On Presenting Audio-Tactile Maps to Visually Impaired Users for Getting Directions

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Abstract

Recent years have witnessed significant efforts on developing computer-based technologies for making maps accessible to people who are blind. Existing work has largely focused on the technological aspects of the problem without adequate attention to the human-computer interaction issues. Using an audio-tactile system as the platform, we present a focused study on such HCI issues for supporting a blind user's effective navigation of a map in getting directions. The ultimate goal of the research is to establish comprehensive design guidelines for building technologies that truly serve the needs of the users in the application of accessible maps. The results of our current study suggest that the proposed designs are effective for supporting a blind user in obtaining directions from online maps.

Keywords

Evaluation, Tactile-audio Map, Accessibility, Guidelines, Assistive Technology, Blind Users, Visual Impairment.

ACM Classification Keywords

H.5.2. User Interfaces.

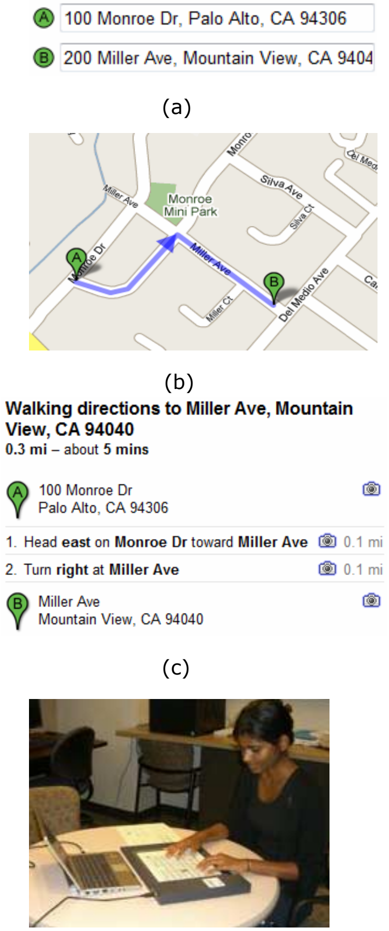
General Terms

Design, Experimentation, Human Factors.

Introduction

Maps are very useful for helping a person to grasp a sense of direction and topography of a location of interest. With the advent of online map services like Google Maps [6] and MapQuest [8], sighted people are increasingly enjoying the instant availability of services like detailed directions for getting around.

CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA.
ACM 978-1-60558-930-5/10/04.



A 100 Monroe Dr, Palo Alto, CA 94306

B 200 Miller Ave, Mountain View, CA 9404

(a)

(b)

Walking directions to Miller Ave, Mountain View, CA 94040
0.3 mi – about **5 mins**

A 100 Monroe Dr
Palo Alto, CA 94306

1. Head **east** on **Monroe Dr** toward **Miller Ave** 0.1 mi
2. Turn **right** at **Miller Ave** 0.1 mi

B Miller Ave
Mountain View, CA 94040

(c)

(d)

Figure 1. Illustration of direction using MapQuest: (a) Input Query; (b) Returned map image with suggested route; (c) Returned textual directions; (d) A user explores the created tactile-audio map on a laptop with a touchpad.

Unfortunately, a blind computer user has been largely deprived of such benefits. The lack of accessible maps is among the significant impediments to many visually-impaired individuals as they strive to lead independent and active lives.

There have been some efforts that attempt to automate the production of maps so as to support on-demand accessibility of maps for people with visual impairment [1, 3-5]. Most of such technologies rely on audio and tactile channels for conveying the information in a map. If such technologies are to be integrated with an online map service for supporting instant access by a blind user to getting directions, the usefulness of such services will be heavily discounted unless effective ways of repurposing the map contents can be designed. For example, it is difficult for a blind user to correlate the text instructions (for directions) with a tactile map, if the system simply reads out the instructions and presents to the user a simple tactile version of the underlying map.

In this study, using an audio-tactile system as the platform, we investigate various design issues that are deemed essential for building a practical system supporting a blind user's online map experiences. We first present the proposed design considerations, and then evaluate the design methods by conducting experiments with six visually-impaired participants. The results validate the effectiveness of the design and provide useful insights for future development.

Related Work

Paper-based tactile maps has been discussed in depth in the book *Tactile Graphics* by Edman [2]. While the general principles remain helpful for a computer-based approach, there are many new issues that need to be addressed when it comes to making online maps independently accessible. For example, most existing computer-based approaches use a touch-sensitive tablet to support navigation of the map by both touch and hearing. More importantly, a computer-based approach has the potential of enabling interactivity. Supporting interactivity certainly brings about new HCI issues that do not need to be considered in creating a simple paper map.

Early work addressing such issues includes [1] and [3], where the design issues were discussed mostly only at the conceptual level. Recently, real prototype systems have been reported [4, 5]. In [4], a system, Talking TMAPS, was described, which automatically produces audio-enabled tactile street maps. In [5], an automatic approach was reported for creating interactive tactile-audio map based on online maps. In preparation for the current study, we built a similar system [9] which can produce tactile-audio maps based on the queries to MapQuest. Our focus of study in the current paper is on the HCI issues in using such tactile-audio maps for supporting effective and efficient exploration of the maps by a blind user. We consider primarily maps for directions: two addresses are supplied by a user and the routing information (both graphical and textual) is returned. The problem and the system setup are illustrated in Fig. 1.

Supporting Interactive tactile-audio map

In this section, we propose our design considerations that we believe are essential for effective rendering of tactile-audio maps for providing directions in a system illustrated in Fig. 1. These include guidelines based on

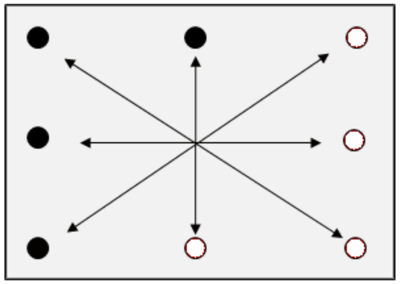


Figure 2. Positioning of the start/end points.

general knowledge on tactile perception and new design suggestions based on our field study and the specificity of our platform for supporting interactivity with online maps. The details of the design are presented below.

Adaptive Rendering of the Map Region

For a sighted person, it is easy to glance at a map of Fig. 1(b) and immediately determine the big-picture of the routing information (e.g., where to start and where to end). However, it would take considerably much more efforts for a blind user to find the start/end points (presumablly rendered as special patterns) by touch. In route tracing, this issue may be exacerbated since the blind user may have to periodically go back to the start end for reference. (These are among the complaints from blind users during our field study.) To solve this problem, we propose an adaptive rendering scheme, which adjusts the rendered region based on the spatial relationship between the input start/end points. Fig. 2 illustrates possible positions for setting the start and end points: each black-white pair connected by a line represents a possible positioning of the start/end points for defining the map region. Essentially, this scheme allows us to maximally use the rendering region while being able to maintain a protocol that tells the user the start/end points will be on fixed locations. (The points may need to have a margin from the edge to accommodate the case where the routes take a detour from the initial direction, but this can be determined automatically from the coordinates of the route returned by the map server).

Utilizing an Information Button

To further help the user to orient him/herself right away, we suggest putting a start information button on the top right corner of the map. The user is asked to use/press the information button before any other action, and audio guidance will read out some essential start information (e.g. "The start location is at the bottom-left corner of the map."). We have used a large round filled circle to represent this information button.

Design of Patterns

Tactile rendering relies primarily on texture and shape for distinction among different objects. While a manually-crafted tactile map may be even made of different materials (e.g. cloth, wood, etc.) to increase the represenational power, a paper-based tactile map (which can be automatically created) is constrained by the almost binary (flat or raised) nature of the representation. Hence the careful design of the patterns is critical.We proposed and evaluated a set of patterns for map rendering. We first conducted an initial round of field study in which a large set of candidate patterns was reduced to a couple of desirable patterns. These chosen patterns were then used for map rendering to test and compare their effectiveness in the final expriments. (Details of evaluations are presented in the next section.) The designed patterns are presented below.

Regular Streets, Landmarks and Audio Labels:

Our field study revealed that using a bold solid line for rendering streets is effective (an alternative of using two parallel lines was deemed not as good by the users). Also, it was suggested by the users that land marks (parks etc) be highlighted on a map using a filled regions. The audio labels that enable the readout of verbal descriptions when the user touches them on a

Figure 3. Patterns of start (top) and end (bottom) points. The first 2 pairs were chosen and named Pattern 1, 2 respectively.

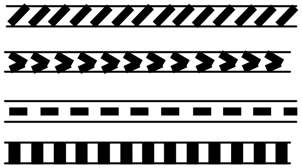


Figure 4. Patterns for the suggested route. The first two were chosen based on user inputs and named as Route 1, 2 respectively.

map (on a touchpad) were determined to be a raised dot of certain size. The size should be small enough to fit them in good numbers on the map and large enough to be easily detected by touch with the fingers.

Start/End Points

With the adaptive rendering region defined earlier, the user can search for a smaller area for the start/end locations. Still, patterns for the start/end points need to be easy to find by touch. We experimented with eight pairs of start/end patterns as illustrated in Fig. 3, and settled down on the first two pairs based on user inputs.

Density of the Audio Labels

One could insert as many as possible audio buttons, e.g., on a long road to remind the user where he/she is. We evaluated two different densities for placing the audio labels, corresponding to 1 inch apart and 0.5 inch apart respectively (referred to as Density 1 and Density 2).

Patterns for Suggested Route

The route suggested by the map service needs to be distinctive. We considered four patterns (Fig. 4) in the field study and chose the first two based on user inputs for further evaluation.

Interlacing Audio Labels

The online map service typically provides instructions corresponding to each turn of the journey. We put an interactive audio label at every turn and use the information from the online map service to create audio tags.

Utilizing a Legend

The patterns that are used should be included in a legend that is provided to the user for quick reference so that they know the shape of the pattern that they are looking for.

Evaluation

Six visually-impaired participants were recruited to evaluate our design solutions. The users have varied levels of experience with tactile maps and different background: one professional Braille proofreader, two college students and three blind working professionals. Three of them were born blind and three of them lost vision later in their lives.

Experimental Setup

Six tactile maps of varying complexity were automatically built from real on-line maps with directions using the system in [9]. The proposed patterns were then manually added to the maps (through editing the SVG files). Each of the six maps was rendered with different combinations of the chosen patterns defined in the previous section (i.e., two start/end pairs, two rendering patterns for the suggested route, and two audio label densities). Before a user started using the map, he/she was given a legend containing a description of what patterns are used for the map. The users could go back and refer to it during the task. For each user, we started off with a map that did not use the proposed adaptive rendering scheme with the information button (everything else is the same as with the other 5 maps). Then the user was introduced to the rendering scheme and the starting information button, which were used on the subsequent

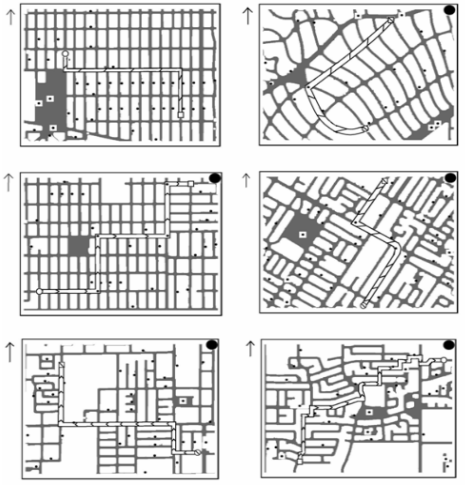


Figure 5. Six maps used in the experiments. Note that the first map does not have the start information button while all the other maps have the button on the upper-right corner.

5 maps. The created tactile maps are illustrated in Fig. 5. The users were asked to give a rating on the scale of zero to ten about each of the patterns used. We also recorded the time taken to find the start information button, the start location, the end location, and to trace the route. This was done silently without informing the participant to avoid rushing them in exploring the map.

User Interface

A Laptop computer with the IVEO viewer software was connected to an IVEO touchpad [7], as shown in Fig. 1. The subject was asked to place the tactile map on the touchpad and calibrate the device using step by step instructions provided to him/her. After calibration, the users can explore the map on the touchpad, and when he/she presses an interactive button, the computer will read out audio associated with that button.

Results and Analysis

We evaluate our rendering scheme and make comparison based on primarily three metrics: the time taken to complete the tasks, the accuracy in grasping the geographic information from the map, and the user rating. The accuracy is simply defined by whether a user is able to traverse all the legs of a route specified by the online map and name the street names correctly. For all the 6 maps, a 100% accuracy was observed for all users (i.e., none of them missed any legs of the journey and they all successfully traced the route suggested by the online map while being able to name the street names on the journey). In the following, we present the results and analysis on the times and ratings.

The information button could be located in 3.5 seconds on average, with the maximum time taken being 10 seconds and the minimum being about 1 second. Younger users turned to be quicker in a majority of the tasks. The users expressed a strong liking for the convenience provided by the information button as it gave them a quick and good idea where to start looking for the start/end locations.

On the Adaptive Rendering Scheme

This was evaluated by comparing the time to find the start location for the first map and the subsequent 5 maps. On average, there was a time reduction from 112 seconds to 16 seconds in finding the start location with the adaptive rendering scheme plus the start information button. This is an impressive improvement which suggests that the proposed scheme should be adopted for such an application.

Start/End point Locating

Three of the maps use Pattern 1 and the other three use Pattern 2. The times taken by the 6 users (including the average) are shown in Fig. 6. The average time taken for the two patterns is close and the difference is not statistically significant. But 5 of the 6 users stated that Pattern 1 is more to their liking. (The average user rating for Pattern 1 was 6.4 which is slightly higher than that of Pattern 2 (5.3)).

Route Tracing

After the users located the start and then end location, they were asked to trace out one possible way to travel from start to end. Then they were asked to trace out the suggested route that uses the route pattern. After they finish tracing the route, they were asked to name some of the streets they traveled on and if they could

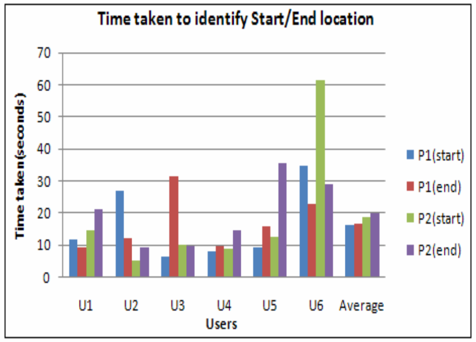


Figure 6. Times taken for locating the start/end addresses.

identify the longest route. All of them could identify the direction in which they were travelling and the longest street. For the sake of simplicity, we have used less than 6 legs and an average of 3 legs in each map.

Density of interactive buttons

We have used two different densities on the selected route that read out the labels associated with locations on the map. The users could not distinguish the usefulness between the two densities on the map. But when asked for their preference from the legend, all of them liked the sparser density (Density 1) better.

Other Preferences and Comments

All six users picked Pattern 1 for start/end location; 4 of the 6 users picked Route 1; 5 of the 6 users thought Density 1 would suffice and anything denser would be redundant; 5 out of 6 users wanted a separate symbol for the start location and the end location. One of the user wanted grids on the bounding box indicating a scale so that he could correlate distances better on the map. He also wanted more information in the start button about the number of legs in the journey. He also suggested having one symbol for start and the end location. Another user wanted more information about landmarks on the route like Starbucks, food joints etc.

Conclusions and Future work

We presented several design solutions and evaluated their effectiveness for supporting a blind user in getting routing information from online map services through a tactile-audio map. The user study suggests that the proposed design is easy to learn and use. And the users affirmed the usefulness of a system that generates such maps for everyday use. The study also led to answers to some key design questions like what patterns should be used and how audio should be interlaced. These methods should be incorporated in making automated tactile maps. Our future work includes factoring the results of this study in building the fully-automatic system of [9] and performing a larger-scale study with more users and more varieties of maps.

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