Telepresence Support for Synchronous Distance Education

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ABSTRACT

This paper describes a telepresence application that combines bi-directional video, audio and a shared virtual environment as means to support synchronous distance education sessions.

In order to validate the effectiveness of the tool, it was used in several courses at our University. Students were divided into an experimental group – using the tool in a simulated distance learning environment – and a control group – receiving traditional face-to-face lectures –. The results show that the use of the telepresence application, hand in hand with an appropriate pedagogical framework, lead the students in the distance education sessions to reach at least the same levels of understanding, and sometimes even better, than those attained by students in the face-to-face sessions.

We are offering the telepresence application to other education institutions in our country, with the hope that it will allow students in regions isolated by the war or by the lack of infrastructure to have access to better education, both at school and university levels.

Categories and Subject Descriptors

I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism—*Virtual Reality*; K.3.1 [**Computers and Education**]: Computer Uses in Education—*Collaborative Learning, Distance Learning*

General Terms

Experimentation

Keywords

Computer Graphics, Networked Virtual Environments, Collaborative Virtual Reality

1. INTRODUCTION

Access to quality education in devloping countries is limited by several factors. Firstly, institutions offering good education are concentrated in the larger cities, and furthermore, in the richest neighborhoods. Secondly, rural areas are isolated by lack of infrastructure and, in some cases, by the violence related to civil war. For this circumstances, only a very small percentage of the population has access to the high quality education. This forms a vicious circle in which poor people have less opportunities to improve their conditions because they live in isolated regions.

This paper reports the construction and evaluation of a tool that combines multimedia (bi-directional audio and video) with a shared virtual environment. The current results show that this tool allows students in distance education to attain good levels of understanding. Wide use of this tool would allow students in isolated regions to receive good quality education, taught by the best instructors, regardless of their location.

The necessary technology needed for running the application described in this paper, namely computers and telephone lines, are readily available in the vast majority of the country. Telephone lines are provided by regional telephone companies and computers are being donated by large companies that donate the PCs that are replaced, motivated by tax benefits. Even computers that are 2 or 3 years old have graphics cards and multimedia peripherals that are capable of running the telepresence application.

The rest of the paper is organized as follows: Section 2 describes similar projects. Section 3 describes the telepresence application. Section 4 describe the experiment that was undertaken in order to test the validity of the application. Section 5 describes the obtained results. Section 6 describe the conclusions reached so far and the plans to offer the application on a nation-wide scope.

2. RELATED WORK

In many traditional Virtual Reality applications, immersing the user in a computer-created environment is the goal. Training applications, such as flight simulators, are examples in which such isolation from reality is desirable [6] .

Several virtual reality applications have been built for educations purposes. The NICE project [5] used a CAVE virtual environment to teach children about the growth of plants, while being tutored by an instructor, represented by an avatar. In MUVEES [3] , several users can meet in a virtual world and communicate via text messages. The appli-

cation can be used for educational purposes also. AVALON [10] , built by our group in 1996, allowed a group of students to explore thematic virtual worlds guided by an instructor. Users communicate using voice. The tool was used as part of an Environmental Education course at our university and the results showed that it improved the students' process of learning. Participants could only see each other's avatars, they could not see the faces of the people they were communicating with. In order to compensate for the lack of non-verbal communication, icons of gestures were added to the avatars, as seen on top of the rightmost avatar in figure 1. Slide presentations were also possible in the system. The instructor showed the slides on a virtual whiteboard, and the students could decide (or not) to approach the whiteboard in order to watch the presentation.

Figure 1: Avatars with gesture icons in AVALON.

Several applications combining shared virtual environments with multimedia (in the form of audio and video) have been created. Reynard et. al [8] added a Q.O.S. scheme to MASSIVE in order to allow participants to observe each other with varying levels of video quality. The FREEWALK system [7] , allows participants to observe each other faces through videos projected on each participant's avatar (a pyramid). The creators of the systems used it to explore the social behavior of groups of people interacting through the application.

3. OUR APPROACH

The application described in this paper was conceived as an improvement over the AVALON system. The idea of a shared virtual environment was shared. But instead of large worlds that the students could explore with the instructor, the space was now conceived as a shared space to put objects and interact with them. The main addition was bi-directional audio and video, allowing the students and the instructor to see each other and communicate with their voices.

Figure 2 describes the window of the application, as seen by the instructor. The panel on the left can be used either to display a slide presentation or a shared virtual environment in which the instructor places virtual objects that are relevant to the subject at hand.

The slide presentation is controlled by the instructor, with controls to go to the first, last, previous or next slide. Once the instructor has explained the theory, using the slide presentation, she switches to the shared virtual environment, in order to demonstrate the theory with pertinent interactive 3D scenes. Figure 2 shows a demonstration for a Computer Graphics lesson on shading. Both the instructor and the students can insert different types of lights, and objects, change their colors, positions and orientations, and observe the results. These 3D scenes are custom-designed for a course aspect.

Additionally, each shared virtual environment window as a graphical panel, in which the 3D scene is rendered, and a theory panel, in which the formulas or numbers that explain the visual content, are displayed. The user can either manipulate the objects and observe how the formulas and numbers are updated in real time or change the formulas and numbers, and then see the result in the graphical panel.

We claim that this closely bound relation between theory and practice, which is experienced by the students on each session using the tool, while being able to interact with the remote instructor, are key to the development of deeper understanding.
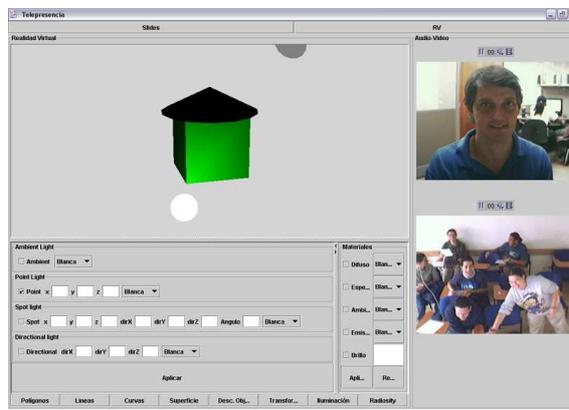

Figure 2: Telepresence tool: combination of audio, video and a shared virtual environment

3D scenes have been created for the courses in which the tool has been tested: Computer Graphics and Electricity and Electromagnetism. Scenes for the Computer Graphics course include: Polygons in 3D (see Figure 3) , Parametric bzier courves and surfaces (see Figure 4) , Transformations, Illumination and Shading, Textures and Radiosity (see Figure 5 .

Scenes for the Electricity and Electromagnetism course include: Charge Transfer, Coulomb's law, Gauss' law, Magnetic fields 6 and others.

The application has been entirely created using Java, Java3D [4] for the rendering of the virtual scenes and Java Media Framework (JMF) [1] for the distribution of audio and video. The application combines TCP for the transmission of the slides and their control messages and UDP for the transmission of the events in the virtual world. Additionally, JMF uses RTP for the transmission of multimedia messages.

The current application is point-to-point, since all the students are located in the same classroom, remote from the instructor. In future instances, we plan to move to multipoint architectures, linking one instructor to several students' locations.

On the instructor side, a regular computer with multimedia is used. A camera and a microphone capture the
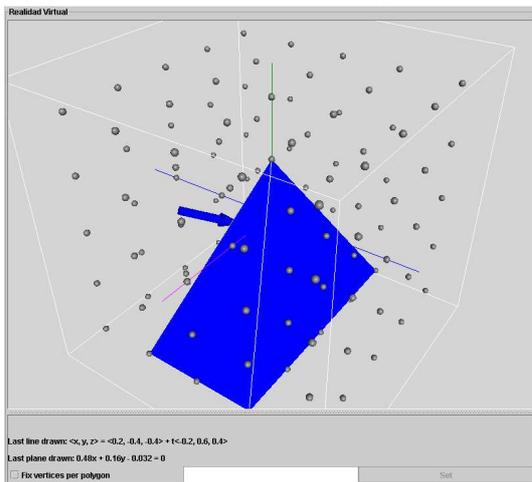
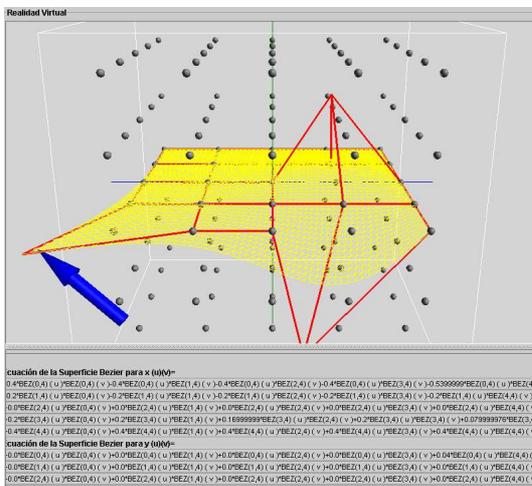**Figure 3: Computer Graphics Course: Polygons in space forming objects**

Figure 4: Computer Graphics Course: bzier surfaces

Figure 5: Computer Graphics Course: radiosity demonstration

groups received a significant part of each course using the tool. The control groups received normal face-to-face classes using whiteboard and markers.

The pedagogical framework used in the project is Teaching for Understanding (TFU) [2]. According to TFU, education should aim at increasing the students profound understanding of the subject at hand. Understanding, in this context refers to being able to extrapolate the acquired knowledge, in order to use it in new environments and settings, different from those used in the classroom.

Understanding is measured in four levels among four dimensions. The dimensions for understanding are as follows: The *Knowledge* dimension is related to the students ability to transform his/her intuitive beliefs into formal knowledge. *Method* has to do with his/her ability to use those methods, accepted in the field of knowledge, to make/validate new assertions. *Purpose* implies the ability to link theory and praxis. Proficiency in the *Form* dimension is demonstrated by the appropriate use of the symbol system of the studied field.

The levels of understanding go from *Naive*, in which the student can only replicate data provided by the instructor or the book, to *Expert*, in which the student is able to create new knowledge, going through *Novice* and *Apprentice*, which are intermediate levels.

Following the guidelines of the TFU framework, students both in the control and the experimental group demonstrated their levels of understanding by creating applications to solve an industry problem or research lab small project. At the end, a panel of experts, including those from the industry and the research labs, graded each student in a level of understanding among each dimension.

instructor's image and sound. The output of both the 3D scene and the video windows is shown on a regular display. The instructor uses a 3D tracker (a Polhemus fastrack) in order to manipulate virtual objects in the scene.

On the students side, the 3D scene and the video windows are projected on a large surface. A camera captures the video of the whole class. A microphone is shared for questions and comments. A single keyboard and mouse is used in turns by the students in order to provide input and manipulate the 3D scene, following the instructions or challenges proposed by the instructor.

4. EXPERIMENTAL SETUP

In order to validate if the tool actually enhanced learning, an experiment was conducted during 3 courses at our University: Computer Graphics, Fall 2003 and Spring 2004, and Electricity and Magnetism, Spring 2004.

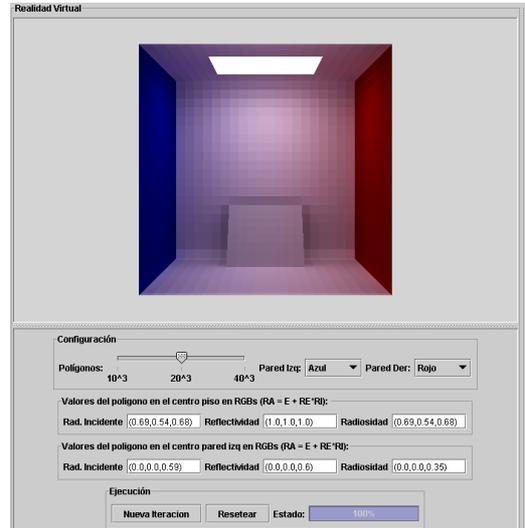Students were divided into two groups. The experimental

5. RESULTS

The Fall-2003 Computer Graphics course was used as a beta-test, allowing the developers to fine-tune the application as well as the hardware setup. USB cameras were replaced by faster fire-wire ones. Speakers on the instructor side were replaced by headphones, in order to reduce sound
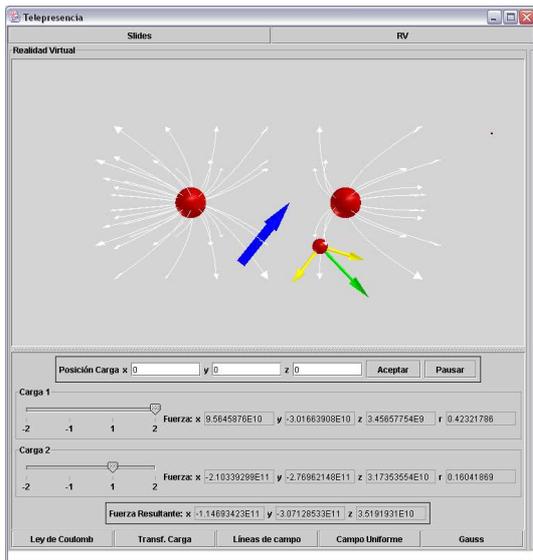
Figure 6: Electricity and Magnetism Course: lines showing the electromagnetic field

feedback. Several positions for the camera on the student classroom were tested, and finally it was located on top of the projection surface.

As mentioned in the experimental setup, for both experiments, students presented their work and were graded by a panel of experts according to the four levels of understanding (1 = naive, 2 = novice, 3 = apprentice, 4 = master). The criterion for assigning a level of understanding on each question were described in rubrics matrices, in order to unify the grading process done by the experts.

For each experiment there were 11 questions. Each question was related to one dimension of understanding (knowledge, method, purpose, form). Averaging over the grades assigned by the experts and the questions for each dimension, each student was assigned a numerical grade in each dimension. Floating point grades were rounded to the nearest integer in order to assign a level of understanding to each student on each dimension of understanding.

5.1 Computer Graphics course

Figures 7 and 8 describe the results of the control and experimental group in the Computer Graphics course.
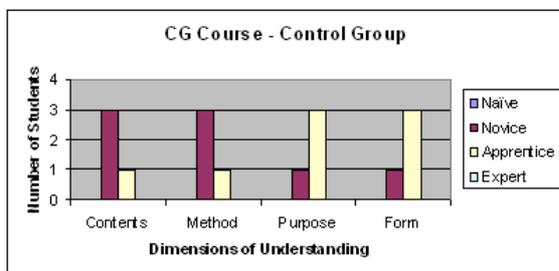

Figure 7: Computer Graphics course: control group.

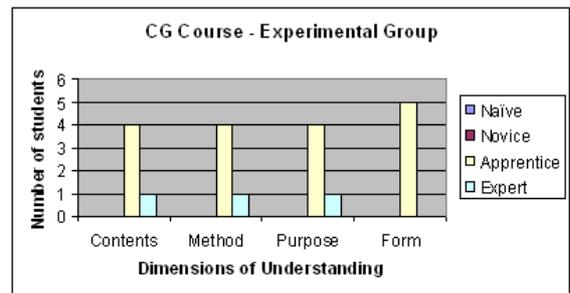Students in the control group attained levels of Novices

Figure 8: Computer Graphics course: experimental group.

and Apprentices, while students in the experimental group attained levels of Apprentices and Experts. Nevertheless, probably due to the small size of the sample, a Mann-Whitney test determines that there is no statistically meaningful difference between the groups.

5.2 Electricity and Electromagnetism course

Figures 9 and 10 describe the results of the control and experimental group in the Electricity and Electromagnetism course.
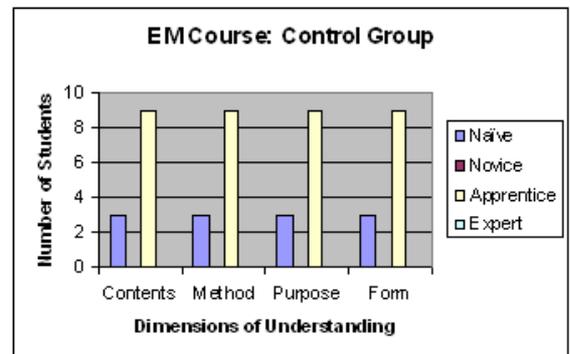

Figure 9: Electricity and Electromagnetism course: control group.

Students in the control group attained levels of Naives and Apprentices. Students in the experimental group attained levels of Novices, Apprentices and Experts. In this case, a Student-t test (0.047) determines that there is a statistically significant difference in the understanding attained by experimental and control group.

These results are very encouraging, since they suggest that the use of the tool, hand in hand with an appropriate pedagogical framework (TFU in our case), can compensate for the lack of face-to-face communication that takes place in regular courses.

After the sessions, students in the experimental group filled out questionnaires about the tool and about its impact on their understanding. Several students reported that the tool was an important aid in their process of understanding: "[The tool] allows me to experiment and see the topic at hand". "[The tool] helps me understand the concepts explained by the instructor". Others reported on the interaction among students in the group: "We search for solutions as a group, and this makes understanding easier".
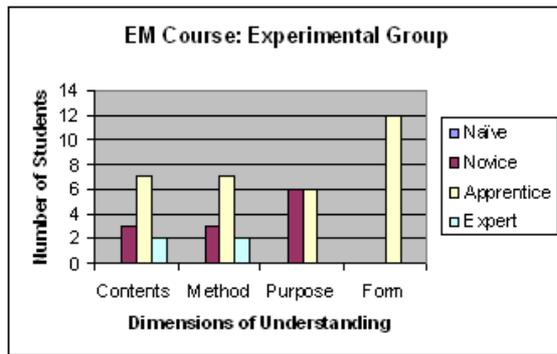
Figure 10: Electricity and Electromagnetism: experimental group.

Visualization of examples aided in the case of complex concepts: "[The tool] allows me to see the concepts at hand, which are already quite abstract, when I can interact with the Virtual Reality part".

6. CONCLUSIONS AND FUTURE WORK

A tool combining audio and video with a shared virtual environment has been built and tested in a simulated distance learning setting. Current pedagogical results are very encouraging since they suggest that the use of the tool, combined with the Teaching for Understanding pedagogical framework, lead students in a distance education setting to obtain levels of understanding that are at least similar, and in some cases better, than those obtained by students in a face-to-face setting.

We have received very positive feedback from several universities in our country where the application has been presented. We plan to create a product based on the current prototype in order to make it available for any institution to use in their distance education courses without any charge. Institutions that develop new 3d scenes will commit to make them available also, thereby extending the usability of the tool. We have already agreements with two universities in our country to develop new 3d scenes and to use the product in pilot distance education courses. We hope that the dissemination of the use of this and similar tools will help making high quality education available to more students who live now in isolated areas.

On the technical side, there are two main challenges: to make the tool work over telephone lines and to make it multipoint. For this purpose, a Quality of Service scheme will have to be implemented. We plan to implement the techniques described in [9] and [11].

7. ACKNOWLEDGMENTS

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