TouchOver Map: Audio-Tactile Exploration of Interactive Maps

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Abstract
This article reports on a preliminary study, which investigates if vibration and speech feedback can be used in order to make a digital map on a touch screen device more accessible. We test if vibration feedback combined with speech, triggered as the finger moves over relevant map objects, works to make sense of the map content. The study results indicate that it is indeed possible to get a basic overview of the map layout even if a person does not have access to the visual presentation. In the conclusions the interaction problems are indentified and suggestions for future improvements are given.

Keywords
Handheld Devices, Mobile Computing, Multimodal Interfaces, Tactile & Haptic UIs

ACM Classification Keywords
H.5.2 User Interfaces: Haptic I/O; I.3.6 Methodology and Techniques: Interaction techniques

General Terms
Human Factors, Design

Introduction
With the success of iPhone and Android, the handheld devices of today are more and more controlled by touch screens. As at the same time the use of GPS and

mobile Internet has increased, we nowadays find a large variety of location-based services for these devices. Typically, these services use visual maps to communicate location data.

However, interacting with such maps on touch screen devices require the user to look at the display. This prevents users with visual impairments from accessing map-based information. Visual impairments may occur in various ways, ranging from congenital blindness over age-related impairments, to sighted people with situational impairments, such as moving through a crowd of people.

A solution to this problem is the use of non-visual presentation modalities, namely audio and haptic feedback, to present geospatial information. Thereby, two key challenges need to be addressed: first, the meaning or name of geospatial objects has to be provided and secondly, the spatial relation between the geospatial objects has to be communicated. In this paper we investigate how this information can be conveyed interactively by using a smart phone's vibration motor together with speech output.

Related Work

An early solution from the last century is the use of raised paper maps. Small rises in the paper indicate the shape of geospatial objects and braille letters communicate names. McGookin et al. [3] investigated using raised paper as touch screen overlays to enable non-visual interaction. They found that visually impaired users could effectively interact with raised paper-enhanced touch screens. Nevertheless, a disadvantage of raised paper is that it can hardly be created or altered on-the-fly to accommodate a certain desire, such as searching for restaurants in the vicinity.

Another approach that has been investigated independently from touch screens is sonification of geospatial data. Sonification refers to data conveyed by non-speech sound. Jacobson [2] proposed to associate geospatial objects on the map with natural non-speech sounds. For example, a lake would be represented by the sound of water bubbles. In their design prototype, users explore a map by moving a finger over a digitizer tablet. When the finger enters a geospatial object the associated sound is played. The design was evaluated with 5 blind and 5 sighted people. Exploring a map in its non-visual representation only, they could successfully draw a sketch of the presented map.

Parente and Bishop [4] proposed not only displaying the touched geospatial object, but also presenting the adjacent geospatial objects while mapping the spatial relation to 3D sound. For example, a lake left of the touched geospatial entity would be heard from the left. Heuten et al. [1] showed that such information presentation allows visually impaired people to reconstruct the shape of a city with Lego bricks.

Recently, Su et al. [5] investigated the sonification on handheld touch screens. Their Timbremap prototype investigated how to support people in exploring lines and areas by sound feedback. They showed that people identify shapes with a recognition rate of 81% and can develop an understanding of an indoor floor plan.

All the above solutions are directed specifically at severely visually impaired persons. If one instead starts from existing map formats, we suggest it is potentially useful to extend this by providing the information also through non-visual channels. Although such enhancements are likely to be most useful for persons who have some visual ability (using the non visual modalities together with the visual presentation), we wanted to start by testing our design in the extreme case where they user is unable to see the screen at all.

Beyond previous design, our work bases on publicly available OpenStreetMap data. Our goal was to find out to what extend the existing work could be applied to a geographic street network from a real world city.

Design and Realization

The key elements, a sighted person gets from a map are roads and certain points of interest, e.g. the location of a church. However, either for way finding or to get an overview over the map, streets are often more important than points of interests.

Our approach is to use vibration and speech to make the road network accessible to a visually impaired or blind person. We think that the most intuitive approach would be to explore the map with one's finger, like e.g. a blind person reads Braille. Interaction-wise it is questionable, how this touch-over behavior can be integrated into recent interactive map applications. For the moment we are approaching this problem with two different modes a map can provide: the usual interactive mode, and the touch-over mode. A button allows switching between these modes.

Once a finger touches the map and a road is underlying, vibration is issued and the name of the road is read out continuously. If the finger leaves the road, both signals stop. However, the speech continues to read the name until the end. We assume that the continuous feedback allows the user to follow the road on the map to get a decent knowledge on where the road actually is on the screen.

As platform we decided to use Android. We integrated the concept by implementing an overlay for an existing map-based navigation application. In practice, the overlay does both: drawing the raw map data for debug and testing purposes, and handling the user generated touch events to trigger vibration and speech feedback.

As one can't use pre-rendered map tiles, we need raw map vector data. This data is obtained from a geo server, providing data from OpenStreetMap. We use an XML-based format to query and transport the map data. On the smart phone the XML is parsed and stored as line segment in an internal data structure.

These line segments don't come with a width. However, line width for the touch handling is a very important design factor. On the one hand, a line can be easier discovered if it is wider. On the other hand, we lose spatial precision if the lines are too wide. Through empirical tests on multiple devices we end up with a preliminary ideal line width of approx. 48 pixels.

Most challenging implementation-wise was the mapping of a touch event to a line fragment. A finger movement on mobile phone's touch screen causes multiple touch events and each of these events must be analyzed, if it touches one of the line segments or not. OpenStreetMap aims to be very accurate and, thus, provides lots of line fragments. This ends up with a quite complex calculation task, even for the powerful mobile phones of today. This results in slight delays in the interaction process. For the next iteration we aim at more intelligent algorithms, which maintain the precision, but are less complex.

Evaluation

The test task was to explore the map non-visually and draw a map of it with pen and paper. To avoid making the test into a test of how well the person was able to remember the map, we allowed the person to draw and explore at the same time. To keep the person from seeing the screen the setup in Figure 1 was used.

Figure 1. Test setup.

Eight sighted persons carried out the test (4 women and 4 men). The ages of the participants were 15, 24, 28, 33, 39, 42, 49 and 50. The phone used for the test was a Google Nexus One. Since this phone has software buttons that the user might accidentally trigger during the test, these buttons were covered with paper (see Figure 2). We tested two different levels of complexity by using two different zoom levels of the map. The map was centered on the GPS coordinates 56.667406 N, 12.873412 E (Halmstad, Sweden). This location was selected since it was expected to be unfamiliar to the test persons. We used "My Fake Location" to manually set the location.

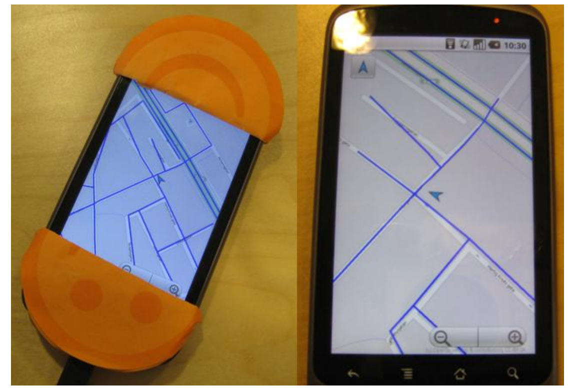

Figure 2. Left: phone with paper covers and the "zoomed out" map. Right: phone with "zoomed in" map.

As was stated earlier our implementation makes use of OpenStreetMap, and the street information used for audio and tactile feedback is indicated by blue lines in Figure 2. The exploration time was limited to 15 minutes although participants were allowed to stop earlier if they wanted. As we expected learning effects both for the interaction and the map area, half of the participants tested the "zoomed out" map first, and half of them started with the "zoomed in" map instead.

Results

The maps generated by the participants for the "zoomed in" map are shown in Figure 3. The maps for the "zoomed out" map are shown in Figure 5. For reference the actual maps are given in Figure 4.

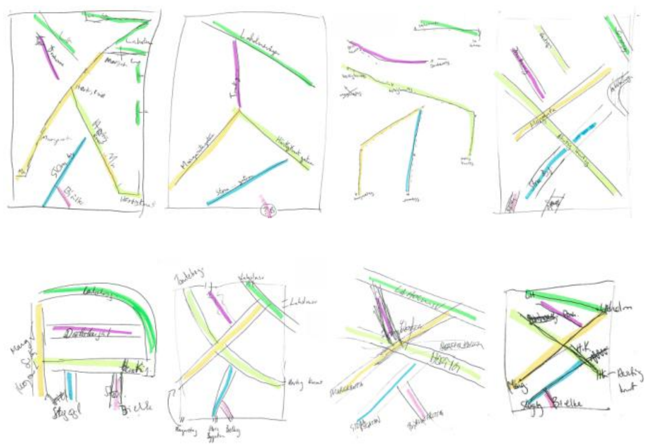

Figure 3. Maps drawn for the “zoomed in” condition.

The maps are color coded to help identification of the different streets. Although it is obvious that none of the drawn maps replicate the original map perfectly it is clear that all participants got basic objects and relations right. The big green road (Laholmsvägen) is put in the upper right part of the screen, the orange road (Margaretegatan) is somewhere in the left and goes upwards. The yellow-green road (Hertig Knutsgatan) goes from the right across the screen, etc. On the whole the “zoomed in” maps appear more accurate – all streets are present and some of the maps (e.g. Figure 3, lower rightmost) are quite accurate. The fact that participants needed up to 15 minutes to get a map together shows that without visual support this is quite a cognitively demanding task. Comments during the test showed that participants felt the “zoomed out” condition was too difficult (and also confusing) while they handled the “zoomed in” condition better.

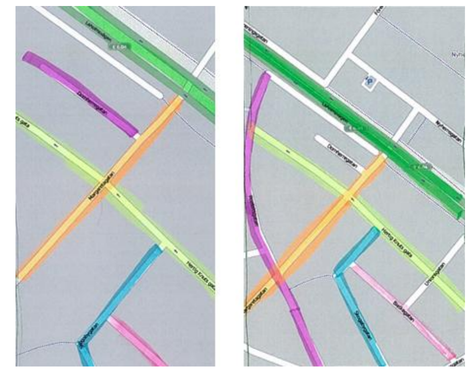

Figure 4. Left: Actual “zoomed in” map. Right: Actual “zoomed out” map.

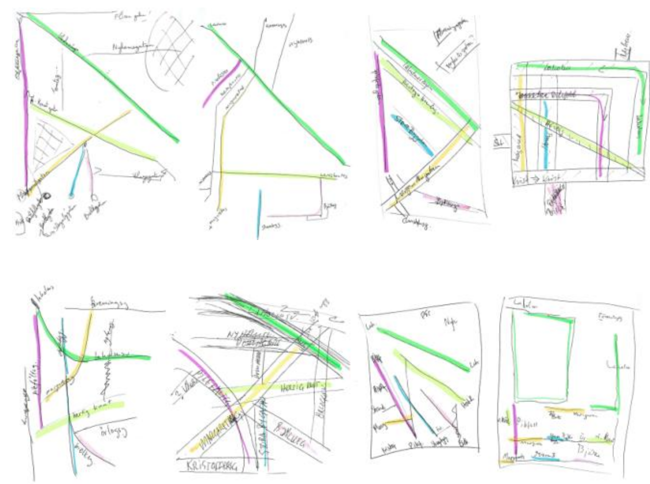

Figure 5. Maps drawn for the “zoomed out” condition.

The high cognitive load in the “zoomed out” condition is also reflected by the fact that all participants had to be stopped from continuing in this condition, while in the “zoomed in” condition they were mostly doing checks/small fixes by the time was up (two users even finished before the time was up). Finally, some identified problems with the current implementation were:

1. The speech would keep talking also after the finger no longer touched the street. This confused some users into thinking roads were more extended or at different locations from where they really were.

2. That the speech kept talking also led to it being possible to move to a new street before the speech had finished (leading users to think this was the wrong street).

3. It is impossible to know if roads are close or if they cross.

4. It is hard to tell the direction of short roads.

Discussion and Conclusions

This reported results show that it is indeed possible to use vibration and speech feedback as the finger moves over relevant map objects works as a means of perceptualizing the map content. Compared to earlier work which has been directed at severely visually impaired or blind persons, we start from the "design for all" perspective and enhance an existing real visual map. We still chose to do a first test in the extreme case of the user not having access to the visual information in order to check if this kind of solution could also work for this type of setting. Our results show that it is indeed possible to make basic features of a map layout accessible by using our approach, although it is quite a cognitively demanding task. The results in combination with user comments indicate that the level of detail in the "zoomed in" condition appears manageable while the "zoomed out" condition is perceived as more demanding/confusing. Thus we get a preliminary recommendation that the amount of content one can deal with non-visually should be kept at the level of complexity used in the "zoomed in" condition. We also note some problems in the current interaction design. In particular we suggest that the feedback for on/off a road needs to be made clearer and that information about crossings is needed. Small objects are a problem which needs to be considered carefully. Finally, in order to test this design in real situations and with both sighted and visually impaired users, future designs need to include feedback for the user's own position in the map.

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