AGENT-BASED VIRTUAL REALITY (AVR) IN SCIENCE, TECHNOLOGY AND MATH EDUCATION

Mary A. Farwell[1], Christine Russell[2], Deborah Ferrell[3], Brown McFadden[4], M.N.H. Tabrizi[5]

Abstract *— One of the significant issues in STEM education today is how to integrate 3-D Virtual Reality worlds (3DVR) into the classroom. While 3DVR has allowed us to add versatility, it has also created a new set of problems. Distance education students do feel more social connection when 3DVR is implemented. However, students are failing to learn the class content material well in these environments. We are currently testing the Agent-based Virtual Reality (AVR) system. This system has significant advantages over other 3DVR. The AVR system is easy to deploy, can record lectures synchronously or asynchronously, and does not require faculty or students to create and operate their own avatars unless they wish to do so. This allows students and faculty to focus on the content material more fully by removing distractions in the environment. The AVR system operates on low bandwidth frequencies to reach rural and disadvantaged populations.*

Index Terms — 3-D virtual reality, online education,

INTRODUCTION

While there has been significant inquiry into online education and new technology tools designed to enhance that environment, there is still a very new area of study related to the use and implementation of 3-D virtual reality environments. It is becoming more and more common for instructors to use such environments as Second Life and Quest to attempt to bring a sense of more personal involvement and community belonging to the online student in the learning environment. This new and shifting community of learning, however, has not yet been integrated completely or effectively into online learning environments. The process of using 3-D virtual reality environments has not been without some stops and starts and concerns about how to blend the environments with other tools currently in use in online learning classrooms. The authors of this paper have designed and developed lecture contents and are currently testing a new 3-D virtual reality classroom environment called the Agent-based Virtual Reality, or AVR, system. AVR is user-friendly, easy to integrate into any online learning environment, and may be adjusted easily, making it effective for use with students new to virtual reality environments. More importantly, the AVR system has been designed exclusively for use in education. The AVR system is easy to use because the environment is controlled and the students are not required to navigate in the environment. Therefore, there is less likelihood of students being distracted by the in-world experience itself. Distraction by the in world environment has been a consistent challenge for classroom educators when attempting to integrate 3-D virtual reality space for classroom learning. While students report satisfaction regarding feeling a part of the community, preliminary tests indicate students are not faring as well in learning the material content in the 3-D virtual reality environments. Finally, the AVR environment can be accessed over the Internet with low bandwidth requirements, without sacrificing transmission of material and content. This means the AVR environment can be used for outreach in more rural areas of the world, or in areas where students may not have access to high bandwidth Internet.

Additionally, the AVR system can be adjusted to work either as a live, interactive immersive environment for students and faculty who wish to use the technology to improve student's sense of community and in real time communication, or it may be extended to work on teams and in groups in problem solving projects and assignments. However, its most innovative feature is that it can also be used as a method of lecture delivery that allows the student to view the faculty member's lecture, either from a live classroom or from an archived lecture created by the instructor, without the student actually having to create and command an avatar themselves. The system renders the instructor's lecture directly into the 3-D virtual reality environment so that the instructor also does not need to manage the avatar animation and aesthetics. This unique feature of the AVR system overcomes one of the most serious problems with large scale deployment of 3-D virtual reality environments—that is the problem of barrier to entry for use because of a relatively steep learning curve related to in world navigation and/or avatar creation and look. Instructors also control strictly the environment and student's immersion there, which can cut back on environmental distractions when they might be detrimental to the learning process itself.

This paper considers the most common uses for 3-D virtual reality environments or multi-user environments (MUVEs) in online educational environments. There seem to be two primary issues related to learning outcomes and online or blended course education. One issue is that the 3-D virtual reality environments can be distracting for the users and therefore they don't learn complex content well in the environment. The second issue is related to the ways 3-D environments can be used to enhance online students and blended course students' sense of community and belonging. Additionally, these kinds of environments, if leveraged properly, can begin to more effectively make learning an individual process tailored to the learning needs and inclinations of each student [1]. It is with these goals in mind that the authors are testing the new AVR system.

This paper is concerned particularly with describing the AVR system and the ways the AVR system can be used to improve student-learning outcomes related to content particularly, by removing the distraction issues in the learning environment. AVR removes distractions in the environment by taking the student/avatar out of the physical navigation space while still allowing the student to feel immersed in a lecture or learning classroom environment. This is of course just one way to use 3-D virtual reality

1 Mary A. Farwell, Dept. of Biology, Harriot College of Arts and Sciences, East Carolina University, Greenville NC 27858 USA, farwellm@ecu.edu
2 Christine Russell, Dept. of Technology Systems, College of Technology and Computer Science, East Carolina University, Greenville NC 27858 USA, russellc@ecu.edu
3 Deborah Ferrell, Dept. of Mathematics, Harriot College of Arts and Sciences, East Carolina University, Greenville NC 27858 USA, ferrelld@ecu.edu
4 Brown McFadden, Administrative Services, Beaufort Community College, P.O. Box 1069 Washington, NC 27889 USA BrownMcF@beaufortccc.edu
5 M.H.N. Tabrizi, Dept. of Computer Science, College of Technology and Computer Science, East Carolina University, Greenville NC 27858 USA, tabrizim@ecu.edu

environments and it is not the intention of these authors to suggest that this use is the only one that can be employed; but rather the AVR system used in the specific classroom lecture archival manner is one solution to learning certain STEM content without being distracted by navigational and environmental options.

HISTORY OF ONLINE AND 3-D MUVE DEVELOPMENT AND DEPLOYMENT

"The common features of online education course management systems include the following: computer-mediated communications, navigational tools, course management, assessment, and authoring tools [2]. A number of studies have indicated that virtual reality environments and multimedia can be used effectively to support a constructivist paradigm of instruction and suggested that including a 3D immersive environment could help bridge the gap between experiential learning and information representation [3-5]."

In fact, three-dimensional models clearly open the doorway for students to experience a richer, more interactive classroom environment. The 3D technologies available today are a powerful tool allowing students to engage in interactive classroom lectures as well as to engage in lab like experimentation and modeling exercises, which are critical to STEM education.

Although virtual reality-based systems and 3D educational technologies are reasonably well developed, their implementation and adaptation for use in educational settings has created a number of challenges for the educator [6]. One example of such a project features effective implementation of a Web-based learning environment called "School for All" [7]. Even without the addition of 3D environments, basic issues of tool integration have plagued the historical development of online instruction. For example, navigability and content organization in online learning environments have often been difficult and critical pedagogical issues for online educational content developers [8]. Another example of the difficulties that erupt when integrating new technology into online education, occurred in the case reported by Song, et al., in which the researchers developed a human tutorial conversation system for the Web that enhances educational courseware through mixed-initiative dialog with natural language processing [9].

Yet 3-dimensional representation and virtual reality can be powerful additions to both face-to face classes and online class settings. While, 2-dimensional textbook illustrations provide a limited description of the content being discussed, 3D models provide a more realistic and engaging look at the same materials. While the academic sciences teach mainly process-oriented content that requires more than a static image on a page. Three-dimensional models provide students with fully interactive content. These web-based 3D-model technologies can be important tools for visualization in the classroom to ensure an enriching learning experience [5, 10].

"Virtual Reality Model Language (VRML) is used to manipulate virtual reality in face to face and online learning environments [11]. Examples include biological structures [12] biochemical structures [10], applications in medicine with near real-time 3D data on a fast network [13], and the use of visualization toolkit and showing that VRML is less expensive than a virtual reality learning environment (VRLE) such as CAVE and ImmersaDesk [11]."[5].

Other relevant examples of the ways 3D and virtual reality have been included in early learning and educational experiment include applications in earth science [14], computerized manufacturing [15], general applications in education [16] and computer graphics education [17, 18]. An additional, issue for integration of 3D and virtual reality environments for many educational institutions both in the US and abroad are bandwidth requirements. This issue is especially critical when attempting to deliver content to rural areas. "Naka et al has extended VRML Humanoid Animation Specification Ver.1.0 so as to send/receive motion data in real time on a network with a narrow bandwidth such as a telephone line [19]. Moreover, sending motion data with streaming data from server to client can greatly reduce the time required before playback." [5]

While the technology application in online learning environments is relatively new, there is growing evidence that we are going to need to adapt our assessment techniques and application processes of 3D virtual reality environments to meet student's needs and to be sure that the technology is working to help the student learn material effectively as opposed to becoming a distraction itself. According to Omale et al (p. 482), recent research has been "conducted to investigate the affect of 3D MUVEs on learning outcomes (Dalgarno 2002; Lim et al 2006). Overall findings from these studies indicate that 3-D MUVEs do not enhance student learning because students were distracted and got off-task during their online activity" [1].

Omale's research team sought to determine how these 3-D environments were unique and how their unique attributes might affect and/or contribute to online learner's experience and performance [1]. Like other research Omale et al conclude that the avatars and visual space, including the ability to navigate community and space present a unique opportunity and way for students and faculty to interact that is more like live human interaction. It is therefore, an environment that can create significant satisfaction in relation to student's sense of social connectedness and community in the learning environment. However 3-D

MUVEs have the unique problem of also being a distraction--likely because of its newness for students and because of gaming environment's inherent exploratory invitation. The suggestion then by Omale et al's research is that we are going to have to adapt the learning material and the assessment process appropriately to be certain that students reach the external learning objectives in each class.

Like Omale et al, other researchers including Jones et al [20] make the same kind of case for the support and importance of 3-D MUVES in online education stating that some sources indicate that 3-D immersive worlds may be the most important step in technological innovation in recent history for online education. Jones et al also recognize that there is going to have to be an adjustment made by educators in the way we approach the educational process, the materials to be learned and the assessment process itself if we are going to integrate 3-D MUVEs into our online learning environments.

> 3-Dimensional online learning environments provide a vehicle for situated learning, allowing students to do activities created in the virtual environment (MUVEES Project, 2003). The 3-dimensional approach shows the potential to provide transferability from performing tasks in the virtual environment to performing the same tasks and interactions in the real world. A 3-dimensional online learning environment can easily support multiple modes of interactions at the same time. The modes are only limited by the bandwidth available, the technology for display and the capabilities of the student [20].

Given this overview of the state of the art in virtual and visual delivery systems, inquirers may ask, "Why should visualization technology be given special emphasis?" The answer might begin with the old adage that "a picture is worth 1000 words." The proliferation and ubiquitous nature of new and old visually based professional tools of communication support this adage: elevations and blueprints in engineering, UML in software engineering, work flows in project management, fishbone diagrams in brainstorming, molecular models, visual story boards in gaming, organization charts, interactive statistical multivariate analysis (e.g., JMP software by SAS), showing houses for sale via virtual tours. Indeed, it is difficult to find problem solving unsupported by visual models and visualizations. Certainly traditional learning, collaborative learning, and online learning environments all involve complex problem solving.

Additionally, evidence exists that anonymity offered via online learning environments (like chat rooms) reduces anxiety in some student groups and fosters oral participation for others. Avatars, via the AVR system, offer a way to maintain the educational value of the perceived anonymity, while allowing the student a more multidimensional interaction than chats and e-mail currently provide. Not only does the technology allow the use of traditional lecture environments where appropriate, but it also allows the integration of other supports for visual thinking to be incorporated into the lecture format.

DESCRIPTION OF THE AGENT-BASED VIRTUAL REALITY SYSTEM

One of the most attractive features of the AVR system is that it bypasses the historically challenging time investment impediments related to offering an online course, by automating the course design process. Thus, the time investment in utilizing AVR is comparable to the time involved in delivering a standard face-to-face lecture. Ultimately, the AVR system will make online offerings more plentiful as it will encourage STEM instructors who previously have not taught online courses to do so in the future. Ultimately, use of the AVR system may result in an increase in accessibility to online courses for STEM students because more instructors will be willing and able to use the technology effectively in their class environments. In addition, face-to-face instructors will be able to easily archive live lectures, including what they write "on the board."

The VR-based course delivery system, the early development of which has already been reported by the authors [5, 21], achieves the synergetic fusion of different technological elements, to include:

- A 3-D virtual reality platform,
- A course management system,
- A dynamic learning assessment system,
- A multimedia-based communication environment,
- An effective client/server model with an advanced security layer,
- An electronic whiteboard and PowerPoint presentation,
- E-campus features (virtual reality labs), and
- Motion-capture and tracking with a communication architecture that optimizes the bandwidth usage.

Using the AVR system, the instructor will appear as an animated character, with his/her facial expression, voice, and motion broadcast to the students' computers along with supporting course materials. The AVR system is ideal for delivery of online courses with multimedia content. Students view lectures online in a virtual reality environment setting. The instructor appears as an animated figure, with real-time facial expression, body posture, position, and movements captured by the system. (Real time facial expression and body posture is unique to this medium and not currently available in other systems like Second Life.) Students can hear the instructor, see notes written on the blackboard,

observe demonstrations, ask questions, and engage in classroom discussion. An interactive lecture with full screen multimedia content can be received in real time or archived, regardless of the type of network connection, including dial-up.

The primary strengths of this system are:

- Detected Cartesian coordinate (X, Y, and Z) points of the instructor's position, facial expression, and body posture are the only data streamed, reducing the bandwidth requirement tremendously,
- The students' interface will enable re-generation of the animated 3-dimensional objects (representing virtual instructor, students, and the classroom) tracking the real instructor's movements while teaching,
- The instructor can deliver a lecture with a tablet PC and wireless microphone with FTF students in the class however, there will be
- Increased engagement of online learners
- Students (online and face to face) can stop the teacher and ask questions
- The lectures can be archived for all students to use in the future

RESOURCES

1. Omale N, Hung W-C, Leutkenhans L, Cooke-Plagwitz J: **Learning in 3-D multiuser virtual environments: Exploring the use of unique 3-D attirbutes for problem-based learning**. *British Journal of Educational Technology* 2009, **40**(3):480-495.
2. Robson R: **Course support systems: The first generation**. *International Journal of Telecommunications in Education* 1999, **5**:271–282.
3. Winn W: **A conceptual basis for educational applications of virtual reality (HITL report No.R-93-9)**. In. Seattle, WA: University of Washington, Human Interface Technology Laboratory; 1993.
4. Winn W: **The Impact of three-dimensional immersive virtual environments on modern pedagogy** In: *HITL Technical Report R-97-15* Seattle: University of Washington Human Interference Technology Laboratory; 1997.
5. Tabrizi M: **Agent and Virtual Reality Based Online Course Delivery System**. In: *Computational Methods and Applied Computing: Proceedings of the Appied Computing Conference: 2008; Istanbul, Turkey*: WSEAS Press; 2008: 73-76.
6. Lee J, Hong NL, Ling NL: **An Analysis of students' preparation for the virtual learning environment**. *The Internet and Higher Education* 2003, **4**:231-242.
7. Lin CB, Young SSC, Chan T, W., Chen YH: **Teacher-oriented adaptive web-based environment for supporting practical teaching models: A case study of "School for All"**. *Computers and Education* 2005, **44**:155-172.
8. Stefansson G: **The tutor-web: an educational system for classroom presentation, evaluation and self-study**. *Computers and Education* 2004, **43**:315-343.
9. Song KS, Hu H, Olney A, Graesse AC: **A framework of synthesizing tutoring conversation capability with web-based distance education courseware**. *Computers and Education* 2004, **42**:375-388.
10. Rourk W: **Virtual biochemistry — a case study**. *Future Generation Computer Systems* 2000, **17**:7-14.
11. Lu J, Pan Z, Lin H, Zhan M, Shi J: **Virtual learning for medical education based on VRML and VTK**. *Computer & Graphics* 2005, **29**:283-288.
12. Amon T, Valencic V: **VRML — Enhanced learning in biology and medicine**. *Future Generation Computer Systems* 2000, **17**:1-6.
13. Samothrakis S, Arvanitis TN, Plataniotis A, McNeill MDJ, Lister PF: **WWW creates new interactive 3D graphics and collaborative environments for medical research and education**. *International Journal of Medical Informatics* 1997, **47**:69-73.
14. Brown IM: **Ageneric system for integrated modelling of multi-dimensional spatial data**. *Physics and Chemistry of The Earth* 1998, **23**:285-287.
15. Avgoustinov N: **VRML as means of expressive 4D illustration in CAM education**. *Future Generation Computer Systems* 2000, **17**:39-48.
16. Jonkers H: **On the use of VRML in educational software: Experiences from project: JIMM Problem Solver**. *Future Generation Computer Systems* 2000, **17**:49-56.
17. Baerten H, Reeth FV: **Using VRML and Java to visualize 3D algorithms in computer graphics education**. *Computer Networks and ISDN systems* 1998, **30**:1833-1839.
18. Silverman L, Felder R: **Learning and teaching styles**. *Engineering Education 78, pp674-681* 1988, **78**:674-681.
19. Naka T, Mochizuki Y, Asahara S: **WonderSpace: web based humanoid animation**. *Future Generation Computer Systems* 2000, **17**:57-64.
20. Jones JG, Morales C, Knezek GA: **3-Dimensional online learning environments: examining attitudes toward information toward**

informational technology between students in Internet –based 3-dimensional and face-to-face classroom instruction. *Educational Media International* 2005, **42**(3):219-236.

21. Hodge EM, Tabrizi MHN, Farwell MA, Wuensch KL: **Virtual reality classrooms: Strategies for creating a social presence**. *International Journal of Social Sciences* 2008, **2**(2):105-109.