Navigating Desktop GeoVirtual Environments

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ABSTRACT

Desktop GeoVirtual Environments, particularly ones intended to facilitate geographic visualization, require the design of special interface methods for navigation and orientation. These methods, ideally, should support movement through the environment with little cognitive effort. For desktop (and immersive) GeoVEs developed thus far, interface methods have been borrowed from other virtual environment applications, with little or no modification. This paper introduces research, directed specifically to the design of interface methods that facilitate movement within GeoVEs. In the course of the research possible metaphors for navigation and orientation were examined. Here, the implementation of one metaphor is described, and approaches to usability testing are discussed. Our initial efforts suggest that a ‘virtual vehicle’ metaphor may provide an effective framework for the design of navigation and orientation tools for GeoVEs.

KEYWORDS: GeoVirtual Environments, Desktop VR, VRML, GeoVRML, Graphical User Interface Design, Navigation, Orientation, Geographic Visualization.

1. INTRODUCTION

Geographic Visualization (GVis) integrates a centuries-long tradition in cartographic representation of geospatial information with more recent advances in image analysis, exploratory data analysis, and scientific visualization more generally [12]. Virtual Environment (VE) technology offers the potential to enhance the effectiveness of GVis methods developed thus far. However, the integration of GVis with VE methods raises both technical and conceptual questions that must be addressed before this potential is realized [5, 14, 21, 25].

The project reported upon here focuses on navigation and orientation within desktop GeoVirtual Environments (GeoVE). It is part of a larger effort that considers a range of GeoVEs from desktop through semi-immersive (ImmersaDesk and Virtual Workbench) to fully immersive (CAVE) environments [14]. The goal that underlies the range of GeoVirtual Environments we are developing is to facilitate both the analysis of geospatial data and the understanding of geographic phenomena.

GVis has several characteristics (some shared individually by other visualization application areas) that together result in a set of unique research problems (particularly in the context of GVis-VE integration). These features include:

(a) typically two, and sometimes three, dimensions of the virtual display space are reserved for representing geographic space,
(b) emphasis in representation is on exploration of 'spaces' rather than 'objects',
(c) a substantial reduction in scale is required from the geographic space represented to the display space, and
(d) visual representations used in GVis typically contain a mix of abstraction levels; while the display space iconically represents geographic space, objects in that geographic space (often not visible in the world) can be represented abstractly (e.g., atmospheric pressure depicted by isobars or isosurfaces).

GeoVEs are typically used to explore spaces too large to be seen in one glance. Navigation and orientation have been identified as 'primary functions' for GeoVEs, functions that support all other interaction necessary to analyze geospatial data and understand geographic phenomena [6]. Navigation in this context is defined as 'the method of determining the direction of a familiar goal across unfamiliar terrain' [1] where orientation is described as 'concerned solely with direction and not with destination' [1]. Other important functions for GeoVEs include identification and selection of objects, highlighting sets of objects (e.g., 'geographic brushing' [17]), and filtering operations used to enhance particular features or attribute ranges (e.g., attribute 'focusing' [13]).

Failure of navigation and orientation functions will make productive application of these additional functions impossible. Our specific focus in this short paper, therefore, is on efforts to develop and test new metaphors for interaction with GeoVEs that emphasize navigation and orientation and that take into account the characteristics of geospatial data and their visualization noted above. The research was stimulated by difficulties we experienced (and observed others experience) when trying to use existing VRML browsers to explore (navigate and orient in) GeoVRML worlds. Users of desktop GeoVEs are often quickly ‘lost in space’ and fail to navigate and orient successfully. Such failures may be due to (a) use (in current browsers) of conceptual models for the interface that are inappropriate to exploration of geospatial environments or, perhaps, (b) to inconsistent or conflicting conceptual models.

Our specific goal in this paper is to outline an approach to designing interfaces for desktop GeoVEs and to illustrate that approach with a prototype GeoVE implemented using an integration of VRML and JavaScript methods. The interface design approach is grounded in a theoretical understanding of metaphor and compares advantages and disadvantages of a range of possible metaphors that might facilitate navigation and orientation through local to global scale geographic representations. Only a brief sketch of the theoretical framework that underlies our work can, of course, be provided here.

2. GUI DESIGN ISSUES FOR DESKTOP GeoVIRTUAL ENVIRONMENTS

Since desktop GeoVEs are seldom immersive, navigation and orientation are typically controlled from 'outside' the environment. Control is through a GUI that provides 2D tools for indirect
manipulation of user viewpoint, display parameters, and objects in the scene. Considerable attention has been directed to the design of GUIs for computer environments generally [23,26], for 2D desktop mapping/GIS [16,19], and for 2D GVIs [4,8]. Much less attention has been given to design of 2D GUIs for control of 3D geospatial displays (see [9] for one example).

A typical user for the 3D environments being designed is an expert (e.g. geoscientist, environmental manager) in the task domain but a novice in the underlying computer concepts [23]. The designer's goal in creating an effective GUI for such users has been suggested to be 'having the computer vanish as users become completely absorbed in their task domain' [23]. The research tasks suggested by this contention are to determine what characteristics make interface controls 'transparent' and to explore the implicit hypothesis that 'transparent' user interface controls are advantageous for use in GeoVEs.

If transparency of interface controls is interpreted to mean controls that the user can ignore because they take little cognitive effort to use, then one approach to achieving the goal of transparency is to design controls that take advantage of intuitive metaphors [10,15,22,24]. The abstract nature of information technology creates a need for interface metaphors that allow users to conceptualize and understand software without having to master its technical details. Successful metaphors will be ones that map familiar source concepts into the abstract, computational target domain.

The main role of metaphors in GUI design is to afford ways of interacting with the computer environment and to help users master complex tasks. Interface metaphors are a conceptual, not only a presentational, device. They act as 'sense makers' - an indispensable function for any user interface [10]. In a desktop GeoVE, many important GUI operations (e.g., navigation, orientation, selection, identification) could be realized using metaphors, because relevant abstract concepts like state, action, purpose, means, change, time and causation are mostly described metaphorically [11]. Here we focus on new navigation and orientation metaphors.

Appropriate and usable metaphors do not pop up by chance. They need to be carefully designed and their usability tested. For our desktop GeoVEs, we are looking for metaphors that are meaningful to a broad audience of geospatial information users. In our ongoing research we will investigate and evaluate how a range of metaphors can be used for effective, intuitive, and 'transparent' visual exploration within GeoVEs.

### 3. METAPHORS FOR NAVIGATION

Selecting and testing metaphors involves identifying candidates from familiar domains that share key features with the target domain. It is important to note that the choice of a metaphor has to fit the purpose in the interface usage correctly. For navigation in desktop GeoVEs we need to find a navigation metaphor which supports freedom of movement (similar to, but perhaps more flexible than, our movement in real geographic space). A second requirement is that the metaphor invokes little cognitive effort. Third, the metaphor should suggest practical and understandable interface controls for necessary operations.

A logical starting point in designing and implementing a navigation-orientation metaphor for GeoVEs is to take a close look at ways we move around in geographic space. First, we can distinguish between walking and vehicles. Walking is certainly a good metaphor for navigation in virtual buildings, since the size and movement of avatars can be directly related to these large-scale environments. For exploring larger data sets, e.g. a country, walking is impractical as a metaphor, due to expectations it would prompt about speed and difficulty of progress across the terrain. For the environmental extent to be depicted in GeoVEs, vehicle metaphors seem more suitable. Pertaining to vehicles, important distinctions include (a) whether the vehicle stays in contact with the surface or travels through the air and (b) what method of propulsion is used (e.g., pedaling, an engine, wind). The former distinction establishes fundamental constraints on movement while the latter suggests the kinds of controls used in directing movement.

In our everyday lives we usually use a car or bicycle to traverse the landscape surface. As a source of metaphor, these and other surface vehicles suggest that travel will be limited to the paths typical for that vehicle (e.g., roads, sidewalks). Such a constraint is overly restrictive for the exploratory GVIs uses envisioned for the GeoVEs being designed.

An air travel vehicle metaphor is much more flexible and, thus, more suited to facilitating exploratory GeoVE use. A commonly used air travel metaphor is the airplane but there are many possible metaphors available to choose from, e.g., helicopters, zeppelins, balloons, etc. Most of these air travel vehicles, while providing more flexible navigation and orientation metaphors than surface vehicles, still have distinct limitations. Important conceptual problems, which have to be considered, are:

- the average user does not know how to maneuver air vehicles because he or she has no experience using them,
- the controls in the vehicles are far too complex and would distract the user from his or her visualization goals (e.g. identifying features, geographic brushing and focusing),
- most air travel vehicles (e.g. airplanes), by their nature, do not move backwards.

An alternative to navigation metaphors based upon real world travel is provided by science fiction, the concept of 'teleportation'. Teleportation gives the user freedom to move in all directions with travel time not dependent on distance between locations. Several limitations, however, exist with this metaphor for instantaneous travel. Travel is restricted to use of fixed 'portals' and the sudden relocations involved are likely to result in a 'lost in space-feeling'. More importantly (for our application context) teleportation is suited to travel between known points of interest, but not to exploration of unknown spaces.

Assessing the advantages and disadvantages of the metaphor possibilities described (and others) has lead to a set of base criteria for an effective GeoVE interface metaphor. The metaphor should:

- (a) afford air travel, thus avoiding implicit restrictions to paths or portals;
- (b) support travel in any direction; and
- (c) suggest simple and easy to use navigation controls. No existing physical vehicle meets all of these criteria.

To meet the criteria, we have opted to use a virtual vehicle, a 'flying saucer' as the core metaphor in our initial prototype. This metaphor, while based on a fictional vehicle, is commonly understood. Using a virtual, rather than a physical, vehicle as a source metaphor gives us an opportunity to design easy to learn navigation interface controls that support flexible movement. The selection of a flying saucer as the vehicle metaphor has several specific advantages:

- its movement characteristics are commonly conceived, and movement in all directions is expected to be possible.
• the metaphor is understood in the context of GeoVEs (the flying saucers of science fiction operate in geographic scale environments),
• expertise in controlling flying saucers is not an issue (no particular user, such as a pilot, has an advantage or disadvantage in using the GUI),
• because the vehicle has no apparent moving parts, and there is an assumption of a sophisticated system that is accessed easily, control design and arrangement can be simple (levers that correspond directly to intended movements),
• graphically a flying saucer has a very simple object shape, resulting in a clean user interface.

4. PROTOTYPE FOR VIRTUAL VEHICLE-BASED GeoVE NAVIGATION

The prototype can be described as a spatially iconic GeoVE (see: www.geovista.psu.edu/publications/aag99vr), using the three display dimensions to represent the three dimensions of physical space. Spatially iconic GeoVEs are expected to provide a very intuitive environment for the typical user because they take advantage of human experience in real environments.

The geographic context for the prototype is the catchment of Spring Creek, which runs through Centre County, Pennsylvania. A 30-meter resolution Digital Elevation Model (DEM) of the Spring Creek watershed and a digital raster 1:24000 USGS topographic map were integrated in a VRML world.

Implementing our virtual vehicle metaphor required linking a custom GUI based upon the metaphor to the VRML world (with the custom GUI replacing functions of a standard VRML browser). Both Java and JavaScript provide a means to create functions for a GUI that can be linked to a VRML world (through the VRML Script-Node and the External Authoring Interface) [2,3,20]. For our initial prototype, we opted to make use of the VRML Script-Node, using JavaScript to add GUI functions. This choice was made because the result is supported on all common web-browsers, e.g. the Netscape Communicator or Microsoft Internet Explorer. This choice increases the opportunities to conduct usability testing with, and to obtain other feedback from, potential users.

The navigation tools in our 'flying saucer' interface implementation are designed as a heads up display (HUD) in the VRML scene. Due to the character of Huds, the tools are 'fixed' in relation to the frame that represents the 'bridge' or 'control center' of the virtual vehicle and move (in relation to the environment) with any change in position. The navigation tools schematically display the flying saucer (light colored spheres) and translate user actions directly into changes in viewpoint within the scene (see fig. 1). As the user drags the schematic flying saucer over the interface, the vehicle moves as indicated (see arrows), thus, there is little cognitive effort to use the controls. The dashboard has four basic movements (see fig. 1):
• changing the altitude,
• gliding over the 'ground' plane,
• switching the viewing (forward) direction and
• changing the vehicle's pitch.

In addition to navigation and orientation controls, the prototype interface includes a memory function to record interesting viewpoints. This function becomes very important in the context of exploratory visualization, making it possible to compare viewpoints quickly. To facilitate the task, we implemented a virtual camera (another metaphor) in the GUI. The user is able to take a 'snap shot' using one of three cameras and return to the selected viewpoints by clicking on the 'pictures' next to each camera icon (see fig. 1).

Additional functions of the prototype include an orientation window that informs the user about his/her current position in the desktop GeoVE, displaying the virtual vehicle above a 3D fixed orientation virtual map of the environment. In addition to position, the orientation window also indicates:
• the current behavior of the vehicle, e.g. the pitch,
• the viewing direction and focal point on the ground,
• the actual height over ground, and (in the near future)
• the travel path, for a set time or distance in the past.

Further directional information is given through a compass, which can be directly called up in the HUD. Using the reset button, the vehicle/viewpoint is set back to the original starting position. A help system is included, featuring narrative audio files that explain operation of the interface to first time users.

5. FUTURE DIRECTIONS

The advantages we propose for the virtual vehicle metaphor developed here constitute a hypothesis that must be assessed. An important research question besides an isolated assessment is the testing of this metaphor against other metaphors to determine their relative advantages, e.g. alternative metaphor candidates are real world vehicles such as airplane or helicopter.

Over the next months, we will conduct a series of usability tests that rely on a mix of assessment measures. Assessment will begin with focus group sessions to refine details of the interface. This will be followed by performance measurements (accuracy and speed) for a group of users performing a predefined set of tasks. A task analysis of interaction logs collected during less structured exploration will be used to investigate different navigation experiences.
strategies, uncover systematic errors, and identify novel uses of the navigation tools. These measures of system use will be combined with the qualitative technique of protocol analysis (analysis of verbalization, thinking aloud, while working with the system) [7,18]. The overall assessment will allow us to (a) determine whether the virtual vehicle metaphor is understood and effectively used, (b) identify particular limitations of the metaphor or flaws in the interface controls, (c) develop a strategy for improving implementation of the metaphor (if generally successful) or for choosing alternatives to the metaphor (if unsuccessful), and (d) learn more about how people navigate in a desktop GeoVE.

Once our initial assessment is completed we will revise our interface based upon results, then explore extensions of the result for use in semi-immersive, large screen stereo displays. Please visit our web site at http://www.geovista.psu.edu/publications/InfoVis99/ for the latest version of our prototype.

6. ACKNOWLEDGMENTS

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7. REFERENCES