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ABSTRACT

This paper reports on a study that conceptualizes a research framework to aid software design and development for virtual reality (VR) computer applications for instruction in the sciences. The framework provides methodologies for the processing, collection, examination, classification, and presentation of multimedia information within hyperlinked VR environments. Traditional teaching and VR are referenced. The analysis also provides a framework to help assess whether children can use VR to supplement their traditional education and learn concepts in science, and thus seeks to help justify VR instruction as a viable supplement for standard teaching methods in science. Topics discussed include: VR environments, including immersive VR and VR modeling language (VRML); VR science instructional designs, including science instruction, and VR and science; and VR hypermedia component integration frameworks, including VR and classroom integration, VR and learning objectives, and VR and hypermedia components. Contains 19 references. (DLS)

Virtual Reality Hypermedia Design Frameworks for Science Instruction

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Abstract: This paper develops a framework to categorize virtual reality applications in science education. Examined are the implications of VR in science instruction, components to integrate VR into hypermedia presentations, and considerations when utilizing VR in classroom settings. The framework explores methodologies for the processing, collection, examination, classification and presentation of multimedia information within hyperlinked virtual reality environments. The analysis is intended to help assess whether children can use VR to supplement their traditional education and learn concepts in science.

1. Introduction

This study conceptualizes a research framework to aid software design and development for virtual reality computer applications for instruction in the sciences. The framework will provide methodologies for the processing, collection, examination, classification and presentation of multimedia information within hyperlinked virtual reality environments. Referenced are traditional teaching and virtual reality instruction. The analysis will also provide a framework to help assess whether children can use VR to supplement their traditional education and learn concepts in science. The framework will thereby help justify VR instruction is a viable supplement for standard teaching methods in science.

2. Virtual Reality Environments

Virtual Reality (VR) is a new way to use computers. It offers the possibil ity of becoming immersed in, and interacting with, a computer-based environment that engages visual, auditory, and tactile perceptions. It features a "high-end interface" that involves real time simulations and interactions through multiple sensory channels [Mikropoulis 1996]. Virtual reality is currently in the very early stages of development, but has the potential to be a highly effective method for training people who learn and remember best by doing. The two most popular environments are immersive VR and VRML.

2.1 Immersive Virtual Reality

Virtual Reality is currently used to describe an extensive gamut of technologies. Within the genre are semantic and technical breakdowns--including virtual reality, artificial reality, and cyberspace [Helsel 1992]. Herein, we will specifically focus on the technology of virtual reality and its commonly associated characteristics. From a technological standpoint, virtual reality may be defined as a form of human-computer interface characterized by an environmental simulation controlled in part by the user [Springer 1991]. Virtual reality typically features hardware and software that furnish a sense of: (a) inclusion or immersion, (b) navigation, and (c) manipulation [Mikropoulis 1996]. In a comprehensive implementation, a virtual reality configuration consists of a head-mounted display, a data-glove, and a tracking device. The viewer wears the head-mounted display that contains sensors to track the position of three-dimensional coordinates of the head as it moves. The data-glove provides hands-on interaction within the virtual world by registering finger and hand gestures using fiber-optic cables that act as sensors to detect the flexing of fingers. Electromagnetic sensors then report the positions of the goggles and glove. The computer calculates what the artificial world looks like from those angles, draws it in 3-D, and shows it on the LCD screens mounted in the headset in front of the user's eyes.

2.2 Virtual Reality Modeling Language (VRML)

Simpler VR implementations mimic the immersion effect and VR hardware to enable user navigation through a 3D world simulated on a 2D computer screen. Navigational and interactive capabilities are essentially the same, albeit the sense of immersion is partial. Still, for instructional applications the designs and objectives are essentially the same. Limited immersion VR is currently being popularized in non-immersive arcade-style computer games, and in advances with the VRML computer language for creating VR on the World Wide Web. Technically, VRML is a universal description language designed to support 3-dimensional environments on the WWW—complete with multi-participant interaction, and real-time user defined simulation [Ames, Nadeau & Moreland 1996]. As such, it provides a WWW-based VR user-interface to online media. VRML is used to create virtual reality environments (worlds), which are networked through the Internet, and reside as an application or functionality atop the WWW. These environments are fully compatible with the hypermedia linkages characteristic of Web interactions. VRML specifies all aspects of virtual world display, interaction and internetworking.

The technology consists of a language specification and a software browser—which is generally integrated into other Web browsers to form a comprehensive utility. In perspective, HTML describes documents and their layout in two-dimensional space, while VRML describes three-dimensional environments and their interactive capabilities [Maule 1997]. The specification provides for worlds with multiple levels of detail, dependent on the chosen rendering resolution of the user, and the display capabilities of the browser. As a graphics composition language, it enables a structured display to be composed on the screen from a number of items, each of which may be local or remote. Elements may be identified by their network, local, or URL addresses. If properly cached, operations are quite rapid since screen refreshes only invoke a reissuance of the specifications—which the machine would draw using its internal capabilities (as opposed to downloading images). [Note that this is similar to Postscript wherein a description language alleviates the need for the loading of bitmaps, with the output devices than able to process and represent the data to the ability of that particular system.]

VRML 1.0 adopted the Open Inventor file format from Silicon Graphics (SGI) for its ability to support complete descriptions of 3D scenes with polygonal rendered objects, lighting, materials, ambient properties, and realism effects. Extensions to support networking were added and became the basis for VRML. The VRML file format was then released into the public domain. As such, VRML is not an extension to HTML, but is compatible with HTML, and in typical applications both HTML and VRML will exist. Generally, VRML requires more finely tuned network optimizations than HTML, is composed of many more inline objects, and involves many more servers than typical HTML documents. The VRML 1.0 specification enables the creation of virtual worlds with interactive behavior via objects with hyperlinks to other worlds, HTML documents, or other valid MIME types. When the user selects an object with a hyperlink, the appropriate MIME viewer or display routine is launched. Similarly, when the user selects a link to a VRML document from within a correctly configured WWW browser, a VRML viewer is launched or routine activated. Thus, VRML viewers are designed to be integrated into standard WWW browsing as a means for navigating and visualizing the Web. Evolving versions of VRML, and compatible software developed by independent programmers, support animation, motion physics, and real-time multiuser interaction.

The Moving Worlds standard, developed by Silicon Graphics, with important contributions from Sony Research and Mitra, became the VRML 2.0 specification in March of 1996. Moving Worlds is an event- or message-passing system dependent on a scripting language, such as Java or JavaScript. Because Moving Worlds is simply a file format, other languages can also be used. It uses a platform-neutral open architecture and file format to support the 3D animation, behaviors, and interactivity. VRML 2.0 also accommodates dynamic object behaviors, multiuser interaction, and multimedia components such as animation, sound, and streaming video. In operation, VRML 2.0 navigation within the virtual spaces is through a mouse, trackball and/or joystick. Control keys can be used to provide more advanced navigation. When encountering an interactive object the cursor changes to a hand symbol to provide the user with the capability to grab the object. Joysticks provide additional tilt and turn controls. A SeekTool is to enable quick and easy movement toward a selected target. Of course, the display and interactive capabilities depend on the hardware and software components available to the user. The better the equipment, the better the graphics and interactivity.

3. VR Science Instructional Designs

Science has been defined as a way of "knowing"—a derivative of the Latin scientia, meaning "to know, or having knowledge." One acquires knowledge through various intellectual activities concerned with the physical world and its phenomenon." Even more essential than knowing about the physical world is the curiosity, the urge to discover, and the need to know that motivates students to pursue knowledge and seek truth. Science education is thereby discovery learning, the teaching of meta-reasoning, with emphasis on the intuitive perspective. Selected topics generally reflect fundamental problems, and fundamental concepts in biology, physics, chemistry and earth science. VR may ultimately be the most natural artificial interface to discovery learning.

3.1 Science Instruction

Many nations are at a crisis stage in science education. Students are graduating from high school with limited knowledge in science, and little understanding of the application of science in the real world. In the U.S., the science abilities of elementary and secondary students has been declining for several decades [ETS 1988]. Internationally, in a survey of 17 countries, the United States was ranked near the bottom in achievement in science and math [IAEEA 1988]. Many believe this inexperience with science may have negative impacts on society. Nations are either directly or indirectly impacted by the astuteness of their citizens in science. Modern societies demand technically literate, informed, involved and proactive citizens. Organizations are dependent on workers for their ability to understand scientific concepts. Without an educated public, politicians and voters will make their decisions based on ignorance, or an unhealthy reliance on others to make their decisions for them. In the U.S., the National Commission on Excellence in Education argues that a scientifically literate public is essential for the United States to remain economically competitive in the world market [NCEE 1984].

A major problem faced in science education results from the way science is taught through rote learning and memorization. In many instructional settings, students acquire only "facts" rather than "tools" for problem solving. They do not experience the kinds of problems that make information relevant and useful, so they do not understand the value of this information [Bransford, Sherwood, Hasselbring, Kinzer & Williams 1990]. Thus, many students consider that science is boring, irrelevant, or a fragmented collection of knowledge. VR technology may help.

3.2 VR and Science

Educators are slowly becoming exposed to the theories and ideas of constructivist philosophy, which emphasizes building children's own categories of thought about the world and encouraging students to construct their own knowledge. "Virtual worlds" are constructive environments in which participants can create, manipulate and edit any form of digital information. Objects, processes and programmed inhabitants of the "virtual worlds" are elements for active problem solving. Thus, virtual reality programming can be used to facilitate an awareness of problems and encourage the personal seeking of solutions. Students can develop important science-process skills rather than just rote learning. Virtual reality curricula may engage students experientially in scientific investigation and application. Students may participate in responsive environments in which they become engaged in full body-mind kinesthetic learning. Studies have shown that students and users are able to benefit when given the capability to shape their personal learning environments [Maule 1991]. Ideally, such learning may combine cognitive, affective, and psychomotor skills as students pursue their own learning strategies [Walser 1990].

Investigations into the potential of virtual reality to enhance children's learning of science may have far-reaching consequences. VR instructional designs can provide structures to help ascertain whether or not critical multimedia variables in virtual reality programming are effective in the learning and teaching of specific science concepts. Through this testing and analysis, important information design variables appropriate for virtual reality programming may be documented. Collectively, these variables, consisting of information designs, systems and processes, will provide critical insight into the potential for multimedia virtual reality programming to improve children's achievement, interest and motivation in science.

4.0 VR Hypermedia Component Integration Frameworks

There is certainly no substitute for actually performing scientific experiments in real world and laboratory settings. Of course, the time, money, technology and expertise for real world science is rarely available, especially at an elementary school level. Students generally experience textbook explanations and examples. The increasing availability of computers and the Internet in elementary school classrooms means that VR and VRML resources may be a viable supplement to traditional textbook instruction. They may experience science more safely, in less time, and with less expense than field or laboratory work.

4.1 VR and Classroom Integration

Virtual reality systems will provide a less formal experience than a true laboratory or field trip, but they may be equally fun, and certainly more "realistic" than mere pictures in a textbook when considering the wealth of experiences that may be generated. As learners begin to work, study and communicate in virtual environments, whether singularly or collectively (through computer networks), they learn not only the subject matter, but new ways of thinking and structuring information [Maule 1992, 1993]. The customization and interactivity may permit users to shape their interpersonal and collaborative electronic experiences. Stand-alone and networked virtual reality technologies thereby offer the potential to not only change the way students learn, but also the way teachers teach and interact with technology [Wolsey 1996].

4.2 VR and Learning Objectives

In the past, the costs of virtual reality technology limited use to specialized fields of research and study—such as those found in higher education and corporate and military training. Today, VR technology is finding its place in public elementary schools. The learning objectives of VR are becoming adopted by school systems and standardized [Pantelidis 1996]. In one of the first research studies on K-12 virtual reality applications, Sherman and Judkins [Sherman & Judkins 1992] studied virtual reality in educational curricula for five groups of children, aged 9 to 15. The children were able to design and create virtual worlds of their own. Although technical assistance came from the HITLab at the University of Washington, initial predications actually underestimated the children's ability to understand and assimilate the virtual reality technology. Children worked cooperatively and collaboratively. Moreover, they were highly motivated. Children completed the project, plus, they learned programming, networking and design. The technology had a short learning curve, and children could easily retrace their steps. This was a very successful educational program for both teachers and students.

4.3 VR and Hypermedia Components

Studies have not fully researched information designs for virtual interaction, nor the interplay among highly complex media variables. Studies of media interactivity within programmed environments have generally isolated and tested simple, controllable variables [Maule 1991]. Virtual reality presents highly complex interactions. While complex authoring environments have been tested for their impact on learning and perception [Maule, Gregg & Petry 1991], the impact of complex multimedia within virtual environments, and issues stemming from information designs for complex multimedia learning systems, have not been adequately addressed [Maule 1994]. Frameworks are needed to structure variables to help determine the overall effectiveness of the virtual reality instructional experiences.

Previous studies have drawn insight from working applications of VR in education [Pantelidis 1994]. From the integration of traditional instructional objectives, and VR capabilities, primary content design initiatives may be drawn to address the integration of the media components—including the graphic, video, audio, and animation elements, and the linkages between the media. Linkages, and the arrangement of media, then become the design framework for the instructional objectives. For purposes of analysis, the following schema has been developed to represent primary media and instructional design variables for science instruction in hyperlinked virtual reality:

o VR Collection Variables: psychomotor skills(explore, navigate, look, manipulate)
o VR Examination Variables: cognitive skills (assess, determine, calculate)
o VR Classification Variables: spatial skills (arrange, sort, structure, inference)
o VR Processing Variables: affective skills (interact, feel, associate, participate)
o VR Presentation Variables: interactive skills (links, relationships, associations)

The VR evaluation variables would then determine the degree to which the above schema accurately convey the needed information and deliver the appropriate learning experience. Secondary assessment would address the effectiveness of pertinent information design and multimedia interaction variables. The virtual reality programs may use hypermedia branching to customize and target both advanced and disadvantaged students. For example, it may be relatively easy to develop applications for above average students because they may have an easier time comprehending the subject matter. It is more difficult to develop a program for the average learner or uninitiated learner who may have difficulty concentrating. Multiple testing formats may determine if motivation has increased for each level of interaction, for each individual student, and for each class of student. Knowledge retention may be tested cumulatively with each interaction.

5. Conclusions

In anticipation of the widespread availability of virtual reality technology, frameworks are needed to help structure VR and hypermedia designs to enhance the experience of children learning science. Secondary issues would involve the effectiveness of the virtual reality teaching process, supporting VR information design issues, and the interactions of complex media variables which may not be available in traditional teaching. Hopefully, VR instructional designs will demonstrate that the knowledge acquired from interactive, virtual reality experiences will enable children to retain knowledge and appreciate the importance of science. This will occur as children "live" the experience. Moreover, different levels of learning may be programmed into the environments. Further frameworks can be developed to help structure the branching necessary to provide different levels of science to different levels of students.

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