Making Digital Maps Accessible Using Vibrations

Bernhard Schmitz and Thomas Ertl

Institute for Visualization and Interactive Systems, Universität Stuttgart
Universitätsstr. 38, 70569 Stuttgart, Germany
{Bernhard.Schmitz, Thomas.Ertl}@vis.uni-stuttgart.de

Abstract. In order to allow blind and deafblind people to use and explore electronically available maps, we have developed a system that displays maps in a tactile way using a standard rumble gamepad. The system is intended for both on-site and off-site use and therefore includes mechanisms for getting overviews of larger regions as well as for the exploration of small areas.

Key words: Haptic Maps, Vibrating Maps, Blind Users

1 Introduction

Maps form an integral part of navigation, especially in unknown areas. They give information about an area even before visiting it and provide guidance once in the area. However, blind people cannot access maps as easily as sighted people. Therefore we have developed a system that is capable of conveying maps using only a standard rumble gamepad and a text-to-speech engine or a Braille display. In this paper we first introduce some related work in the field of maps for blind users. After that, we introduce our system by first explaining the basic mode of operation and then detailing some more advanced techniques that we introduced for better interaction. Before we get to the conclusion, the results of a preliminary user study are presened.

2 Related Work

Maps for blind people can be distinguished by the sense that is used to convey the desired information, normally hearing or touch, whereas maps for deafblind people must rely solely on touch.

Auditory Maps Heuten et al. play different sounds corresponding to different locations on the map, where the connection between the location and the sound can either be natural (e.g. a water sound for a lake) or artificially created [3, 2]. These sounds are then played in a 3D environment in which the user can locate their source. The approach by Cohen et al. was not primarily developed with the intention to display maps, however it can be used to do so [1]. It was developed to convey graphs to blind users by representing edges and vertices by sound. Zhao et al. use auditory maps to present the geographic distribution of statistical data (e.g. number of inhabitants) but do not concentrate on exploring standard city maps [6].

Tactile Maps In the HyperBraille project it was shown that maps can be produced on a tactile graphics display [5]. The TANIA system uses a tactile-acoustical map that consists of a touchscreen augmented with tactile strips indicating the points of the compass [4]. The user can explore the map by tapping anywhere on the screen and having the name of the object announced by a text-to-speech engine or displayed on a Braille device.

3 Standard Map Interaction

3.1 The Virtual Observer

A sighted person observing any standard map can get an immediate two-dimensional overview of the general layout. But when acoustic or tactile maps are used, this immediate overview is not as easy to get. Even if tactile maps are layed out two-dimensionally and the user employs several fingers, the overview is limited. Therefore most approaches to digital maps for blind users employ a cursor or "virtual observer" that can be moved across the (virtual) map. Feedback is only given about the area under the cursor or immediately surrounding it. Accordingly, only one point (or its immediate surroundings) can be observed at any given point in time. Getting an idea of a larger area therefore necessarily involves moving the cursor. This is equivalent to a single finger moving across a real tactile map.

Our Approach to the Virtual Observer In our approach the user can move the virtual observer across the map using the gamepad's controls. A vibration is emanated from the gamepad whenever the virtual observer is on or near a street. This conveys a basic idea of the layout of the streets. The user can then inquire about the name of the current street with a press of a button. The name is output by a text-to-speech engine or a Braille device. However, due to hardware limitations, there are some additional tweaks that need to be introduced before the tactile map is usable.

3.2 Moving the Virtual Observer

The virtual observer has to be moved by the user. Moving it with an analog stick of the gamepad is an obvious choice. However, there are two fundamentally different ways of implementing this movement.

Scrolling Movement The intuitive implementation is to allow the user to move the virtual observer freely across the map. This is akin to scrolling. As we use an analog stick, the speed of the movement can be made adjustable by linking it to the inclination of the stick. This implementation has the disadvantage of not having a fixed mapping of the stick position to a map position, which can make the examination of an area rather unintuitive.

Fixed Area Movement The other possible implementation is to directly map a stick position to a map position. In this implementation, the center position of the stick is fixed to a position on the map. Moving the stick results in a movement in a fixed area around that position. As an example, pushing the stick slightly up will result in the virtual observer going to a position slightly to the north of the center position. Pushing it all the way down will result the virtual observer going to a position further to the south. The obvious disadvantage of this implementation is that it limits the area of observation. However, as each position of the stick is directly mapped to a position on the map the examination of a certain area is much easier than using scrolling movement. Another advantage of fixed area movement is that the center position can be fixed to the current position of the user if used in a navigation system. This allows a quick and easy exploration of the area immediately surrounding the user.

Combination of Scrolling and Fixed Area Movement As both implementations have their pros and cons, we have included both versions in our prototype, mapping one to each of both analog sticks. We call the one that allows free movement the scrolling stick and the one that allows for the detailed examination of a certain area the observer stick. This enables the user to scroll quickly across the map and then examine a certain area in detail.

3.3 Vibration

As vibration is our choice for announcing a street, the different possibilities of implementing vibrations need to be discussed.

Vibrating Near a Street It might seem obvious, that vibration should occur when the virtual observer is on or near a street. However, as our test implementation showed, this mode of operation has serious drawbacks. Because of the latency inherent to the hardware it is possible to cross streets without any feedback from the device. The resulting effect is similar to streets appearing and disappearing at random. This seriously hampers the ability to build a mental map of a certain area.

Vibrating when Crossing a Street The solution to the problem mentioned above is easy: Check whether a street has been crossed and in that case emanate a short vibration regardless of the current position of the stick. The disadvantage of this solution is that it slightly reduces the connection between stick position and map position in the fixed area movement implementation of the virtual observer, because a vibration might occur when no street is beneath the virtual observer. However, we have found this to be a minor inconvenience when compared to the disappearing streets problem mentioned above.

3.4 Street Announcement

The virtual observer combined with the vibration gives the user an idea of the general layout of the streets. However, the names of the street are not conveyed by the vibration and need to be announced by a text-to-speech engine or a Braille device. We chose to announce a street name upon user request by pressing a button. Again, there are different ways of implementing this.

Announcing Nearest Street The intuitive implementation of street announcement always outputs the name of the street that is currently closest to the virtual observer. This works best together with the “Vibrating Near a Street” implementation. However, the user will make a connection between the vibration and the street name, which does not always reference the same street in this implementation.

Announcing Last Crossed Street This problem can be overcome by announcing the street that was last crossed by the virtual observer. This street is not necessarily the one closest to the current position of the stick. However, this allows the user to build a direct connection between the vibration and the announced street name, improving the mental map built by the user.

3.5 Zooming

Exploring a map does not only involve scrolling around but also zooming. Zooming out has different effects on scrolling and fixed area movement.

Zooming Effects on Scrolling When zoomed out, the scroller stick will scroll over a larger area in the same time and with the same inclination of the stick.

Zooming Effects on Fixed Area Movement The observer stick will cover a large area when zoomed out. This has a negative effect on the facility of inspection of the area, as more and more streets are accumulated in the area covered by the stick.

Reduced Details on Zooming Out Therefore we display fewer details when zooming out. We display all streets when zoomed in and remove residential roads when zooming out. Upon zooming out even more, all roads are removed and only towns or suburbs are displayed, with their borders activating the vibration. This loss of details is equivalent to the reduced details in small scale maps as compared to large scale maps. Zooming with reduced detail allows the user to both gain an overview and get more detailed information about certain areas.

4 Advanced Map Features

The techniques presented so far can convey an idea of the layout of a map; however there remain several problems which need to be overcome.

4.1 Intelligent Zoom

First, there is the problem of cluttering the output with too many streets. Often there are still more roads than can be reasonably handled with a small analog stick on many zoom levels, even if roads are masked when zooming out. A minimal movement of the stick will result in the virtual observer crossing several streets, making a clear distinction between these hard if not impossible. However, on certain zoom levels there is an appropriate number of streets within reach of the observer stick. Therefore, presenting the user only with those views that deliver a satisfying result is a reasonable solution to the problem of "street cluttering".

Implementation of Intelligent Zoom Unfortunately there are no fixed zoom levels that will always yield satisfying results. The optimal zoom levels depend on the density of the streets in the observed region. We therefore developed an intelligent zoom, that will always zoom to a level that displays a reasonable number of streets, main streets or suburbs.

4.2 Single Street Observation Mode

The methods described above are well suited for getting an overview of the general layout of streets in an area, and for finding out which streets lie next to each other. However, a user inspecting a map will often also be interested in the exact layout of a specific street. This can become problematic when streets are bent or winding. Following the street with the observer stick becomes hard or impossible, especially when it is connected to many side streets. For this reason, we have developed the "Single Street Observation Mode".

Implementation of Single Street Observation Mode When the user presses a button, all but the last crossed street are removed from the display. Upon the button press the name of the street is announced so that the user is aware which street he is currently observing. At the same time, the vibration mode is switched to “Vibrating Near a Street” (see 3.3). The street can be displayed wider, i.e. the distance to the street necessary for vibration is increased. As it is now the only street being displayed, this cannot lead to problems related to overlapping streets but leads to an easier observation of the street.

5 Evaluation

As a way of evaluating our concept and implementation, we have conducted a preliminary user study with four participants. All participants are sighted but could not see any output on the screen. Two of the four participants had never used a gamepad with analog sticks before, one participant had used one once several years before, and one was a regular user of such a gamepad. We have designed two tasks with the goal of testing the intelligent zoom and Single Street Observation Mode.

The first task was to name the southern parallel street of a given street. We gave a rough location description for these streets wich consisted of the suburb and a triangle of major streets in which they are located. At the beginning of the task, the virtual observer was located in another suburb.

The second task was to roughly draw the course of a certain street (which has one notable turn). For this task the virtual observer was already located on that street.

5.1 Results for Intelligent Zoom

Table 1 shows the time that was needed by each participant to finish the task and whether the result was correct. Participants 1 and 3 (using Intelligent Zoom) were able to complete the task correctly in about 11 minutes each. Of those without fixed zoom participant 2 canceled the task after 20 minutes without a result; participant 4 was able to complete the task in 8:32 minutes. Thus, we have no clear conclusion about the effects of Intelligent Zoom. We suspect that participant 4 profited from his regular use of a gamepad with two analog sticks and would have been even faster with Intelligent Zoom.

Table 1. Results of Task 1 (Intelligent Zoom)

Mode	Intelligent Zoom		Fixed Zoom	
Participant	1	3	2	4
Gamepad Use	Never	Once	Never	Regularly
Time (min:sec)	11:06	10:55	20:00+	8:32
Correct Answer	Yes	Yes	No	Yes

5.2 Results for Single Street Observation

The results for Single Street Observation are shown in table 2. Participants 1 and 2 (both using Single Street Observation) were able to complete the task, taking 4:10 and 9:10 minutes. Of those with no Single Street Observation, participant 3 stopped after 5:41 minutes without a correct result and declared the task to be "very difficult". Participant 4 took 10:43 minutes for the correct result. Again it has to be kept in mind that participant 4 was the only proficient dual analog stick user. Participant 4 suggested a mode similar to Single Street Observation for this task on his own. With these results we feel confident to assert that the Single Street Observation mode is indeed an improvement that makes it possible to inspect the layout of a street.

Table 2. Results of Task 2 (Single Street Observation)

Mode	Single Street Observation		No Single Street Observation	
Participant	1	2	3	4
Gamepad Use	Never	Never	Once	Regularly
Time (min:sec)	4:10	9:10	5:41	10:43
Correct Answer	Yes	Yes	No	Yes

5.3 General Results

Our preliminary user study has shown that it is possible to inspect maps using a standard rumble gamepad with our implementation. Furthermore, both the results and our observations during the study seem to suggest that routine in using analog thumbsticks are an important factor regarding the efficiency of the system's use. One user suggested a bookmark function that would allow the user to save the current location of the virtual observer and quickly jump back to that location.

6 Future Work

Currently, our system is based on maps downloaded from OpenStreetMap and is not fully accessible in all components. Its current state was sufficient for our testing purposes, however, it should be fully accessible and interact directly with OpenStreetMap in order to be useful for blind users. Further improvements could be made to the basic functionality with different vibration patterns for the distinction of streets, main streets, crossings and other relevant entities. Regarding the hardware, we want to keep using cheap and easily available products for the end-user market, however the performance of a force feedback joystick in comparison to a rumble gamepad should be examined.

Spatial conceptualization skills of blind people vary greatly, depending on whether they were blind from birth, when they have lost their vision and how these skills were taught during their childhood. Therefore, the results of our preliminary study can not be transfered directly to the realm of blind users. Accordingly, the effects of these factors on the use of our system should be evaluated in a further study.

7 Acknowledgements

This project is funded by the Deutsche Forschungsgemeinschaft within the Collaborative Research Center 627 “Spatial World Models for Mobile Context-Aware Applications”. We would like to thank Dr. Andreas Hub for his valuable input and all participants in our study for their time and effort.

References

1. Cohen, R.F., Haven, V., Lanzoni, J.A., Meacham, A., Skaff, J., Wissell, M.: Using an audio interface to assist users who are visually impaired with steering tasks. In: Assets ’06: Proceedings of the 8th international ACM SIGACCESS conference on Computers and accessibility. pp. 119–124. ACM, New York, NY, USA (2006)
2. Heuten, W., Henze, N., Boll, S.: Interactive exploration of city maps with auditory torches. In: CHI ’07: CHI ’07 extended abstracts on Human factors in computing systems. pp. 1959–1964. ACM, New York, NY, USA (2007)
3. Heuten, W., Wichmann, D., Boll, S.: Interactive 3d sonification for the exploration of city maps. In: NordiCHI ’06: Proceedings of the 4th Nordic conference on Human-computer interaction. pp. 155–164. ACM, New York, NY, USA (2006)
4. Hub, A., Kombrink, S., Bosse, K., Ertl, T.: TANIA – a tactile-acoustical navigation and information assistant for the 2007 CSUN conference. In: Proceedings of the California State University, Northridge Center on Disabilities’ 22nd Annual International Technology and Persons with Disabilities Conference (CSUN 2007). Online, Los Angeles, CA, USA (March 2007),
5. Rotard, M., Taras, C., Ertl, T.: Tactile web browsing for blind people. Multimedia Tools and Applications 37(1), 53–69 (2008)
6. Zhao, H., Smith, B.K., Norman, K., Plaisant, C., Shneiderman, B.: Interactive sonification of choropleth maps. IEEE Multimedia 12(2), 26–35 (Apr/Jun 2005)