Multifaceted Interaction with a Virtual Engineering Environment using a Scenegraph-oriented Approach

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ABSTRACT

To provide an adequate user interface to the large amount of geometrical and alphanumerical date coupled to the geometries, the 3D interaction in the virtual environment is combined with 2D interaction techniques using a portable touchscreen computer. Therefore, the consequences are analyzed, when the scenegraph structure of the underlying VR system is applied to the design of the 2D interface to the engineering data. This paper describes methods of using a scenegraph-oriented approach for structured interaction and information display in a virtual engineering application.

Keywords

Virtual Reality, 2D/3D interaction, scenegraph, OpenGL Performer, AVANGO

1. INTRODUCTION

Within the gradual process of maturation of Virtual Environments, the demand on proper interaction techniques supporting a larger, multivariate corpus of functionality rises. Especially within engineering applications, the amount and diversity of functions increases, as so does the amount of different kinds of information to be handled within the system.

In the field of engineering the tasks need to be performed with high precision. Several efforts approach this problem by developing task-specific interaction devices that best match the task at hand [1]. Nevertheless, this generally works only for three-dimensional tasks. Tasks that have a two-dimensional, or even one-dimensional control structure are especially hard to support via a three-dimensional interaction technique.

It can be observed that many of the tasks performed in engineering applications are based on symbolic input, which is predominantly a one-dimensional task. Till now, symbolic input in Virtual Environments is rather unsatisfactory. Ways are required to combine two- and three-dimensional input for the whole application.

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This paper discusses a way of using a scenegraph-oriented approach for handling interaction and external data management with an engineering environment. The interaction on the scenegraph primarily takes place on a webpad coupled to our Virtual Environment system framework, whereas general three-dimensional tasks are being performed using a variety of 3D input devices. The scenegraph approach allows highly structured and precise interaction with the objects in the Virtual Environment, as well as a way of structuring interaction-task processes. Furthermore, it allows the logical coupling of external information to specific objects in the geometrical scene.

2. RELATED WORK

We can subdivide three-dimensional interaction techniques in four groups: navigation, selection, manipulation and system control [2]. The usage of symbolic input methods, partly also referred to as quantification methods [3], is strongly connected to the group of techniques fitting under system control.

System control is normally understood as the group of interaction techniques suitable to perform “menu interaction”, but it actually consists of every kind of action in which a command is issued to either change the mode of interaction or the system state. In order to perform system control, users often make use of menu systems. The same kind of menu systems can be used to perform symbolic input too, for example to manipulate an object.

System control techniques have hardly been investigated and can be seen as open issue in the field of 3D user interfaces. The majority of system control techniques used in Virtual Environments refer to desktop methods optimized for 2D interaction, thereby often being unsuitable for 3D interaction. Previous examples of desktop-like interaction in a Virtual Environment are the *Virtual Tricorder* [4], the three-dimensional widgets developed by [5], *VUI* [18] and *Tweek* [19]. Furthermore, so called non-conventional control methods are generally used for system control [6] [7]. The major problem with current system control methods is that often only rough data input is allowed; fine numerical input is often cumbersome. For example, the usage of sliders to control numerical values has not proven to be suitable. The display of numerical and textual data in Virtual Environments still suffers from bad readability, because here the resolution provided by the display system is not good enough.

Symbolic input can primarily be subdivided in three different kinds of methods. First of all, there is the group of handheld keyboard or keyboard-like devices like the chord-keyboard (for example the Bat One Handed Keyboard by *Infogrip*). The second group is the usage of some kind of gesture, like a glove using sign language [8], or pen-tablet methods like the Virtual Notepad [9]. The third kind of symbolic input is via speech-input.

The usage of a webpad to control certain actions in a Virtual Environment is not uncommon, but foremost focussed at wearable devices like PDA’s. Some examples of using a PDA in a Virtual Environment are [10] [11].

A large number of 3D (and even 2D [16]) modeling and visualization tools are using the scenegraph as the preferred data structure to store scene descriptions. 3D renderers like *Inventor*[15], *Performer* [14], *Java3D* and *OpenSG* [17] use the scenegraph as a data structure for efficient traversal and rendering algorithms.

The use of the 3D scenegraph as a logical structure for a 2D graphical interface to the 3D scene is known from modeling applications like *Maya*, the *OpenSG* GUI and the *aview* environment of the VR framework *AVANGO* [18]. Here the 3D scenegraph is visualized in a 2D tree graph or a hierarchical list to navigate through the renderer’s underlying data.

3. INTERACTION FACTORS

The advantage of using the webpad is the clear display of numerical and textual data, and the visualization of external 2D documents attached to objects in the scene. The webpad is capable of all kinds of 2D interaction, including use of virtual controls (i.e. widgets / GUI elements), menus, keyboard and handwriting.

The screen of the webpad is more spacious when compared to PDAs, which have been integrated into Virtual Environment projects before. More complex data can be visualized (e.g the scenegraph) in addition to menus and other controls. It uses the X-Window System, so multiple open windows with different views on the data are possible. We use this feature to display information concerning the current operation over the scenegraph view in small dialog boxes.

The potential of a sophisticated true-color high-resolution display is definitely bigger than that of a PDA. It only suffers in terms of portability. For this reason, the webpad will reside on a table aside the Responsive Workbench most of the time, e.g. when working with Virtual Environment devices that require both hands or also when using the keyboard.

On the other hand, it should be said that users need to switch their focus regularly between webpad and Responsive Workbench, which can hinder the work-process. The webpad’s TFT display may flicker with polarization glasses in other immersive setups. Naturally it makes no sense to integrate it with head mounted displays.

4. SCENEGRAPH ORIENTED INTERACTION

The application at hand is a networked immersive design review application, in which up to four partners are working on a common data set, from remote locations. The large data sets come from the domains of machine, ship and airplane design.

Performing a task analysis on the networked engineering environment shows a rather straight dispersion of tasks in subgroups. Basically, we can subdivide the applications functionality in manipulation of geometrical objects, the management of object properties (including external data), the control of viewpoints on the scene (including general navigation), the usage of whiteboard-like functionality, and the handling of session management aspects, due to the focus on distribution of data between multiple partners.

Resulting from the task analysis, we can state the following for both the interaction and the information integrated in the application:

- *Complex interaction*: a high level of functionality needs to be supported. Interaction is not specifically focused at one of the basic interaction task groups (navigation, manipulation/selection, and system control), but is rather multifaceted.
- *Integration of 2D and 3D interaction techniques*: the diversity of functionality demands the seamless integration of 2D and 3D interaction techniques.
- *Logical coupling of information*: external object properties (CAD files, annotations or text-files, renderings) need to be logically coupled to the data objects in the scene.

The scenegraph is primarily used by the renderer as an efficient data structure. Its treelike structure is used for logical and spatial grouping of objects and geometry.

The VR system *AVANGO*, which is used for our application, is based on *OpenGL Performer* and inherits its scenegraph concept. Since the internal structure of the data in this system is already present in the form of a scenegraph it is an obvious approach to investigate whether the advantages of this structure for the renderer are applicable to the user of a 2D GUI representation of this structure. To enable the user to work on the scenegraph through a 2D interface, it is necessary to reduce its complexity by making details which are only important for the renderer, like leaf nodes with geometry details, transparent to her/him.

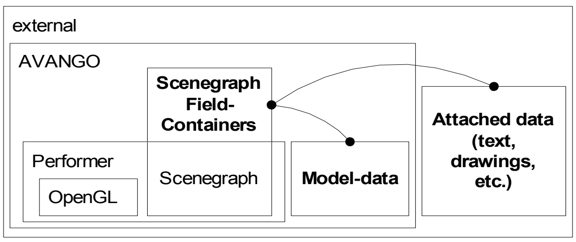

Figure 1: the AVANGO scenegraph nodes link different kinds of data into the scenegraph

This approach focuses at providing the user with clearly structured methods for handling the large amount of functionality, and the logical coupling of information to the actual objects in the scene (see Figure 1).

The large amount of functionality is currently mapped to a multitude of input and output devices that are "coupled" to each other via the scenegraph. This means, that whatever action is undertaken, the scenegraph always integrates and visualizes all activities – the scenegraph is the *integrator* of all actions and information. For example, when a user clicks an object in the Virtual Environment and moves it around, the scenegraph manager will automatically select the object within the scenegraph and make suitable alternations to the specific object node. For the user, this means that he can always have a well-structured, up to date overview of the system state and the currently performed actions, by looking at the visualisation of the scenegraph at the webpad. The other way around, alternations in the scenegraph done at the webpad will have a direct affect on the visualised scene in the Virtual Environment.

The concept of using a webpad for 2D oriented interaction and information, and the Virtual Environment (as being the L-shaped Responsive Workbench display) for 3D oriented interaction and information, theoretically allows a clear separation of tasks. Specific actions can be mapped to certain interaction devices in a plausible way. Currently in use are an adapted stylus with pen-tip (to write directly at the webpad), a Cubic Mouse, and the webpad (*Pacebook* from *Paceblade Technologies*, that can also be run with a keyboard).

Navigation through the environment, rough manipulation and some specific tasks like using a clipping plane are performed in the Virtual Environment. On the other hand, detailed manipulation via symbolic input, and so-called *logical manipulation* (including, grouping and ungrouping, and inserting objects) is predominantly performed via the webpad. Manipulating the scene-graph (deleting, inserting nodes, changing the hierarchy) is a two-dimensional task as well as it is visualization as a tree structure works well in two dimensions. Symbolic input is a one-dimensional task. Therefore these things map very well to the webpad and worse to 3D input- and output-devices. There is no gain here working with the graph-structure in the immersive environment.

Nevertheless, theoretically the larger part of functions can be performed using different kinds of input devices. This allows the user to follow multiple control structures, building up different kinds of action flows. This topic, though, is not handled yet, and is open for further investigation.

5. CONCLUSION AND FUTURE WORK

We analyzed the scenegraph as the central structure containing all data of the virtual environment application. It affects the way of how engineering tasks may be accomplished and also what kind of tasks exist and it adds the possibility of including external non-3D-data in a structured way into the VR application. To use this feature engineers have to be able to view and manipulate this kind of data as well in an efficient manner. The use of the Webpad as interaction device instead of a PDA provides a platform to use all state of the art 2D GUI metaphors within the virtual environment.

In future special software-tools have to be developed supporting the engineering tasks and flow of action. Furthermore the classical GUI metaphors and elements should be reviewed regarding their suitability when working with shutter-glasses and under special light conditions. Also, the GUI output has to be readable form further away than usual. All these specific requirements will have to be considered, when implementing GUI software to control the 2D/3D mixed application.

Also an important topic for further investigation is the actual flow of action in multi-I/O system setups, especially when 2D and 3D interaction is mixed. Even though some initial efforts have been performed, like [12][19], the actual integration of multiple devices has not been of much focus.

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