Tangible and Body-Based Interaction with Auditory Maps

Andrew P. Milne
School of Interactive Arts and
Technology (SIAT)
Simon Fraser University
250-13450 102nd Avenue
Surrey, B.C., Canada V3T 0A3
amilne@sfu.ca

Alissa N. Antle
School of Interactive Arts and
Technology (SIAT)
Simon Fraser University
250-13450 102nd Avenue
Surrey, B.C., Canada V3T 0A3
aantle@sfu.ca

Bernhard E. Riecke
School of Interactive Arts and
Technology (SIAT)
Simon Fraser University
250-13450 102nd Avenue
Surrey, B.C., Canada V3T 0A3
ber1@sfu.ca

Abstract

Blind people face a significant challenge navigating through the world, especially in novel environments. Maps, the most common of navigational aids, are of little use to the blind, who could benefit greatly from the information they contain. Recent work in auditory maps has shown the potential for delivering spatial information through sound. Users control their position and orientation on a digitally enhanced map and listen for the location of important landmarks. Orientation control is important because sound localization cues can sometimes be ambiguous, especially when in front of and behind a listener. Previous devices have used a tangible interface, in which users manipulate a small motion tracked object, to allow users to control their position and orientation on a map. Motivated by research that has identified the importance of body-based cues, from the joints, muscles and vestibular system in spatial perception, we expanded on previous interfaces by constructing an auditory map prototype that allows users to control their orientation through natural head movements. A pilot study was conducted to compare the head-movement-based interface to a tangible interface.

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Introduction

Everyone knows the feeling of being lost. Whether in a new city or a sprawling shopping mall, it is easy to become disoriented when we haven't learned the spatial relationships between the landmarks around us. To prevent such confusion, most of us make use of maps, the most common of navigational aids. Unfortunately, basic maps are of no use to one of the populations which need them most, the blind.

Blind people face significant challenges when navigating through the world. They use hearing and touch to slowly build up an understanding of the spatial relations that are normally obvious through vision. This process makes new environments so daunting that many blind people restrict their travel to familiar routes, or avoid travel all together [1] . Making map information available to the blind, through sense of touch or sound, could help them navigate new environments and greatly increase their mobility.

Tactile maps, which typically consist of raised lines over a conventional map, have existed for several decades, but haven't achieved widespread use. This is partly due to the time consuming process of creating the maps; low demand prohibits mass manufacture, so new technologies must be found to generate maps in low volume and at low cost.

Over the past decade, a wealth of digital map information has become freely available, and work is being done to render this information haptically. However, cheap, flexible haptic rendering technology is not yet commonplace [2].

Sound has also been used to convey map information, both in combination with touch based maps and in purely auditory forms [3,4]. In most hybrid maps, a 'sound label' is played when users touch a specific map object, but this type of interface is limited to presenting one sound object at a time, so the spatial relationships between landmarks are not contained in the sound cues.

Experimenters developing auditory maps have overcome this problem through the use of sound spatialization software. By tracking the user's position and orientation on the map, multiple sounds around their position can be rendered in the appropriate locations. This approach allows for multiple landmarks to be presented simultaneously, and, by using non-verbal sounds to represent landmarks (e.g. a church bell sound for a church, a water sound for a pond) a naturalistic sound scene can be constructed. Spatialized sound has also been used in personal guidance systems for the blind, to guide users to a target destination [5, 6].

Spatialized auditory map environments simulate the actual sensory experience of being in the place they represent. This property makes them more akin to virtual reality displays than normal maps, which are highly symbolic.

Motivation for Design

While conducting studies with an auditory map, Pielot et al. found that users had significant difficulties locating sounds, specifically with front/back confusion [4]. The primary cues we use to locate sound are the difference in intensity of a sound striking our two ears and the slight delay between the time it is heard by each ear. Front/back confusion occurs because there are multiple positions that can produce the same intensity difference and delay. A sound three feet in front of and to the right of us, will produce the same intensity and delay cues as a sound three feet behind and to the right of us. In the real world we turn our heads to resolve this ambiguity [7]. This observation inspired Pielot et al. to update their prototype to allow users to turn left and right in the auditory map environment. This was accomplished by using a tangible object that was tracked by a computer vision system. Users would position the object on the map surface, and then rotate it to control their orientation. It was found that giving users the ability to control orientation helped them resolve ambiguous sound cues and better locate landmarks on the auditory map.

We propose a modification of the tangible object interface, in which users control orientation by turning their heads instead of rotating the tangible object. We suggest that this will result in a more natural interface, as head movement is the motion we instinctively perform in the real world. In addition, research in spatial perception suggests that mapping changes in orientation to real body movements may enhance understanding of the spatial relations that the map is trying to convey.

Much of the research that links real body movements to spatial understanding concerns a process called *spatial updating*. Imagine standing in your living room while a television program plays on your television. If you were asked to close your eyes and turn slowly in a circle you could easily keep track of where the television was. As you turn you hear the television in front of you, then off to your side, then behind you, but you always have the impression that the television stays in one place. The subconscious process by which our brains update our mental model of the space around us as we move is called spatial updating.

The process of spatial updating is often diminished or absent in virtual reality environments where bodily movement is absent [8]. One of the reasons that you know that it is you, not the television, that is moving in the example mentioned above, is that you can feel your body in motion. Your inner ear senses subtle accelerations as you turn your head and you can sense your joints and muscles twisting and moving. In fact, even if you turned the television off (so that it was completely silent) you could probably still keep track of its position for some time as you moved about with your eyes closed. Research has shown that body movement is important for learning the spatial relations between objects around us, even in large scale environments, like those represented by auditory maps [9].

We hypothesize that auditory maps that use head motion to control orientation will be more effective in successfully conveying map information than those which use tangible interfaces, for the reasons mentioned above. To test this hypothesis, we are developing an auditory map prototype that can switch between both head-movement-based and tangible interaction modes.

Prototype

Three auditory landmarks were arranged on a 2D plane in a virtual environment (created using Vizard VR software), and each landmark was assigned a characteristic sound. For instance, a church would have bells playing, a fountain the sound of splashing water, and a market the soft clamor of many voices. A 'virtual listener' was then placed in the environment, and sound objects were rendered according to the listener's position and orientation.

Audio was rendered on a high end gaming sound card (Creative Labs X-FI Titaneum) and presented over headphones. Users sat on a swivel chair, allowing for full rotation, and a pen tablet (Wacom Intuos 3) was affixed to the chair and positioned in front of them.

The users then controlled the position of the virtual listener with a stylus on the pen tablet. An unused button on the pen indicated the forward facing direction. The pen was chosen because it could be rotated easily with one hand, without interfering with the wires from the tracking system. This also freed the user's other hand to feel the boundaries of the map, which were marked by a change in texture. Position on the tablet was measured in absolute coordinates, allowing the user to move the pen on a surface which corresponded to the entire virtual environment.

Orientation of the virtual listener was controlled in one of two ways. In the first condition, the rotation of the stylus controlled orientation, making the interface analogous to previous designs using a tangible object. In the second condition, the user's head movement controlled orientation.

Pen and head rotations were tracked using a Polhemus magnetic tracking system affixed to the stylus and headphones. Wired trackers were used, and the wires were routed through a cable guide suspended over the subjects.

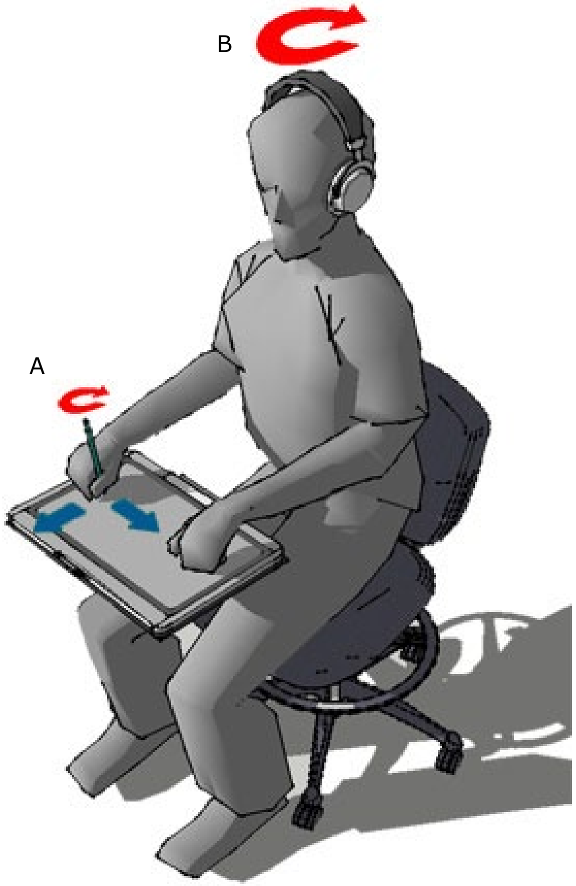

Figure 1. Users controlled their position using a pen tablet, and controlled orientation using either (A) the rotation of the pen, or (B) the rotation of their head.

Discussion

Initial user testing of five sighted, but blindfolded, participants provided interesting qualitative feedback. Several users preferred the head-motion based mode of interaction, commenting that it was easier to localize sound by turning their head than turning the pen. Some participants complained that it was hard to interpret sound changes due to pen rotation because they had to imagine themselves in the position of the pen on the map. However, other participants preferred the pen based interaction mode for this very reason, commenting that they found it easier to imagine the pen as themselves moving about the map than having the control split between hand (for position) and head (for orientation).

One participant explained that he was inclined to move the pen towards the perceived location of a sound source relative to his body. For example, if the sound was off to his left, his instinct was to move the pen to the left, even though this was often not in the direction of the sound source on the map. He was expecting the map representation on the tablet to rotate with him as he turned in the swivel chair. This did not occur with our prototype, but it is an interesting possibility and could be achieved by motion tracking the tablet.

The users' comments highlight the fact that constructing maps involves the transformation of spatial relations between different coordinate systems. We must turn egocentric directions and distances from ourselves into relationships between objects (e.g. the fact that that *I have to turn right* at the next corner to get to the museum *means that it is south* of the subway station). In auditory maps, imagining the space from the right frame of reference (either the pen or your body) may be critical to effective interaction.

Future Work

The next step is to conduct a larger scale user study. We will quantify the accuracy of the users spatial understanding by testing them on spatial relations and comparing their responses to the actual map layout, and will also continue to collect qualitative feedback from users about the interfaces. This information will be used to compare tangible and head-movement-based interaction modes and further improve our prototype.

The magnetic tracking system currently being used to track pen and head rotation is relatively expensive for consumer devices. We will be working to replace it with a lower cost system that uses accelerometer information from game controllers, with the goal of demonstrating a system that remains effective while being low enough cost for widespread use.

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