Pre-journey Visualization of Travel Routes for the Blind on Refreshable Interactive Tactile Displays

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Abstract. In this paper we report on our continuing research of an audio-tactile system for visualizing travel routes on modern interactive refreshable tactile displays for blind users. The system is especially well suited for pre-journey route learning. Similar to systems for sighted users, e. g. online map services like Google Maps, we utilize an audio-tactile interactive map based on a concept from third-party research work and freely available geographic data. The system was implemented as a prototype for a touch-sensitive tactile display. Our main research interest is to explore audio-tactile concepts for displaying routes on a slippy map. We therefore developed a catalogue of ideas currently featuring tactile textures and indications for the route's course, waypoint symbols, audio indications etc. We summarize the results of an initial user test which indicates that the route visualization with our set of strategies is feasible and justifies further research.

Keywords: GIS, Accessible Geographic Routes, Visually Impaired, Blind.

1 Introduction

The wide availability of general-purpose geographical maps and route visualization tools on modern personal computers simplifies a lot of everyday tasks for the sighted user. The user is able to collect information on nearly all traveling aspects of an upcoming journey by simply accessing a web map service like Google Maps. Having effective tools for learning, a route prior to a journey is crucial for every traveler. Our work provides an easily operable tool for blind users to learn routes similar to the conventional usage of interactive maps.

Learning a route from a proper graphical representation is usually more efficient than studying a textual description [1]. A common way to visualize a route is to plot it onto a general-purpose geographical map by marking objects along its course. The route is often represented as a sequence of straight lines connecting waypoints. Highly interactive map visualizations on computers referred to as slippy maps simplify the learning even further. Routes can be automatically generated and visualized on top of a slippy map. Moreover, the user can generate a route by freely positioning waypoints. Focusing, zooming and receiving additional information on points of interest (POI) are available functions.

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Plotting routes on tactile maps has been a subject of research since at least 1980 [2]. Swell paper and tactile plots are static print-outs and thus bound to significant production costs and handling inconvenience compared to the actual state of the art. Human interface devices (HID) as the Talking Tactile Tablet bridge between tactile maps and computer technology. Thus, they enable interactive exploration of maps by blind users. Refreshable interactive tactile displays offer dynamic maps with no additional cost because their tactile surface is freely reconfigurable. The tactile display, referred to as BrailleDis, developed in the research project HyperBraille[1] , has a resolution of 120×60 dots and features multi-touch sensitivity.

In this paper, we report on our research on audio-tactile concepts for plotting travel routes in a slippy map for refreshable tactile displays. We begin by describing the design of the slippy map we use for our conceptual research and the implementation of a functional prototype for the touch-sensitive BrailleDis. We then elaborate on the different concepts for displaying routes with the slippy map and summarize the outcome of an explorative user test of the route visualization configurations. The computation of accessible routes is beyond the scope of our work.

2 Slippy Maps on Refreshable Tactile Displays

Slippy maps leverage the capabilities of modern computer hardware to provide a highly dynamic and productive environment for working with map data. Since slippy maps greatly simplify the access to geographical information, they are currently found across a wide number of application types. It is natural to assume that visually impaired users could also benefit from the convenience of such interfaces.

A thorough overview on the current research is provided by Senette et.al. in their survey [3]. A slippy map interface for tactile displays was pioneered by Zeng and Weber [4]. They also designed a tactile map concept including a special symbol set which takes into account the low device resolution. The interface supports nearly all features of slippy maps for sighted users: dynamic map generation with layering, panning, zooming and searching to name a few. [5] added a community approach to make accessible maps available, and performed a formative evaluation of their work with positive results. Another system was suggested by Schmitz and Ertl [6].

A useful function often found in slippy maps is the ability to visualize travel routes by selecting checkpoints on the map and providing secondary options such as the desired mode of travel or time constraints. The service calculates and highlights a suitable route, e.g. by indicating the course with straight lines of a single color.

Showing travel routes on refreshable tactile displays is an unaddressed research problem. Therefore, we suggest a catalogue of audio-tactile concepts for the visualization of routes on this device class. For the reasons described above, all our ideas are embedded in the context of an audio-tactile slippy map. Thus, we strive to provide the visually impaired user with an experience as close as possible to that of a sighted user working with a slippy map in order to learn a travel route.

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[1] Developed in the HyperBraille project (BMWi grant 01MT07004) `http://www.hyperbraille.de/`

To test our ideas in practice, we implemented a functional prototype of a slippy map for the BrailleDis. Our system uses the tactile map concept of [4], but we simplified it reducing the symbols in the prototype. Paths are rendered as straight lines of one pin thickness, and points of interest are represented using the house symbol. All depicted points of interest in the prototype are buildings.

In order to use existing and standardized technologies for processing geographical data and to be able to experiment with different route visualization techniques in an efficient manner, we based our system on a client-server architecture with standard geo-information services. The server manages a source of geographical data, renders the tactile maps and computes the requested travel routes. The client manages the refreshable tactile display, handles the user interactions, provides the audio-tactile slippy map interface, requests tactile maps, synthesizes audio notifications etc. With this setup, changes in the route visualization strategy require no reconfiguration of the client application. Instead, the client polls the available concepts from the server and the user just chooses an interaction mechanism.

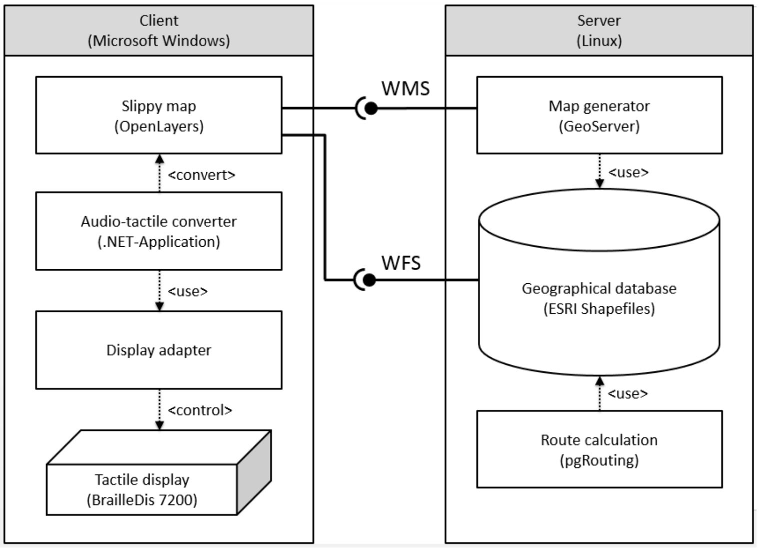


Fig. 1. Software architecture of the slippy map and the translator to the tactile display

This architectural approach (Fig. 1) guarantees high performance and technological independence. It is meaningful to assume that the server is a resourceful system. Thus, the maximum time for an update following a user interaction is roughly equal to the time required to send the server request and receive the response. The technological freedom is guaranteed on the conceptual level, because the architecture makes use of standardized web interfaces for the exchange of geographical data instead of proprietary software tools. These interfaces are already implemented by a large body of existing applications.

The functions on the server are provided by an instance of GeoServer[2] , a widely used application for processing geographical data. GeoServer supports numerous data formats and is highly interoperable with many other data processing technologies through means of standardized interfaces. It also features an elaborate and highly configurable map renderer in which the map structure and design can be described using a standardized domain-specific language.

As a source of geographical information we used a regional extract of the OpenStreetMap[3] database for the German capital city Berlin from an online archive in the format ESRI Shapefile. Also, instead of implementing a route planning service, we pre-calculated three routes in Berlin and stored them on the server for the evalua-tion. The routes are not necessarily accessible for handicapped persons. The server is responsible for highlighting the route on the produced map images using the same map renderer.

The client application is based on the idea that a conventional graphical slippy map interface can be automatically converted to a tactile representation for the target device. This simplifies the development to a great extent, because it allows existing graphical software to be used. The slippy map in the prototype is provided by the JavaScript library OpenLayers[4]. The client application itself is implemented with the .NET framework and embeds OpenLayers in a web browser GUI element. OpenLayers provides the graphical components of the map interface. Moreover, it manages the user interactions and handles the communication with the server for obtaining map images and other geographical data.

To display the slippy map on BrailleDis, we configured the OpenLayers user interface to have a fixed size of 120×60 pixels and only three colors: white, black and blue. Since we have the same number of pixels and in the same arrangement as the pins of the device, we use the color of pixel (i,j) to control the state of pin (i,j). Black implies a raised pin, white implies a lowered pin and blue implies a pin which alternates between the two states in a rapid succession – we refer to this state as “blinking”. The described mapping is illustrated in Fig. 2. The application listens for changes in the visual contents of OpenLayers and updates the pin states accordingly. The map renderer on the server follows this coloring scheme when producing map images, facilitating the concept of [4].

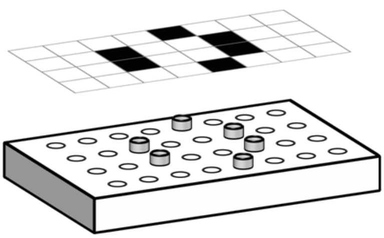
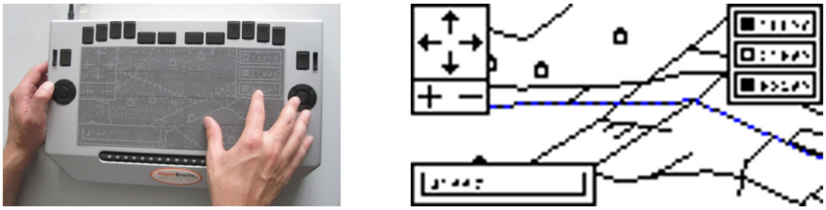


Fig. 2. The mapping between the pixels of the slippy map and the pins of the device

[2] `http://geoserver.org/`
[3] `http://www.openstreetmap.org/`
[4] `http://openlayers.org/`

Due to this mapping, the tactile map exactly resembles the visual representation of the GUI of interactive map environments for sighted users as shown in Fig. 3. A route is highlighted in the map image by coloring every third pixel blue along its course. In the tactile representation, this results in every third pin blinking.



(a) (b)

Fig. 3. Slippy map with a route (a) on BrailleDis and (b) with the adapted OpenLayers GUI

The user can touch any point on the map and receives spoken information about the geographical objects in the vicinity of the touched point. The text is synthesized from server-provided data using the standard speech synthesis tools of the operating system. Every interaction of the user with the slippy map is acknowledged by an audible indication. Text is shown in 6-dot Braille code using the standard text display mechanisms of the operating system. For this purpose, a pixel-perfect TTF font was crafted. The BrailleDis hardware buttons are mapped to keyboard keys, and surface touches are translated to mouse clicks. Thus, the user has different means of controlling the map interface and cycling through the route visualization concepts.

3 Route Visualization Concepts

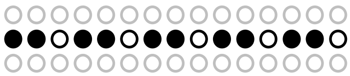
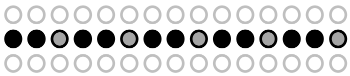
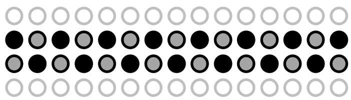
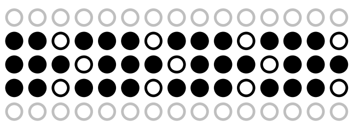
Our main research focus is to explore different audio-tactile concepts for visualizing routes in the map interface described. We developed a catalogue of ideas divided into the following categories: (1) tactile line textures for the route's course, (2) tactile symbols for the route's waypoints, (3) tactile indications of the route's direction and (4) audio indications. Additionally, we analyzed measures for improving the usability of the slippy map regarding the route visualization. The catalogue considers the advanced features of BrailleDis: the blinking mode of the pins and the multi-touch sensitivity of the surface. One of our goals was to analyze the importance of these features for the user experience.

To systematize the conceptual work we established intuitive guidelines characterizing the ideas, for example: (A) the route is the most important object in the map interface, (B) the user should be able to locate the route in a simple and quick manner and (C) the user should be able to confidently follow the route with his hands. An important design factor influencing our decisions is the implementation complexity of the concept in the described slippy map system.

Similar to systems for sighted users, we highlight the route's course with straight line segments textured with a tactile pattern. The largest part of our research effort so far is concerned with the study of different tactile textures for the route's course. We considered textures of up to three pins thickness. All suggested textures can be implemented by stacking dashed lines of variable thickness, dash length and dash spacing on top of each other. This approach is particularly easy to implement using our setup. The tactile textures partially make use of blinking pins with a blinking rate of 3 s-1, which was found to be sufficient for capturing the user's attention. Additionally, with our method of constructing line textures it is possible to construct textures of 3 pins thickness which allow the user not only to follow the route, but also to discover its direction. For example, small arrow-like shapes are embedded in some of the textures. Unfortunately, the line rendering algorithm of the map renderer used perturbs the intended texture when the route course is not parallel to the x-axis or the y-axis.

A selection of our tactile strategies is given in Table 1. The left side shows a 15 pins long cutout of a fully horizontal route passing from the left to right. This is the intended pattern of the texture without rendering artifacts. Filled black dots are raised pins, unfilled black dots are lowered pins, gray dots are blinking pins, and unfilled gray dots are pins which are not part of the texture and whose state is thus unaffected by the texture. The first two textures are identical except that the permanently lowered pins in the first are turned into blinking pins in the second. By making this change throughout the catalogue we analyze the significance of the blinking mode for the discoverability of the route. The given texture of 3 pins thickness consists of visually clearly distinguishable arrow symbols which are 2 pins apart pointing in the direction of the route. Our intention is to enable the user to recognize the direction of the route from the orientation of the arrows.

Table 1. Selected tactile line textures for visualizing the course of the route

Pattern	Description
	1 pin thickness: 2 raised pins followed by 1 lowered pin.
	1 pin thickness: 2 raised pins followed by 1 blinking pin.
	2 pin route thickness: diagonally stippled pins, thickness and stroke length of 1 pin, raised and blinking pins.
	3 pin route thickness: stippled pins with arrows pointing in the route direction.

For the end point markers we adapted the symbols suggested in [7] using a resolution of 11×11 pins. For the interior waypoints on the BrailleDis we designed custom symbols with a size of 7×7 pins. Blinking pins are used for half of the interior way-point symbols. No blinking pins are used for the end point markers. Our design decisions were mainly guided by the requirement that waypoint symbols should be discoverable through a quick scanning motion across the tactile surface. Thus, we assumed that the waypoint markers should be significantly larger than the rest of the map symbols.

Aside from suggesting tactile textures and waypoint symbols, we examined several possibilities how the user could learn the direction of the route's course with a minimal effort. This is important, because otherwise the blind user has to tediously trace the whole route in order to discover its direction. Should the end points not be visible in the map region currently displayed, the task becomes even more complicated. An immediate solution is to make sure that the end points are always visible on the map. This could be achieved either by rendering them at their true locations when they lie inside the map region or at the intersections of the route with the map borders.

Another approach to indicate the direction of the route is to send a wave or an impulse along the route using blinking pins. At regular intervals, all pins of the route would be lowered and then they would begin to assume their original state one by one in the direction of the route. However, caution should be exercised not to confuse the user.

Both described strategies are ineffective when the route contains loops. Therefore, a third approach is to let the user blend in the segments of the route one after another using an additional control mechanism.

Additional information about the route can sometimes be recognized more efficiently via audio than via touch. For instance, if a sound is played as soon as the user touches a waypoint symbol, the user would know immediately the type of the object. We distinguish two types of audio indicators: earcons and speech. Earcons are quite suitable for marking waypoints as already pointed out. Furthermore, the direction of the route can simply be transmitted as a tone whose pitch rises with a decreasing according with the distance to the destination. This would also render the task of discovering and following the route trivial.

4 Evaluation and Conclusion

We conducted a pilot study with a female blind expert-user in order to assess the implemented concepts, to identify additional important design factors and to collect suggestions on how to improve and extend the concept catalogue. The evaluation was a cognitive walkthrough applying the thinking aloud method.

The subject stated that the blinking pins render the task of locating and tracing the route largely trivial. They allowed her to follow the route using both hands simultaneously. The user deemed the other factors of the tactile texture to be much more insignificant. Blinking pins are necessary for the waypoint symbols as well. Whether this is true when earcons are used still needs to be evaluated. We observed that the mechanical sound of blinking pins is a useful indication of the route's location. We assume that an experienced user would also be able to tell by the sound where exactly the route is located. The potential of this effect is yet to be studied.

Moreover, the subject provided interesting insights regarding the rendering of lines on the intersections with roads and paths. Overall, the subject was able to find and trace the route reliably with some concepts and unable to do with other implementations. This could be interpreted as a confirmation that the route visualization is indeed practically useful and justifies further research on such concepts. This qualitative analysis provided the necessary basis for later quantitative reviews.

The developed prototype enables visually impaired users to easily explore a route on OpenStreetMap. Different tactile and audio visualization concepts were tested with promising results. The web-based implementation with high performance offers technology-independent enhancements.

In the future, the route should automatically adjust to user-specific needs. Additionally, the delivered map information could be enriched with relevant accessibility details like from the “AccessibleMap Project” [8]. Distinctive properties of the route, e.g. cobblestones or remarkable ambient noise, could be delivered through auditory feedback, which could improve the recall of the route.

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