VIRTUAL REALITY ENVIRONMENTS AND AUTHORING TOOL FOR WEB BASED TRAINING AND EDUCATION

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Abstract – Text and 2D drawings, sketches, graphs and figures have been the traditional tools to support training and education in many areas. With the improvement of technology, new approaches are emerging such as Virtual Reality Environment. Virtual Reality Environments have become increasingly popular in the past few years. Virtual Reality Environments have been used successfully for many applications such as flight simulations, medical training, scientific simulations, education and many more. More recently, however, Virtual Reality Environments have made a significant impact on the Internet. People are able to not only create virtual worlds, but to place them over the World Wide Web so that others may view them and even interact with them within their Internet browser. This paper provides a quick overview of one of the current technologies available to develop Virtual Reality Environments accessible through the Internet. This paper provides the most common features that a virtual reality modeling language offers the user and how these features can be utilized in the creation of a web training and educational tool. It is anticipated that this paper will help the advancement of scholarship in engineering education by providing a foundation for a variety of teaching tools using this or similar technologies.

INTRODUCTION

Virtual reality has made a huge impact in the past few years and like most technologies, it continues to advance at a rapid rate. Virtual reality was born many decades ago with the idea that perhaps computers could be used for more than just number crunching. This idea belonged to an electrical engineer and former naval radar technician named Douglas Engelbart. He believed that computers could also be used for digital display. Soon many others began to think the same way, and soon the first visual radar defense system was invented. Afterwards, other virtual reality technologies surfaced throughout the years such as flight simulations, computer-generated special effects for films, and video games, but these were primitive. Everyone demanded interactivity, and thus computer visualization was pushed to the limits until virtual reality environments were invented. This paper provides a brief history of this technology known as virtual reality environments. This paper also discusses VRML or virtual reality modeling language, which is a language similar to HTML that can be used to create Web-based virtual environments. This paper also provides an overview of a VRML authoring toolkit known as VizX3D that one can use to create a VRML world for use on the Internet.

VIRTUAL REALITY

Virtual reality (VR) has been difficult to define through the years. The term virtual reality was coined by Jason Lanier; he describes virtual reality as an immersive, interactive simulation of realistic or imaginary environments (Brady & O'Sullivan, 1999). John C. Briggs (2002) believes that "VR is best defined as a computer-generated 3-D experience in which a user can navigate around, interact with, and be immersed in another environment or world in real time, or 'at the speed of life'." There are others who believe that one can experience virtual reality by simply

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watching a movie, reading a book, or just using the imagination and many believe that virtual reality is something that can only be experienced through the use of expensive technical equipment such as Head Mounted Displays (HMD), Glove Input Devices, and large immersive systems such as a multi wall immersive ICUBE display. Although these are fine definitions for virtual reality, R.S. Kalawsky (1996) states that "the definition of a VR system lies with a description of what the system enables one to do rather than basing the definition on a technology based description." Kalawsky (1996) also believes that the term 'VR' should be taken in a broader context; doing so allows a participant to:

- Become immersed in a completely synthetic computer generated environment.
- Achieve a sense of presence in the environment.
- Become un-inhibited where conventional laws of physics can be controlled in a way that assists greater understanding.
- Achieve a sense of non-real time; where situations can be presented in slow or fast time.
- Achieve a high degree of interaction that can equal or exceed that achievable in the real world.
- Interact in a completely natural and intuitive manner with the synthetic environment.
- Repeat the task until the desired level of proficiency or skill has been achieved.
- Perform in a safe environment

To simplify the virtual reality system, Kalawsky (1996) also designed a model for what he called a "Generic Model of a Virtual Environment System" (Shown in Figure 1).

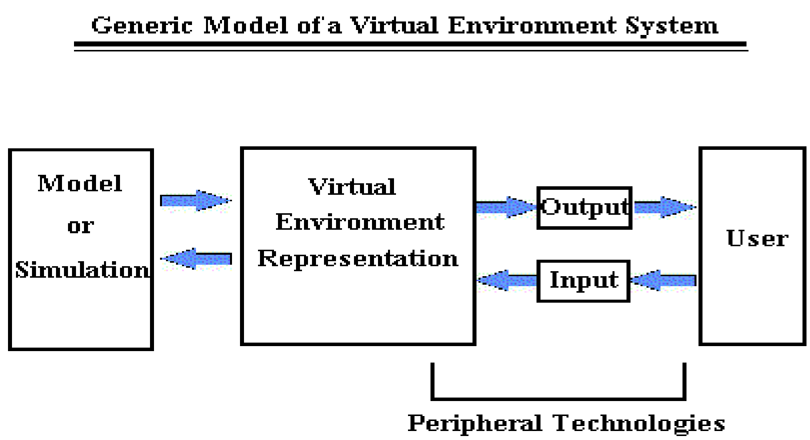

Figure 1. Kawalsky's Generic Model of a Virtual Environment System

Brady and O'Sullivan (1999) explain Kawalsky's model by stating that "when a person interacts with a Virtual Environment (VE), they become engaged in a closed loop. The user interacts with the VE representation, which in turn is based on a model. The effects of this interaction are fed back to the user through the modification of the model based on the user's input and so the cycle begins again."

VRML

VRML, also known as Virtual Reality Modeling Language or vermal, is becoming very popular as a new standard in the development for 3D on the Web. According to Scintillating Graphics (2003), VRML "is the international standard for "Virtual Reality" - 3D content on the internet/web." According to the Web3D Consortium website, VRML is a scene description language, similar to HTML, which allows someone to integrate 3D graphics and multimedia and produce a viewable 3D world on the Internet. Although VRML is an acronym for Virtual Reality Modeling Language, it is not considered by some to be virtual reality or a modeling language. There are four ways to describe VRML according to Rikk Carey and Gavin Bell, authors of The Annotated VRML 2.0 Reference Manual. The first is that it is a 3D interchange format that defines the semantics used in 3D applications such as geometry, light sources, viewpoints, texture mapping, and animation (1997). A second way to describe VRML is as “a 3D analog to HTML” or Hypertext Markup Language, meaning that VRML serves as a language similar to HTML but produces 3D Web pages (Carey & Bell, 1997). Brian Hay of Virtual Realms (2005) states that “VRML is the only standardized 3D format suitable for Web delivery (due to its generally small file size). It is versatile, compact, extensible and constantly evolving - theoretically there is no limit to what can be achieved with VRML given sufficient computing power.” This makes VRML a very useful tool because many Web applications such as games or educational visualizations are better represented and experienced through 3D, something that basic or HTML Web pages are incapable of doing. A third description of VRML is that it provides the ability to integrate three dimensions, two dimensions, text, and multimedia into a coherent model. It is possible not only to broaden the users experience with the classic 2D model, but it can be extended into 3D, and because of this it is believed that 3D will replace the 2D model as the primary user interface in the near future. However, according to Carey and Bell, many challenges will need to be overcome “such as 3D user interface and navigation, user training, and ubiquitous 3D graphics performance” before this can take place. And yet a fourth answer provided by Carey and Bell which is the most publicized and debatable is that “VRML is the foundation for cyberspace and the on-line virtual communities that were painted and popularized by science fiction writers William Gibson in Neuromancer and Neal Stephenson in Snow Crash” (1997). VRML has not completely caught on and taken over, but it is feasible this could happen since there are many working, multi-user systems implemented using VRML.

FEATURES OF VRML

There are many features of VRML, but some of the basics include navigation, viewpoints, models, materials, textures, lighting, special nodes (background and fog), collisions, and animations. There are many options when it comes to navigating through a VRML environment. These options include walk, fly, and examine or study. Turn and pan are also options in navigation but are sub-options of walk, fly, and examine or study. Please refer to Figure 2 below that shows a VRML world opened within an Internet browser.

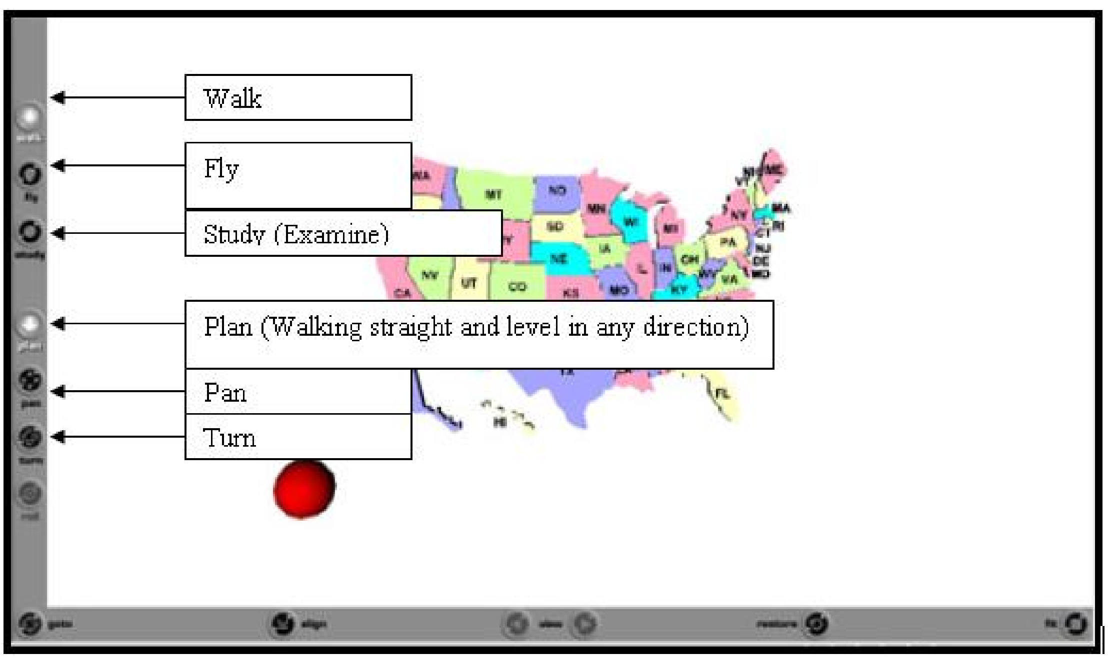

Figure 2. VRML environment opened in an Internet Browser.

When walking through a VRML world, the user is able to walk around at a pre-defined ground level inside the environment. The user is able to turn the first person view to the left, right, up, or down, and they are able to pan, which means to move left or right without changing the current view. When using fly mode, the user is able to fly around the virtual reality environment in every direction. This means the user can walk to an object and, instead of walking around it, can go into fly mode and take to the virtual air above the object and land on the other side. The turn and pan options are also available in fly mode. When the user is in the examine or study mode, he or she is able to view every object in the VRML world as if they were holding it in their hands and rotating the entire world in different directions.

Viewpoints are another important part of VRML. Viewpoints in a VRML environment are camera positions that are pre-defined by the creator of the VRML world. The creator can place as many viewpoints in a world that is necessary and give each a description. Viewpoints can be used in many different ways. One way to use viewpoints is by placing them around a certain object so that the user can see the object from different angles. Another way is to place viewpoints in different rooms of a building created by VRML so that the user is able to jump very quickly from one room to another without having to navigate through the entire building to find a specific room. Viewpoints are also very useful in large VRML environments because they act as transporters for the user. The user is able to travel a long way to get to a certain area of the world without having to walk the entire distance.

Models are one of the most important features of VRML because they are the basis for creating an object. There are primitive shapes available in VRML: box, sphere, cone, and cylinder (Shown in Figure 3).

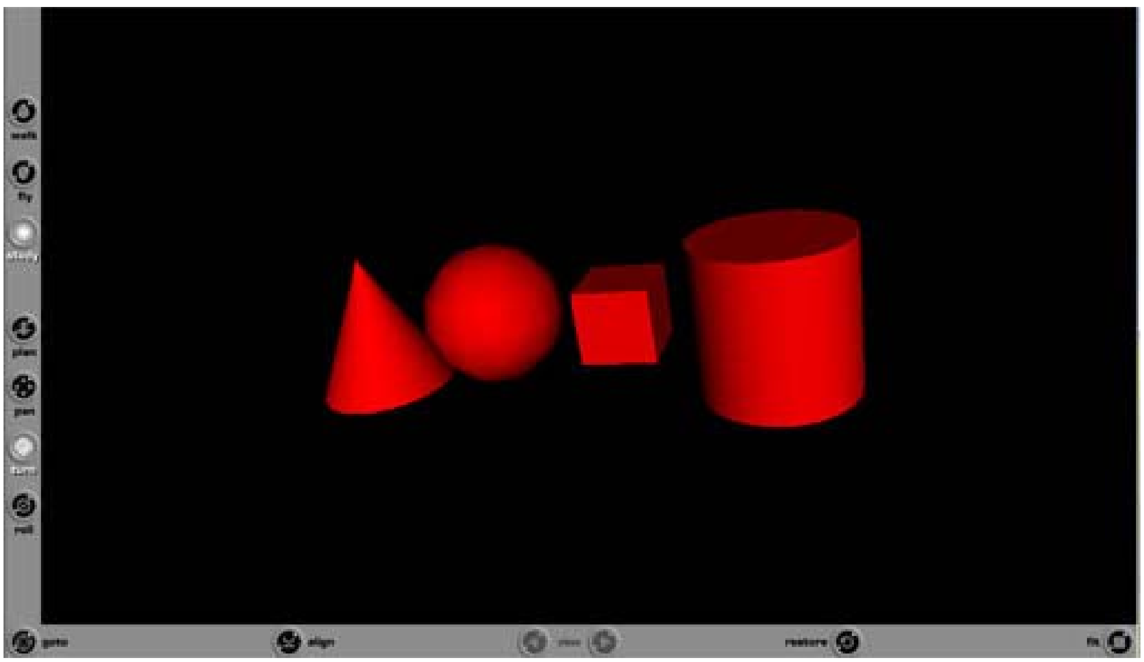

Figure 3. VRML primitive shapes: cone, sphere, box, and cylinder.

There are also other shapes that can be used in creating a VRML object such as indexed line set, indexed face set, extrusions, elevation grid, and text. An indexed line set consists of a set of polylines that are defined by inputting coordinates. An indexed face set is similar to an indexed line set except instead of polylines, a set of planar faces are defined by inputting coordinates. An extrusion is very similar to an indexed face set. Since complex shapes are hard to define by inputting coordinates, an extrusion allows the creator to create complex shapes by inputting only a few points. The most important variables when defining an extrusion are the cross section and the spine. A cross section is the 2D shape that is defined in the XZ plane such as a square to make a cube. The spine is the Y plane or the direction in which the cross section will travel when Y is defined. An elevation grid is defined with specific points and height. It is built in the XZ plane and expands from an origin to the positive axes and is very useful if someone is trying to build a terrain (Fernandes, 2005). Text is another useful VRML model. Using text in VRML makes it possible to display strings and the following fields can be defined: string, font style, length, and max length. The string field is used to define what is to be written in 3D text in VRML. The font style field is used to define which font the string should be written in and length and max length specifies the length of the string in VRML units and scales it up or down when necessary (Fernandes, 2005).

Material is another feature of VRML. Material includes the color of an object, the amount of light reflected off the object, and the transparency of the object. There are six fields that can be defined when using materials: diffuse color, emissive color, ambient intensity, specular color, shininess, and transparency. Diffuse color is the color of the object and emissive color is used to define glowing objects (Fernandes, 2005). Ambient intensity specifies the amount of light reflected off the object, specular color defines the color of the shiny spots on the object, shininess controls the intensity of the glowing spots on the object, and transparency determines whether the object is completely opaque, transparent, or semi-transparent (Fernandes, 2005). A point about the diffuse color field is that it is ignored when a texture is applied to the object.

Textures can bring realism to your objects in the VRML world. Inside of the VRML world, the creator can apply an image such as a JPEG or a GIF to an object and it will become visible on each face of the object. The image can also be translated or moved, rotated, and even scaled to produce a desired look. Another useful feature of the textures in VRML is that a movie can be applied to an object such as a 3D television screen object to produce a realistic effect.

Another important feature to a VRML environment is lighting. There are three types of light sources that can be used in VRML: point, directional, and spot. A point light is very similar to sun light. When it is placed inside the world, light goes in all directions from the source. Point lights have a radius that can be adjusted and every object within the radius is enlightened. There are other fields besides the radius that can be defined. A Boolean field can be turned on or off which toggles the light on and off. Intensity determines the strength of the light while ambient intensity determines how much light is contributed to the overall lighting (Fernandes, 2005). Color can be specified as well as location which is the lights position in the environment. Attenuation is another attribute that determines “how the light looses its intensity as distance from the light source increases” (Fernandes, 2005). Directional light is completely different from point light in that location does not affect the source. This type of lighting relies on the direction in which the light is pointed and the rays are parallel to the direction. It is also important that objects needing to be lit be placed within the same group as the directional light or the object will be ignored by the emitted light rays. Other than direction, the other attributes that can be specified are similar to point light including the intensity, ambient intensity, color, and an on/off switch. Spot lights are very similar to flash lights and have more attributes than directional and point lights. It can be best described as a cone of light with the following attributes: Boolean on/off switch, intensity, ambient intensity, color, location, direction, attenuation, radius, cut off angle, and beam width. The cut off angle field specifies the angle of the cone where light can not be emitted and is constrained. The beam width is the inner cone below the cut off angle cone where the light rays have a uniform intensity (Fernandes, 2005).

There are special nodes available in VRML that can add realism to the world one has created. These nodes are known as background and fog. A background node provides a background in two ways: gradient colors or textures. When using the gradient colors option to add a background, the creator chooses a color for the sky and the ground. The other choice is using realistic textures and applying them to an infinitely large six-sided cube also known as a Sky Box. The six sides are up, down, north, east, west, and south. For example, you could apply a realistic texture of the sky for the up direction of the Sky Box, a texture of ground for the down direction, and textures of the horizon from the north, east, west, and south directions. When the user views the world, he or she will experience a seamless horizon that surrounds them. Also the background node can not be reached by the user inside the world because it is infinite (Shown in Figure 4).

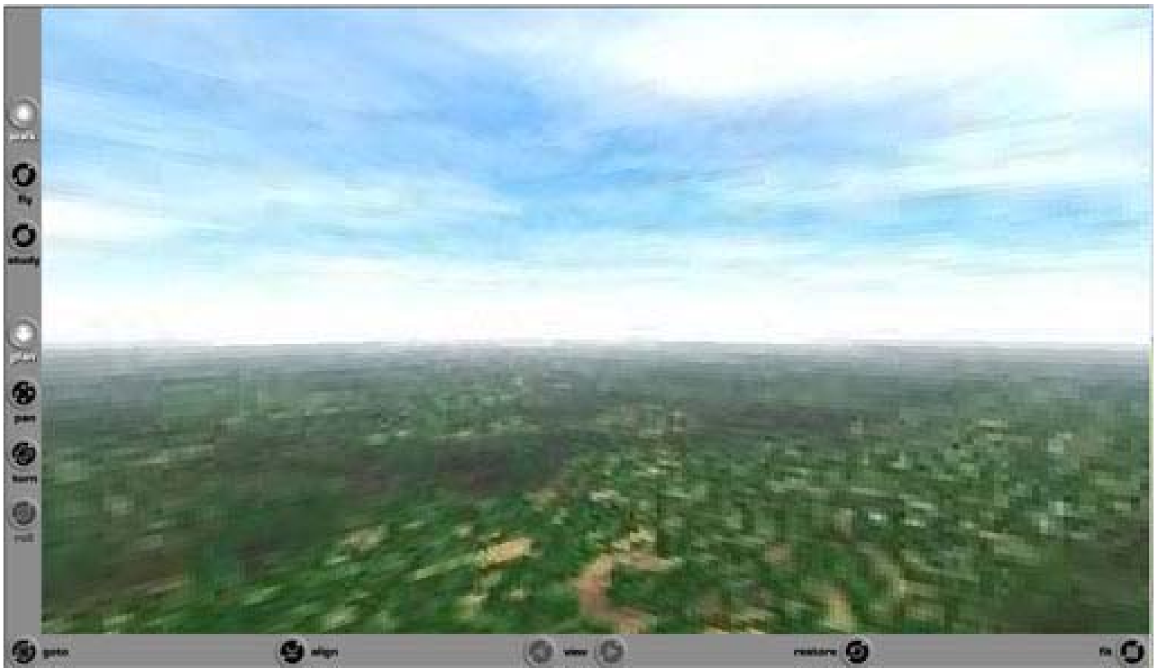

Figure 4. VRML infinite horizon created by applying textures to the skybox.

The fog node is used simply to add a realistic fog or mist to the VRML environment. The attributes of the fog node are the color, fog type, and visibility range. The color specifies the fog color and the visibility range determines how far the user can see an object in the fog. Once the object is past the range, it becomes the color of the fog. The fog type can have two values: linear and exponential. Linear fog affects depth perception by becoming more linear with distance while exponential makes the fog look more natural.

Collision is very important in making a VRML world more realistic. The idea is basically to keep a person from walking through other objects in the world such as walls. The creator can specify the distance from an object a user can get before he or she is stopped. It is also possible to add a sound to a certain object and, when the user collides into it, an event is triggered which plays the sound.

One great thing about VRML is that every object can be animated. The creator is able to animate the translation or movement, rotation, scale, and even color of an object inside VRML. Objects can be animated along a certain path defined by the creator as well. Even the viewpoints in VRML can be animated along a path. For example, if a creator wants the user to ride along in a canoe in the VRML world with only the ability to look around and not leave the canoe, he or she can animate the camera. The way this is done is that the creator will group the camera and the canoe object together. Once they are grouped, then he or she must animate the group along a path. Also the creator will have to turn off the walking option of navigation so the user is not able to leave the canoe. Once this is complete, the user will appear to ride in a canoe down a defined path and only be able to look around and not walk around. The sky is the limit when it comes to what VRML can produce. These are just some of the basic features, but using only these features, one can create an amazing VRML world.

VRML was designed to fit into the infrastructure of the World Wide Web, and many are taking advantage; the number of VRML worlds on the Internet is “mind boggling” (Whitehouse, 2004). VRML is a kind of hub that can bring together other types of multimedia to create one thing. VRML makes use of images, sound, and even video. Images such as JPEG, GIF, and PNG are used and can be applied to any object in VRML. A person can build a terrain object and apply an image of sand to give the illusion of a vast desert or a person can create something as simple as a sphere and apply a baseball image to the object to make a 3D model of a baseball. Sound can be utilized in a VRML world such as background music or a sound that occurs when a user collides with an object, gets within close proximity of an object, or even clicks the object with the mouse. Applying an AVI movie to an object in

VRML really increases the entertainment value for a user. One could create a virtual reality movie theater in VRML, apply a movie to a screen object, and the user can view a film in a 3D theater.

The main point to keep in mind is that the virtual reality training simulation tool is a 3D semi-immersive VR world that allows a user to easily navigate through the environment, view their surroundings in 3D, interact with specific 3D objects within the VR environment, and receive a score once the exercise is completed. VRML is the wisest choice to accomplish this because it allows the use of 3D and 2D graphics (such as textures), animation, user interaction, navigation, user-defined objects, and scripting. By using VRML, this tool can also be accessible through the World Wide Web if so desired, which makes it easily available to anyone with Internet access.

VIZX3D SOFTWARE OVERVIEW

The program that specifically meets the needs of the VR training simulation tool is known as VizX3D. VizX3D is a new and powerful 3D authoring tool that uses a familiar Windows GUI framework and allows the user to import their own VRML code, export interactive 3D scenes as VRML and X3D, and much more. Below in Figure 5 is a screenshot of the VizX3D interface that shows the four different user-defined points of views, three of the basic geometric shapes provided by the program, and a window to the right of the view windows that show the author which objects are currently in the scene.

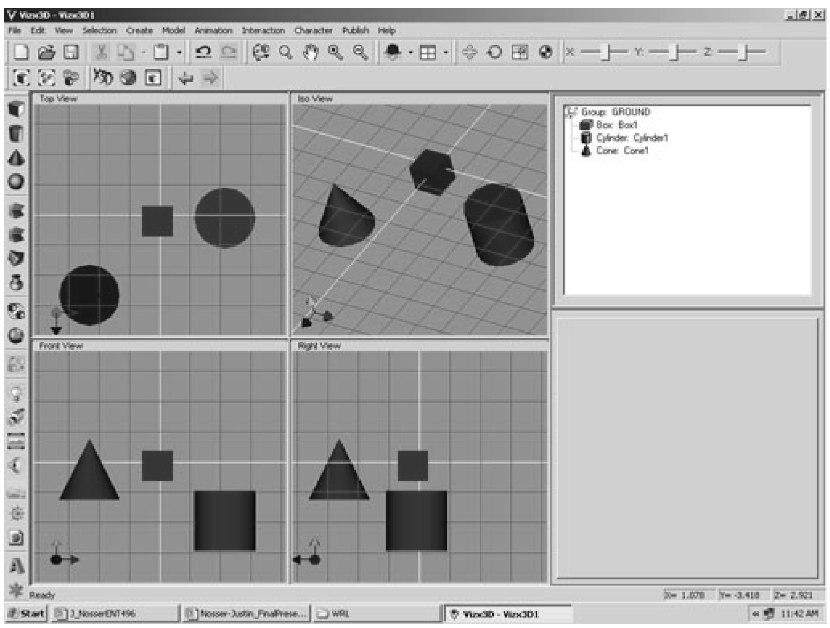

Figure 5. Screenshot of VizX3D.

According to Tony Parisi, co-creator of VRML, "Vizx3D represents a significant step forward in 3D content creation for the web. It has a simple, straightforward interface that can be used by professionals and non-professionals alike, yet also a very powerful set of features. Vizx3D raises the bar for 3D authoring while lowering the barrier to entry" (Cover Pages, 2003). According to the VizX3D website (2003), VizX3D also provides a unique trigger system that allows users to create interaction logic by selecting Nodes, and selecting phrases to complete sentences to describe the desired behavior. Below is a figure from the VizX3D website (2003) that lists many of the features of VizX3D:

Import and Export:
Exports interactive 3D scenes as VRML and X3D.
Exports non-interactive AVI and animated GIF files.
Exports static snapshots as JPG, GIF, BMP, and PovRay.
Imports and Exports many different 3D formats using the integrated Accutrans translator.

Animation and Interactivity:
Animation Editor with sliding Timeline.
The Animations are controlled by the Vizx3D Trigger System.
Cut and Paste Animation Keyframes.
Touch Sensors, Visibility Sensors, Proximity Sensors.
All Sensors and Animations can Trigger other events using the Vizx3D Trigger System.

Mesh Editor:
Includes powerful Tools that let you sculpt your shapes.
Texture Coordinate Generation Tools.
Sphere of Influence Tool.
Mirror Utility
Subdivided Surface support integrated into the Mesh Editor.
NURBS Surface support, with a NURBS Surface Editor.
Boolean Operations, including Extraction, Intersection, and Union.

MultiTexture Support:
MultiTexture Creation Wizard.
Bump Map Texture generation Wizard.
Environment Map generation Wizard.
Simplified and Advanced MultiTexture GUI.

Geometry:
Four Basic Geometric Primitives: Box, Cone, Cylinder, and Sphere.
Four Flavors of Extrusion Nodes:
Simple Cookie Cutter Extrusion.
Swept Surface; A single cross section transformed at each Spine Vertebra.
Sculpted Surface; Different cross sections transformed at each Spine Vertebra.
Surface of Revolution.
Extrusion Nodes provide NURBS Surface option.
Extrusion Nodes can be Morphed.
Powerful 2D Cross Section Editor
General Indexed Face Set Mesh.
NURBS Surfaces.
Subdivided Surfaces.

Nodes:
Group Nodes: Anchor, Billboard, Collision, Switch, LOD.
Switch Node can be controlled by the Vizx3d Trigger System.
Viewpoint Node with tight relationship with Editor Views.
Background Node with Sky and Ground colors, and Panoramas with Universal Media support.
Viewpoints and Backgrounds can be controlled by the Vizx3D Trigger System. Sound Nodes that can be controlled by the Vizx3D Trigger System.
Directional Lights, Point Lights, and Spot Lights that can be controlled by the Vizx3D Trigger System.
Navigation Info, Inline, and Fog Nodes supported.

Integrated Internal Browser:
Internal Browser Debugger. Single step through time.

Create Viewpoints dynamically inside internal Browser.
Take Snapshots inside Browser.

Utilities:
Universal Media support.
File Selection Process integrated with Universal Media.
Cybertown Avatar support, includes support for Avatar Gestures and Walking animation.
Cybertown Avatar Arena for testing Avatars.
Maintains per Node Comments. Comments are imported, Exported, and can be edited.
Integrated HTMLHelp system.
FTP Wizard automates moving your content to your server.
Infinite, adaptive Undo/Redo with History Window.
Hierarchy Tree Window.

Configurable Views and Layouts:
Save and Recall Views and Layouts.
Perspective or Orthogonal Views.
Configurable Grids.
Many Easy to Use View Manipulation Tools; including Mouse Wheel Zoom and Pan.

Nine Flavors of Cut/Copy/Paste:
Basic Cut/Copy/Paste of Nodes.
Copy and Paste Appearance (Material, Texture, MultiTexture, and Texture Transform.).
Copy and Paste 2D cross sections.
Cut/Copy/Paste Mesh Triangles in the Mesh Editor.
Copy/Paste Translation/Rotation/Scale (ability to paste one channel, or all three).
Cut/Copy/Paste/Substitute H-Anim Avatars.
Copy/Paste H-Anim behaviors.
Copy/Paste Animation Keys.
Copy VRML or X3D ASCII text of the selected Node hierarchy directly into the Clipboard.

Figure 6. Features of VizX3D

VRML EDUCATIONAL TOOL EXAMPLES

The following are a few examples of how VRML was used to create an educational virtual environment (EVE). The first EVE example was created by Ms. Frazure, in the School of Construction at the University of Southern Mississippi, for construction cost estimating. This EVE addressed the problem of a client's lack of technical expertise when it comes to cost-impact of construction changes. With this EVE, a user is able to "navigate/visualize the project, make materials changes to the project and calculate cost-impact of these changes in real time" (Frazure, 2005). Please refer to Figure 7 for an image of the construction cost estimating EVE.

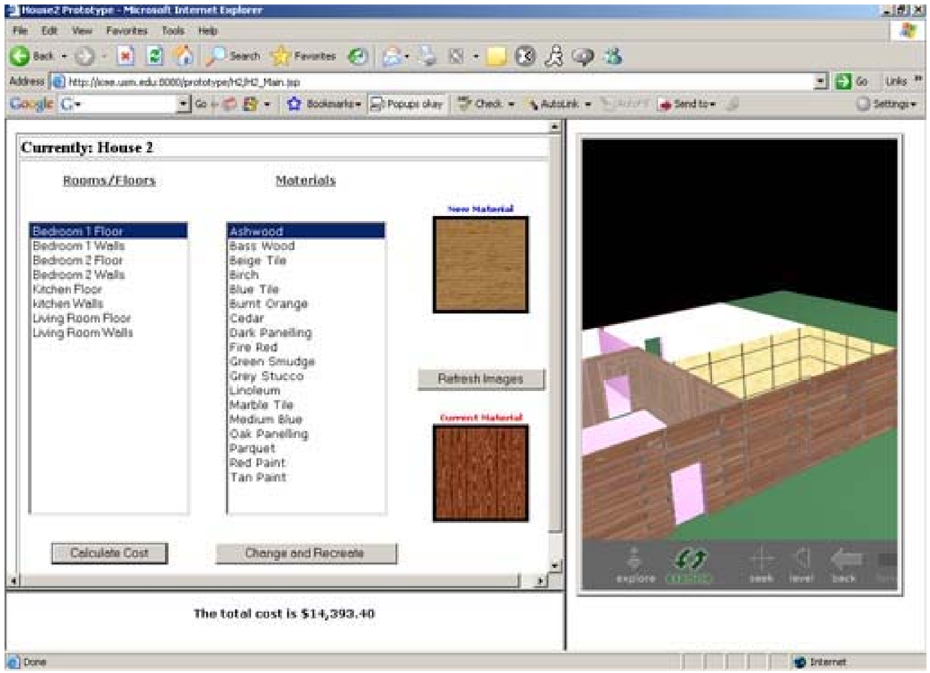

Figure 7. Construction cost estimating EVE

The next example of a virtual learning environment is for medical education. The world of medicine is constantly changing and new and improved medical techniques are rapidly appearing. According to a paper published in Computers & Graphics, "…training with live patients is very risky and this is assuming that there are many patients requiring such medical techniques. So this is why virtual reality (VR) technique is being widely applied" (Lu, J., Pan, Z., Lin, H., Zhang, M., & Shi, J., 2005). The EVE prototype created allows users to view different parts of the human body from different angles. Please refer to figure 8 for an image of a VRML head bone structure and figure 9 for an image of a VRML head model using blending effects so that a user can view the skeleton beneath the skin.

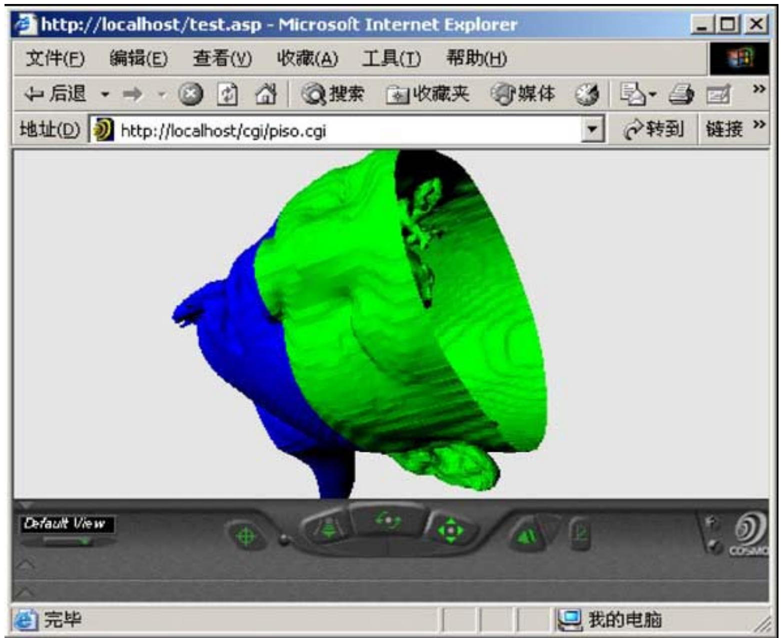

Figure 8. VRML head bone structure

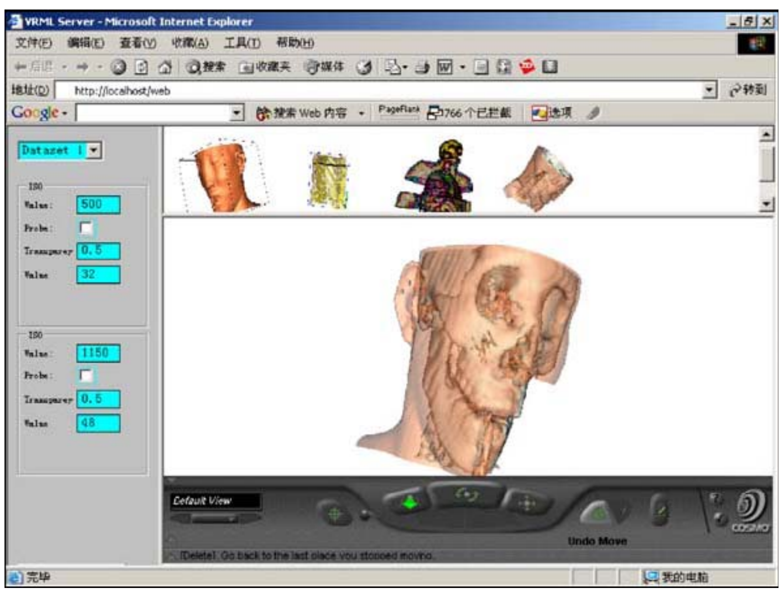

Figure 9. VRML head model using blending effects so skeleton is visible under skin

The final example takes EVE a step further and includes a virtual human inside the virtual environment to act as "informal coaches or more formal instructors" (Ieronutti, L., & Chittaro, L., 2007). Two case studies were done: (1) a virtual human provides architectural information and (2) the same virtual human explains functioning of a punch card. Please refer to Figures 10 and 11 for images of the two case studies.

Figure 10. Virtual human provides architectural information

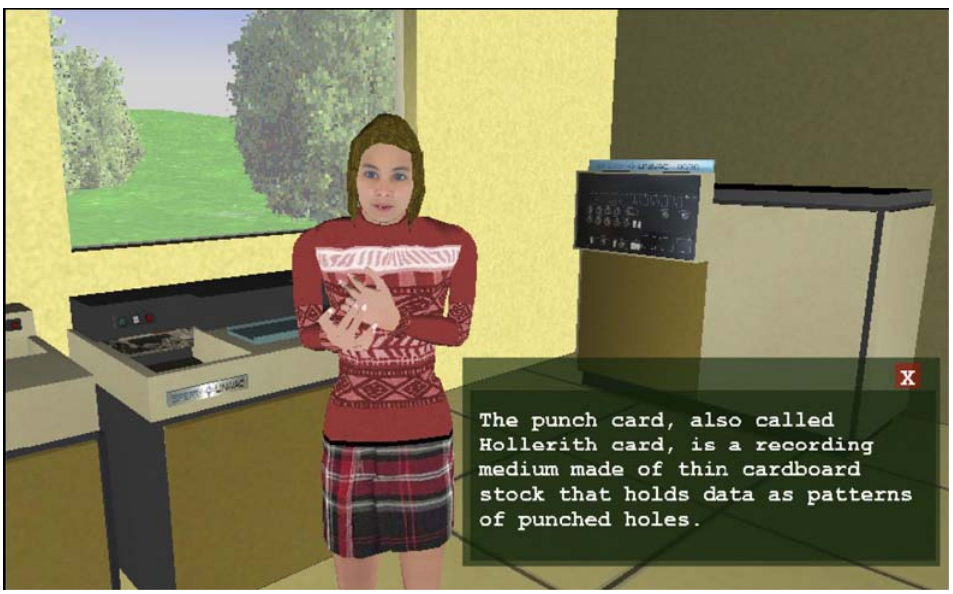

Figure 11. Virtual human explains the punch card

SUMMARY

Virtual reality has been around for decades, but the invention of virtual reality environments, which enable a user to become immersed in a world and interact with it, has only recently become popular. With the emergence of virtual reality environments, other technologies have been invented in order to experience it fully, including Head Mounted Displays, Glove Input Devices, and multi wall immersive ICUBE displays. Since public access to these tools is limited, VRML was created. VRML can be used by anyone with access to a computer and access to the Internet. VRML has many advantages including user interaction and easy navigation, and it is open source which allows for the use of scripting to add behaviors to a VR world that cannot be done with VRML alone. The VRML authoring toolkit known as VizX3D is ideal for creating Web-based virtual environments because of its easy-to-use interface and other beneficial features, including the unique trigger system that allows for the creation of interaction logic by Node selection and the ability to export interactive Web based 3D environments as VRML.

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