3D PHYSICS – AN INTERACTIVE SIMULATION VIRTUAL WORLD

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ABSTRACT

The relation of the study of Kinematics and the use of 3D virtual environments is no big news. Nevertheless, the majority of these researches do not take the student's accomplishments in these environments into account, thus, for lack of data and inefficiency in working with the already acquired data, an effective evaluation on what was studied or discovered cannot be carried out. This paper is part of a project called "3D Physics", which is trying to produce software for educational purposes in all areas of Physics. It's using object-oriented techniques and software engineering, which facilitates the development of new sub-prototypes. The project is also planning to make use of artificial intelligence techniques in order to develop tools that could help the teacher out in the student's performance evaluation, detecting patterns and classifying data. Particularly for this paper, the project's first module will be introduced, "Uniform Motion", which is a field of study in Kinematics, showing how it works, presenting teacher-supporting tools, the student's interface and the evaluation module development principles.

Key-words: Physics Teaching, Virtual Reality in Education, Web base Education.

1. Introduction

The use of computers as a teaching and learning tool at elementary, middle and high schools has becoming important in the knowledge internalization process in the classroom and out of it, the skyrocketing outspread of software for educational purposes may be observed. These programs make use of advanced technology resources with sound, animation, colors and all that's available. Many schools do not have modern computers, though, particularly public schools in Brazil, so the development of software with good interaction and visualization quality is a great challenge [1]. In face of the imposed limitations, the Internet seems to be a natural filter for this kind of applications, once a web page is not attractive, easy to interact and "light", it will be doomed to oblivion in the hard disk of any Web server. Besides, Web teaching turns interesting because the student may bestow and handle what was uploaded anywhere, as long as there's a computer with Internet access, which could be at his parent's workplace, friend's house, etc.

On the other hand, to make all this study material available with the characteristics mentioned above is no easy task. When it comes to teaching using the Web, Khalifa and Lam state that there are two large groups: DPL (Distributed Passive Learning) and DIL (Distributed Interactive Learning) [2]. The former allows a linear use of the study material, which could be, for example, a text file or a multimedia slide show, whereas the latter must allow a non-linear access to the information, using a hypertext structure, and greater interactive and exploiting capabilities. Khalifa and Lam even state that the majority of the Web based courses are DPL and the great challenge lies in the creation of new DIL-based learning environments.

It's likely to be a consensus that Virtual Reality (VR) may contribute to the teaching-learning process [3] [4] [5] [6], setting new levels of visualization and interaction. It would better fit the needs of educational softwares, giving them better graphics and more interactiveness, which are essential for DIL content. Regarding environment fidelity, one must not forget the commitment to foster the development of interactive materials that require low hardware resources. It's important to point out that even with limiting world fidelity it is possible to produce excellent Web contents.

This paper aims to display a prototype of a simulation tool that will help the teaching-learning process of Physics for elementary, middle and high school students, more specifically in the kinematics field and the study of Uniform Motion [7]. In the simulator, the study with only one moving object is possible and the parameters regarding its position, speed and simulation time may be manipulated. It's also possible to work with two moving objects simultaneously, with the same parameter changes, and analyze their position and the moment they run into each other, as well as have the graphics related to the study made. There are tools to aid the teacher in the registering and assorting of the exercises by subjects and by groups or difficulty levels. The simulations performed by the students are stored in a database, for the teacher's further appraisal. This way, the teacher may achieve a more detailed attendance of the learning process and, in the future, this module may be controlled by intelligent software. This prototype is part of a greater project called 3D Physics, which employs object-oriented techniques and software engineering for a faster creation of new sub-prototypes and currently makes use of the following VRML (Virtual Reality Modeling Language) technology, 3D objects and environment construction language, Java language, to enhance the virtual 3D environment interaction and allow the user to change the position, speed and acceleration options for the moving object and EAI (External Authoring Interface), which permits the communication between VRML and Java.

Overall, this research involves concepts on applications of Virtual Reality and Education, the presentation of the proposed prototype and the employed technology. It's structured the following way: on section 2 the reasons in which the use of Virtual Reality in Education is based on. On section 3 the proposed prototype is introduced, along with its goals, the tools that were used in its development and the prototype itself. Finally, on section 4, final considerations on the development of the project and future research are made.

2. Virtual Reality Applied to Education

The relevance of VR to the educational context presumes an array of possibilities with the intent to optimize several learning methods related to a variety of interaction ways, playing an important role as a settlement tool amid teachers, students and information.

The teaching granted by any computer technology that is based on cognitive pedagogical theories, which appraises intelligence related to its mental representations and on behavior observation, may be much more effective if associated to several VR interaction and may generate an endless number of applications on several different fields. Among the cognitive approaches, Jean Piaget's constructivism and Lev Vygotsky's and Henri Wallon's social-interactive theories stand out (Silva, 1998). They take into account epistolary, biologic, cultural, math-reasoning and linguistic factors, which are of great applicability at computerized educational environments.

3. Piaget's Constructivism applied to Virtual Environments

According to Piaget [8] the learning process takes place having epistolary genetics as the cornerstone. That's a process in which knowledge is built, step by step, according to the rhythm of the organizations of both the mental and cognitive structures, having in mind the diverse levels of human intelligence development.

For Piaget, the learning process corresponds to an enduring adaptation process, where one searches for a condition of stability with the environment. Out of this interaction, two distinct processes come out: understanding, in which one improves his intellectual background through environment interaction, allowing intellectual changes, and "settlement", which corresponds to the changes in already existent schemes in relation to the new digested characteristics, altering quality-wise, its intellectual construction and developing new cognitive structures.

If used properly, the virtual environments may promote the unbalance between someone and his surroundings, constantly impeling understanding and accommodation processes through simulations that are able to reproduce real situations with a considerable high-fidelity degree [9].

Museum visits with interactive dialogues and virtual visitors, bacteria manipulation, chemical reactions, physics phenomena simulations, geometric operations and mathematical equations can be reproduced.

What's being presented here deals with the simulation and observation of the laws of Physics related to kinematics, particularly to the Uniform Motion (UM).

4. 3D Physics – Uniform Motion Module

4.1. Motivations and Goals

One of the reasons why 3D Physics - UM Module was created was to make the visualization of practical results of the laws of Physics possible. Before, they used to be merely exposed on the blackboard, but with this new software, the student is encouraged to try out novel situations where he will discover and analyse new results through the simple handling of the virtual objects in the environment, as: speed, space and movement time period.

The UM module is a prototype produced to enrich kinematics study through practical visualization, which turns what has been taught by the teacher in his classes, more appealing to the student.

This prototype has as main goals:

a) Local or remote (Internet) access of the simulator;
b) Make the contents to be studied and complimentary reviews of the subjects involved available;
c) Allow more time for experiences to be conducted, taking the student's rhythm into account;
d) Facilitate the learning process through an interactive interface which uses what was already learned from the real world;
e) Make available for the teacher the tools for the preparation of the simulation activities and students' evaluation.

4.2. Architecture Prototype

The technologies used and their interaction may be seen on Figure 1, and they are: VRML (Virtual Reality Modeling Language) [10], JAVA [11], EAI (External Authoring Interface) [10] and Database, via jdbc-odbc [12].

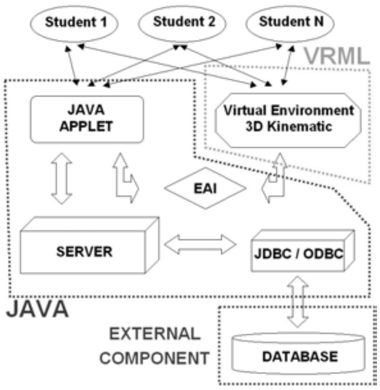

Figure 1 – Used Technologies in 3D Physics.

4.3. Prototype

The prototype presents four main modules: authentication module, teacher module, student module and evaluation module. They will be better detailed on the following sections.

4.3.1. Authentication Module

It's the module that both the teacher and the student login in order to gain access to the pages and start working (Figure 2).

Figure 2 – Authentication Module Screen

4.3.2. Teacher Module

This module is divided into 4 parts that are: user registering, subject registering, level registering and exercise registering.

4.3.2.1. User Registering

It allows two kinds of user to be registered, teachers and students. They will have access granted to the environment according to their characteristics. The registering screen will show blank spaces that should be filled with the name of the teacher or the student and the group to which he or she belongs to.

4.3.2.2. Subject Registering

It allows the registering of subjects related to Physics which will be dealt with in the simulations. In order to fulfill the registering, the teacher must inform the subject and present a brief description of it. Aside from the registering, it's possible to remove, alter and modify the order of previously registered subjects.

4.3.2.3. Level Registering

Similarly to the subject registering, this registering allows the creation of several levels where the exercises will be categorized in relation to the difficulty level shown. These levels may be determined by the teacher throughout the construction of the exercises. This data registering is similar to the subject registering, presenting even the same resources of removal, alteration, and change in its order.

4.3.2.4. Exercise Registering

It allows the insertion of the exercises to be performed during the interactions between the student and the environment. Each registered exercise has to show its identification, description, difficulty level and the definition of the topic it belongs to. Besides that, it allows the removal, alteration and change of the order of the previously registered exercises (Figure 3). Also, it allows the teacher to define the quantity of cars through their qualifications, as well as the values of the variables of each vehicle, related to the final space (S), initial space (So), velocity (V) and time (T), present in every exercise. Actually they are the answer for the proposed exercise. All the data registering process may be done through a Web browser.

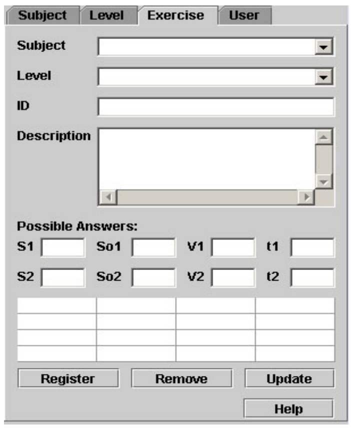

Figure 3 - Exercise Registering Screen

It is important to notice the possibility of browsing among several register screens, through the “Go to” button, allowing a more direct interaction of the teacher during the configuration process of the exercise.

4.3.3. Student Module

After logging in , the student is presented the information about his/her last exercise. The student may also choose a new exercise, subject or level. The "Exercise" button opens the simulation screen (Figure 3).

The simulation of the exercises performed by the students occurs in this module (Figure4). This module is also visualized in a Web page, and presents two main parts: a three-dimensional visualizer and an applet, a type of form used to manipulate the three-dimensional environment and respond to the exercises.

When the page is downloaded by the student, it promptly presents the next exercise to be solved, according to his login. However, in case the student wants to see the exercises previously done, it is possible by browsing the buttons Exercise, Level and Subject, in the Select Activity area.

In order to start the simulation process, the student has to insert one or two cars, and configure their parameters, such as final space, initial space, velocity and simulation time (Figure 4).

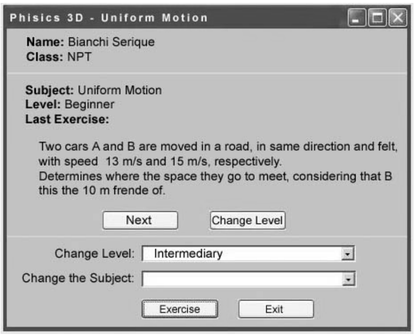

Figure 3. Selection of a new Exercise.

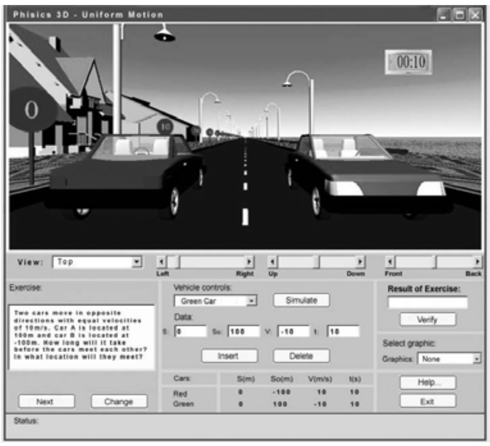

Figure 4. Applet loaded and cars inserted in virtual environment.

It is possible to generate graphics about the simulated problem. Figure 5 presents a space x time graphic.

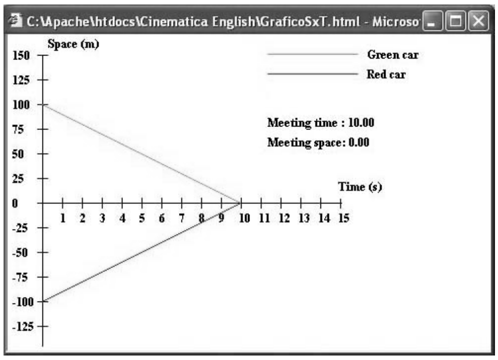

Figure 5. Space x Time Graphic.

Another possibility is to present the problem as a graphic so that the student can trail the learning process backwards as compared to the former example.

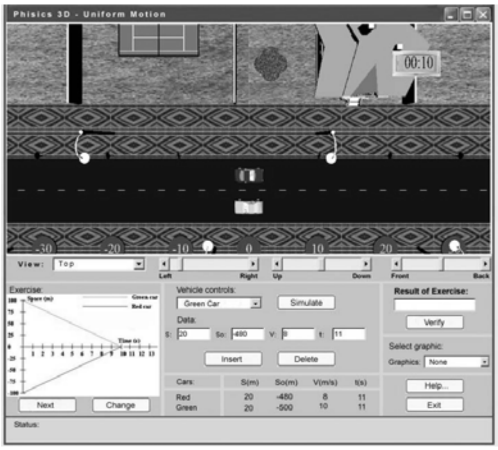

Figure 6. Graphic representing the problem.

4.3.3.1. Virtual Environment Control Applet

The applet (Figure 7) allows the control in all interaction levels between the student and the virtual environment, hence manipulating the vehicles’ simulation according to the resolution of the exercises. It allows control of the following functions: Visualization, Simulation of the given exercise, Manipulation of the vehicles and Selection of activities.

- Visualization – It allows the definition of the desired type of visualization for the exercises before the simulation, and, during it, the modification of its angle.
- Simulation of the proposed exercise – It enables the exhibition of the directions of the proposed exercise and the beginning of the simulation process. It is also possible to restart each simulation as many times as the student desires, so that he/she can watch it from several different available angles and visualizations.
- Manipulation of vehicles – In this section, the student must insert the data obtained when solving the

exercises, applying, for each vehicle, its correspondent set of variables. Once inserted, the data will allow the insertion of the correspondent vehicle into the virtual environment, so that it can be simulated later.

- Selection of activities – This section is responsible for the selection of the subject to be dealt with, its difficulty level, and the exercise to be solved and simulated.

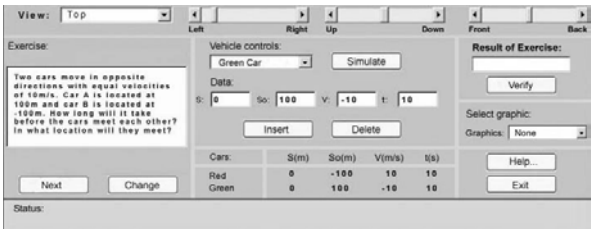

Figure 7 – Applet used by student in the simulation process

4.3.3.2. Simulation

In the simulation process, the insertion of the cars is necessary, then, the students will configure their parameters and click the insert button. When a car is inserted, its data is shown in boldface in the Vehicle Manipulation area. Figure 7 shows that two cars have been inserted with their data.

According to the proposed exercise, after the insertion of one or two cars, the simulation process starts. Notice that the simulation process is different than simply solving exercises. In order to simulate the exercise, the student has to use the "start" button in the Simulation area. Then, the data are stored in a database, so that they can be analyzed by the teacher later. Based on these data, it is possible to obtain statistics related to some questions, such as " How many simulations were necessary until the student was able to solve the exercise correctly?" or "How many of the simulations performed before the solution of the exercise were right? How many were wrong? What kind of mistakes were made?", etc.

In the beginning, the cars start moving according to the data inserted by the student, so that he/she is able to check whether his/her answers correspond to what has been asked on the exercise. Several forms of visualization have been offered, in order to enhance the quality of the above-mentioned perception. That enables the student to have different reference points in only one simulation, as a way to confirm the obtained results. The following visualizations have been made possible: superior (Figure 6), in the course of the vehicle(s) (Figure 8), and, internally, from each vehicle (Figure 9). These visualizations are accessed in the applet's visualization area. According to the chosen reference point, it is possible to browse it in several ways during simulation, making use of the scrolling bars next to Visualization: back and forth, up and down, left and right. When the observation point is internal, the view follows all the simulation process, giving the student the sensation of being right inside the car.

The environment has also a chronometer that registers the time spent in the simulations. It has four digits – two used to count minutes, and the other two stand for the seconds. It begins as soon as the simulation is started and registers the time spent during each exercise. The time registers are very important when it comes to solving exercises.

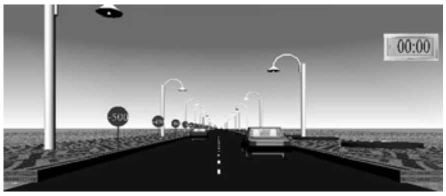

Figure 8. Visualization in the course of the vehicle during the simulation process.

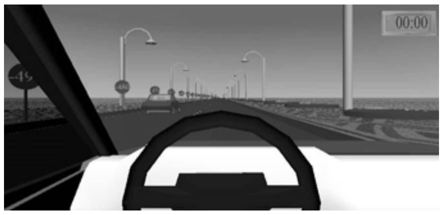

Figure 9. Internal visualization during the simulation process.

These features give the student a great interaction level when simulating the exercises, enabling a more refined analysis of possible mistakes or inconsistencies, facilitating their correction in a more consistent and effective way.

After several simulations, according to his/her necessity, the student is able to solve the exercise. For instance, if the student inserts the following data: "S=1m; T=10s", and clicks the Answer button, the solution, as shown in Figure 5, will be "S=-35m". The data of the simulations and the answers will be kept in a database (Figures 10 and 11) for further analyses by the teacher.

Simulation : Tabela

idIssue	idLevel	idExercise	idStudent	idSimulation	car	So	S	V	T
1	1	1	1	0	Green	-500	-200	15	20
1	1	1	1	1	Red	-480	-220	13	20
1	1	1	1	2	Green	-500	-200	15	20
1	1	1	1	3	Red	-480	-220	13	20
1	1	1	1	4	Green	-500	-200	15	20
1	1	1	1	5	Red	-480	-220	13	20
1	1	1	1	6	Green	-500	-200	15	20
1	1	1	1	7	Red	-480	-220	13	20
1	1	3	1	0	Green	-150	20	10	10
0	0	0	0	0		0	0	0	0

Registro: 10 de 10

Figure 10. Result of the exercises.

Answer : Tabela

idIssue	idLevel	idExercise	idStudent	idAnswer	template	kind	value
1	1	1	1	1	☑	S	-350
1	1	1	1	2	☐	S	-350
1	1	1	1	3	☐	S	-35
1	1	1	1	4	☐	S	-35
1	1	1	1	5	☐	S	-35
1	2	1	1	1	☑	S	100
0	0	0	0	0	☐		0

Registro: 7 de 7

Figure 11. Result of the simulations.

The student then faces different answers for the right resolutions, according to the solution inserted by the teacher and for the mistaken efforts, in order to perform the analysis of the mistakes, taking into account their kind and the number of wrong resolutions. Some kind of answer are show in Figure 12, 13, 14 and 15.

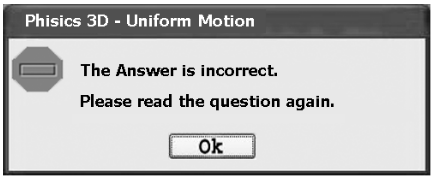

Figure 12. First kind error message.

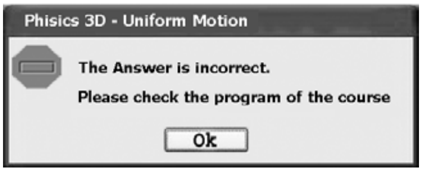

Figure 13. Second kind error message.

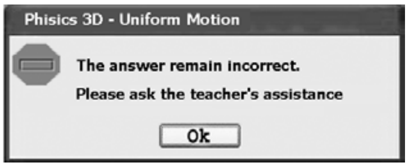

Figure 14. Third kind error message.

Figure 15. First kind message of correct hit.

5. Final Considerations and Future Works

There are many advantages in using virtual environments in the educational fields: it stimulates motivation, creativity, first-person experiences, teaching-learning process by discovering, time and space control, capacity development, overcoming of difficulties, and so on [3].

The usage of VR-based tools and other technologies, will allow the students to make their own experiences exhaustively, until he/she can attain a satisfactory knowledge, turning the teacher's role from source of information into guide of knowledge.

Notice that the goal of this tool is not to replace traditional learning-teaching methods, such as book readings, students-teacher or student-student interactions. It aims to assist that learning process, and even become a part of it.

In the future, the intention is to extend the number of applications of Physics, develop mechanisms that facilitate the development of new applications, create more realistic environments, counting on the usage of unconventional peripherals, such as gloves and stereoscopic glasses. This way, it is possible to have different levels of realism in one single environment. The change of "3D Physics" modules into collaborative virtual environments is intended too. The evaluation module of the user's tasks is being developed. This tool is based on AI techniques, and will help teachers to follow the learning process of their students, once they will have access to the students' performance during simulation and to their answers to the proposed exercises. Finally, it is also intended to use the prototype in real classrooms for pedagogic and ergonomic evaluation purposes.

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