AN EXPERIMENT IN USING VIRTUAL REALITY TO TEACH COMPOSITIONAL PRINCIPLES TO BEGINNING STUDENTS

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Abstract. This paper introduces an experiment in using educational toys as a means for teaching compositional principles to architectural students using: (1) a traditional model-based approach and (2) “BlocksWorld” a computer-based system that utilizes immersive virtual reality technologies. The paper discusses the general nature of the exercise and its objectives and illustrates some of the resulting student projects. Then it introduces an approach to implementing an interactive virtual design environment that is based on this exercise.

1. Background

The interest in educational toys can be traced to the nineteenth century and in particular to Friedrich Froebel, the pioneer of the kindergarten movement. In 1837, Froebel introduced a set of increasingly complex play objects to which kindergarten students were to be exposed sequentially. Froebel designed these objects to help children recognize and appreciate the common patterns and forms found in nature. He believed that children learn abstract concepts of mathematics and composition by manipulating objects. An interesting part of this set of play blocks was called "building blocks" (see Figure 1). By the 1850s, the term "building blocks" was coming into common use and new variations of the building blocks had become available. The British "New Alphabet Game" included wedge-shaped blocks that could be used to form a roughly circular building. "Crandall's ABC Building Slabs" were made in New York in 1867 and consisted of flat, wooden, 1"x2", card-shaped pieces illustrated with letters, and with dovetails on two edges so that they could be assembled. Shortly thereafter, the idea of standardized, interlocking pieces would lead to full-fledged construction kits. Recently, Resnick (Resnick et. al. 1998) implemented digital versions of such traditional building blocks.

It may be argued that there is a link between playing with compositional toys and learning design. Perhaps it is because the basis of students’ work in architecture is "let's pretend." What students do is real enough, yet the worlds they create are, at least temporarily, imagined. According to Huizinga (1955)
who studied the nature and significance of play as an element of culture, play has three salient characteristics. Play is voluntary; it is not "ordinary" since it involves temporary pretense; it is self-contained; and it is bounded in space, time, or both. He argued that rites and rituals as well as many other aspects of human culture incorporate play characteristics.

Bettelheim (1987) described children's play as an activity "characterized by freedom from all but personally imposed rules... by free-willing fantasy involvement, and by the absence of any goals outside the activity itself." Even though the rules of a game can be given, self-imposed, or some combination thereof, this is a relatively good description of what a designer does.

The Design Exercise

This section briefly describes the nature of the design exercise and illustrates some samples of students' work. Students are asked to design a set of architectonic pieces that capture the salient attributes of the architectural element they represent. The pieces should allow for a variety of formal organizations to be created. In creating these formal organizations, students investigate how spatial relations are created for each piece, and how spatial relations are introduced through the pairing of pieces. This is believed to facilitate the undertaking of two distinct tasks. The first is to attempt to identify the formal and spatial conventions to which students were exposed. The second, and perhaps more important task, is to challenge these formal and spatial conventions by generating and exploring alternative conventions. In addition to designing the pieces, students are asked to demonstrate the use of the pieces in creating a variety of formal organizations.

The exercise allows students to isolate and investigate a variety of possible formal rules of composition and their variations. Students quickly realize that complex compositions can be realized with very simple forms. Moreover, they are able to reflect on the results of their choices. For instance, they start to realize how space is created and interpreted as a result of its bounding elements.
and how the organization of the elements reflects on the quality of the resulting space.

Figure 2. Samples of Formal Organizations from Students’ Projects

Figure 3. Some Formal Investigations in Architectural Composition

However, we feel that there is room for improvement. One of the limitations of this approach is that once the pieces are created they cannot be modified and therefore variations within the same composition cannot be explored (e.g., changing the size of an element). Another limitation concerns an issue that we would like to explore further concerning perception. The blocks like other kinds of model-based projects are always experienced from the outside. Compositional choices are made from viewing directions that are difficult to have in the real project. It would be interesting to see how student’s
compositional choices would be affected if they would be able to experience the environment both in full-scale as well as from the outside.

To overcome some of the limitations inherent in the previously mentioned approach, a new approach is being implemented that uses a virtual reality interface. Rather than carving their prototypical pieces out of wood as it is the case in the previous version of the exercise, students will be able to create digital versions of their models and compose them in full scale. We introduce “BlocksWorld” a practical virtual reality compositional tool that can be used both on low-end non-immersive viewing systems as well as high-end immersive virtual reality interfaces such as the CAVE.

Virtual Reality and VRML

This section explores a virtual reality interface to the previous exercise. Modeling in immersive virtual reality has potential benefits over other approaches. We are particularly interested in the idea that objects are presented to the viewer in full scale. We are interested to see how this will reflect on the kind of environments that students will produce as opposed to environments that can be modeled with traditional means.

The work has been done in the Virtual Reality Modeling Language (VRML), a powerful standard for representing real time interactive three dimensional environments. VRML is supported on many virtual reality interfaces including low-end screen-based interfaces (e.g., CosmoPlayer) or high-end immersive virtual reality viewing hardware such as the CAVE and the BOOM. VRML is an ASCII file format for describing three-dimensional geometry. It provides the mechanisms for representing objects and behavior. The file format includes a special header that designates the file to be a VRML file followed by what is called the scene graph or a list of nodes that represents the geometry of the world and its content. Each VRML node accepts options that are referred to as fields. The fields of a node can contain other nodes or they may contain properties such as color or position.

VRML geometry objects are defined based on a Cartesian coordinate system centered at 0,0,0. Geometry in VRML is defined through a special node called the Shape node. A shape node can contain any kind of geometry including any of the predefined VRML objects (i.e., box, cone, sphere, cylinder), or any set of points, lines, or faces that define complex objects. Transform nodes change the position, orientation, and scale of objects contained within a transformable node. Behavior in VRML is triggered by a set of special nodes called Sensors. Sensor nodes capture the viewer’s movement and actions and sends messages to other nodes. These messages include the time when something happened, the type of the action, the time it stopped etc. For instance, the sensor node TouchSensor
tracks the viewer’s actions and device events. If the viewer clicks on or near geometry, this node sends out messages (events) pertaining to the time of the event, and activates the node to indicate that the event is still active. Events from the sensor nodes can be passed to other kinds of special nodes to trigger specific behaviors.

Behavior can be either predefined or generated in real-time. Predefined behavior is recorded using key-framed animation concepts in interpolator nodes. These nodes define a set of time frames called keys and a set of values for these keys. Values reflect the kind of result returned by a node and are used to interpolate among the various keys. For instance, a PositionInterpolator node would interpolate between a set of positions and it returns a value of type position. This value can then be sent a message (routed) to the position of movable object and thus they move. VRML allows for real time interactivity through scripting languages. The one we used in this work is “JavaScript.”

**BlocksWorld: A VRML Composition System**

This section describes how the system was created and discusses some of the ways in which students can interact with it. The aim of this work was to create an interface that is as transparent as possible to the students so that those who do not understand the syntax of VRML can still use it effectively. The work investigated how geometry (which is what students create) would be separated from interactivity that is provided by BlocksWorld.

In creating the system, we have made extensive use of the concept of prototypes in VRML. Using prototypes we were able to define a variety of objects that encapsulate behavior through scripting and connect to external files that contains the geometry. Students simply provide those files into a predefined location and then run the main module of BlocksWorld to use these files in the editor. Students can create their geometry in any modeling tool that supports a VRML export (in our case it would be FormZ, AutoCAD or 3DS Max). The only limitation is that geometry has to be centered on the point of origin to maintain consistency with the way other VRML primitives are defined. In later stages, the BlocksWorld files will reside on a web server and users would be able to create symbolic links to their local files, which could be in any web location in the world.

The initial interface for the application is a customizable grid module upon which the elements will be placed (Figure 4-left). Students can create instances of any of their pre-defined objects using the elements of the interface (Figure 4-right).
Once instantiated, elements can be manipulated in a variety of ways. Students can modify the size (scale), position, or orientation of elements as well as their appearance properties. The interface is simple yet powerful and all movable objects behave in the same way. This is possible because they are derived from the same element prototype. To differentiate between the various states of an element, we create two versions of each element: a faceted version and a wire frame version. The faceted form of an element is the default and it indicates that the element is not selected for editing. Once selected, an element switches to the wire-frame mode and a set of tools for manipulating the element would appear.
To use some of the possibilities offered in immersive virtual reality, we implemented two modes for editing and positioning objects. In immersive virtual reality, one’s body (avatar) is represented by a position in space and an orientation. The environment is presented to the viewer from that position and orientation in full scale and is updated in real time to reflect the changes in the viewer’s position and orientation. This offers opportunities that are not usually available in traditional modeling tools. In BlocksWorld, the viewer can choose to “glue” his/her position to the position of a selected object. Once this is done, any changes to the element location or orientation will update the location and orientation of the viewer location and thus the viewer appears to be moving with the element (i.e., moving the element). The other mode, or the default, allows one to modify element locations without associating them with the viewer’s location. The first mode is more natural and reflects how one would create the objects if they were made of real material. In this mode, the viewer has to be close to an object to modify it and then step back and look to assess how the change reflect on the overall composition. The other mode, is what traditional modeling tools provide and it is useful for quick changes in the positioning of distant objects.

Other possibilities offered by the system include the exploration of spatial fields, or areas in space that are defined by the positioning of an element in relation to others. The system provides a mechanism for visualizing spatial fields and studying the quality of spaces the result from the positioning of elements (Figure 7).

Some of the limitations of the system, which are also inherent in VRML include the difficulty to select and modify multiple objects at the same time. JavaScript does not allow one to access the elements of the scene graph directly. However, it has full access to any node that is passed to a script node. In our implementation the scripts that move an object are part of the movable object prototype node which contains the two modes of representing an object (i.e., faceted, and wireframe) grouped together under one Transform node. The
movement scripts are activated by associating a TouchSensor with the object, which toggles between the faceted and the wireframe modes, and thus triggers the movement scripts. The workaround is to implement locally all the editing tools belonging to an object part of the prototype of the object. Another related limitation is the deletion of objects. Currently, we can delete objects by switching them off, however, it would be desirable to completely remove them from the scene graph.

Figure 7. Spatial Fields

Conclusion

This paper presented an experiment to looking at virtual reality as a new means to teaching architectural design. We demonstrated an approach to translating an existing model-based approach into an approach that used a virtual reality interface to compose a set of prototypical formal pieces. The future steps for this work is to conduct some experiments that would test this approach against traditional model-based approaches to teaching composition. We are interested in studying how students’ decisions concerning compositional choices may be influenced by their ability to perceive the environments they create in full-scale and interact with it in real time.
References

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