Interactive Tactile Maps for Blind People using Smartphones' Integrated Cameras

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Abstract
Tactile maps may support blind persons in orientation and understanding geographical relations, but their availability is still very limited. However, recent technologies such as 3D printers allow to autonomously print individual tactile maps which can be linked with interactive applications. Besides geographical depictions, textual annotation of maps is crucial. However, this often adds much complexity to tactile maps. To limit tactile complexity, interactive approaches may help to complement maps by the auditive modality. The presented approach integrates barcodes into tactile maps to allow their detection by standard smartphones' cameras. Automatically, more detailed map data is obtained to auditively support the exploration of the tactile map. Our experimental implementation shows the principal feasibility and provides the basis of ongoing comprehensive user studies.

Author Keywords
Tactile Graphics; Accessibility; Blind; Interactive Maps; Smartphone; 3D Printer; Annotation; Barcodes

ACM Classification Keywords
H.5.2. [User Interfaces – Haptic I/O, Voice I/O]: Information Interfaces and Presentation; K.4.2. [Social Issues – Assistive technologies for persons with disabilities]: Computers and Society

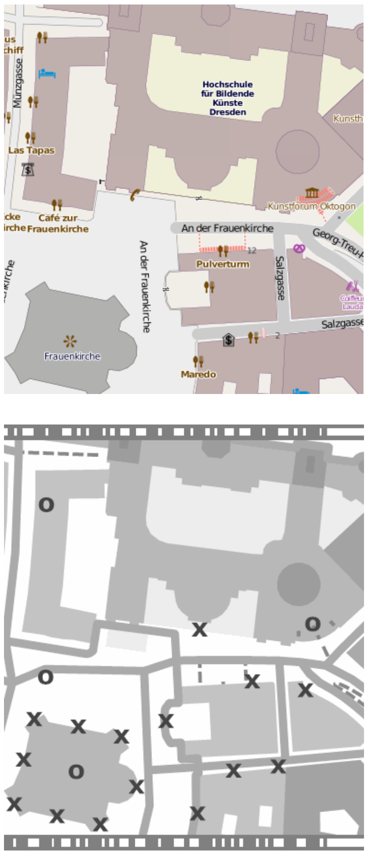

Figure 1. Top: Exemplary original map for sighted people (Source: OpenStreetMap). Bottom: Depth map of generated tactile map integrating barcodes.

Introduction

The usage of maps is common for sighted people. Map visualizations either on mobile devices or as printed version can be carried around and may support the users' orientation and understanding of geographical relations on the way. Analogously, blind people may use tactile maps, which are helping to compensate the human vision by the tactile modality. However, tactile maps have to be drastically limited in their complexity, i.e., map features have to be simplified or even to be removed. Textual annotations by Braille letters are important means to communicate verbal entities. However, due to size constraints their range of use is very limited. Additionally, their usage may negatively influence the legibility of geographic map features (e.g., [2]).

In this approach initially handy tactile maps are automatically generated by rendering simplified map data completely without textual descriptions. These maps integrate barcodes which can be recognized by standard smartphones using their integrated camera. Our concept considers the user holding a smartphone in one hand, directing the smartphone's camera towards the tactile map. After detection of the map the user may explore the tactile map by his or her other hand. By tapping on the smartphone's touch surface the user can request more detailed auditive information of the map features on the specific map position she or he is pointing at.

Related Work

In the last years several approaches for the generation and interaction with tactile maps have been presented. Some approaches generate tactile maps which exclusively support the tactile sense (e.g., [6]). Other approaches assist the tactile exploration by acoustic signals (e.g., [5]) using specialized hardware. An approach based on character recognition [8, 9] used a prototypical tablet device and utilized a popular web service for obtaining route directions and map images to be explored. Another approach [7] allowed blind users to place embossed maps on touch screens, register them manually and to obtain verbal explanations of selected map locations. Finally, there are approaches based on special matrix of pins (e.g., [10]) which allowed to adapt the displayed tactile graphic by a connected computer. In conclusion, there are different interactive approaches addressing the issues of audio/tactile exploration of maps for blind people. However, none of the existing approaches automatically recognized individual tactile maps and detected the user interaction by a standard smartphone's camera.

Our Approach

Generation of Tactile Maps

This approach is based on tactile maps which can be explored by blind people. In order to limit the complexity of the tactile map and to support their legibility these maps are generated completely without labels and keys. In order to allow to link the physical maps with off-the-shelf smartphones, printable visual markers are used which can be read by their integrated camera. These barcodes encode geographical meta-data of the map segment (e.g., longitude, latitude) which is used to obtain detailed map data from a free, worldwide map database [4]. Hence, individual maps have not to be registered with specific mobile devices.

Process of Positioning Smartphone

The initial process of reading the map's integrated

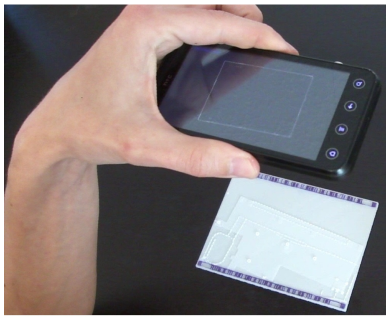

Figure 2. Top: User positioning smart smartphone's camera towards map by one hand. Bottom: While exploring the tactile map the user is pointing at map feature by other hand and obtains more detailed information by touch gesture.

barcodes requires to orient the smartphone's camera towards the tactile map (see Fig. 2-top). The mobile application detects the map's frame and decodes the barcodes attached to the tactile map. The positioning process is supported by verbal advices through a text to speech (*TTS*) interface. During the initialization the mobile application detects whether the smartphone is in a valid position by continuously analyzing the captured frames of the built-in camera. Too small map frames (less than 2/3 of the captured image) and too big frames (frame borders identical with borders of captured frame) as well as partially visible maps (frame borders partially equal borders of captured frame) are acknowledged by auditive instructions.

Map Exploration

Initially, detailed map descriptions are downloaded from OpenStreetMap using the decoded geographic coordinates. In the following, this map data is used to support the map exploration task of blind users. The current smartphone's position is kept by the user by one hand, whilst he or she uses the other hand to explore the tactile map. During map exploration the map frame detection is not carried out unless the smartphone's sensors detect a significant change in its attitude. In contrast, the user's fingertip is detected in order to determine the relative coordinates regarding the map's frame.

When a blind user is interested in more detailed information of specific map features she or he points at it and touches the smartphone's surface with the other hand (see Fig. 2-bottom). By taking the pointing finger position into account the corresponding geographic coordinate of the desired map position can be determined.

Subsequently, this coordinate is used to query the downloaded map data for more detailed information which is then verbalized by the TTS. Multiple touch gestures can be mapped to different actions (e.g., telling map a feature's name or type).

Implementation

As initial step several tactile maps had to be generated which can be automatically detected by a mobile application. In the following, an interactive application had to be developed which is able to recognize visually encoded data of the tactile map and to obtain more detailed map data by a web-interface. Finally, this application had to detect the user's finger to support the exploration of the map by more detailed (name and type of map features) auditive information corresponding the finger position on the map.

Map creation

For the generation of tactile maps a recent approach [3] has been adapted allowing to automatically generate maps which can be printed by consumer 3D printers or alternatively, on microcapsular paper. This approach abstracts OSM map data according to necessities of blind people and generates a height-map which can be printed either on microcapsular paper (only one height level) or be extruded to a 3D model (multiple height levels) of the common Stereo Lithography Format (*STL*) which can be printed by consumer 3D printers (see Fig. 3). To encode geographic information such as longitude and latitude we chose to use two 1D-Barcodes (*ITF-14*) attached on the top and the bottom of the height image. In the case of a 3D printed tactile map cavities of the printed barcode form dark regions which can be detected by the smartphone's camera.

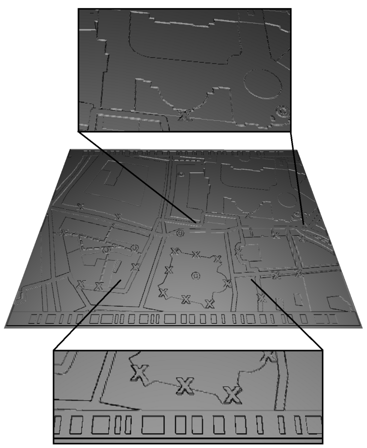

Figure 3. Exemplary STL 3D model for 3D printing containing barcodes.

During the map production process we faced several problems printing barcodes by consumer 3D printers as well as by printing them on microcapsular paper. We used a consumer 3D printer *Ultimaker 2* and experimented with different 3D print materials (*filament*) and settings (printing speed, nozzle temperature). For time-efficient printing of tactile maps on consumer 3D printers, adaptive printing settings had to be implemented, i.e., barcodes and map content can be printed in one single step, but are ideally generated by different printing settings. For several experiments we generated multiple tactile maps by 3D printing and, comparatively, on microcapsular paper each of about 15 by 10 cm physical size.

Interactive application

A prototype application has been implemented for Android smartphones using an image processing library *OpenCV* [1]. When a map's frame was detected, its corners were extracted in order to determine the current perspective distortion. Using the distortion parameters the map's frame was retransformed to rectangular dimensions. Subsequently, the geographic map coordinates were decoded from the barcodes and used to query a common OpenStreetMap web interface called OSM Extended API *XAPI* to obtain detailed map data.

For the fingertip detection we identified the user's fingers contours by color segmentation. Next, the extracted contour was simplified in order to evaluate its convex hull. The fingertip position was determined by the distances of convex hull point set to the camera frames' borders. Using the parameters of the perspective correction we determined the corresponding geographic coordinates of the fingertip position. Finally, the minimum distances between this coordinate and map features were evaluated. Hence, when the user tapped the smartphone's touch surface our implementation auditively provided more detailed information about the map feature with the smallest distance to his or her finger. The experimental application showed the principal feasibility of our approach. It has been successfully tested with several combinations of tactile maps and standard smartphones.

Conclusion

We presented a novel technique to complement tactile maps by auditive explanations through an interactive mobile application to be used on standard smartphones. Using visual markers allows to establish the link between the physical map and detailed digital map data visually. The smartphone application automatically obtains all necessary map information by a free worldwide available map database. In our approach there is no need for prior registration of tactile maps with mobile devices. By using finger detection algorithms the blind user's map exploration can be supported by auditive explanations of the map features initiated by tapping on the smartphone's touch surface. Our solution is handy enough to be carried in blind users' pockets which allows to consult the tactile map on the way. In our opinion the potential of linking tactile maps with a mobile application can be leveraged by incorporating multiple sensors and actuators built in today’s smartphones. We tested the feasibility of our approach with multiple generated tactile maps and a smartphone application implementing the detection of maps and the proposed interaction. In our ongoing work a user study is being carried out to evaluate multiple interaction design alternatives.

The limited space requirements of our approach has advantages for mobility. However, this approach is designed to complement existing techniques which support larger maps, e.g., for obtaining a map overview at a larger scale.

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