Enriching Graphic Maps to Enable Multimodal Interaction by Blind People

Caterina Senette[1], Maria Claudia Buzzi[1], Marina Buzzi[1], Barbara Leporini[2], and Loredana Martusciello[1]

[1] CNR-IIT via Moruzzi 1, 56124 Pisa, Italy
{caterina.senette,claudia.buzzi,marina.buzzi, loredana.martusciello}@iit.cnr.it
[2] CNR-ISTI, via Moruzzi 1, 56124 Pisa, Italy
Barbara.Leporini@isti.cnr.it

Abstract. Geographical maps are by their nature inherently inaccessible to blind users since the information is conveyed mainly in a visual way. The attempt to convert all the information to an alternative modality allowing satisfactory exploration by blind people is a very active field of research. Several studies offer interesting solutions currently only available as prototypes. The work described herein investigates multimodality, focusing on the tactile interaction skills of a blind subject. Given the difficulty of rendering all the information available in a generic map in a tactile and/or text (Braille) format, the challenge is to provide additional substantial information content through different means: speech synthesizer, text or sound alerts and vibration events that the user may call as needed. A further challenge of our work is to make a map opportunely modified to "speak" for itself, without using dedicated devices, through web technologies and the possibility of easily developing programs for Android-based mobile devices.

Keywords: Blind, visual impairment, tactile maps, graphics maps, multimodal interaction, Android, accessibility.

1 Introduction

In this study we investigated designing an architecture that addresses the accessibility problems experienced by blind users when exploring geographic maps, by providing more efficient information. We believe that the use of multi-modal interaction (i.e., conveying information through multiple channels) is the key to more satisfactory use of the map. In Web exploration, ensuring accessibility to the blind means allowing the screen reader to correctly interpret page content, making navigation via keyboard less sequential and more usable. The issue of a sequential reading is more evident if the content to be accessed is mainly visual, as in a map. Some attempts to make maps accessible use virtual cursors managed by a keyboard. The use of cursors is an improvement, since the map is navigable and accessible, but does not resolve the problem: navigation is still sequential, even with a keyboard controller

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(right-left/high-low). Furthermore, all vision-oriented information such as shape, arrangement, type of item, and so on, can be lost by a blind person who relies on only textual and non-graphical content. In addition, information is conveyed mainly through audio, so the user must listen to a large amount of data, often leading to greater disorientation. In contrast, we attempt to enable the user to rely on touch for basic exploration, and on hearing (sounds or audio texts) for more detailed exploration. Involving more than one sense can help create a mental model of the map that is more immediate and closer to the real content.

In this paper we illustrate our proposed approach through a case study, analyzing opportunities and modalities to combine tactile and gestural interaction and audio feedback to make maps easy to explore on a mobile device for the blind. To this end, we designed a prototype for an enriched multimodal map, focusing on the user interface rather than on the implementation. In the following, after a related work section, we will introduce our approach by describing aspects and issues encountered when designing a map to use in our approach. Section 4 describes the methodology used to apply multimodal contents to a case study. The paper ends with Conclusions.

2 Related Work

Literature on accessibility and usability of geographic maps for visually impaired people can be grouped into two main categories: 1) Maps that allow one's localization and orientation in real time, including applications that use a GPS signal to detect the user's current position and provide information within a limited spatial range; 2) Maps providing information on a region of interest, for planning travel, destinations, stays, etc. In this case the interface for exploration can be fundamental and thus its design accuracy is crucial. The output of existing applications is generally vibration or voice. Focusing on the latter group, some studies have investigated how to generate the ideal accessible map starting from common online maps, retrieved in a variety of sizes/formats, neglecting the final user interface (UI). Several algorithms have been developed to extract the type of information they contain to present it in a more accessible format [1], [2]. Another branch of research focuses on user needs and behavior in map exploration, studying which information is relevant and the typical way a blind person interacts to obtain more effective feedback [3]. Poppinga et al. [4] conducted a preliminary study on how the information provided by relationships between relevant objects on the map can be conveyed in an interactive way with the smartphone's vibration motor combined with speech synthesis, in order to increase the map's accessibility on touchscreen devices. The study showed that it is possible to get a basic overview of the map layout even if a person does not have access to the visual representation. Zeng et al. proposed ATMap [5], an interactive tactile map system that enables users to act and search on the map, shown on a graphic-enabled Braille display, and to create and share annotations on geographical reference to points of interest, such as text attached to the geographical position of the objects on a 2D tactile map. Graf [6] proposed the concept of Verbally Annotated Tactile (VAT) maps to support the task of navigating complex environments indoors and outdoors. VAT maps combine a verbal annotation system as a propositional component and a tactile map as a spatial component. Zeng et al. [7] analyzed what other types of information, not only geographic, could be acquired from the location-based *You-are-here* maps, and presented a tactile *You-are-here* map system on a portable pin-matrix device (PMD) proposing a collaborative approach to gathering information, accessibility of geographic annotation by users. Schmitz et al. [8] experimented with a system that allows blind users to explore indoor and outdoor maps on a Tactile Graphics Display having additional information via text-to-speech output. The maps are stored in XML files and displayed as normal graphical output, thus the system is not limited to a specific graphics display.

However, most of the proposed applications are still in prototype form, and a practical platform that could support a blind person in their orientation is not yet available. Despite the complexity of the investigation, the problem of the quality of the feedback provided to the final user remains a challenge. In addition, the typical architecture proposed includes a desktop PC connected via USB with a touch/Braille display that does not guarantee the portability of the system [9], [1], [5].

3 The Proposed Solution

3.1 Method

Our study aims to design and apply sounds, spoken messages, vibrations and gestures offered by the mobile touch-screen devices to allow a blind user to perceive element distribution, shapes and types, and more easily obtain additional information. Furthermore, a mobile device is useful for taking the "enriched map" anywhere, and no dedicated device is required to explore the map. In our approach, we first need a physical map (hard copy) of the desired area, such as a tactile map obtained using special heat-sensitized paper containing microcapsules, ink, and a heat fuser. Next, we enrich content and interaction with sounds, vocal messages and gestures so that the map can be easier to perceive and explore for blind users. When the tactile map is superimposed on an electronic version on a touch-screen device (tablet), the user can interact with it by gestures and taps in a more interactive way.

3.2 Designing the MAP

The design of a tactile map should be a recursive process involving the end user in the early stages, not only in the subsequent evaluation. The goodness (quality) of a tactile map is the result of various considerations, including the technology used to realize it. Currently, two types of technologies dominate the large-scale production of maps: (shaping) vacuum modeling and the use of microcapsule paper with heating machines. Some studies compare the two technologies [10], [11], [12]. The results show preference for one or the other technology from time to time, since everything depends on the context in which the map is used and on user experience [11]. Regarding best practices in the use of symbols and the design, no standardized conventions are available [13]. Gardiner in his doctoral thesis in 2001 [14] proposed a set of guidelines which emphasizes the context of use of the map, the importance of having a clear idea of user needs and demands regarding the map, and the fact that the choice of symbols reflects a preliminary choice of the technology/material to be used. Other authors [15] proposed a set of symbols, each with their maximum/minimum perceptible size. Paladugu et al. [16] also evaluated their different patterns, proposing a specific set of symbols.

Based on current literature and previous considerations, we began designing the map. It should be portable and usable indoors and outdoors. The purpose of our map will be to represent a region and provide an overall picture of the place before visiting it. For providing well-built and fully satisfactory maps for the user, we follow criteria suggested in [14]: 1. Simplify the images as much as possible; 2. Represent only items with a certain specificity; 3. Objects cannot be represented in a superimposed way, they must be aligned and separated; 4. Eliminate perspective; 5. Observe the scaling ratio and respect the proportions between different elements; 6. Observe the minimum threshold of perceptual ability (about 2 mm); 7. Contextualize the drawing with a caption. To provide the user with an overview of the place to visit, we used maps from OSMs (Open Street Maps). A typical scenario might be that the user wants to know in advance what is around a certain area, e.g., the hotel s/he has booked or the venue for a conference. Some studies showed that exploring the region in advance in a virtual environment is significantly helpful for orientation in the real context [17], [7].

We chose for our study a map of Lucca (Tuscany, Italy) covering a range of 0.65 km^2 in the downtown area. The OSMs web platform provides the map in osm (xml-like) format as well as in SVG format. We downloaded the map descriptions in both formats in order to be able to modify it according to our needs. We modified it by means of an xml compiler and the APIs provided by OSM using Inkscape. The resulting map was then embossed using swell paper and a Minolta heating machine. The original map was modified in order to eliminate unnecessary elements and add the symbols needed to improve tactile exploration. All the modifications on the map needed to be made taking into account how the embosser (heating machine) works. The main constraint was to concentrate the ink on the point of interest (POI), allowing its discrimination among the other elements. All POI need to be well-pronounced. Essentially we chose these modifications: 1. Eliminate the buildings (because they make it difficult to reveal an event/gesture on the screen; 2. Maintain the text along the street even when not readable (too small) because it helps to associate its presence with a street; 3. Add a symbol (a spiral line) at the center of a large space to indicate that is a square; 4. Add small rectangular pieces on a circumscribed space to indicate that the space (route or square) is pedestrian; 5. Accentuate the profile of routes to make them more perceivable in a tactile format; 6. Maintain the shape of historical buildings such as churches; 7. Add a label in a specific position on the map to allow exploration in the correct position in terms of cardinal points.

Passing the map through the "oven" produces an embossed map with about 1-mm relief well-perceptible by touch (Fig. 2). It has the disadvantage of not allowing any adjustment of the height, which is the same for all the elements (symbols).

Fig. 1. Example of map: on the left the original SVG map, on the right the modified map

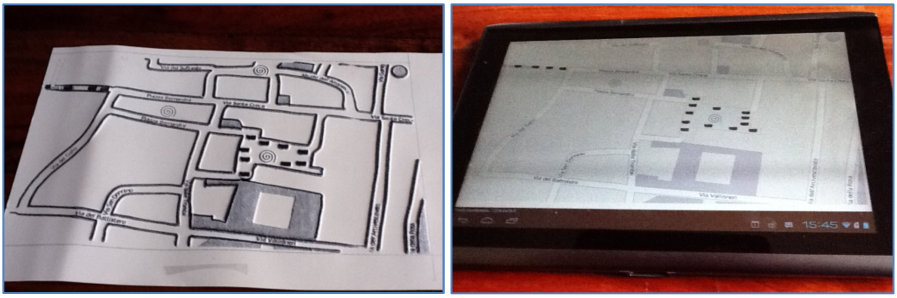

Fig. 2. Embossed map on the left and digital map over the tablet on the right

4 Adding Multimodal Content

In this section we present several different modalities considered for obtaining a multimodal enriched map accessible to a blind person. In particular, we focused on the third one for our purposes.

4.1 SVG Map with a Touch Screen Monitor

We intend to design a system for creating multimodal maps that are portable and usable everywhere. The constraint of portability limits the choice of available devices, power and features that could reduce the efficacy of the interaction. To evaluate this potential reduction, we first tested our prototype using non-portable hardware equipment. In this first example the previously designed SVG map is uploaded on a server and read by an internet browser (such as Chrome or Mozilla Firefox). A monitor touch screen (3M multitouch, 22 inch) is connected to the PC. The tactile map is placed above the screen, superimposed on an electronic version of the same map, and the blind user can interact with it using both hands simultaneously. The electronic map is enriched with events, implemented in Javascript and embedded on the SVG tags, that are able to respond to the user interaction. An SVG file includes several tag paths; retrieving the id of each path and adding specific classes to each one, we are able to read it through DOM associating each one with an mp3 file containing information to be read or sounds alerts. The information is thus accessible each time a

Javascript listener detects a user interaction. To avoid an overflow of information, we decided to activate each feedback with a single/double tap and not for events such as mouse over. Thus, the user can explore the map without disturbance and activate a call back only when s/he need information not provided by touch. The advantage of this solution is that the map has a good size that allows screen exploration with two hands in a more natural interaction. The browsers for the PC read correctly almost all SVG tags and attributes, and feedback is provided quickly. A disadvantage is related to the non-portable large touch screen.

4.2 SVG Map with Tablet

We tested the same solution described above by using a 10-inch touch-screen tablet, thus adapting the size of the swell paper to the 10-inch size of the tablet. Considering that the interaction is based on the browser's ability to read SVG tags and all the elements added via Javascript, performance greatly depends on the browser. Unfortunately, cross-browser compatibility is not yet assured for PC desktop browsers nor for mobile browses, so with this solution we faced problems such as reduced compatibility with SVG tags, reduced compatibility with javascript, and poor readability of different formats for sounds or vocal feedback. In addition, the small screen size degrades the layout rendering of the map, and the audio file process is often slow, requiring more than 20 seconds to be played.

4.3 Android App with PNG Map

To tackle the problem described above, another solution was investigated making use of a PNG image read by an Android app. In this case the multimodality will be added using a 10-inch Tablet Android Honeycomb v.3.0. The small size probably limits the information inserted in the map but enhances the portability of the system. The Android App has been implemented using an Image View widget that is associated with our map converted to a PNG file. All the information retrievable in the SVG format is preloaded in specific arrays that are then read by the App. For this reason we do not need an SVG image during the interaction, but just its associated PNG file. The java class implemented on Android makes use of an e-gesture library to intercept the user interaction. Feedback is provided to the user in three possible formats: using a TTS Engine, using vibration or using an mp3 player.

To provide an example of application of this methodology, we used the map on Fig.1(b). We have added the following multimodal content:

1. TTS engine is used to pronounce the name of each route; the gesture listener is activated along the entire path representing a route, thus the user can tap anywhere along the path.
2. When the user touches a filled-in shape, it means it is a historical building and its name is vocalized by the TTS. In particular, if it is a church, a bell sound can be also heard for 2 seconds.
3. A vibration is sent to the user for pedestrian regions (squares, routes, etc.) along with tactile feedback through small pieces embossed on the map.

4. In correspondence with a large space with well-defined contours, if it is a square the user receives its name and can have confirmation by means of a symbol placed in the center of the space (spiral line).

5 Evaluation/Results

All the prototypes have been evaluated by a blind user who is part of our research team. As expected, interaction is more comfortable with a medium-sized screen that allows a larger scale for each element of the map and more effective discrimination among elements. However, since in this case the interaction depends on the browser's ability to correctly interpret SVG tags, feedback (called with TTS Engine or mp3 player) is often not promptly provided and is difficult to customize. The multimodal map on the Android tablet and the tactile paper sheet are perceived as more interactive and rapid in responses: feedback provided could be as detailed as possible and its reproduction is quick and efficient. However, the screen's small size requires a smaller, simplified map, and exploration is conducted using one hand at time.

6 Conclusions and Future Work

The work presented here is an attempt to make geographical maps more accessible to blind people. The main challenges faced in our approach regard information extraction from the selected map and its conversion to a machine-readable form as well as to implementation of a client-side application that enables the device to respond to the user's interaction by providing all the (previously extracted) desired information. The multimodal prototype described for our case study provides the user with information by exploiting a prepared tactile map that is superimposed on an electronic version of the same map running in a SVG player or embedded in an Android App. Our case study aimed to investigate a possible multimodal enriched interface that can be suitably perceived by a blind person through different modalities – i.e., tactile, vocal and audio messages. Thus, we did not consider how the procedure could be automatized in practice. For our present purpose we concentrated on how tactile and audio aspects could be combined to obtain a more enriched multimodal user interface. The design phase is a crucial step in the entire work and it is the most difficult to automate. Future studies will address improvements in terms of process automation.

References

1. Spencer, C., Morsley, K., Ungar, S., Pike, E., Blades, M.: Developing the blind child's cognition of the environment: the role of direct and map-given experience. Geoforum 23(2), 191–197 (1992)
2. Wang, Z., Li, N., Li, B.: Fast and indipendent access to map directions for people who are blind. Interacting with Computers 24(2), 91–106 (2012)

3. Brock, A., Truillet, P., Oriola, B., Jouffrais, C., Lebaz, S., Picard, D.: Kin'touch: Understanding How Visually Impaired People Explore Tactile Maps. In: ACM CHI Conference on Human Factors in Computing Systems - Extended Abstracts, pp. 2471–2476 (2012)
4. Poppinga, B., Pielot, M., Magnusson, C., Rassmus-Gröhn, K.: TouchOver Map: Audio-Tactile Exploration of Interactive Maps. In: MobileHCI 2011, pp. 545–550. ACM (2011)
5. Zeng, L., Weber, G.: ATMap: Annotated Tactile Maps for the Visually Impaired. In: Esposito, A., Esposito, A.M., Vinciarelli, A., Hoffmann, R., Müller, V.C. (eds.) COST 2102. LNCS, vol. 7403, pp. 290–298. Springer, Heidelberg (2012)
6. Graf, C.: Verbally Annotated Tactile Maps - Challenges and Approaches. In: Hölscher, C., Shipley, T.F., Olivetti Belardinelli, M., Bateman, J.A., Newcombe, N.S. (eds.) Spatial Cognition VII. LNCS, vol. 6222, pp. 303–318. Springer, Heidelberg (2010)
7. Zeng, L., Weber, G.: Building Augmented You-are-here Maps through Collaborative Annotations for the Visually Impaired. In: SKALID 2012, Germany, p. 7 (2012)
8. Schmitz, B., Ertl, T.: Interactively Displaying Maps on a Tactile Graphics Display. In: SKALID 2012, Germany, p. 13 (2012)
9. Helal, A., Moore, S., Ramachandran, B.: Drishti: An integrated navigation system for visually impaired and disabled. In: 5th Symposium on Wearable Computer, pp. 149–156 (2001)
10. Nagel, D.L.D., Coulson, M.R.C.: Tactual mobility maps: a comparative study. Cartographica 27(2), 47–63 (1990)
11. Perkins, C., Gardiner, A.: "What I really, really want": how visually impaired people can improve tactile map design. In: Ottoson, L. (ed.) 18th ICA/ACI International Cartographic Conference, pp. 1159–1166. Swedish Cartographic Society, Stockholm (1997)
12. Pike, E., Blades, M., Spencer, C.: A comparison of two types of tactile maps for blind children. Cartographica 29(3), 83–88 (1992)
13. Brock, A., Truillet, P., Oriola, B., Picard, D., Jouffrais, C.: Design and User Satisfaction of Interactive Maps for Visually Impaired People. In: Miesenberger, K., Karshmer, A., Penaz, P., Zagler, W. (eds.) ICCHP 2012, Part II. LNCS, vol. 7383, pp. 544–551. Springer, Heidelberg (2012)
14. Gardiner, E.A.H.: The Role of Tactile Maps in Environmental Education and Recreation in Areas of Managed Countryside. University of Manchester, PhD Thesis (2001) (unpublished)
15. Tatham, A.F.: Using Cartography To Facilitate The Inclusion of Visually Impaired People Ii Sustainable Development. In: 21st International Cartographic Conference (ICC), Durban, South Africa (2003)
16. Paladugu, A., Wang, Z., Li, B.: On Presenting Audio-Tactile Maps to Visually Impaired Users for Getting Directions. In: CHI 2010 Extended Abstracts on Human Factors in Computing Systems, pp. 3955–3960. ACM, doi:978-1-60558-930-5/10/04
17. Zeng, L., Weber, G.: Audio-Haptic Browser for a Geographical Information System. In: Miesenberger, K., Klaus, J., Zagler, W., Karshmer, A. (eds.) ICCHP 2010, Part II. LNCS, vol. 6180, pp. 466–473. Springer, Heidelberg (2010)