Interactive Exploration of City Maps with Auditory Torches

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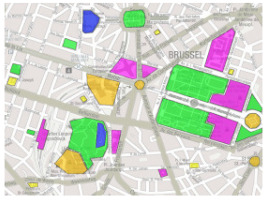

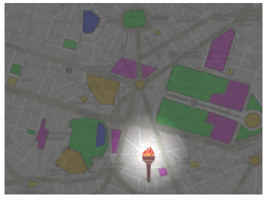

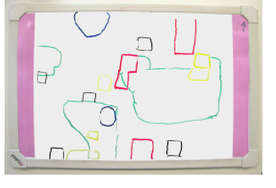

Abstract
City maps are an important means to get an impression of the structure of cities. They represent visual abstraction of urban areas with different geographic entities, their locations, and spatial relations. However, this information is not sufficiently accessible today to blind and visually impaired people. To provide a non-visual access to map information, we developed an interactive auditory city map, which uses 3D non-speech sound to convey the position, shape, and type of geographic objects. For the interactive exploration of the auditory map, we designed a virtual walk-through. This allows the user to gain an overview of an area. To be able to focus on certain regions of the map, we equip the user with an auditory torch. With the auditory torch users can change the number of displayed objects in a self directed way. To further aid in getting a global idea of the displayed area we additionally introduce a bird's eye view on the auditory map. Our evaluation shows that our approaches enable the user to gain an understanding of the explored environment.

Keywords
sonification, auditory display, 3D sound, exploration, interaction techniques, city maps, orientation

ACM Classification Keywords

H.5.1 Multimedia Information Systems, Audio input/output; H.5.2 User Interfaces, Auditory (non-speech) feedback.

Introduction

Whether blind, visually impaired, or sighted, our quality of life greatly depends on our ability to make spatial decisions. Sighted people typically use visual maps to make themselves familiar with spatial relations. Access to visual maps is very difficult if not impossible for blind and visually impaired people. However, spatial knowledge is very important for them, for example to have a understanding of the environment before leaving the house. They do not feel prepared to explore new routes and, consequently, do not leave their homes alone. A general idea of an area leads to more confidence in the own navigation skills and supports the conversation about geographic information.

An information presentation is needed, which allows a blind or visually impaired user to access the same map information as a sighted person, however, with a different sense and channel. Different approaches to provide blind and visually impaired people with geographic information have been developed in the past: The most common projects focus on tactile exploration of maps. With physical tactile maps and computer based tactile [1], [2] and similar auditory [3] approaches the user moves a finger or a pointing device across maps. However, geographic objects are only perceivable, if the user directly points to the object. Therefore, it is difficult to find certain objects, as the whole map has to be explored, e.g., from the top left to the bottom right. Also, current approaches suffer from the inability of presenting more than one object at the same time. Thus, it is challenging to understand spatial relations between geographic objects like distances and directions. We can overcome these drawbacks by presenting map entities through non-speech sound objects, which are played concurrently and also provide information about their location at the same time.

We developed a system, which enables the user to explore digital city maps using an auditory display [4]. With our system each geographic feature such as a lake or a park is represented by a corresponding natural sound like dabbling water or a singing bird. These sounds are placed on a horizontal plane within a virtual room. Their location illustrated in Figure 1 is equivalent to the position of their visual peer on the map.

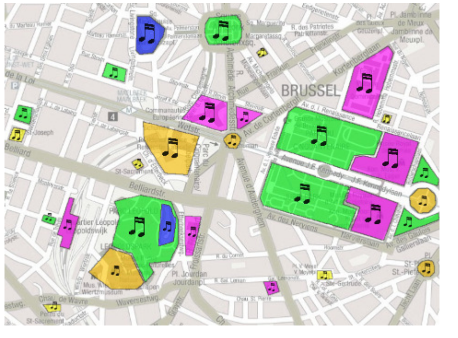

figure 1. Illustration of our sonfication of city maps. The highlighted areas represent different geographic objects. Each object type is sonified by a corresponding sound.

City maps typically contain many hundreds of geographic objects such as buildings, parks, and specific points of interest. For a beholder, to get a global idea of the city it is sufficient to display only the most prominent features. Nevertheless, the number of objects needed to provide an appropriate overview exceeds the humans' ability to perceive parallel sounds with the auditory sense. Recent research by Brazil and Fernström [5] showed that the identification accuracy of different sounds clearly decreases with incrementing the number of concurrently played sound objects. When playing less than six concurrent sound objects, almost 85% of the objects can be recognized correctly. When playing more than six objects, the identification accuracy decreases below 50%.

Therefore, the number of the simultaneously played objects must be reduced while maintaining the concept of auditory map display. We filter the objects according to their location. Interacting with the auditory display the user chooses a region of interest on the map which is displayed with the auditory map. By actively changing the region the user interactively explore the map. We developed different techniques to interact with the auditory map. With the first one described in [4] the user virtually walks on the maps and perceives all objects in the surrounding area by changing the position of a virtual listener. We enhanced this technique by equipping the user with a so called "auditory torch", which acoustically illuminates the users surrounding. With the auditory torch the user can change the size of the perceived region and focus on smaller details by using a small torch or get a global impression using a larger one. To further aid in getting a general idea of the map, we introduced a third technique, which raises the user's virtual position from the map to a bird's eye view. While all approaches focus on different aspects the goal of all interaction techniques is to aid the user in exploring the map and gain a cognitive model of the displayed area.

The remainder of this paper is organized as follows. In the next section we describe the interaction technique virtual walk-through. Afterwards we present two additional interaction techniques: Illuminating the City and Listening like a Bird. Following our presentation of these interaction techniques we describe the results of our evaluations. The paper closes with a conclusion and an outline of our future work.

Virtual Walk through the City

To get an idea of the city's general spatial layout it is necessary that the user can easily perceive the most prominent features of the city. In a first step, we analyzed city maps and identified parks, lakes, sights, squares, and public buildings as main features. As basis for our presentation we use maps which are reduced to these objects only. The objects are presented using an auditory display. According to their type, location, and shape, each geographic object is represented by an individual sound. Different object types are sonified using non-speech sounds that provide some correlation to the real live object. For example, a lake is represented by the sound of dabbling water and parks by singing birds. To display the objects' shape and location we place the sounds in a 3D sound room. All objects represented by a two dimensional area are located on a plane within the sound room. Their position and shape on the plane is true to scale according to the position and shape on the map.

If all main features of the map are sonified at the same time the user cannot distinguish the objects and identify their properties like type and position. Therefore, we make the objects accessible, by placing their sounds relative to a virtual listener. The user can freely move this listener across the plane on which the objects are located as shown in Figure 2. Thus, the user virtually walks through the city. As long as the listener is outside of an object, its sound is placed at the point of the objects border with the smallest distance between the border and the listener. Moving the listener around an object changes the position of the sound on the objects border. Thus, the user always hears the objects nearest point and can thereby construct the objects silhouette.

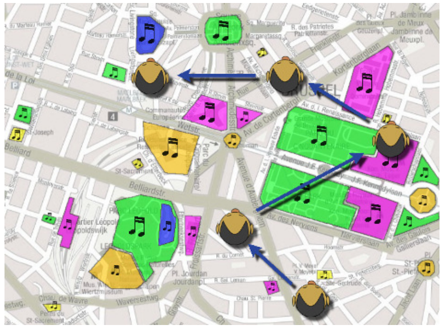

figure 2. The user explores the map by moving the listener across the map. Depending on the listener's position the objects can be heard in different intensity and from different directions.

To ease the understanding of the objects relative arrangement, for instance that a park is left of a lake, the user perceives all nearby objects simultaneously from the listener's position on the map. If the user points between a park on the left and a lake on the right the user hear the park from left and the lake from the right accordingly. Thus, the user can sense relative directions. Because nearby objects are louder than farther objects the user is enabled to perceive the distance between objects as well.

To further aid in understanding the map's global structure the listener's position is controlled by an absolute input device. The displayed objects are mapped on the surface of a digitizer tablet and the listener can be moved with the tablet's stylus. Moving the stylus to the tablet's upper left corner accordingly moves the listener to the upper left corner of the map. The user can feel the borders and the extent of the tablet. By feeling and controlling the stylus position the user perceives the listener's position relative to the maps border. Knowing the listener's exact position on the map eases locating the surrounding objects.

Illuminating the City

Displaying more and more objects raises the problem that it becomes difficult to distinguish objects of the same kind, which are located close to each other. Furthermore it becomes difficult to perceive the objects shape and size. Therefore, we enable the user to dynamically concentrate on a certain region of the map.

Our solution is an "auditory torch" which is moved with the listener and virtually illuminates the torch's surrounding as introduced by Donker et al. [6]. As shown in Figure 3, some objects on the map are shadowed which means that they remain silent. Only illuminated objects are hearable. When the torch approaches an object the object gets enlightened and its sound gets smoothly louder. By changing the "brightness" of the torch the user determines the area he or she is currently hearing. The brighter the torch, the larger is the illuminated area and farther objects are added to the auditory presentation. The user perceives a wider region at the same time and it becomes easier to find more distant objects. In order to focus on a smaller region and get a more detailed description, the user can dim the brightness of the torch.

figure 3. The objects located in the shade remain silent, while the lighted objects are playing gently.

Listening like a Bird

The auditory torch enables the user to investigate either small or large regions, depending on personal preferences or tasks. The user’s mental model is created from the listener’s point of view on the map. The auditory localization of objects is always related to the listener’s position. For example, a lake on the left side of the map may appear on the user’s right, if her position is even further left. Absolute localization can performed only through the absolute pointing device. To enhance absolute localization and thus the perception of the map's global layout, we developed a third technique, which presents the auditory map from a bird's eye view. To underline the objects’ absolute positions on the map, we enable the user to step back and take a look on the map from a more distant point of view. The user's listening position is raised out of the map’s plane to a bird’s eye view position as shown in Figure 4. That means that the sound of an object in the upper left corner of the map is perceived as being in the upper left as well no matter how the cursor is moved.

To still enable the user to focus on parts of the map we use the same torch metaphor as described above. Moving the cursor around the map the user can select the perceived region and its size.

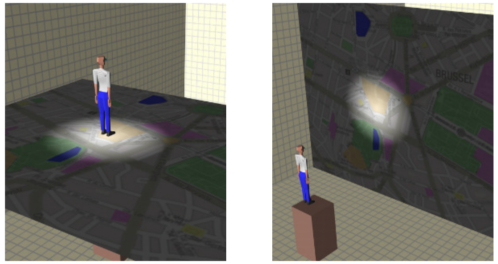

figure 4. On the left the virtual listener walks through the map while on the right the listener looks on the map from a bird’s view perspective.

Evaluations

To test our interaction techniques we conducted three evaluations. After a preliminary evaluation with sighted participants described in [4] we evaluated the virtual walk-through technique with eleven blind participants. The evaluation consisted of the three experiments according to the following aspects: The auditory map should aid in building and reproducing a mental model of an unknown area, mediate spatial relations between objects, and show relative distances between objects. We found that performing concrete tasks like “find a lake which is inside a park” or “find the lake which is most nearby a building” were managed easily. Even though our results are promising we found two main challenges. Even with only ten displayed objects it was difficult to exactly distinguishing objects of the same type which are close together and most participants could not reproduce the objects' shapes precisely.

Our tests of the two torch-based interaction techniques focused on testing the first aspect only. Six untrained sighted persons explored and reproduced a map of Brussels with one of the two techniques. An example of the results is shown in figure 5.

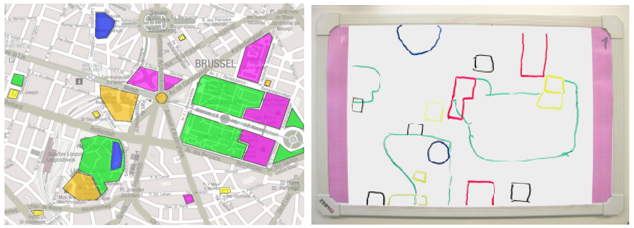

figure 5. The presented auditory map of Brussels is shown on the left and the drawn impression on the right.

Conclusion and Future Work

We presented Auditory Maps, a system that sonifies city maps using 3D non-speech sound and enables blind users to build a mental model of a city. User may explore maps without any visual feedback identifying the shape, size, and location of geographic objects. We developed three interaction metaphors to explore an auditory map: a virtual walk-through, an auditory torch, and a bird's eye view. All techniques support the user in getting a non-visual overview of a city. The user can choose the mode, which best meets the personal preferences and task.

Getting a global idea of an area is the first step of the navigation process. The next step is the planning and exploration of routes. Therefore, we are working on the integration of a haptic map [2] which guides the user along paths. Another aspect of other future research is the combination of tools to create a homogenous non-visual navigation support system.

Acknowledgments

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