Collaborative Virtual Environments for Teaching Physics

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Abstract - **Eafit University created a Telepresence application for distance education. It supports bi-directional audio and video and a shared virtual environment that allows the instructor and students to manipulate virtual objects in a collaborative manner, thereby reinforcing the learning process. In this paper we report the experience of creating new contents and deploying the tool in a Physics course at Universidad del Quindío. The tool was improved an extended in order to include new functionality and make it easier for development teams to create new content. Teaching for Understanding was used as pedagogical framework for course creation and also as a guide to develop the interviews that were used to capture user's perceptions and to asses the improvements in the learning process. The results showed that the use of the tool had a positive impact on the students' understanding of the topics at hand.**

I. INTRODUCTION

Most Virtual Reality applications were, in the beginning, designed for only one user. Through the use of head mounted displays and gloves, the user was immersed in a synthetic world and isolated from the real environment. The availability of the Internet and powerful graphics commodity hardware has made it possible to use shared virtual environments in many applications, such as entertainment (multi-user games), training and education.

In this paper we describe the development of a shared virtual environment application to support synchronous distance education sessions. This tool allows an instructor and a group of students to communicate through bi-directional audio and video, as well as to interact with virtual objects in a shared virtual environment. We call this application a "Telepresence Application", since it allows the instructor to be "present" in a distance place: the place where the remote students meet.

This application was first developed in 2004 and used within Eafit University. We intend to make the code available for any institution to use with no cost. The only condition is that contents developed for the course should also be made available for any other institution to use. We hope to have a growing community of institutions creating a growing set of contents that can be deployed in various fields of knowledge

In this paper, we describe the first use of the application framework outside of Eafit University. The tool was used at Universidad del Quindío to support a distance course on Physics for a degree in Building Construction. A group of undergraduate students created new contents that were deployed in the course. An appropriate pedagogical framework (Teaching for Understanding) was used by the pedagogical team in order to structure the course around the use of the tool and to asses the students' learning process when using the tool.

The rest of this paper is organized as follows: Section II describes similar work and our previous projects on mixed reality in education. Our tool and the contents created for this project are described in section III. Section IV reports the results achieved with the students and, finally, section V describes the conclusions and future work.

II. BACKGROUND AND RELATED WORK

A. Distributed Virtual Reality in Education

Virtual Reality has been used in numerous educational settings. Pantelidis has been studying the impact of this technology in teaching online courses on various subjects, both at K-12 level and college level [1], [2]. They report that

Virtual Reality can be used to support learning in subjects that benefit from interaction with real (or virtual) objects.
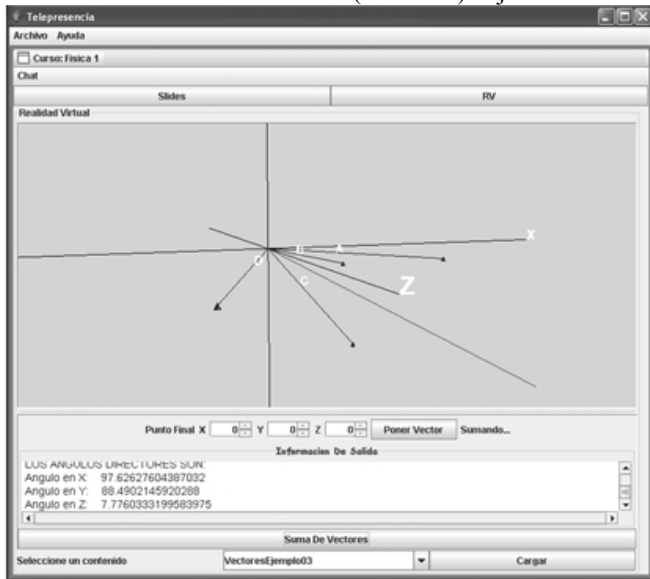

Fig. 1. Addition of two vectors in 3D space.

The availability of higher speed networks, low-cost graphics cards and powerful computers, have made it possible to create networked virtual environments that can be used by a large number of users, as explained in by Singhal and Zyda [3]. More recently, Xen et. al built a collaborative virtual reality system called MUVEES to create a digitized museum that middle-school students can visit [4]. They report that the system is a powerful vehicle for collaboration and learning.

We have also explored the use of shared virtual environments for university-level education. In [5] we report the building and deployment of the Telepresence tool, used in this paper, to support distance learning. The tool had been used in a Computer Graphics and in an Electromagnetism course. In [6] we describe the use of single– and multi–user augmented reality for tutoring in a Multi-Variate Calculus course. In both cases, the use of the mixed reality tool, hand in hand with the Teaching for Understanding framework, lead to more profound understanding of the concepts by the students.

B. Teaching for Understanding

In the previous projects we have used Mixed Reality applications for teaching Math [7] or Physics, we have used Teaching for Understanding (TFU) as pedagogical framework. The combination of an innovative tool with the appropriate pedagogical approach has fostered students' understanding of the topics in relation with their environments. In this way, concepts become immediately pertinent, since they can be used to solve meaningful problems.

Teaching for Understanding can be used in all phases of the teaching/learning process. It has two main components: dimensions and components. Dimensions serve as guidelines to design the activities of the course in an integral manner; components allow for the actual deployment of the course

design. TFU proposes four dimensions: (i) contents, directly related to the curriculum, (ii) methods, or particular ways to create new knowledge, particular for each field, (iii) praxis is the way how the knowledge is applied and (iv) communication, related to the specific language of the field of knowledge.

The four components are: (i) Goals of understanding: what level of understanding will students achieve at the end of the learning process, (ii) Generative Topics: what motivates students to understand the really main ideas of the course, (iii) Performances of Understanding: what activities do students undertake in order to, increment and, at the same time, demonstrate their understanding? (iv) Continuous Assessment: How to measure students' advances and understanding? [8]

There is a tendency to assign all parts of a curriculum the same relative relevance, and to present all parts in isolation, without any relationship among them. When using TFU, one of the first tasks is to determine the most important topics in the subject, in order to concentrate on them. This means that the objective is not to cover all parts of the curriculum, but to give more emphasis to those that articulate better with other parts. Students are asked to dedicate most of the time, energy

Fig. 2. Movement in the presence of friction.

and resources to those parts. This approach helps students to "...make better use of the developed intelligence, discovering and developing their potential" [9].

This pedagogical framework allows the instructor to define short- medium- and long-term goals; allowing for a prioritization of the subject objectives and their application in the classroom. The way how concepts are presented and the instructor's understanding about them, play a fundamental roll in the development of the curriculum.

III. OUR APPROACH

The development of the Physics I course involve two teams: One team was in charge of the pedagogical approach and the other one was in charge of the technological part. The existing curriculum was used as a starting point. The pedagogical team determined the goals of understanding and the various activities that student should be exposed to in order to reach them. The technology team was responsible for the Java3D implementation of the different contents developed for the course. Each illustration was discussed from both point of view (pedagogical and technological) before their actual deployment in the course.
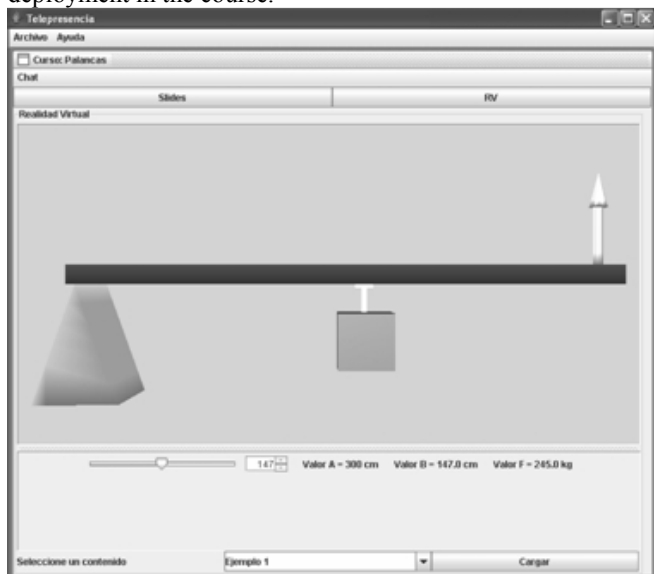

Fig. 3. Levers: users can move the support and change the weight to be lifted.

The Telepresence tool built at Eafit University was used in a Physics I course taught at the Building Construction Technological program at Universidad del Quindío. This subject covers fundamentals of physics, such as vector operations, Newton laws, simple machines and others.

The program is partly a distance program. This is to say, students meet every 15 days for face-to-face classes, but the rest of the time they study by themselves, following the distance program guidelines. Each meeting takes four hours, and students receive tutoring on the subjects they have prepared previously. Instructors can also asses the learning process via workshops or exams.

In this case, there were 21 students in the class, each of them with diverse backgrounds. Some students had almost no previous experience using computers, while others had a basic experience using them. Students live in several cities and towns of the region, including various states (Quindío, Risaralda, Caldas and Valle). Their age range goes from 18 to 44 years. Some of the students work as waiters, construction assistants, house keepers, taxi drivers, and bank cashiers.

A. Course Contents

Various contents were created using the telepresence course, covering the following topics:
- Deformation due to external forces
- Vector operations in 3D
- Hanging weights
- Movement in the presence of friction
- Column bases
- Simple Machines

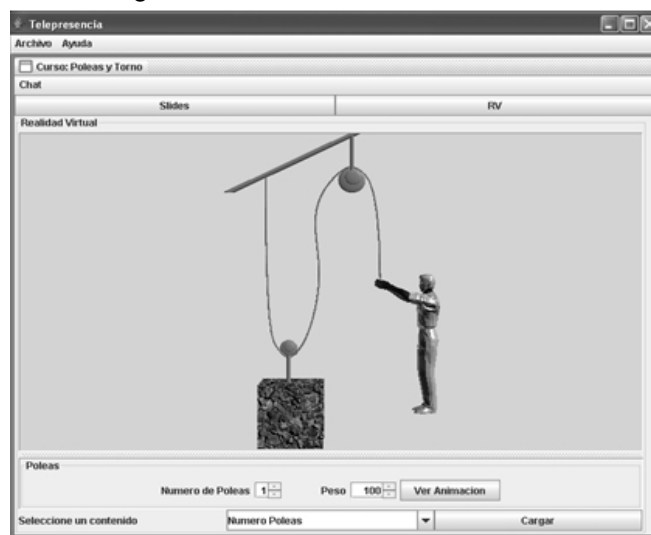Due to space limitations, a brief description is provided for the following contents:

Fig. 4. Pulleys: the user can select the number of moving pulleys and the weight of the object.

1) *Vector operations in 3D*: This content helps students understand basic vector operation in 2D and 3D. The application is particularly useful to demonstrate concepts in 3D, which are difficult to understand when they are drawn on a whiteboard. Vector addition (through various methods) and vector cross product was demonstrated. Figure 1 describes the addition of two unit vectors in 3D space.

2) *Movement in the presence of friction*: This content demonstrates the movement of an object, under a given external force, in the presence of friction. The student enters the weight of a body, the friction coefficient, and then uses the application to provide an external force and direction. After applying different forces, directions and providing various friction coefficients, the student internalizes the phenomenon. Figure 2 shows the body moving after the force is applied.

3) *Simple Machines*: Using this content, users can play with various types of simple machines. In the case of a lever, for instance, students have to compute the force to be applied at the end of a lever, given the position of the support and the weight at the other end. In figure 3, the arrow size at the right end of the lever describes the magnitude of the force that has to be applied in order to lift the weight.

Content was created to demonstrate the functioning of pulleys. Students can select the number of moving pulleys (between one and three) in order to reduce the effort done by the avatar.

Figure 4 shows the contents when the user has selected two pulleys.

Fig. 5. Students using the telepresence tool.

B. Pedagogical support

The pedagogical team determined that the best way to present the goals of understanding was through the use of questions. These questions should invite students to think and discuss about the importance of physics, motivating students to explore their environment and find answers to the proposed questions. In an initial session, students were explained the methodology and the following questions were asked:

• How can current technological developments help me to understand Physics in a better way? This question aims at the use of the Telepresence tool. In particular, how theory and practice are integrated through the use of the tool.

• How does Physics influence our daily lives? This question intends students to become aware that physics is always present in their daily lives.

• Which things I use on a daily basis are product of Physics? The idea is to lead students to observe their environment carefully, looking for Physics applications.

• Can Physics help to build a better future? The idea is to invite students to think about their future professional career, and find the roll Physics play in their futures.

• How can I use Physics in building technology? This question invites students to transcend the theoretical concepts in Physics and to visualize its application in Building Technology, so they can use it in their professional lives.

Due to the interest that Physics concepts evoke, it was determined that the generative topic should be Physics itself. Newton laws, electrical circuits and pressure in fluids were determined to be, among other concepts, the goals of understanding. The goals students reached as they progressed through the course were written down in a journal, describing the individual and group achievements throughout the course.

C. Technical developments

The Telepresence tool used in this work was built at Eafit University in 2004. It was built entirely in the Java language. Audio and video were handled using Java Media Framework. For the purpose of this project, the following modifications were done:

• A larger number of codecs was used, in order to accommodate lower bandwidth channels. In the presence of very low bandwidth, the video quality is affected in order to maintain the audio contact. In this case, only one frame is sent over the network every 5 seconds.

• The application was organized as a framework, in order to make it easier for the new programmers to develop new contents. Patterns were used extensively in order to lower the unnecessary dependencies among the classes comprising the application.

• Modifications were done to accommodate various hardware settings. If a 3D tracker is available, for instance, the application starts using it. Otherwise, the interaction is achieved through a regular mouse.

IV. RESULTS

In order to analyze the students' understanding during the course, three tests were conducted: (i) a pre-test at the beginning of the course in order to determine previous knowledge. Students were asked to describe daily life situations in which Physics concepts applied. In most cases, students answered "none, everything is already built". This showed that Physics concepts were only important for people designing building structures. (ii) A test at the end of each experience, with questions about the functioning of the experience and the physical concepts that were demonstrated. All students provided a very positive evaluation of the tool and contents. The part they liked the most was the fact that they could repeat the experience with a content over and over, until they grasped the concept. (iii) A test was done at the end of the experience. When asked about applications of Physics in daily life, all students were able to explain how the concepts of the course were applied in their environment, even in their own houses or buildings in the university.

During the course, a high level of motivation and interest toward the use of the tool was showed. The following behaviors were observed:

• Students made teams to work on the contents, and discussed lively until the result was understood by every participant.

• Students showed a high level of concentration, which was not always the case in the sessions developed without the use of the tool.

• Students checked the results by hand, and in one or two cases found mistakes in the program.

• Students reported a high level of satisfaction and motivation with the tool.

Figure 5 shows several users working with the Telepresence tool.

In the interviews conducted during and after the experience, students reported positive opinions. For instance:

• "Concepts are easily understood when using the tool".

• "2D and 3D graphics helped me to overcome my doubts, and observe a direct application of the formulas".

• "The use of 3D objects helped me to understand better than the traditional methodologies".

• "It is good to be able to observe the demonstration from various points of view".

• "The tool is agile; we can see the results immediately".

• "This is an innovative tool; it helps me to understand better than traditional methods".

In their final projects, students had to report on situations, about their daily lives, in which the concepts learned along the course were applied. They had to build prototypes of those situations and explain how the physics principles apply. In these projects most students demonstrated that they had achieved a profound understanding of the concepts.

V. Conclusions and Future Works

The results of the application of the tool show that students were highly motivated and achieved deeper levels of understanding along the different dimensions of understanding. The use of Teaching for Understanding helped students to understand the concepts, not only to memorize the formulas or the theory. This fact was very clear in the applications of physics concepts they found on real life situations when developing their final projects. This extrapolation showed, also, that they reached more profound levels of understanding.

We intend to implement the following improvements to the application in the near future:

• To make it multi-point. This will allow one instructor to conduct a session with several student locations.

• To replace the video and audio application. We plan to explore other freely available tools to handle audio and video with better compression rates and lower bandwidth consumption.

• To develop an application that allows non-programmers to create simple contents. The tool should allow instructors with no programming abilities to import virtual objects and define simple behaviors and interactions between objects and its users.

VI. Acknowledgements

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