Frame of Reference Interaction

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ABSTRACT
We present a unified set of 3D interaction techniques that demonstrates an alternative way of thinking about the navigation of large virtual spaces in non-immersive environments. Our alternative conceptual framework views navigation from a cognitive perspective—as a way of facilitating changes in user attention from one reference frame to another—rather than from the mechanical perspective of moving a camera between different points of interest. All of our techniques link multiple frames of reference in some meaningful way. Some techniques link multiple windows within a zooming environment while others allow seamless changes of user attention between static objects, moving objects, and groups of moving objects. We present our techniques as they are implemented in GeoZui3D, a geographic visualization system for ocean data.

Keywords: interaction techniques, multiscale, ZUI, multiple 3D windows

INTRODUCTION
GeoZui3D is a *Geo*graphic *Z*oomable *U*ser *I*nterface that affords rapid interaction through multiple linked views. Its interaction is built from the perspective of facilitating changes in the user's attention from one reference frame to another. This differs in two major ways from the mechanical perspective of moving a camera between different points of interest. First, by characterizing an item of interest by its frame of reference (its position of origin, orientation, and scale), we can accommodate not just objects, but object components and aggregates, spatial regions, and more amorphous items of attention that change over time. Second, by characterizing display windows as frames for user attention, multiple views can be tied together using interaction in more meaningful ways than just moving one camera around within the view of another camera.

INTEGRATING ZOOMING & MULTIPLE WORKSPACES
A fundamental unit in GeoZui3D is the zoomport, a 3D zoomable workspace. Each zoomport supports an adaptation of center-of-workspace navigation, as presented by Parker et al. [1] for their NV3D system. The center of workspace, located just behind the screen at about arm's reach, is intended to map directly to the focus of the user's attention. A single-button mouse interface allows the user to click on any item to bring it to the center of the workspace, and simultaneously push forward or backward on the mouse to scale up or down about this new focus. Each workspace center provides a minimal set of rotation widgets and makes other useful tools readily available at or near the workspace center, such as the (optional) adaptive ruler shown in Figure 1 that provides scale information at all times. The presence of these center-of-workspace tools is minimal enough that users of GeoZui3D have not complained of them getting in the way.

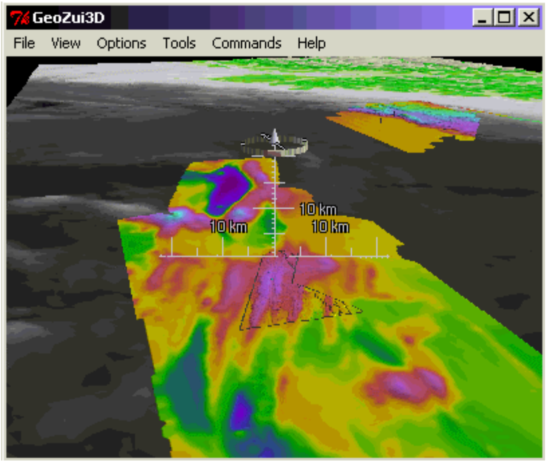

Figure 1: Rotation widgets embedded in the scene. The center of workspace is at the intersection of the central crosshairs.

This formulation of zoomport allows us to bring multi-window interaction in the 2D style of Ware and Lewis [3] to three dimensions. Multiple windows are useful for tasks that require a user to remember visual stimuli between two or more locations [2]. Because we have mapped the focus of user attention to a center of workspace, we can represent this focus in other contexts. Figure 2 demonstrates this in a couple of ways. First, we can represent the view of a zoomport within its parent window, as is done by the triangular proxy. The user can drag the proxy around within the parent window to move the associated zoomport's center of workspace to whatever item is under the cursor. Second, when the user decides to minimize the window, the marker that is left behind clearly indicates the focus of attention for that window. The location of the viewpoint in Figure 2 demonstrates the futility of trying to do the same with a camera-centric interaction style.

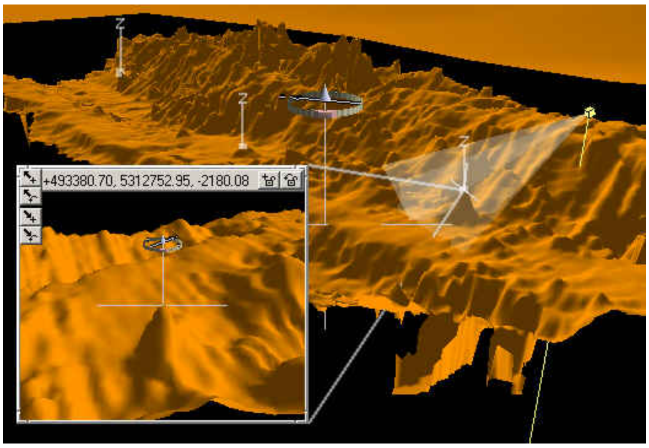

Figure 2: A zoomport, with proxy and tethers linking its center of workspace to its parents view. Two minimized zoomports are shown as well.

FRAME-OF-REFERENCE OPERATIONS

In order to better describe additional techniques, we first characterize the center of workspace more formally in terms of a frame of reference. We assign a zoomport's center of workspace to a frame of reference (FoR) with six degrees of freedom (DoF): 3-DoF for position, 2-DoF for orientation (azimuth and elevation), and 1-DoF for scale. We allow other information to be associated with the FoR, such as home values, "preferred" values, and limits on the original 6-DoF. We assign visual and abstract objects to their own FoRs in similar manners.

Using a frame-of-reference characterization such as this, it is possible to *couple* FoR's to one another in various ways. For instance in GeoZui3D, if the user selects a moving object to bring to a workspace center, the workspace automatically couples its FoR to that of the object. The coupling is done in such a way that changes in the object's position or heading make the orientation of the world appear different in the coupled zoomport, rather than the object. The user is still free to scale, use rotation widgets, etc., but all of these operations take place as if the user had "hopped aboard" the moving object, taking on its reference frame. If the user later selects another focus of attention, the coupling is automatically broken and a new one is established with the new focus. Users have reported this behavior to be very natural, although in practice it is hard to use if the intended focus object is moving too fast. Other instances of coupling include coupling between zoomports, for effects like heading-up overview maps created by establishing a coupling in position and heading components of two zoomport FoRs.

Higher-order operations are possible by aggregating the spatial information of FoRs in useful ways. We call such aggregations *FoR-operations* or *FoR-ops*. An example is a FoR-op that takes for its position the average of its member FoRs' positions, while it computes its scale as inverse to the furthest distance between this average and any of it's members. When a zoomport is coupled to such a FoR-op, it acts as an overview for the group—zooming in as members close ranks, zooming out as they spread apart, all the while keeping the group at the center of the workspace. Another example is a FoR-op that creates a similar overview on the *nearest two* of any of its neighbors. Combined with a trigger mechanism and zoomport coupling, this FoR-op acts to alert the user when any two member objects come within a critical range.

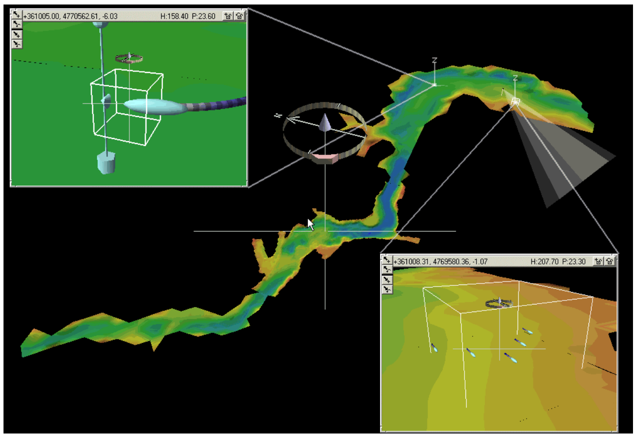

Figure 3: FoR-ops (represented by white boxes for illustration purposes) to monitor a vehicle group (lower right) or potential collisions (upper left).

CONCLUSION

We have briefly presented part of a unified set of 3D interaction techniques that demonstrates the utility of considering navigation from a cognitive perspective: the perspective of facilitating changes in user attention from one reference frame to another. A demonstration copy of GeoZui3D can be downloaded from our web site: http://www.ccom.unh.edu/vislab.

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