Accessible Indoor Maps for Visually Impaired People

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Abstract
Due to the diversity of indoor environments and the special requirements by blind people, it is a challenge to offer accessible indoor maps for blind people over the world. Tactile pin-matrix displays, as one of emerging accessible displays, have demonstrated their advantages to render digital maps and related spatial information in the last years. We discuss the main research challenges of the development of accessible indoor maps on pin-matrix displays, and present a preliminary study by utilizing an audio-tactile indoor map prototype system.

Author Keywords
Visual impairments; blind; accessible indoor maps; multimodal; tactile interaction.

ACM Classification Keywords
H.5.2. [User Interfaces] Haptic I/O, Auditory feedback;

Introduction
Although blind people would benefit from the more and more precise turn-by-turn navigation systems nowadays [1, 6], maps are still an important medium to learn geographic related information, such as the overview layout of a city, or the spatial relationships among multiple points of interest (POIs). Blind people benefit from accessible maps for undertaking an independent journey, specifically when travelling in unfamiliar areas.

In the last decades, a large number of methods have been proposed to produce accessible maps for the blind [9]. The traditional accessible maps (e.g., swell-paper based and thermoform based maps) are still popular due to their haptic representation, the mature production process, and training in their exploration while under Orientation & Mobility (O&M) training. Pure auditory map systems on touch-screen based devices cannot easily satisfy blind people due to the lack of real tactile feedback on their fingertips. Although there are many augmented paper-based tactile maps [2, 8] and 3D printing overlay based tactile maps [3, 7], those systems require map production in advance and hence limit blind users to get map services while on the move.
Even if tactile maps can be rendered on a refreshable display, there is no a map system which is able to offer indoor map services on a pin-matrix display, because of:

1) Lack of indoor map data,
2) Complexity and diversity of indoor environment,
3) Cost of data collection
4) Technical challenges to render indoor maps.

In this paper, we share our pilot study how to develop an interactive indoor map system on a pin-matrix display at first. Then we list and discuss the main technical challenges.

**Pilot Study: The HBIndoorMap System**

To offer blind people an accessible indoor map system, we designed and developed our original prototype (named HBIndoorMap) based on a touch sensitive pin-matrix display, i.e., the HyperBraille display which has an array of 60 x 120 pins. Figure 1 illustrates the overview architecture of HBIndoorMap system, as a classic server/client structure. On the server side, in addition to the Node.js based web server, we employ the OGC standard IndoorGML to store indoor map data. IndoorGML, based on a XML schema, intentionally focuses on modelling indoor spaces for navigation purposes. On the client side, after parsing indoor map data received in IndoorGML format, a renderer presents the related map elements by tactile map symbols.

To present map data on a pin-matrix display, one of the most important design decisions is how to render the map elements via raised pins. On a tactile swell paper map solid raised lines and shapes can be distinguished easily (see Figure 3). It is challenging for the user to distinguish between tactile map symbols and text, hence we avoid Braille. In this study, we propose two different methods to present an indoor floor plan. As illustrated in Figure 4, the first rendering method (Render 1) is more or less a direct transform from its visual floor plan, while the second rendering method (Render 2) focuses on representing the overview layout and the paths, but ignores the size and the space of the rooms. The Render 2 is inspired by topological maps in

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**Figure 2**: An initial set of tactile indoor map symbols

**Figure 3**: An example of indoor floor plan on a swell paper (solid line means a wall)

**Figure 1**: Architecture of our HBIndoorMap system.
robot navigations, to deliver a clear structure information.

In our preliminary study, we invited three blind subjects to evaluate the two different rendering styles and acquire their feedback. They counted the number of walkable paths, POIs, and looked for a route between two predefined POIs. The results indicate Render 2 would help them quickly and easily to find out walkable paths and the routes between POIs. In the next steps, more blind participants should be invited to conduct formal user studies, to investigate which rendering style is better.

Our research on accessible indoor maps
We are studying how to develop accessible indoor maps for different mediums (e.g., pin-matrix displays, and swell-paper), and how to collect and use crowdsourcing approaches in indoor wayfinding systems for blind people, as well as the evaluation methods of mental indoor maps, see Figure 5 [14].

Pin-matrix displays, as a new type of medium to present indoor maps, have many advantages while rendering indoor maps, however, in addition to other issues (e.g., the cost of a pin-matrix display, the acceptance of a pin-matrix display and the O&M training lectures of using a pin-matrix display), there are still a number of technical challenges:

1. **Indoor data sources**: There is no (indoor) map system which would contain all indoor floor plans over the world. Although some map service providers (e.g., Google and Openstreetmap) offer indoor maps for a few buildings (e.g., airports, stations and shopping malls), it is still a challenge to produce digital indoor maps of millions of complex buildings.

2. **Categories of indoor map elements needed by the blind**: Indoor maps are more complex than outdoor maps, as buildings not only have multiple levels but also have more types of indoor map elements (e.g., lifts, rooms and doors, see [4]). It will be difficult to present all map elements on a pin-matrix display, therefore, it is necessary to categorize the important map elements for blind people.

3. **Low resolution of pin-matrix displays**: The resolution of the current HyperBraille display is 10 DPI (dots per inch), which is very lower than today’s’ visual displays. It means only a limited number of map information can be presented. Besides, a pin-matrix display does not allow to overlap map information. These issues make the representation of an indoor map challengeable.

4. **Tactile map symbols of indoor elements**: There is no a set of map symbols for indoor elements when presented on a pin-matrix display. It is important and necessary to design such a set of tactile map symbols, based on the importance of indoor elements for the blind.

5. **Rendering style of indoor elements**: It is not clear which rendering style is suitable and effective for blind people to learn spatial information and make a route while reading a map on a pin-matrix display. A hybrid rendering style could allow to acquire more detailed information on rooms and routes.

6. **Accessible user interfaces and interactions**: It is always changeable to develop accessible user interfaces for blind people to access map information. In addition to panning, zooming and audio output, it is helpful to guide their fingers to target map symbols (e.g., a search result) in a quick way, otherwise, blind users have to touch the whole screen that is time-consuming.

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**Figure 5**: Reconstruction of an indoor cognitive map in Range-IT project by a blind user
Through this workshop, we would like to share our experience and listen to comments. Although our goal is to develop an indoor map for pin-matrix displays, we think the discussions about these challenges would also benefit other researchers to develop accessible indoor navigation systems.

Our past research
In the last decade, our group has been involved in several research projects to improve independent mobility by blind people:

- **Accessible maps**: A tactile-audio street map system is developed on a desktop-based pin-matrix display [11] and a tactile-audio GPS-enabled map is evaluated on a mobile pin-matrix display [13].

- **Indoor and outdoor navigations**: An indoor mobile navigation system has been developed for Frankfurt Airport [5], and a crowd-sourcing based navigation approach is used to guide blind people to find entrances in the last 10 meters [12].

- **Wearable ETAs**: To help blind people avoid obstacles while walking and acquire spatial information of surrounding environment, we developed two different wearable ETA prototypes, the 3DOD system [10] and the Range-IT system [14] based on depth cameras.

- **Interactive guide robots**: Our goal is to design and develop accessible human-robot interfaces to allow blind people to make use of a guide robot. Two prototyped guide robots have been finished, where a haptic handle is developed in the Kuka Guidance Robot [15] and an autonomous driving robot would guide blind people to a target room after creating an indoor map [16].

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References