Direct Interaction with a 3D Volumetric Environment

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1. Introduction

A 3D user interface for a volume visualization system is presented. It provides direct interaction and visceral exploration of the volumetric objects employing true 3D input devices such as the 3SPACE Polhemus Isotrak and the VPL DataGlove. The user interface presents on the workstation screen a small-scale virtual 3D reality supported by a rich set of interaction paradigms. As an integral part of the environment, we developed a volume editor, *edvol*, for generating, manipulating, and viewing sampled and/or synthetic volumetric objects. The novelty of our research and development effort is in providing paradigms for direct interaction, with a focus on volume visualization applications.

2. 3D Volumetric Editor

The volumetric editor *edvol* provides the tools necessary to generate and interact with a 3D voxel based environment [4] of both sampled images (such as in medical imaging) and synthetic models. *edvol* supports the manipulation and display of voxel-based data including image reconstruction, density segmentation, arbitrary slicing, translucency control, discrete projection, and discrete shading.

edvol also provides the tools to create templates of geometric objects (e.g., line, box, polygon, sphere, cone, cylinder, torus). Different attributes of these canonical objects can then be dynamically altered. For example, a user might create a cone and then directly resize its height or radius, assign it a different color (material), or reposition and reorient it.

A geometric object or a whole scene can then be scan-converted into their volumetric representation [3]. A volume, representing 3D sampled data or previously scan-converted synthetic objects, can also be read into *edvol* and presented on the screen intermixed with the geometric surfaces.

3. Interaction Paradigms

The user interface to *edvol* has been using direct object manipulation, constraint based interaction and dynamic (smooth) feedback [1]. In order to implement more natural interaction paradigm, *edvol* employes the DataGlove and Kite input devices. The DataGlove is a nylon glove with optical sensors that measure the bending angles of the hand fingers [2, 8]. An electromagnetic 3SPACE Polhemus Isotrak sensor, called a *kite* (or a *bat*), is mounted on the back of the glove. The kite, which can also be utilized separately from the glove [7], provides a six dimensional reading measuring 3D position and orientation. A small subset of the actual paradigms and tools employed is presented below. A more complete set, complemented with a videotape, will be presented in the final paper and the symposium presentation.

The 3D scene presentation and interaction feedback should convey the spatial structure of the work space and the user's position and orientation in it. The work space (called also *world space*) is presented as a 3D rectilinear space in perspective view. This frame consists of all the defined objects and volumetric data. The user's movements are confined to this frame. The *jack* (a 6D cursor) is represented by full three crosshairs or by a small six-leg toy jack enhanced with shadows on the front and/or back walls of the surrounding frame. The jack has six degrees of freedom in order to dynamically feedback the kite position and orientation. The kite status can also be used to position and orient the entire world space or any other object.

To aid in the natural maneuvering in 3D constraint-based steering is supported. A grid (visible or invisible) assists in aligning multiple objects. A user controllable gravity facilitates the selection of a point, and the motion along a surface or a line. Each one of the motion/orientation axes can be frozen in order to allow movement parallel to the main axis/axes. An object can be chosen (or defined) to serve as a basis for constrained transformation.

edvol exploits all the available input devices. The keyboard is utilized for "discrete" operations such as action approval, mode change, speedup of menu selection, and delicate positioning. The mouse is used primarily for menu control, but can also be used as a 3D input device (i.e., as a *triad mouse* [5]) by augmenting it with a 3D mapping function. This is a useful feature as, for example, the triad mouse can rotate the world while the glove position and orientation are used to dynamically drag an object.

The glove, in addition to being a gesture/posture device, is used for pick and valuator input. The user can position the jack (optionally in the shape of a hand) in the neighborhood of an object, perform a grasp gesture[‡], thereby picking the object which becomes the subject of the next operation. The bending of a finger (measured as a combination of both knuckles) is used as a valuator device when scaling for example. Approval and disapproval are expressed by the famous "thumb up" and "thumb down" respectively, which are actually the same posture distinguishable only by the hand orientation. We have also defined a set of postures that are used to specify objects (e.g., straight pinkie finger indicates a line, all lower knuckles at 90° indicates a box, index finger creating a circle with the thumb - indicates a circle, and so on).

Observing that a gesture consists of a sequence of postures, one can implement gesture recognition through the available posture recognition mechanism. We are experimenting with the recognition of gestures such as horizontal movement of flat hand to mean *cancel*, opening of the fingers from a fist posture to a flat hand posture to indicate *create*, and so on.

4. Implementation

The 3D user interface including *edvol* has been implemented in the framework of the Cube workstation [4] on SUN 4-260, Silicon Graphics IRIS 4D and Hewlett Packard 825 Turbo SRX workstations. Cube caters for a variety of applications, including traditional volumetric applications such as medical, biological, geological, and 3D image processing, as well as geometry-based applications such as CAD, animation and simulation, and scientific visualization. Although there is a substantial difference in interacting with geometry-based scenes and sampled images, Cube unifies geometric modeling and volume visualization in the same environment.

‡ We define *posture* as a stationary hand or finger position, and *gesture* as a motion of the hand or fingers [6].

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5. References

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