Navigation through Geospatial Environments with a Multi-Touch enabled Human-Transporter Metaphor

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Abstract

Geospatial environments often provide users with complex and detailed 3D data sets. Although, many different visualization techniques allow interesting insights, intuitive and natural exploration approaches are often missing such that only domain-experts are able to efficiently explore these data sets.

In this paper we present an interaction metaphor, which allows even non-expert to naturally navigate through a virtual 3D city model based on a real-world metaphor. Recent developments in the area of interactive surfaces enable the construction of low-cost multi-touch displays and relatively inexpensive sensor technology to detect foot gestures, which allows to explore these input modalities. We demonstrate how multi-touch hand gestures in combination with foot gestures can be used to perform navigation tasks in interactive 3D geospatial environments. We describe the 3D navigation metaphor as well as the corresponding hardware and implementation. Furthermore, we have performed an experiment in which we observed and analyzed users using our navigation technique.

Keywords: 3D geospatial environments, navigation techniques, multi-touch interaction

1 Introduction

Many applications require intuitive metaphors and techniques to explore the data displayed in a certain domain. In particular, 3D geospatial data has grown in popularity and has been used widely in many different application domains in recent years. While generating, processing and visualizing these complex data sets has been addressed through many sophisticated algorithms, current navigation and exploration techniques are often not sufficient for such complex environments and often allow only experts to explore the data. In order to navigate through geospatial data from an ego-centric point of view, it has been motivated that walking is the most intuitive and natural locomotion technique [8]. However, real walking introduces problems in setups with limited or even none walking space, such as desktop-based environment, museum setups, or presentation rooms. Locomotor simulators, omni-directional treadmills, and "redirected walking" [6] provide certain solutions in this context, but often require a complex setup and can be exhausting during long term use. Similarly, many 3D input devices are complex and exhausting to use. They may divert the user's focus from her primary task, or can result in the user losing orientation due to unnatural motion techniques or unintended input actions.

Instead of using solely 3D hand-based input or physical locomotion systems, we propose to use a combination of hand and foot gestures for 3D traveling. Hand gestures allow precise input regarding point and area information. Foot interaction, in contrast, can provide continuous input in more natural way by just shifting the body weight on the respective foot. Instead of using a traditional 3D input device to specify, for example, direction or speed of travel, we use multi-touch technology, which gives the user tactile feedback during the interaction and allows to rest the arms.

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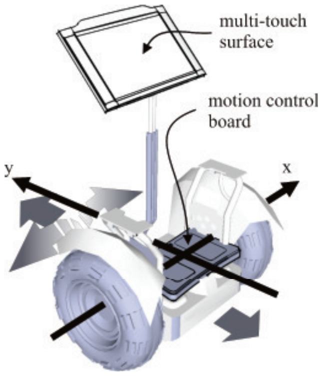

Figure 1: Illustration sketch of the multi-touch enabled Human-Transporter metaphor.

In this paper we propose a navigation device based on a Nintendo BalanceBoard and a transparent FTIR-based multi-touch surface for navigation in 3D geospatial data from an ego-centric perspective, as well as a map-based *Worlds In Miniature (WIM)* [7] approach for wayfinding. We simulate a Human-Transport vehicle with a physically inspired steering technique in combination with a multi-touch device to interact with the WIM.

2 Related Work

Many different approaches for exploring geospatial data have been introduced in the last decades. Some of them require the user to locomote through the real world while these movements are mapped to motions of the virtual camera [4, 6], other approaches make use of 2D or 3D input devices, which are used to specify motion parameters like direction, speed, start and stop [1].

The BalanceBoard by Nintendo contains multiple pressure sensors that are used to measure the user's center of balance and weight. Since it has been introduced, it has already been applied in some research projects. For instance, De Haan et al. [2] have applied the board to define a 3 DOF input device, which they used to implement 3D rotation or basic navigation techniques. Schöning et al. [5] have examined simultaneous usage of hands and feet to manipulate two-dimensional GIS data sets. Hilsendeger et al. [3] proposed a navigation technique similar to a Human-Transporter. In their research different transfer functions for steering control, as well as differences between speed and acceleration control are evaluated.

Tactile feedback provided by a multi-touch enabled surface is beneficial, especially in tasks where visual feedback is often occluded by the pointing device or graphical representations. Another advantage of multi-touch surfaces is that the user does not need to wear any instrumentation in order to interact in an intuitive way.

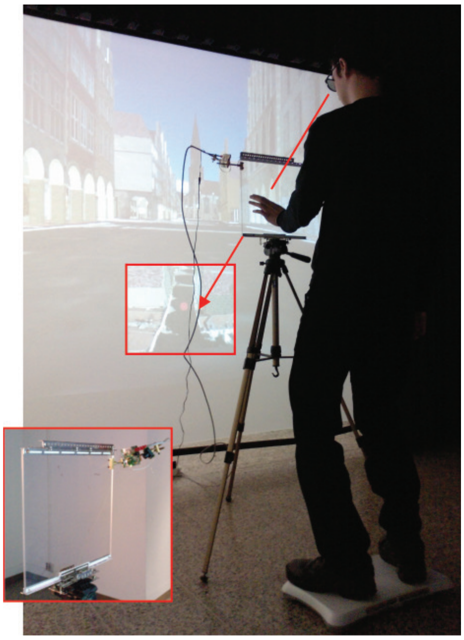

Figure 2: User using the multi-touch enabled human transporter metaphor to travel through a virtual 3D city model. The map appears stereoscopically displayed on the multi-touch prop.

However, until now challenges and limitations of multi-touch interaction in the context of 3D navigation, in particular for geospatial environments, have rarely been considered.

3 Implementation

3.1 Hardware Setup

The hardware setup (shown in Figure 2) consists of a BalanceBoard and a transparent FTIR-based multi-touch surface. The multi-touch surface is an acrylic plate with a set of IR LEDs and a wide-angle (107°) camera mounted on its side. The camera is mounted outside the view frustum defined by the border of the acrylic plate and the user's head. It is used to measure the user's center of balance as well as her weight.

3.2 Simulation of a Human Transporter

As mentioned above, we use the BalanceBoard for navigation in a virtual world. The steering and speed control are inspired by the Human-Transporter vehicle and are based on the simulated setup illustrated in Figure 1. Leaning forward or backward leads to forward/backward motion of the vehicle, while leaning left or right turns it in this direction. In order to implement such a control a 2D projection of the user's center of gravity, i. e., her center of balance, is used to move a *uniform* mass across the board. This way we minimize the impact of different user weights.

3.3 Transparent Multi-touch Surface

In order to support the user's orientation in the geospatial environment, we provide a WIM view, which the user can control using multi-touch gestures. The WIM view is displayed as inset in the viewport that is used to render the ego-centric view of the VE, which the user perceives on the projection wall. The position of this viewport is calculated separately for the left and the right eye according to the frustum defined by the user's head and the multi-touch surface in such a way, that the WIM appears attached to the multi-touch surface (illustrated in Figure 2). The WIM view is created by rendering the virtual city model from the viewpoint of an additional (slave) camera, placed with an offset relative to the ego-centric camera and directed to it. Multi-touch input affect only this slave camera, whereas the view on the projection wall is not altered. On the other hand, when using the BalanceBoard to move the ego-centric viewpoint, the focus point for the WIM changes accordingly. This allows users to get additional information about the environment via the WIM, while traveling using the BalanceBoard. We map single-finger pan gestures to azimuth and elevation of a virtual trackball control centered around the user's current position as used to render the ego-centric view on the projection wall. The two-finger rotation gesture is used to rotate the slave camera around the Human-Transporter's up axis and the two-finger pinch gesture is mapped to scalings of the WIM, providing users with the ability to get a detailed view of the current surroundings or a broader overview of the environment. The speed sensitivity of the Human-Transporter is adjusted with the scaling factor of the WIM to provide an adequate motion speed according to the WIM view.

We also implemented long distance travel via the WIM. Therefore, a user has to double-tap on the desired position on the WIM view, which places the main camera used for the projection wall (and thus the Human-Transporter) at the corresponding position and aligns the WIM accordingly.

4 Conclusion and Future Work

We have presented the hardware setup and the metaphor to six subjects in a virtual 3D city model. Overall, the feedback of the subjects was very positive. All six subjects remarked that after a short adaptation they were able to navigate easily through the virtual world, and found the steering very natural. Nevertheless, some subjects had particular problems to make a turn in place or in short distances and some of the subjects remarked that it was difficult to maintain direction for a long time. However, the results of the preliminary usability test motivated us to further develop the proposed metaphor. In the future we want to further improve the setup used to implement the described metaphor. Moreover, we want to incorporate further interaction metaphors, which make use of the multi-touch capability of the transparent surface and further investigate the combination of a WIM metaphor and multi-touch input.

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