as well as the type of spatial knowledge (landmark, route, survey) that had to be acquired. We presented the results of this study in (Brock, Truillet, Oriola, Picard, & Jouffrais, 2015).

3 Advanced non-visual interaction with geographic maps

The non-visual interaction techniques evaluated in the previously described study were quite simple (double tap to acquire verbal information about names of streets and buildings). With the advancement of new technologies it is possible to design more advanced interaction techniques. Concretely we were interested in how gestural and tangible interaction could be used for interaction with accessible maps and whether smartwatches could be integrated into accessible maps.

3.1 Non-visual gestural interaction for geographic maps

Touch displays possess a poor accessibility for visually impaired people due to the fact that they do not provide any cutaneous feedback or information about the placement of interactive elements. One possibility to make them more accessible without sight is through gestural interaction. Yet, there are still few studies on using gestural interaction for visually impaired people. We suggest that gestural interaction is especially interesting for accessing geographic maps, as it would provide the possibility to enrich them. First, gestures would enable the possibility to access important information, such as distances, directions, or itineraries. Second, it would be possible to present more complex information than names. Concretely, we showed how gestural interaction techniques can be used in interactive maps for visually impaired people for accessing more-detailed information about points of interest and determining distances between these points (Brock, Truillet, Oriola, & Jouffrais, 2014).

3.2 Non-visual tangible interaction for geographic maps

Tangible interaction investigates interaction with the digital world through the use of physical artifacts (Ullmer & Ishii, 2000). Although tangible interaction has raised a lot of interest in the HCI community, it is still very rarely used in the context of accessible interaction. We have worked on the design of non-visual tangible interaction for geographic maps (Brock, Ducasse, Dubois, & Jouffrais, 2014).

3.3 Non-visual interaction with smartwatches for geographic maps

Only few projects have studied the interaction with wearable technology without sight (see for example Ye, Malu, Oh, & Findlater, 2014), and especially there is a lack of knowledge concerning the use of smartwatches by blind people. Concretely, we combined use of a smartwatch with a large multi-touch table. We proposed a two-step non-visual interaction technique to speed up exploration of a large geographic map without sight. The first step (Quick-Glance) allows quickly acquiring a global but sparse mental representation of the map by using mid-air gestures. In a second step (In-Depth), users can select a point of interest (POI) to which the hand is guided (Bardot, Brock, Serrano, & Jouffrais, 2014).

4 Designing with and for visually impaired users

It is an important principle in Human-Computer Interaction to include users throughout the whole design cycle in order to assure that the developed technologies meet the users' needs. This can be done through the use of participatory design or codesign methods (Sanders, 2002). When designing for people with special needs it is especially important to include them into the design process. First, a designer or researcher without impairments cannot imagine how technology needs to be designed for special needs. Second, not considering user needs in the design of assistive technology results in a high abandoning rate (Phillips & Zhao, 1993).

Our research with visually impaired people has been based on using participatory design methods for all design phases: analysis, ideation, prototyping and evaluation (Brock, 2013b). Through a close collaboration with the Institute of the Young Blind in Toulouse (CESDV-IJA) we have been able to meet many visually impaired people as well as locomotion trainers and teachers. As most design methods largely make use of the visual sense (for instance sharing of ideas during a brainstorming session by writing them on a whiteboard), we have been forced to adapt existing methods accordingly when working with blind people (Brock et al., 2010).

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