Here Or There Is Where? Haptic Egocentric Interaction With Topographic Torch

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ABSTRACT

In this paper we present and describe Topographic Torch; a handheld digital mapping tool featuring a novel egocentric interaction model. Topographic Torch was designed to encourage and enable people to explore spatial relationships of the world around them in a "natural" manner. Users of Topographic Torch can physically point at objects of interest in the world to automatically see those objects on a map. Enabling people to physically point at objects of interest forces them to use their location in the world as an egocentric frame of reference. An egocentric frame of reference may enhance people's ability to understand the relationships between where they are in the world and where other objects of interest are in relation to them. We describe Topographic Torch's interaction model and elaborate on how it functions, along with an outline of a preliminary user study.

Author Keywords

Egocentric Interaction, Embodied Interaction, Haptics, Spatial Cognition, Wayfinding, Maps, Zoomable Displays, Handheld Devices

ACM Classification Keywords

H5.2. Information Interfaces and Presentation: Input Devices and Strategies, Graphical User Interfaces, Interaction Styles.

INTRODUCTION

In this paper we present Topographic Torch; a handheld digital mapping tool featuring a novel egocentric interaction model. Our design motivation with Topographic Torch was to enable people to explore geographical spatial relationships of the world around them in a "natural" manner. Specifically we wanted to enhance people's ability to understand the relationships between where they are in the world and where other objects of interest are in relation to them. For example, when visiting an unfamiliar city it is not uncommon to:

1. locate where you are on a map
2. rotate the map so it is aligned with the world, and,
3. figure out the direction and location of objects of interest in the world and on the map with reference to your location.

Figure 1. Example of what a Topographic Torch user of sees on-screen. The red dot represents the user's location in the world.

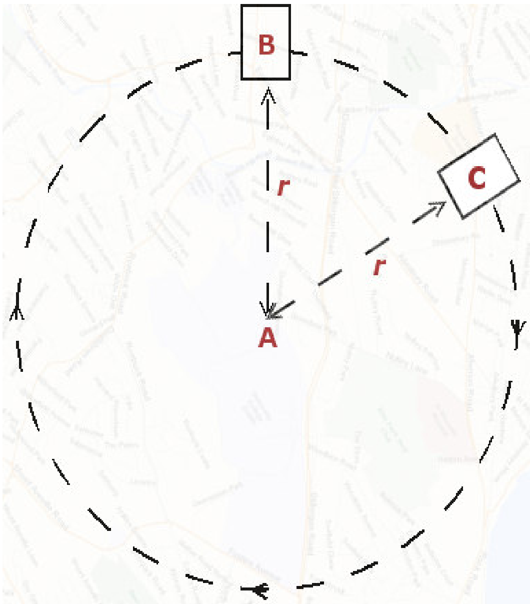

Figure 2. Representation of how the viewport rotates around the user in Topographic Torch. Point A is the location of the user in the world, Point B is the region of the map shown on-screen, Point C is a region of the map that is shown after user rotation. r is the radius of the circle around which B moves when the user rotates on the spot.

When using Topographic Torch people can physically point at objects of interest in the world, such as distant buildings, and see where those objects are on a map in relation to where they are.

Using Topographic Torch can be thought of as similar to using a handheld torch in a dark room. With a handheld torch you can point in various directions to shed light on areas of interest, with limitations on how far the beam of light will travel. A second way of thinking about Topographic Torch is as a tool for carrying out "Point-and-Query" interactions with the world and data overlaid on the world. An important aspect of Topographic Torch is that actions, e.g. pointing, are carried out with reference to the location of the person in the world (embodied interaction).

BACKGROUND & RELATED WORK

Maps displayed on handheld devices are increasingly used in variety of contexts for wayfinding tasks, e.g. where is the nearest supermarket, what is the shortest route from location A to location B, etc. Yet there are a number of serious challenges with using these maps [1, 2, 4]. Limited screen sizes of handheld devices restrict how much of a map can be displayed to the user at any one time. Small display sizes make it harder to understand the spatial relationship between two points on a map, i.e. if the two points are far enough apart they cannot be simultaneously displayed on screen [6]. An inability to see different parts of the map at once, especially multiple points of interest, restricts a person's ability to understand spatial relationships.

Previous work, particular in psychology, has shown that there are a number of ways of navigating and understanding spaces, i.e. survey, procedural and landmark knowledge [9, 10, 11]. Most of these variations can be viewed as differences in the frames of reference used for navigating spaces, i.e. relative, egocentric, and intrinsic frames of reference [4, 8].

Levine [6, 7] explored the implications of these differences for map reading and design. The results of this were a number of experiments that lead to the following principles about map design [2]:

1. Alignment Principle, maps should be aligned with the world they represent.
2. Forward-Up Principle, the upward direction of the map should correspond to what is in front of the person using the map.
3. Two-Point Theorem, a person should be able to relate two points in the world to two points on the map.

In Topographic Torch each of Levine's principles are employed in the context of an egocentric frame of reference.

TOPOGRAPHIC TORCH

Interaction Model

Topographic Torch is a handheld tool, consisting of an iPaq PDA (Personal Digital Assistant) running custom developed software.

Users are presented with a map on the PDA screen (Figure 1). The map is centered on the location where the user is standing in the world (Figure 2, Point A). The map is initially displayed at a level of zoom such that streets and street names can be readily identified. A user does not press buttons or adjust sliders to interact with the map. Movement around and explorations of the map are controlled in two separate though related ways. The two ways of moving around the map are by pointing and tilting. By moving around the map the user is able to see different parts of the map in the viewport, i.e. on the PDA screen.

Pointing

To use Topographic Torch the user holds the PDA so that the screen is reasonably parallel with the surface of the Earth. Then the user points the PDA in any direction, e.g. North, South, East or West. This causes the map to automatically rotate around the point where the user is located in the world (Figure 2, Point A). Rotation stops when the map is properly aligned with the world. For example when a user physically points North the on-screen map will update to show what is North of the user (Figure 2, anywhere along line r).

Topographic Torch's automatic alignment means users do not have to physically or mentally rotate maps. All alignment is done with regards to the user's physical location, i.e. an egocentric frame of reference. Therefore Levine's Alignment Principle automatically occurs as part of the fundamental design of Topographic Torch.

Tilting

Tilting the PDA scrolls the on-screen map backwards and forwards along the direction the user is pointing in (Figure 2, line r). To scroll forward the user tilts the device forward, and to scroll backwards the user tilts the device backwards. When tilted forward the PDA should be angled such that the front of the device becomes closer to the ground, and the back of the device becomes further away from the ground. It is not possible for a user to scroll so far back they begin to see what is behind them. A user can only scroll back to where they are located on the map. If they wish to see what is behind them they must turn around and point in that direction. Unlike other digital maps pressing left or right buttons, or tilting left or right in the case of Topographic Torch, has no effect – it does not cause the map to scroll left or right. Tilting enables users to explore parts of the map that can be physically distant and off-screen.

Tilting, as implemented in Topographic Torch, automatically fulfills Levine's Forward-Up principle. What the user sees on-screen is always in front of the direction the user is pointing in.

Egocentric Scrolling

With the interaction model described so far an important question is: What would happen if a user rotates/points in different directions when the region of the map at Point B in Figure 2 is displayed on-screen? In existing mapping tools a user would expect to see what is directly to the left or right of Point B, i.e. the on-screen map would scroll left or right. This is not the case with Topographic Torch because scrolling and movement around the map are tightly integrated with where the user is located in the world.

Instead user rotation causes the viewport, which is initially at Point B, to traverse the circumference of a circle. The centre of the circle is Point A, where the user is located in the world, and the radius of the circle is the distance between Point A and Point B. As a user tilts forward and back the radius r increases or decreases. For example in Figure 2 if the user is facing North (Point B), and then rotates approximately 50 degrees right they would see the region of the map at Point C.

It should be noted that the viewport rotates as well. The viewport maintains a tangent to the circle while traversing the circumference of the circle. By maintaining the viewport at a tangent to the circle scrolling will always occur from the top to the bottom or from the bottom to the top of the screen. This top to bottom scrolling is important to do because it maintains Levine's Forward-Up Principle for user interactions with maps.

Distant-Dependent Automatic Zooming (DDAZ)

As the user looks at regions of the map that are further and further away from them the map is automatically zoomed out. They can see less detail but more overview. As they look at regions closer and closer to their location the map zooms in more and more. They can see more detail but less overview. This is done for a number of reasons. Distant-Dependent Automatic Zooming can be viewed as a variation of Speed-dependent Automatic Zooming [5]

Firstly it is done to try and build on how we see objects in the world. We are unable to see distant objects as clearly as we can see close objects, e.g. buildings, and distant objects can appear smaller than close objects. By dynamically altering the scale and level of detail as a function of distance (length of r) we are attempting to influence a user's sense of the distance between where they are and where what they are looking at is.

Secondly, as a user looks at parts of the map that are further and further away the sensitivity of pointing increases. As r increases in length then the distance traveled per degree around the circle circumference increases. A one degree change in the direction a user is pointing, when looking at regions of the map that are close by, does not traverse a large amount of the map. A one degree change when r is large causes large amounts of the map to be traversed. Therefore when r is large there are two potential negative effects:

1. Slight changes in the direction the user is pointing cause very large changes in what is shown on-screen, thus any kind of small physical jitter or movement by the user leads to a constantly updating unreadable screen display.
2. If the user is trying to explore the area around a point, then a small change in pointing angle leads to a large amount of the map getting traversed. This makes it hard to understand the relationship between regions of the map, because there is no visual scrolling continuation between the regions.

By using DDAZ in Topographic Torch we prevent these two potential issues. By zooming out as r increases the rate of traversal around the circumference of the circle can be maintained as a fixed rate of movement.

IMPLEMENTATION DETAILS

Topographic Torch runs on an iPaq plugged into a MESH [3]. MESH is a hardware platform for the iPaq that captures a wide range of haptic information. MESH has X, Y, and Z axis magnetic compasses, gyroscopes and accelerometers, and a number of other very useful features, e.g. vibro-tactile feedback, GPS, etc. The magnetic compass and the accelerometer are used for carrying out tilt compensation to establish what direction Topographic Torch is being pointed in. Tilt compensation adjusts the magnetic compass data so that the direction of magnetic North is not lost when Topographic Torch is tilted. For example if you tilt a traditional magnetic compass too much the compass needle gets stuck and provides incorrect directional information.

Low pass filtering is carried out on the data captured from MESH. This reduces the jitter introduced by the users' kinesthetic system and contributes to making display updates smoother. Maps are stored as bitmaps, though vector based maps would be better for the map transforms, i.e. zooms and rotations.

PRELIMINARY STUDY

We have carried out a preliminary study of Topographic Torch. The purpose of the study was to provisional examine whether Topographic Torch helped users understand the relationship between where they are in the world and where various target locations were. Is angular error greater or less with Topographic Torch when a user had to understand the relationship between two points in the world and on a map? Angular error is defined as the difference in degrees between the direction a user thinks a location is in and what direction it actually is in. A secondary purpose of the study was to establish how to experimental examine Topographic Torch.

There were two groups in the experiment, with four subjects taking part. Group 1 carried out the tasks using a paper based map, and Group 2 carried out the tasks using Topographic Torch. Both maps were the same. In both Groups the subjects stood in the same fixed location. There were two main tasks. Task 1 was a timed task which consisted of pointing in a specific direction and asking users to find a specific location in that direction. In Task 2 users were given a target on a map, and then asked to indicate the direction of the target in the real world relative to their location. Though the number of subjects is not large enough to draw meaningful conclusions it would seem that Topographic Torch subjects faired better at Task 2, while paper based map subjects were faster at Task 1.

After the experiment we informally exposed all subjects, along with number of others, to Topographic Torch. In general users appeared to quickly understand how pointing Topographic Torch would automatically align the map, and how tilting backward and forwards scrolled the viewport along the direction they were facing. A number of these users initially kept on tilting Topographic Torch left and right to scroll left and right. Even though they did understand how Topographic Torch worked they took time to adjust to the idea of rotating their whole body to point in directions of interest. This may indicate the egocentric frame of reference in Topographic Torch is not something everyone immediately adapts to.

CONCLUSION

In this paper we have presented a novel egocentric mapping reading tool. Motivations for the interactive design decisions behind Topographic Torch have been covered while touching on how these decisions meet Levine's map design principles. The impact of maintaining an egocentric frame of reference in each of the interactions is covered. The impact of the egocentric frame of reference for interactive design can be especially seen in the Distant-Dependent Automatic Zooming and the Egocentric Scrolling.

ACKNOWLEDGMENTS

Thanks to Ken Haase and Stephen Hughes for their suggestions and help. A portion of this research was carried out while the first two authors worked at Media Lab Europe.

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