Audio-Haptic Browser for a Geographical Information System

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Abstract. People who are blind or low vision currently hasn't obtained an effectual solution to access map applications. Although there are existing several paper-based tactile map projects, most of them need additional processing when product of new area of a map. Besides because of the size limitation of paper materials, these kinds of map fail to provide detailed information. In order to improvement accessibility of geographic data, we develop an audio-haptic map browser to access geo-data from an off-the-shelf GIS through a large-scale Braille display. The browser enables to not only maintain lively haptic sensation via raised pins, but also speech out detailed information of each map element stored in the GIS database. Furthermore, in principle it is possible to carry out worldwide map without any additional processing, if the GIS database supports. We employ a novel method, blinking pins, aimed at locating map elements quickly when implementing map search operations. Excepting introduction of our methodologies, we evaluate the system in 2 phases by participation of 4 blind persons. The results of evaluations have been issued in the end.

Keywords: accessible geographic data, audio-haptic interaction, GIS, the visually impaired.

1 Motivation

Geographic Information System (GIS) are applied worldwide due to the location independence of networks and ever growing performance. People enable to look for a street, a hotel, etc., and find the required spot on a vision-based map conveniently. However, for the visually impaired and blind users, it seems to be impossible to benefit from current GIS technology widely, although there are few alternative approaches, like Google Map Textual Interface[1]. Even if users with blind and severe low vision utilize screen reader software to access cyberspace, it is impossible to establish some spatial cognition of maps only with speech, independently from visual abilities. A major obstacle is the lack of explicit semantic knowledge linked to spatial geo-information and therefore the inability to represent maps by audio or at least verbal

[1] Google Map Textual Interface (http://maps.google.com/?output=html)

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explanations. On the other hand, maps made on paper-based materials like swell-paper provide a possibility of building up spatial cognition for the blind, but fail to represent much more detailed and dynamic information, as a result of their limitation of size and characteristic.

In this paper, how to improve accessibility of digital maps and related services from an off-the-shelf GIS are discussed, as well as a haptic map system and its implementation is presented. Based on a novel large-scale refreshable Braille display, the haptic map has the capability of rendering up-to-date geographic data from a Web-based GIS server, which supports Web Feature Service (WFS) specification of OGC[2]. We illustrate the design of multimodal interaction techniques including speech output and gestural input by fingers when exploring maps. With the help of refreshable pins offering haptic perception and audio information of graphical data, the interactive haptic map tries to establish users' spatial cognition comprehensively. Furthermore, an innovative approach for tactile animations through blinking pins has been developed to guide the user while searching.

2 Background

In recent years more and more researchers and projects focus on improving accessibility of maps. Paper-based maps are one of the most common methods to access geospatial data, like via swell paper or Braille embosser. In an international survey of tactile maps [1], microcapsule and thermoform are the two most popular production methods, respectively 68% and 55% of respondents. In addition to their low-cost, both of them could represent tactile discrimination of map elements clearly. Smith-kettlewell's Tactile Map Automated Production (TMAP) Project [2] supports rapid production of tactile street maps of any location in the USA through embossing technologies. It employs a free GIS to render roads and other features in Braille or raised print.

Given the size limitation of only tactile perception map, auditory interaction is a better supplement to render much more information. T3 (Tactile Talking Technology) system [3] is a improvement version of previous TMAP system, enhanced by audio output through the Talking Tactile Tablet (TTT), a portable and inexpensive computer peripheral device as a 'viewer' for tactile graphic materials. When the user touches the surface of the display, which is covered with the embossed map, to explore the area of map, audio feedback is synchronized with the haptic scene. The Blind Audio Tactile Mapping System (BATS) project [4] focuses on the area of spatial awareness provided by visual maps, whose combination of spatial auditory icons and simple tactile vibrations, offers a chance to access additional map information.

With capability of real haptic perception of maps, electronic tactile displays have been employed in recent projects, specifically based on refreshable Braille display. Intelligent Glasses (IG) [5] is aiming at outdoor guidance for the persons with visual impairment, and its tactile map is a simple edge-like representation of the obstacle's location in the scene through an 8 x 8 array of raised actuators. NIST's prototype tactile visual display uses 3600 pins [6] that are raised and lowered to create haptic sensation while rendering graphic documents and maps.

[2] OGC's WFS standard, `http://www.opengeospatial.org/standards/wfs`

In the meantime, a great deal of new potential materials has been researched to manufacture paperless tactile displays, specifically in micro/nanotechnology. In [7], the Korean researchers evaluate a Braille dot display module equipped thermopneumatic actuators to drive poly-dimethylsiloxane (PDMS) membranes via adjusting the input power of a micro-heater. In [8], a so-called “artificial skin” is demonstrated, which integrates large-scale micro electro mechanical systems (MEMS) based on a stimuli-responsive polymer. The temperature-sensitive polymer can reversibly change its volume by up to 90% through swelling or shrinking in nearly real-time. Swell height is about 0.5mm. Despite this limitation of swollen height, its spatial actuator density of 297 elements per cm^2, enable to represent objects in high-resolution. It is promising that in the future most users with visually impairments could afford a large-scale tactile display based on novel materials, in order to adopt new applications, specifically geospatial services.

In brief, off-the-shelf GIS embodied mass storage of geographical data, offer a chance to let blind persons understand their living environments via accessible technologies. Among those technologies, a paperless electronic tactile map considered as one of the best potential approach, not only represents dynamic and detailed information, but also enable to establish spatial cognition via combination of real touch sensation and auditory explanation.

3 Methodology

3.1 Infrastructure and Architecture

The BrailleDis 9000 tablet Braille display[3] [9] (see Figure 1) can represent tactile graphics on a matrix of 60x120 refreshable pins, in which each module covers 10 (2x5) pins. The 7200 piezo-electric actuators control each pin separately. Touch-sensitivity, low energy consumption and high speed refreshing allow novel interaction techniques. Multitouch sensitivity is based on capacitive sensors, mounted on top of each (2x5) module. Due to its touch sensitive surface, users’ fingers not only explore map directly and conveniently, but the user may also create gestures interaction.

Lines and graphics are rendered similarly on black and white pixel-based monitor on a refreshable Braille display by raised or lowered pins. In our approach, representation of map data from mass-market WebGIS requires geographic data in the format of Geography Markup Language (GML)[4]. Compared to the approach of map image processing, our method is not necessary to require an amount of computer resources, because GML XML-encoding language represents geographic information in the form of text. According to the specification of GML, an item of feature indicates a physical entity, e.g. a road, a building, which describes a list of locations, geometries, and properties. As below, Fig. 2 illustrates the flow-processing of our haptic map system, in which there are 7 main steps.

[3] The product is funded by HyperBraille Project, `http://www.hyperbraille.de/`

[4] GML standards: `http://www.opengeospatial.org/standards/gml`

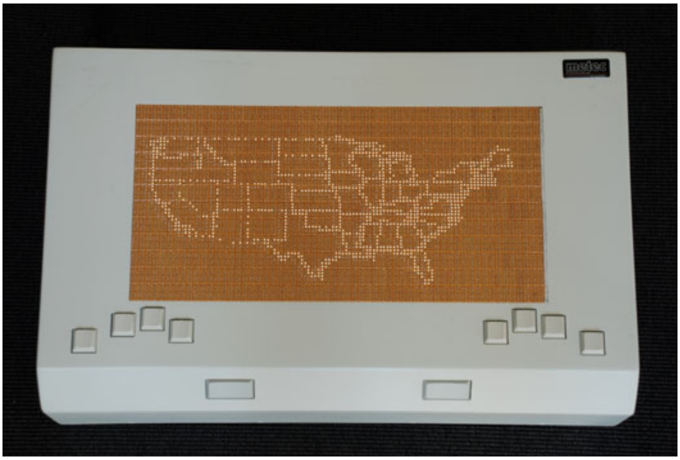

Fig. 1. A US state map (without Alaska) on BrailleDis 9000 (white dots are raised pins)

3.2 Haptic Map Rendering

The task of rendering a haptic map on a large-scale refreshable Braille display is demanding, as the resolution is low compared to a normal screen and only two levels of pins may be utilized to represent lines, textures, text or symbols. Initially the rendering pipeline maps the geographic coordinates into device coordinates and ensures each geo-element is proportionally aligned and corresponds to the correct location. Due to huge amount of information available in a normal WebGIS system, which is suitable for vision representation, but not for tactile output, it is necessary to simplify and filter parts of geographic elements as part of the rendering pipeline. Finally, non-proportional information such as tactile symbols will be inserted where possible.

As shown in Fig. 2, at step 5 all features of geographic elements are determined and map symbols selected according to the various features. For example, when the map element is a bus station, the system looks up the tactile symbol in its map symbol library, and renders corresponding bitmaps.

3.3 Multimodal Interaction

In addition to rendering tactile maps, the haptic map systems supports interactive multimodal interaction. The maps become more readable and accessible through combining audio and haptics feedback. Haptic interaction lets users not only find out “where are you”, but also explore the surroundings via different shaped tactile symbols. Synchronisation of modalities is achieved through sensing contact by one or more fingers or even the palm [10]. By surfing on its surface with one or two fingers the user operates the haptic map for a couple of functions, such as panning, zoom in, zoom out, and verbal explanations.

Blinking pins of an object might be a better method to help users locate points of interest (POI) in a fast manner. The approach of blinking pins is a recurrence of raised or lowered involved pins against the fingertips with tactile sensation. Thus, it is possible to find a blinking element without a slowly scanning the whole of display surface.

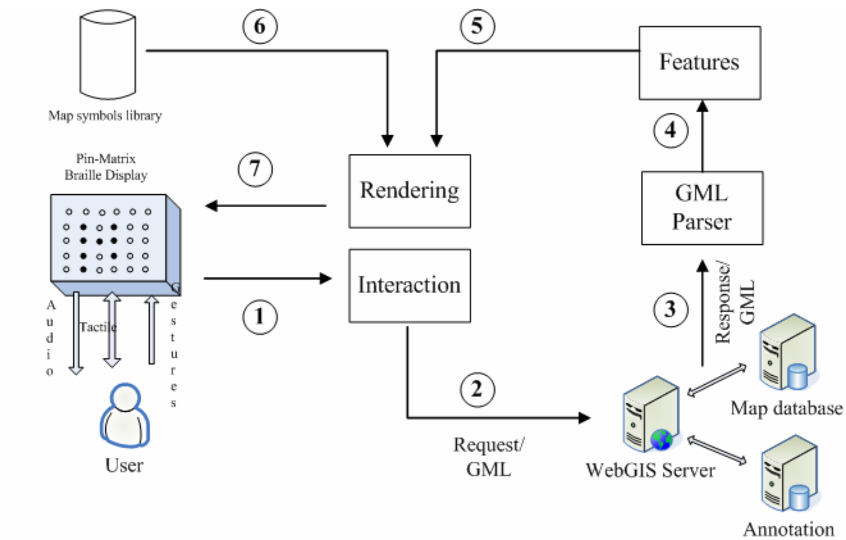

Fig. 2. Data flow by the haptic map system

4 Evaluation

In order to investigate the efficiency of our audio-haptic map browser for the visually impaired to access geographic data, from a GIS, we evaluate the area of our university campus with 4 blind users, among who two are female and two are male. Most of them are familiar with our campus, because one is a worker in university, and two are students in university. The system employs an open source software server, namely GeoServer[5] allowed users to view and edit geospatial data, as its WebGIS server. The software PostGIS[6] as a backend spatial database, supports storage of geographic data, as well as implementation of geo-instruction services. Furthermore, we download our university campus map from OpenStreetMap[7], which is a free collaborative worldwide map platform.

In the evaluation, our tasks focus on estimating accessibility and readability of map elements from a GIS, e.g. roads, buildings, POI, when the subjects explore the tactile campus map. There are 2 phases of evaluation due to improvement of representation technology. Both of them have the same takes.

In the first phase, we received some significant feedback after one blind subject finished the test, that lead us to launch on improving, instead of further evaluations. Among feedback from the subject, the most severe problem was rendering too much geo-information with raised pins at the same time, e.g. roads, buildings, symbols of POI, to understand the map elements where the user was touching. Specifically,

[5] Geoserver website: `www.geoserver.org`
[6] PostGIS website: `www.postgis.org`
[7] OpenStreetMap website: `www.openstreetmap.org`

because of representing the shape of buildings in raised-pin line, it is difficult that the users distinguishes between a building and a road, even if the shape of a building is a closed polygon. Raw geographic data from normal GIS are represented visually and there readability benefits from color, width of lines, icons, etc. but this same effect is not suitable for pin-matrix devices due to its low resolution.

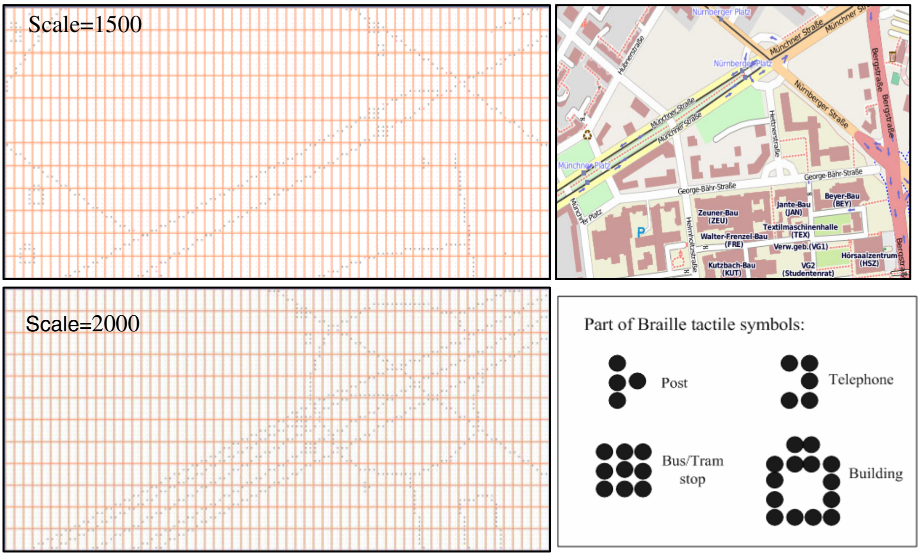

Fig. 3. Different scale of haptic map. Overall-view:Top-left, scale=1500; Detailed-view: Bottom-left,scale=2000; It shows a crossing near highways, tramlines and footpaths (black dot denotes raised pins on Pin-matrix display); top-right image shows campus of TU Dresden from OpenStreetMap; bottom-right image indicates part of Braille tactile symbols.

However, the method of Braille tactile symbols of POI has been accepted by blind pilot users. We design several Braille tactile symbols consisting of raised pins in different combinations to render several POIs, e.g. a bus stop, a traffic light. After a few minutes training of these symbols, the subject not only find out how many symbols on the surface, but also figure out which are of the same kind. Compared to visual map symbols for the sighted and tactile symbols on paper-based map for the visual impaired, Braille tactile symbols help the users know the meaning of a place only with touch.

In the second phase, we invited 4 other blind persons to take part in our evaluation. The system utilizes raised-pins lines only to render roads, while buildings and other map elements are rendered as Braille tactile symbols. Secondly, the system enables to provide 2 kinds of views of the haptic map depended on its scale. One is an overall-view rendering of main roads and POI, the other is a detailed-view with increased number of roads and but including the shape of buildings. Thirdly, ensuring space between elements, which is crucial factor of readability of tactile map, has been implemented though special algorithms. At last, we redesign a set of Braille tactile symbols systematically, including buildings, bus stop, and other POI.

The study shows that all of them could easily find where a street was, the direction of the street and a crossing consisted of 2 or 3 streets in the overall-view. Their fingers were able to go along the line of a road until its end. These benefited from continuous raised pins and enough space between streets. Additionally, all of them no longer mixed up streets and buildings. Subject confirmed, it is important, the name of the street, the building where her/his finger was pointing is spoken out through pressing one function key on the display simultaneously. 3 of the subjects described this interaction as very easily, and one said “it is indeed easy, but I prefer this information in Braille label”. When we tested zoom in/out with a crossing (see Fig.3) transforming into detailed-view from overall-view, all of them could feel changes and recognize a circle as a sign of crossing, as well as more roads in the area.

After a short time learning the graphical Braille tactile symbols for POIs, maximum lasting 3 minutes, all of them could find some symbols, and know their meanings like a bus station or a telephone booth. However, sometimes participants failed to figure out meaning of a symbol, as they said some of those symbols were too similar to distinguish. Perhaps, after a longer-term of use they can remember all of the symbols. We evaluated also the approach of blinking pins to represent the result of a map search after typing the name of a POI. Blinking pins were highly recommended to locate the result very fast. An approach without blinking required the user to scan the whole map very slowly. Sometimes, they even missed the result.

5 Conclusion and Further Research

For the people with low vision and blind it is difficult to access graphics and in particular maps, thus, we develop an interactive audio-haptic map browser based on a planar tactile display to read a real map from GIS. By implementing a multimodal user interface, users can directly touch the map to enable their spatial cognition, and listen to audio information for requesting more detailed information keeping in the GIS. Blinking pins is a novel method for locating a point of interest or an area fast. Moreover, gesture recognition of fingers is supported to establish a natural interaction for navigating tactile maps. Thereby, these features provide a novel experience and opportunity to access spatial geographic data.

Benefitting from the large-scale Braille display, we can represent a wider area map on it. On the other side, we are developing a smaller and lighter model for portable applications in near future. Future work will take into account feedback during the second evaluation. For instance, when the user just needs to know the shape of a building in the overall-view, there should be a way to show only the shape of the building, without changing into a detailed-view which renders everything in detail. Because there is a huge amount of geo-data in a GIS, a better approach of filtering and simplifying of geo-elements should be evolved in future. Representing a pre-journey route is ongoing via source place and destination, which has been considered helpful by subjects. Moreover, more subjects will be invited to take part in our evaluation to collect feedback and validate effectiveness of our map system. Most of all, we are planning to implement a collaborative platform with the Braille display, in the future, the visually impaired not only can view geo-data from GIS, but also contribute annotated data to others by themselves.

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