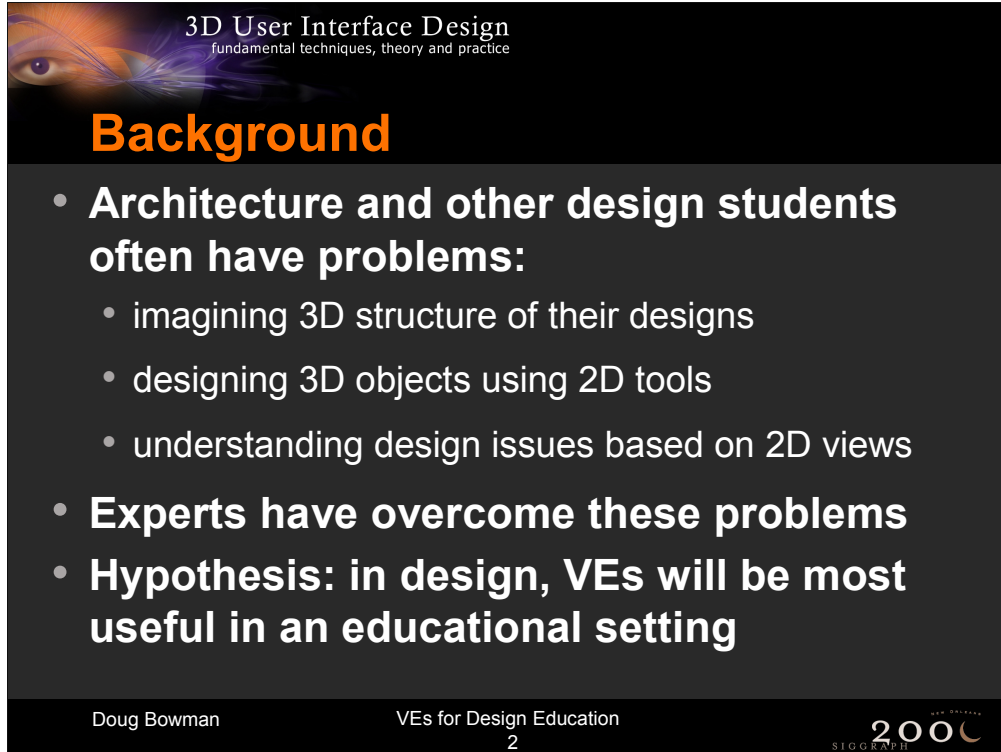


VEs for Design Education

Presented by Doug Bowman

In this lecture we discuss the application of virtual environments to design education. That is, how do we use VEs to teach students about the principles of design and how to design?

A presentation slide with a dark background. At the top left, there is a graphic of a human eye with glowing lines radiating from it. The text '3D User Interface Design' is centered at the top, with the subtitle 'fundamental techniques, theory and practice' below it. The main title 'Background' is in large, bold, orange letters. Below it is a bulleted list of points. At the bottom, there are three footer elements: 'Doug Bowman' on the left, 'VEs for Design Education' and the number '2' in the center, and a '2008 SIGGRAPH' logo on the right.

3D User Interface Design
fundamental techniques, theory and practice

Background

- **Architecture and other design students often have problems:**
 - imagining 3D structure of their designs
 - designing 3D objects using 2D tools
 - understanding design issues based on 2D views
- **Experts have overcome these problems**
- **Hypothesis: in design, VEs will be most useful in an educational setting**

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I worked with faculty members in Georgia Tech's College of Architecture for over 5 years. It is difficult for computer scientists and architects to collaborate because of vocabulary differences and differences in ways of thinking about things. It seems, however, that architecture is one of the application areas that should greatly benefit from VEs, because of its emphasis on perception and understanding of space.

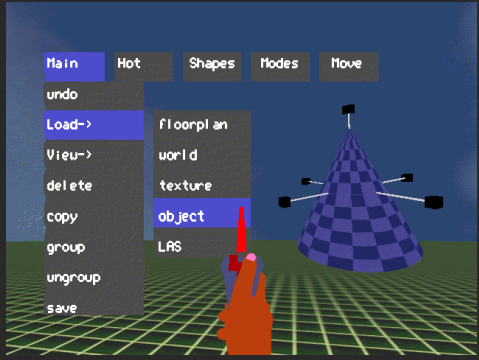
I found in working with these colleagues that it was difficult for architecture and other design students to become comfortable and proficient at the tasks architects have to do because of the tools they have to work with. The main tools are still drafting table, pencil, and paper, although 2D and 3D CAD are becoming more and more prevalent. Students have difficulty envisioning the 3D structure of an object from standard 2D plans and elevations; they have trouble expressing their 3D design ideas using 2D tools; and there are problems with understanding 3D design principles based on static 2D views. Even in 3D CAD programs, most of the work is done in 2D orthogonal views, and the 3D output is limited to static renderings.

By the time architects become professionals, they have generally become proficient at most of these tasks, so we reasoned that the place to introduce VR was in the educational environment.

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Conceptual Design Space

- Create, view, and modify geometric objects from within an immersive VE
- 2.5D, 3D interface elements
- Usability problems
- Design “from scratch”
- No notion of quality of design



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Our first attempt at a VE for design education was the Conceptual Design Space (CDS). This was an ambitious project that aimed to allow students to create, visualize, and modify 3D geometric structures while immersed in a VE using a head-mounted display, trackers, and a button device. Users could start with a blank environment and create primitive shapes and building units, or import CAD models. We learned two lessons from this effort

First, 3D user interfaces are difficult to construct! This tool required a lot of interactive control (like a small CAD package without the benefit of mouse or keyboard). We tried to adapt 2D interface elements (menus, sliders, file choosers, palettes, etc.) to our 3D VE, and also included some direct manipulation of 3D widgets and objects using ray-casting. The system had lots of usability problems which effectively frustrated most of the users. However, this had an indirect benefit as it led me to the study of 3D interaction and interfaces for VEs.

Second, we learned that our approach was probably naïve. Designing from scratch in a 3D environment was not a natural thing for these students to do. Even when they brought in their CAD models, CDS was used mostly for interactive visualization, not design modification. Also, it was just as easy to create a bad design in CDS than a good one. We didn't support good design principles.

CDS references:

1. <http://www.cc.gatech.edu/gvu/virtual/CDS/>
2. Bowman, D. , "Conceptual Design Space - Beyond Walk-through to Immersive Design," in Bertol, D., Designing Digital Space, John Wiley & Sons, New York, 1996.
3. Bowman, D. and Hodges, L., "User Interface Constraints for Immersive Virtual Environment Applications," Graphics, Visualization, and Usability Center Technical Report GIT-GVU-95-26. Available at: <http://www.cc.gatech.edu/gvu/people/Phd/Doug.Bowman/constraints.ps>

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Virtual Habitat



- **New approach**
 - Focus on education
 - Domain-specific design tools
 - Start with existing environment

User tasks

- Learn about existing design
- Modify design based on knowledge

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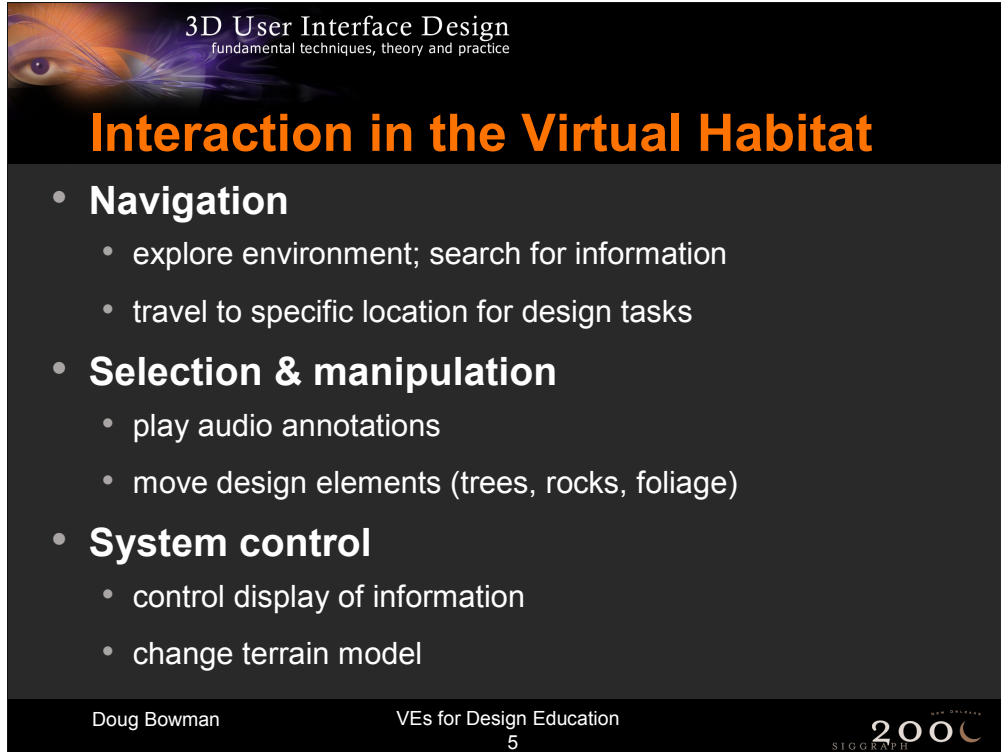
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After some work on 3D interaction, we returned to the problem of immersive design education. This time, we took a new approach.

First, we focused on education and learning, not just providing a tool. This meant supporting good design principles. Second, we decided to focus on a narrow domain, not just 3D design in general. This would allow us to customize the tools for that domain. Finally, we did not give the user a blank slate. Instead, we gave them an existing environment as a starting point.

This environment was the main gorilla habitat at Zoo Atlanta (top image). It was designed by a prominent group of environmental architects using important principles for zoo design. We interviewed the main designer and one of the gorilla experts at the zoo about the major design elements, and incorporated them into the environment as text and audio annotations (see image). The idea was that the student would first view the environment and learn why it was designed in a certain way, thus learning design principles in the context of a real-world example. Then, the student could use this new knowledge to modify the design of the habitat. There's both traditional media-based learning and experiential or constructive learning going on.

A presentation slide with a dark background. At the top left, there is a graphic of a human eye with glowing purple and blue lines radiating from it. The text '3D User Interface Design' is in white, with 'fundamental techniques, theory and practice' in smaller white text below it. The main title 'Interaction in the Virtual Habitat' is in large, bold, orange letters. Below the title is a bulleted list of three main categories: 'Navigation', 'Selection & manipulation', and 'System control', each with its own sub-bullets. At the bottom, there is a footer with 'Doug Bowman' on the left, 'VEs for Design Education' and the number '5' in the center, and a '200' logo with 'SIGGRAPH' and a crescent moon on the right.

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Interaction in the Virtual Habitat

- **Navigation**
 - explore environment; search for information
 - travel to specific location for design tasks
- **Selection & manipulation**
 - play audio annotations
 - move design elements (trees, rocks, foliage)
- **System control**
 - control display of information
 - change terrain model

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This application is fairly complex in terms of interaction. Users had to navigate for the purpose of exploration, as well as task-specific travel. This suggested that we might need multiple travel techniques.



Selection is used to play the audio annotations in the environment, as well as to begin manipulation of the design elements. The selection technique needed to be versatile, long-range (the environment is relatively large), and efficient. Manipulation needed to be expressive, but precision was not overly important since students are only working on design concepts, not precise placement.

System control tasks included turning on and off different types of information in the environment and on a map of the environment, and changing the terrain model. We included eight different terrains so that users could choose a terrain based on their design ideas.

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Interaction Design

- **System control**
 - *Pen & tablet*
 - 2D buttons
- **Travel**
 - Pointing (steering)
 - Map icon (target-based)
- **Selection & Manip.**
 - Go-Go
 - Map icons

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Here are the interaction techniques used in the first version of the virtual habitat.

For system control, we implemented a pen & tablet technique, pictured on the slide, in which the user holds a physical stylus and tablet. In the VE, the user sees a virtual stylus and a map of the habitat along with some interface elements on the tablet. This supports 2D operations such as button presses, icon dragging, etc. Buttons are used to control the display of information and to change the terrain.

For travel, we included two techniques. To support exploration and search, we used a pointing technique, based on the steering metaphor. To support target-based travel, we used a technique in which the user dragged an icon on the map to a new location, and then was taken by the system to that location.

We also used two techniques for selection & manipulation. The Go-Go technique was used to directly select and manipulate objects in the environment, while icons on the map could also be dragged in order to move the corresponding objects in the larger environment.

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Interaction Design (2nd iteration)

<ul style="list-style-type: none"> • System control <ul style="list-style-type: none"> • Pen & tablet • 2D buttons • Travel <ul style="list-style-type: none"> • Pointing (steering) → • Map icon (target-based) • Selection & Manip. <ul style="list-style-type: none"> • Go-Go → • Map icons 	<ul style="list-style-type: none"> • System control <ul style="list-style-type: none"> • Pen & tablet • 2D buttons • Travel <ul style="list-style-type: none"> • Pointing <i>with training</i> • Map icons • Selection & manip. <ul style="list-style-type: none"> • Ray-cast / HOMER • Map icons
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Based on the results of experiments we performed on travel and selection/manipulation techniques, we made modifications to the Virtual Habitat interface. System control techniques remained the same, since we did not evaluate those.

One of our travel experiments (Bowman, Davis, Hodges, & Badre, Maintaining Spatial Orientation during Travel in an Immersive VE, Presence, 1999) showed that users were more likely to understand and keep track of the environment while moving if they used a steering technique *and* used appropriate strategies, such as flying upward to get an overview of the space. We had seen many problems in the first iteration of the Virtual Habitat with users getting lost. So, although the interaction technique itself remained the same, we gave users both written and verbal instructions regarding good strategies for remaining spatially aware.

Our selection and manipulation testbed (Bowman, Johnson, & Hodges, Testbed Evaluation of VE Interaction Techniques VRST, 1999) showed that the Go-Go technique was poor at selecting small objects at great distances, while ray-casting was much more efficient. HOMER is a manipulation technique using ray-casting for selection which is also expressive and efficient, so we used HOMER in the 2nd iteration.

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Usability Evaluation

- **Qualitative; 5-point scale; interviews**
- **Selection: usability rank #1 in 2nd iteration**
- **Pointing: rank 8 (3.71) to rank 2 (4.10)**
- **Direct manip.: rank 9 (3.14) to rank 4 (4.00)**

- **VE great for immediate viz; understanding**
- **All groups created novel designs based on design principles**

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With both versions of the Virtual Habitat, we did a simple qualitative usability evaluation, where users (architecture students in a class on environmental design) ranked the different features of the system on a 5-point scale of usability. We also interviewed the students to get their impressions of the tool and its usefulness in the domain of design.

The move from Go-Go to ray-casting for selection was clearly a big win. This was ranked the most usable feature in the 2nd iteration of the tool. The use of pointing as a travel technique, although unchanged in terms of actual interaction, moved from the 8th most usable to the 2nd most usable simply on the basis of the enhanced training given users. Direct manipulation of objects using HOMER moved from 9th to 4th, mostly because of more efficient selection. The complete results are given on the next page. The numbers in circles are the rankings, and starred features are the ones that changed between design iterations.

Usability Categories	Final iteration	Intermediate iteration
selecting annotations *	4.70	N/A
changing terrain	① 4.20	4.21 ②
user movement with stylus *	② 4.10	3.71 ⑧
tablet: dragging user icon to move *	② 4.10	4.21 ②
direct object manipulation *	④ 4.00	3.14 ⑨
tablet: object creation	④ 4.00	4.43 ①
moving viewpoints	⑥ 3.55	4.20 ④
tablet: object manipulation	⑦ 3.50	3.86 ⑥
moving viewpoint barriers *	⑧ 3.40	4.10 ⑤
tablet: general interaction	⑨ 2.90	3.86 ⑥

In asking about the utility of this tool for design, most students remarked that the VE was much better than CAD tools for get a first-person point of view into the scene, an understanding of the 3D space, and an immediate visualization of the results of a change.

Also, since students were using the tool in the context of a class project, they were actually creating alternate designs for the habitat. All of the groups were able to do this successfully, and their designs were based on the knowledge they gained about environmental design principles from the class and the information embedded within the Virtual Habitat.



This is an example of student work using the Virtual Habitat's design tools. The left image shows a view from one of the visitor viewpoints (where zoo visitors stand to look at the animals) as it exists in the real world. The right image is a view from the same location after modification by a group of students. Notice that they have raised the terrain so the animals are more prominent, added a rock and moved trees to add visual interest, and occluded the building with foliage so the focus is on the animals, not other people.

Virtual Habitat references:

http://www.cs.vt.edu/~bowman/gorilla_design.html

Bowman, Wineman, Hodges, and Allison, Designing Animal Habitats within an Immersive VE. IEEE Computer Graphics & Applications, 10(1), 1999.

Bowman, Wineman, Hodges, and Allison, The Educational Value of an Information-Rich Virtual Environment, Presence, 8(3), 1999.