Haptic Interface for Center-of-Workspace Interaction

Demonstration Paper

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Introduction

In our laboratory, we are involved in creating highly interactive 3D visualizations of various oceanographic data as well as investigating issues related to monitoring and control of remotely operated and autonomous undersea vehicles [1]. For these applications, it is necessary to sometimes examine features at the centimeter scale and to see these in the context of environments covering kilometers. To address this problem, we build upon a new interaction style for 3D interfaces called *center of workspace interaction* [2]. This style of interaction is defined with respect to a central fixed point in 3D space, conceptually within arm's length of the user. This metaphor mimics typical physical workspaces that are commonly constructed, such as an office desk or technician's workbench. Objects in the environment are brought to the center of the workspace, and operated on by contextually appropriate tools.

It has long been recognized that for many user interface problems, adding task-related constraints can improve a user interface. For instance, computer-aided design systems employ sophisticated constraints based on concepts such as snap-dragging [3], forcing objects to line up or rotate about certain fixed axes. A related concept is the notion of "virtual fixtures", which employ force feedback to guide a user in carrying out manual and supervisory control tasks [4, 5]. There are of course many constraints inherent in real world interaction; e.g. physical objects do not in general interpenetrate each other when they come into contact.

An interesting way of combining constraints with a direct manipulation interface is to create haptic widgets [6]. The idea of a widget is to encapsulate both behavior and affordances in a single object. Thus if an object looks like a handle, and behaves like a handle when clicked on with a mouse, learning time will be minimized. Force feedback enables users to feel constraints embodied in a virtual input widget. Thus, for example, if a particular object should only be allowed to rotate about a certain axis, then that constraint can be physically imposed to restrict the range of motion of the input device.

For this demonstration, we will show a haptically enabled fish tank VR that utilizes a set of interaction widgets to support rapid navigation within a large virtual space. Fish tank VR refers to the creation of a small but high quality virtual reality that combines a number of technologies, such as head-tracking and stereo glasses, to their mutual advantage [7].

Haptically Enabled GeoZui3D

The fish tank VR system described is built upon our GeoZui3D geographic visualization system [2], which uses center of workspace interaction as a unifying concept, and incorporates a SensAble Technologies Phantom 1.0 haptic input device. The VR workspace lies within the region of personal space where we normally interact haptically with objects in our environment. Although the working volume of the Phantom device is small, approximately 12 x 17 x 25 cu. cm, this matches well with the size of the VR workspace.

To support haptic interaction, we have evolved the following set of design principles:

- Haptically represent constraints rather than objects
- Display constraints both visually and haptically (constraints are possibilities for movement, limits on motion)
- Visually emphasize potential for interaction (manipulation hot spots)
- On contact, visually reveal additional constraints
- Make state information both haptically and visually accessible

Our widget set, shown partially in Figure 1, is designed to control the viewpoint by bringing a large space (i.e., the virtual environment) into the range of a small device (the Phantom workspace). It encapsulates the following behaviors: rotation, tilting (about the pitch axis), scaling, centering and lighting orientation. In general, the user interacts with the widgets by simply touching them with their Phantom proxy. This action attaches the user (Phantom proxy) to the widget. Detaching requires the user to pull (or push) away from the widget in an orthogonal direction to that widget's constrained axis.

The rotate widget is modeled as a circular band centered about the vertical axis, and is used to rotate the world about this axis. The widget uses positional control and is activated when the user touches the hotspot in the front of the band. Once activated, the user's motion is constrained along the surface of the band. Detents are established at fixed increments to indicate position and provide a sense of the total rotation angle traversed.

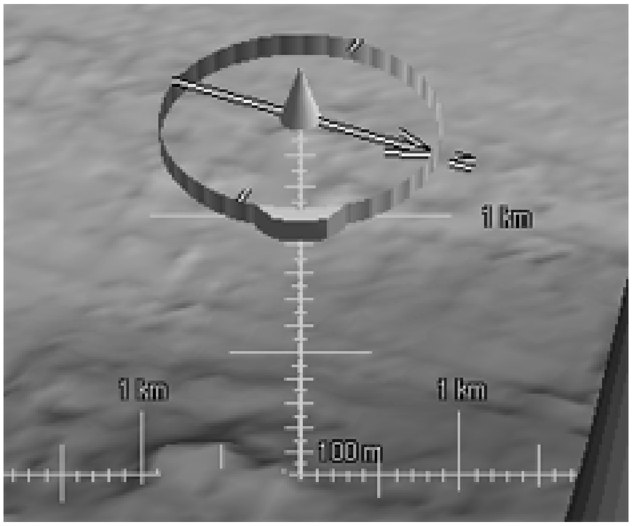

Figure 1. Haptic widget set in GeoZui3D.

The tilt and scale behaviors are modeled as a single widget having two degrees of freedom. The tilt degree of freedom uses the vertical axis as a lever and, once activated, constrains the user's motion along a circle whose radius is the length of the lever arm. The user touches the cone at the top of the vertical axis to activate the widget. The lever arm is attached to the horizontal axis about which the tilt rotation occurs. Note that this radius, as do all the widget motion constraints, fits within the Phantom workspace limits. Again, detents are used to indicate distance traveled and to anchor against drifting. Uniform scaling about the center of the workspace is initiated by touching the same cone object, but instead of pushing or pulling tangential to the lever radius arm, the user pushes or pulls *along* the lever arm axis to zoom in or out, respectively. Haptically, this is modeled as a bi-directional spring and provides velocity control for magnification and minification rate. Separation between the two modes of tilt and scale is aided by the use of orthogonal constraint axes and the constraint that the user can only induce tilt while the cone is in the neutral spring position; i.e. no scaling taking place.

The center-of-workspace metaphor requires a method to allow the user to re-center the environment about various locations. We have developed two means for doing this; one uses direct translation and one uses combined translation and unidirectional scaling. To directly translate a point in the environment to the center of the workspace, the user moves the Phantom proxy to the desired location within the haptic workspace and simply presses and releases the stylus switch. That location is then moved to the center of the workspace. If the location lies outside of the haptic workspace, the user first zooms out (using the scaling widget) such that the location is reachable, then uses the described method to translate. Alternately, to translate to a new location and zoom in at the same time, the user moves to the desired location in space and depresses the stylus switch. With the switch depressed, the user pulls away from the point; a bounding box is created about the proxy location whose size provides an indication of the limits of the new center-of-workspace. When the user releases the stylus switch, the translation and zoom behavior occur.

In addition to the viewpoint control widgets, we are currently developing a set of application specific haptic widgets to aid in the monitoring and control of undersea vehicles. One goal is to help mission planners to define transit paths for vehicles that best utilize vehicle sensors to accomplish a given task or mission. Requirements, which may include maintaining constant transponder line-of-sight, maintaining a given sensor swath coverage, and accounting for bathymetric depth uncertainties as well as vehicle energy and time limitations, impose constraints on the selection of transit paths. These application-specific widgets leverage both the center of workspace metaphor and design guidelines previously discussed to help the operator in these particular tasks.

References

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