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1. Introduction

Three-dimensional models allow students to step away from the two-dimensional character of conventional diagrams, and start visualizing scientific phenomena as they might appear in the “real world.” Furthermore, if the three-dimensional model could be made interactive, students could explore the model from any perspective in 3-d space, creating the basis for a Virtual Reality Learning Environment. The scientific research community already has 3-d visualization tools at their disposal, such as CAVE¹, ImmersaDesk², or Vis5d³, but these tools would not be deployed in a classroom setting due to their high cost, and high complexity. In addition, these complex tools cannot be operated from the Internet.

With rapid improvements in desktop computers, and the increased use of the Internet, new inexpensive multimedia technologies for three-dimensional visualization have been developed. One such technology is Virtual Reality Modeling Language (VRML). VRML runs on a desktop computer, and can be operated from the Internet. We have utilized VRML to make a Virtual Reality Learning Tool (VRLT) for scientific data. This tool could be used in a constructivist setting, where students could learn the material through “hands-on” exploration rather than just passively viewing slides or videos.

2. What is VRML?

VRML is a scripting language developed by

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^{1,2} <http://www.ncsa.uiuc.edu/Vis/Facilities/>

³ <http://hpux.cict.fr/hppd/hpux/Maths/Misc/vis5d-4.3/>

Silicon Graphics, Inc. which allows a programmer to render three-dimensional scenes in a Web browser. A scene includes the model and the three-dimensional space where the model resides. With the use of a freeware browser plug-in, such as Cosmo Player⁴, a VRML scene can be viewed via the Internet, CD-ROM, hard disk, or floppy disk. When a user accesses a VRML file through a Web browser, the plug-in automatically launches, giving the user interactive control over the three-dimensional VRML scene through the use of a mouse or keyboard commands. The scenes load and render quickly, even those that are downloaded from the Internet, and the interactive controls are simple to operate. With these controls, the user can move the model on any axis, allowing the model to be viewed from all angles, or “fly

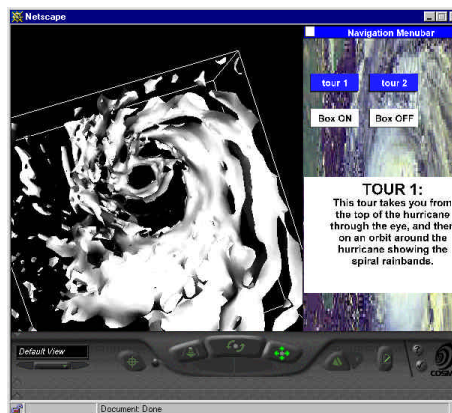


Figure 1: An example of the VRLT displaying a “virtual tour” of Hurricane Opal.

through” the model as if he or she were “in” the model itself. Although the rendering quality of VRML may be somewhat less than that of the expensive software packages, for most desktop computers, VRML can produce high-quality renderings of phenomena such as thunderstorms and hurricanes, showing cloud structure, vertical or horizontal cross sections, wind flow, temperature, rainwater, pressure, or any

⁴ <http://cosmosoftware.com>

other applicable variable. VRML allows for 3-d model visualizations to be readily accessed in homes and schools from just a desktop computer with a Web browser.

The latest specification of VRML is VRML97 (ISO/IEC 14772), which we used in our Virtual Reality Learning Tool. VRML97 contains many interactive features such as animation, touch sensing and proximity sensing. Virtually any parameter within a VRML97 scene can be altered by the user by including separate functions within the VRML script to recognize when a user has interacted with the scene.

3. Why Virtual Reality?

With the interactive capabilities of VRML, the student becomes an active participant in the material he or she is viewing. Multimedia presentations in the classroom are nothing new—but until now, these presentations consisted of videos, transparencies and slide shows—all passive learning tools, where the student would simply watch what is presented, and ask questions later. In the Virtual Reality Learning Environment, the student can navigate through a “virtual world,” as if he or she were flying, walking, or hovering through the scene. A student can see the scene from all angles and distances, and can choose a destination or trajectory at will. Using a three-dimensional movable scene, the question “what is behind the diagram?” will no longer need to be asked. Students are likely to be more intrigued by the subject of the scene if they can interact and “travel” through the scene. This is a clear advantage to students who learn better with the “hands-on” learning style.

The user can also “peel away” areas of the model to see obscured areas using the interactive controls within the scene. This automatically takes the place of several immovable diagrams, which only display visualization from one perspective. It is the unlimited control over perspective, which can allow a thoroughly three-dimensional virtual reality view of a scientific phenomenon. This paves the way for a stand-alone virtual reality tool which contains the scene, interactive controls, and textual explanations of the scene. This would allow

the student to visualize a scientific phenomena (in the form of a numerical model simulation) at his or her own pace.

The real value in using VRML and virtual reality for learning is not simply the fact that a student may liken the VRML controls to a video game. Otherwise, the Virtual Reality Learning Tool may be considered merely a toy. The value comes in when the VRML scene is linked to activities relating to that scene.

The instructor may give out assignments asking students to identify key features within a VRML scene, and through a series of questions or activities, ask students to relate what they have explored to the lecture or textbook material. Interactive controls may be provided within the VRML scene to guide the student to key features through a particular trajectory. Also, destinations to all the major features may be pre-programmed within the controls so students can see these features close-up, far away, above, below, or from any angle. The student could then do their own exploration of that feature in order to answer the questions provided.

4. The Audience

The Virtual Reality Learning Environment may be beneficial to all grade levels--grade school through graduate school. The variable would certainly be the difficulty and detail of the activities relating to the virtual reality VRML scene.

In addition, scientists may find the virtual reality environment of VRML to be a quick, and effective way to visualize numerical model data on the desktop, or over the Internet.

5. The Virtual Reality Learning Tool

Using VRML97, we have developed a Virtual Reality Learning Tool (VRLT) prototype in order to visualize scientific data over the Internet or from disk, on desktop computers. The prototype makes use of a numerical model simulation of Hurricane Opal. The data comes from the MM-5 model

at 5km resolution, inner grid⁵. For details of the MM5 simulation of Hurricane Opal, see Ramamurthy & Jewett (1999). The data was fed into vtk⁶ Software programs and converted to VRML2.0 (VRML2.0 was the previous version to VRML97). The VRML2.0 files in ASCII format were edited to include the interactive controls such as the "tour" feature. Many of the edits to the files used the VRML97 Standard, and thus the VRML files became VRML97 files. These files were reduced in size by compression (gz) and other methods. The files were then displayed using the freeware Cosmo Player¹ plug-in and the Netscape 4.0 browser on an IBM PC Compatible running Windows 95 or NT.

Figure 1 shows an example of the VRLT prototype in action. The variable displayed is rainwater with an isosurface value of 0.01g/kg. The time of the simulation is 84 hours, just before the hurricane made landfall. The VRML scenes are produced by surface rendering, which means that each isosurface is hollow, and additional isosurfaces would have to be included in the scene to produce more of a volume rendering, or more "real" interpretation of the object in the scene. This can be accomplished, but the more isosurfaces that are added, the larger the VRML file, and the slower the download and render time. Therefore, the VRLT prototype uses the fewest isosurfaces possible to convey the general structure of the features being rendered. Figure 1 also displays the "tour" feature, where clicking on one of the "tour" buttons in the navigation menubar on the right of the window will take the user on a virtual tour of the Opal simulation. A pop-up box describes the tour trajectory. Also, other controls may be included in the navigation menubar to display cross sections or other variables (Figure 1 has "box on", "box off" controls). The navigation menubar can be minimized to broaden the field of view. In addition, the VRLT prototype has pre-programmed destinations within the Cosmo Player controls. The mouse can control the Cosmo Player controls for further

navigation using the self-described buttons below the scene. The file size of this particular scene in Figure 1 is 390 kilobytes.

6. Adaptability

At the time of this article, the VRLT prototype ran best using Cosmo Player in Netscape 4.0 in a Windows environment. There is currently a version of Cosmo Player designed for Macintosh, but it has not yet been thoroughly tested with the VRLT prototype.

7. Future Work

Advanced Multimedia Educational Websites:

These would be a new generation of scientific educational modules which would include VRML, streaming video and animations. Key frames of the streaming video of an actual weather phenomenon, such as a hurricane, would be hyperlinked to VRML simulations (using the VRLT) of the phenomenon for a virtual reality study. Textual information would supplement the VRML and streaming video content. The VRML scene itself could contain hyperlinks to pages describing the content of the scene in more detail using text and diagrams.

Additional interactive controls utilizing Java or JavaScript could be added to retrieve numerical data from the VRML scene as it is being explored. This would allow a student to see, for instance, how the temperature changes through a hurricane as if the student were "holding a thermometer" while "flying" through the scene.

Use in the Classroom: The virtual reality learning environment would be introduced into Atmospheric Science survey courses at the University of Illinois to supplement the traditional multimedia presentations. The effectiveness of the virtual reality tools could be observed first-hand, and improvements or additions to the tools could be implemented.

Activities could be designed to explore the structure of an atmospheric phenomenon such as a hurricane. Students could be asked to comment on the eyewall structure, spiral rainbands, airflow, and thermal structure, and then relate what they see in

⁵ provided by Crystal Shaw, Brian Jewett, NCSA, Urbana, IL 61801

⁶ <http://www.kitware.com>

the VRLT to what is presented in lecture. The real difference between 2-d and 3-d would clearly become evident.

8. Additional Information

Additional information on VRML97 can be found at the Website:

<http://vrml.miningco.com>

The vtk Software Website:

<http://www.kitware.com>

9. Acknowledgements

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