Navigation and Interaction in a Multi-Scale Stereoscopic Environment

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Abstract

This poster explores navigation, interaction and stereoscopic display in a multi-scale virtual space. When interaction, especially two-handed, direct manipulation, is combined with stereoscopic stationary displays, there are trade-offs that must be considered. This poster gives an overview of these design issues and briefly describes our current multi-scale, application for exploring volumetric weather in its geospatial context in a VR system. The general importance of recognizing and using defined areas of user focus and of semi-automatically bringing these areas into the optimal interaction volume of the display system is described.

CR Categories: H.5.2 [User Interfaces]; I.3.7 [Three-Dimensional Graphics and Realism]: Virtual Reality; I.3.8 [Application]

Additional Keywords: geospatial, 3D interaction, direct manipulation, stereoscopy, large display

1 Introduction

In a multi-scale virtual space, the geometric details that interest the user are at spatial scales covering several orders of magnitude. Navigation and interaction in multi-scale virtual spaces is a topic of interest because of the growing number of such large spaces that must be explored and analyzed. They require a variety of interaction techniques. For example, there are global geospatial environments, such as the one described in this paper, that require seamless navigation from hemispheric overviews to flying or walking directly over or on the terrain (with sub-meter features). In our current software the terrain can be populated with 3D objects (such as building, trees, and bridges) and covered with time-dependent weather or other atmospheric phenomena. Exploration and analysis of these features require interaction and manipulation techniques that go beyond navigation.

This poster concerns interaction and viewing on stereoscopic displays where the head is tracked but the display is stationary, attached to desk, tabletop or wall. Such displays are often called HTDs (head-tracked displays) which are distinguished from HMDs (head-mounted displays). Our current geospatial application is for a Fakespace ImmersaDesk where the user holds two tracked 3-button sensors, one in each hand.

Navigating through multi-scale virtual spaces on stereoscopic HTD's presents three major challenges (see [5] for details):

- managing 7 degrees of freedom: 6 Euclidean ones plus scale
- maintaining good stereo imagery
- ensuring that interaction methods (navigation and manipulation) work at all spatial scales

The necessity of supporting 7 degrees of freedom arises when a VR interface employs a head-tracked display, a stereoscopic display, or manipulation with a six DOF device [5]. Controlling seven degrees of freedom is an excessive burden on a user and therefore the navigation and manipulation techniques must intelligently combine them.

Previously we developed a method that addresses these issues for general navigation in a global geospatial environment, including orbital (top-down) zooming and panning and airplane-like flying [5]. However, this is for a situation where the earth's surface is always the center of user focus. When objects are placed on and especially above the earth (such as volumetric atmospheric fields), the user will often want to explore these objects in detail and the objects should be the center of focus. These objects may be quite complex, are embedded in the multi-scale space, and are themselves multi-scale. Furthermore, the user will want to use modes of interaction beyond navigation such as direct manipulation and handling of the object of interest. In a virtual environment, we define direct manipulation as having a minimal spatial displacement (ideally zero) between the user's physical hand and of its virtual representation and also the manipulated virtual object. Our present work combines direct manipulation and navigation on a two handed, stereo HTD system and aims to support quick switching between these modes.

2 Design Issues

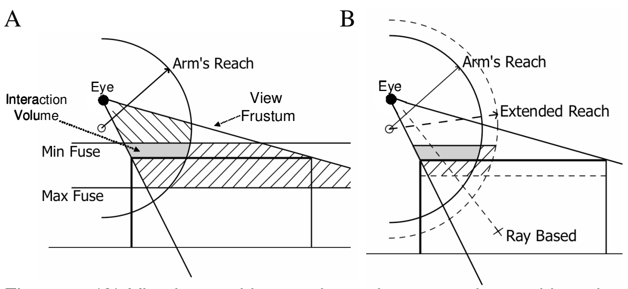

Figure 1. (A) Viewing and interaction volumes on the workbench assuming direct manipulation (B) Alternative extended reach or ray-based manipulation interaction volumes.

Consider a virtual workbench with a horizontal screen. The interaction volume is the region where virtual objects can reside and be best manipulated. Without consideration of stereo or interaction, the interaction volume is the view frustum, large and theoretically infinite in depth (Figure 1A). However, as we consider more application constraints, the interaction volume becomes a small subset of the view frustum. Like Meyer and Barr [5], we are interested in optimizing the available interaction volume, but unlike [5] we address stereoscopic display issues and we assume an extensive, multi-scale virtual space that requires navigation in addition to physical head motion. This can produce views with virtual geometry that extends outside even a multi-screen system's expanded interaction volume as defined in [5].

Stereoscopic fusion limits restrict the interaction volume in which the user is able to comfortably, perceive depth. Literature provides us with many suggestions on what part of the volume to use, relative to the head-to-screen distance (see references in [5]). In the workbench configuration, two planes are defined, the Nearest Fusible Depth plane, and the Farthest Fusible Depth plane. Virtual objects in front of the minimum plane or beyond the maximum plane yield negative and positive screen parallaxes that

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can cause eye strain, visual fatigue and diplopia. Acceptable stereoscopic effects are achieved in the right-slanted cross-hatched plus shaded region in Figure 1A.

Using direct manipulation further limits the interaction volume. to that part of the volume lying in the user's reach. While the human factors literature contains empirical studies of a human's sitting reachable volume [3], as a first approximation we'll treat this reachable space as two spheres around the user's shoulder joints with a radius of an arm's length. Since the user cannot reach beneath the display surface, the available space is restricted even more to that part of the sphere lying above the display surface. This is the left-slanted cross-hatched plus the shaded region in Figure 1A.

Alternative manipulation approaches such as ray-based manipulation or extended reach manipulation [2] could enlarge the interaction volume (Figure 1B). However, these techniques are less natural because in the physical world humans typically grab and manipulate objects in a direct, unmediated manner. Direct manipulation closely couples with the proprioceptive sense [4] which can bring out further information about structure and 3D relations. If we use tools that extend the reach of the user, the usable volume can increase tremendously by both increasing the radius of the user's reachable space and permitting her to reach under the display surface (Figure 1B). A trade-off has to be made between ease-of-use and the size of the usable volume.

The stereoscopic interaction volume for direct manipulation is thus the small solid shaded area in Figure 1A. This volume is approximate. Some of its constraints are hard, such as the view frustum from the eyes through the corners of the workbench and the requirement for the direct manipulation to be above the display surface. In contrast, the stereoscopic constraints are softer.

The interaction volume is a small, limited commodity. We should use the volume in the best way possible, and we should try to enlarge the volume when appropriate. When we want to use the volume optimally, we need to know which part of the world the user is interested in. The problem then reduces to positioning the area of user focus optimally within the interaction volume.

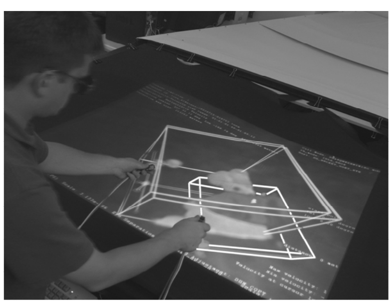

Figure 2: User manipulates pair of condition boxes which are semi-automatically kept within the interaction volume.

To determine the user's focus, the system must infer both what he wants to see and what he wants to interact with. This is a challenging problem in an extensive, multi-scale environment. At many of the scales, the spatial extent of the environment will be much larger than what is displayed on the screen. When a selected point on the earth is the center of focus, we have shown that appropriate scaling and positioning decisions can be made, at least for navigation [5]. But when the focus is away from a reference surface and/or involves a volume of space, the decisions are more complicated. We use a "conditional box" [1] to define the region of focus. The conditional box defines the current volume of interest and is so named because selected conditions can be placed on its contents. In addition to setting the focus, the conditional box defines the volume where detailed 3D visualizations should occur. This is important because with complex and extended data, the system often cannot render everything at interactive rates. It also helps keep central details from being obscured or occluded by surrounding data. We have shown that the conditional box can be accurately and efficiently positioned and manipulated in 3D space using two-handed tracked interaction [1]. The system's inferred center of focus depends on the user's selection (the conditional box), which is done as part of the natural process of exploring and analyzing the data.

In our weather application, the user navigates using methods of [5] but he can also create and select one or two conditional boxes and directly manipulate each box with one hand (Figure 2). The user can explore correlations between the different volumetric weather data types selected by each box. The user may either manipulate a box so that it acts as a magic lens to survey different regions of the atmosphere or the user may rotate and zoom the view point about a box's center to gain different views of a fixed region of the atmosphere. When the user manipulates a box or performs box-centered navigation, the software attempts to bring that box into the interaction volume by semi-automatic view scale and view position adjustments. When the boxes are released, the software reverts to semi-automatic view scale and view position adjustments based on the terrain surface [5]. The rules that bring the box into the interaction volume must balance keeping the selection box in the volume while avoiding automated view adjustments that are too abrupt or visually jarring. These rules and the rules for switching between box and terrain automated view scale/position adjustments were iteratively developed using our stereoscopic display experience and trial-and-error.

3 Conclusions and Future Work

There is a trade-off between optimizing stereo display and using different manipulation methods. Our anecdotal evaluations of our multi-scale weather application suggest that many of the negative effects can be minimized by the use of appropriate interaction tools and areas of user focus. We observed that the comfort and effectiveness of interaction with objects in the multi-scale space is much improved by the addition of automatic view adjustments based on the conditional boxes and not just on the terrain geometry. Future work includes informal evaluations with weather experts and formal user studies to get a quantitative measure of the improvement in interaction and stereoscopy.

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