EDUCATIONAL PRACTICE IN VIRTUAL LABORATORIES FOR ENGINEERING STUDIES

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In this article new ways to approach the educative process are presented, they are shown from a point of view of the education methodology, as the virtual laboratories. A study of the necessity to incorporate in the education of engineering degrees, virtual laboratories. In addition, the advantages that these laboratories offer are analyzed and the disadvantages that the students have when they use them and other new technologies which are involved in the use of this means of education. The study and analysis that appear here have been made with computer science engineering and technical engineering students. This studies have a technical-scientific character and are intimately linked to the use of new technologies and virtual laboratories.

1 Introduction

Traditionally, the contents of practice classes in engineering has been strongly influenced by the equipment available in the laboratories. However, nowadays this problem can be overcome with the use of new technology employed in virtual laboratories (internet, virtual reality, etc.).

In this article, we describe the different functions of the virtual laboratory employed in educational tasks at the university level, and a study carried out on the advantages and disadvantages that it offers for teaching. This virtual laboratory has been applied to educational practice for engineering studies at University of Alicante. Its aim is to provide access for all of the students to the available robotic equipment, generally limited, due to its high cost.

This virtual laboratory affords the simulation of the students' practices and evaluates their skills in the correct use of the robotic equipment. It also permits the students to do a self-evaluation of the knowledge they have acquired. This is done by means of a series of practical exercises that they can do from any location with the use of a PC and access to the Internet, affording a virtual experience that is comparable to actually being in the laboratory of the University. Furthermore, it also offers the teacher the facility of a more complete monitoring of the students' exercises.

This study not only describes the functioning of the virtual laboratory, but the impact that it has on the student's progress as well. To do so, a comparison is done between the use of these laboratories and the conventional way of teaching without them, based on our teaching experience over the last few years.

The different advantages, such as the flexibility of time-tables, and possible inconveniences of use these laboratories, from the students' point of view, are also taking into account. These inconveniences imply that a teaching support is required to allow a bi-directional communication teacher-student.

Studies have been carried out on typical university engineering student profile which reveals some interesting data, which should be taken into account when remote education is attempted using modern technology. This data and its impact on the remote students' learning process are described in this article.
Finally, graphic data that compares the results of different students, those who have used the virtual laboratories and those who have not, are also shown. This data is accompanied by our conclusions, as well as a series of suggestions for the most convenient use of the virtual laboratory, based on these conclusions.

2 Description of the virtual laboratory.

The student make use of the virtual laboratory, connecting with a Web server located at the University of Alicante. The means required are a computer connected to the Internet and suitable software [5,6].

The simulation is carried out with virtual reality software, while the tele-operation can be done in different ways: by means of a recorded sequence of videos which the user receives when a command has finished, asa remote execution using a video flow, by means of a feedback in real time of the information about the robot's basic parameters.

Nowadays, the bandwidth of the common accesses to Internet considerably limits the transmission of video images in time-real. The solution that has been adopted to obtain a tele-operation in real time consists of transmitting the information about the basic parameters of the robot (positions of joints) from the real laboratory to the user. These values are used by the virtual reality interface that each user has. With this method, the user observes a simulation of the robot, but, in contrast to a simulation based on a mathematical model, this one corresponds to the real values of the robot's position.

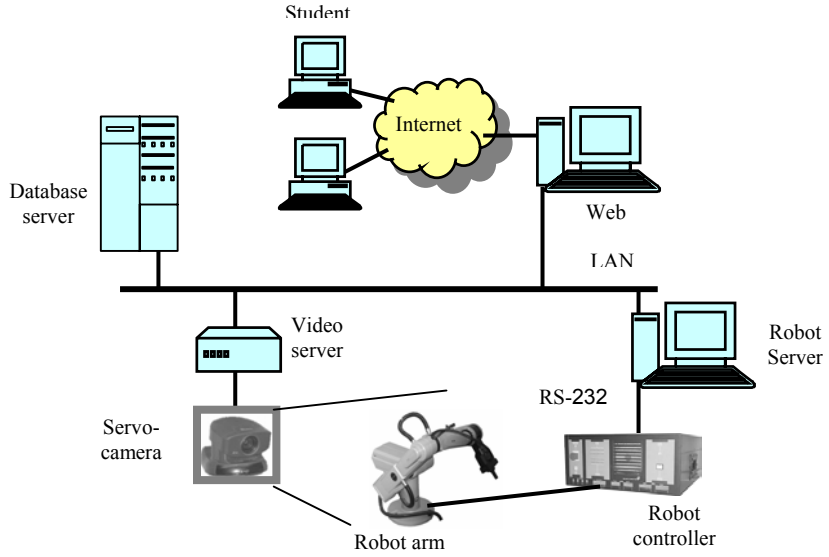


Figure 1. Architecture of the system

Figure 1 shows the different components that make up the system. There are two well-defined parts, the student's computer and the laboratory equipment, both connected through Internet. The following points describe, in greater detail, the characteristics and functions of the different pieces of equipment.

2.1 Architecture of the system

Among the laboratory equipment, the Scorbot Er-ix robot of Eshed Robotec Ltd is the most outstanding. It is a robotic arm of five degrees of freedom plus a clamp. The robot is governed by a controller which is programmed, using ACL language. A PC computer acts as a server for the robot, whose functions are to manage the commands directed to the robot and to obtain data on their present state, to be able to make the feedback in real time.

The equipment labelled "web server" in Figure 1 has two programs: the web server and the feedback server. The first program controls the user's connections, the applet download for the simulation and the remote execution, while the second program allows the real-time tele-operation.

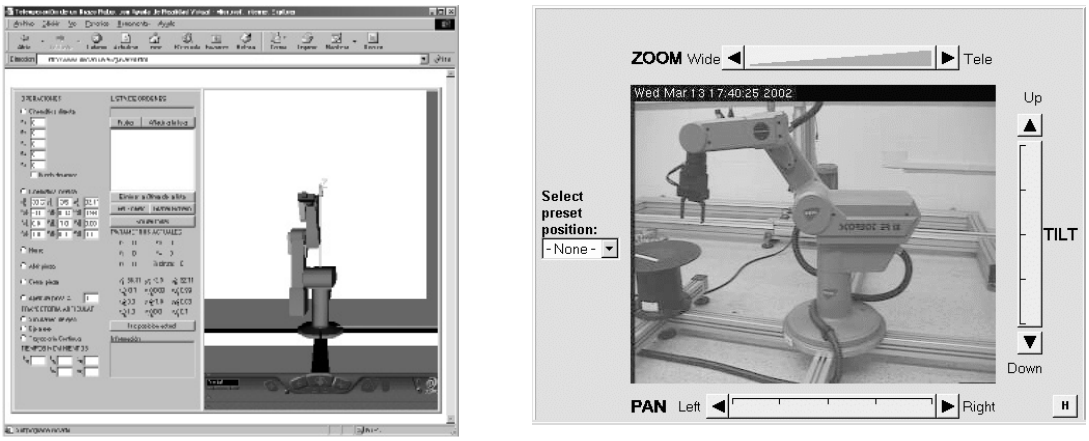
There are two other important pieces of equipment: a data base server and a video server. The first computer is a PC that stores information about the users and their practices, and the second one is an AXIS 2400 server which is used to get the tele-operation video streams. The video server is connected to a Sony EVI-D31 camera, allocated near the robot's work area, and it allows more than just watching the camera video stream; it also affords the control of the camera's orientation and zoom, through its web page.

2.2 User's interface.

The student can use all of the functions of the virtual laboratory thought a Java applet on a web page [2]. In addition, in the simulation uses VRML (Virtual Reality Markup Language), the standard Internet language, which gives an easy user interface for managing different points of view in the simulation [1,7,8]. Thus, it

is necessary for the student to have the proper software installed in his computer, i.e., a browser that allows the execution of Java and VRML.

In Figure 2a, the web page is shown as the student sees it. The page has two parts: the Java applet with the different options for controlling the local robot simulation, and a VRML window with the current simulated state [3,4].



a) b)

Figure 2. a) User interface b) Tele-operation with a video stream

The simulation allows a student to determine whether the execution of a group of commands is correct and does not imply any problems with the real robotic arm. After doing a simulation and getting a correct command list, the student can execute the tele-operation option, commanding the web server to execute the movements in the list through the real robot arm. This execution can be evaluated in three different ways:

- The user gets a video sequence after the execution, that can be seen with a standard video player application. This option does not allow a real-time tele-operation.
- The student gets a compressed video stream while the robot executes the command list. To do so, a connection is established between the student's computer and the video server. This option allows a real-time tele-operation if the net's bandwidth is wide enough. Figure 2b shows the last image in the video sequence obtained from the simulation in Figure 2a.
- The VRML simulation is updated in real-time with the information received from the web-server while the real robot arm is in movement. This option does allow a real-time tele-operation.

The correct use of the robot is guaranteed, since the practices are first executed with a simulation, and only the valid lists of commands will be tested in the real equipment. Furthermore, the web-server makes a second verification of all the parameters of the commands in order to prevent the system from being damaged. As a result, the life-span of the equipment is increased.

3 Methodology for analyzing learning, with virtual laboratories.

The progress of the students who have done the practices from their homes or from the laboratory located at the university, has been evaluated. To do so, we have considered 52 students registered in "Technology and Control of Robots and Sensorial Systems", which is taught for the degree in "Computer Science" at the University of Alicante, and we have carried out a statistical study of the results obtained, using the virtual laboratory to resolve the technical questions planned for the practical experiments. The results have been measured by means of tests and the evaluation of the teacher.

Among the contents of the subject, we have considered the technical part that is resolved by using the virtual laboratory presented in the previous sections. This practical part is composed of five experiments,

and we have a statistical study for each one of them, to be able to highlight the general conclusions later on. The scheme in the following figure 3.a shows the average time required by the students to resolve each experiment:

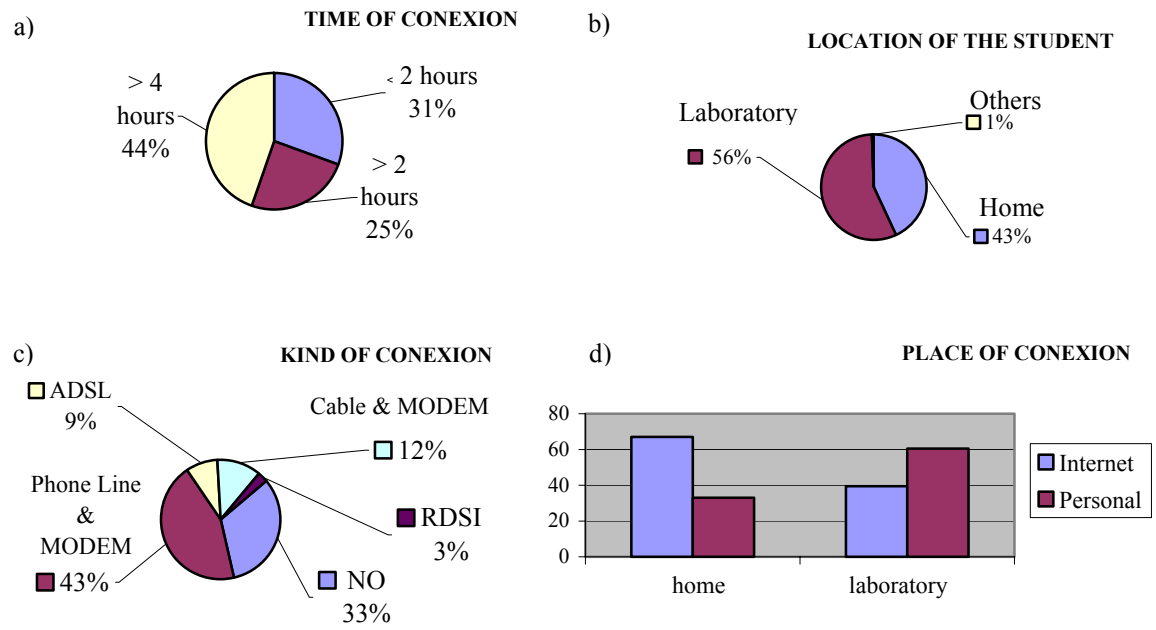


Figure 3. a) Average time required by students to resolve the experiments. b) Place of execution of the practices. c) Distribution of availability of Internet access. d) Preferences in the ways of handing in practices relative to where there are done.

In Figure 3.b, we can observe that 43% of the students have chosen to do the practices from their homes in contrast to 56% who have preferred to do it at the laboratory at the university through a connection to the Internet and access to the remote laboratory where the robot is located via the Web. The reason for offering them the choice of doing the practices at the laboratory of the university is due to the fact that most of the students consider the explanations of the professor essential, which is in contrast to the present tendency to decentralize education, making it less dependent on the explanations of professors and/or tutors. Nevertheless, 44% prefer to do it at home or in other places, due mainly to a lack of time or convenience. Figure 3.c shows the types of connections that the students uses to do the practices when they do them from home. We should point out that 67% of the students of computer science engineering at the University of Alicante already have some form of access to the Internet.

Most of the students who have connected to the virtual laboratory for practices have done so during the afternoon hours (60.3%), but we must also emphasize that a small percentage of students do them during the evening hours (11.3%) as opposed to 28,4% who do it in the morning.

The study done show that, in opinion of the students, it is beneficial and interesting, since the use of these laboratories makes it possible to access costly tools and resources, such as robots. Nevertheless, we should emphasize that the great majority of the students prefer to do practices in the laboratory at the university, where they can have the help and support of the professor. While 56% who do practices at the laboratory of the university, 96% considers that the presence of a professor, for clarifying of doubts, is necessary.

On the other hand, of that 56% of students, 63% consider the explanations of the professor essential, while 37% do not (a manual for the handling of this laboratory is furnished). In addition, of the 44% of students who did the practices outside the university's laboratory, only 50% would prefer to continue with this method. Furthermore, when the students are asked which evaluation method they prefer, either the traditional system of evaluation in which it is the professor who corrects the technical questions of the practice and evaluates the knowledge acquired, or the system of automatic correction in which a computer

analyzes their connection times and the results obtained, 93.2% prefer the traditional method of evaluation in contrast to 6.8% who prefer the automatic one.

In summary, we can conclude that the average computer science engineering student prefers to do practices in the laboratory at the university, whenever this is possible. On the other hand, they also value the possibility and flexibility of being able to hand in their practices through the Internet from any computer, and not just form the computers at the laboratory of the university (Figure 3.d).

4 Conclusions

In this article, a virtual laboratory for the teaching of robotics in engineering subjects and its impact on the students has been presented. The use of virtual laboratories in www is greatly accepted among students, specially those who studying Computer Science Engineering, who have tested the system in this study.

From this study, different conclusions can be obtained. However, one of the most important points is that virtual laboratories can serve as a complement to the professor's teaching but can not supplant it. The results obtained show the preference of the students to have personal access to the professor and to use the laboratory of the university, due to the flexibility of schedules that it allows. Another aspect valued by a great number of the students is the possibility of acceding to resources, such as robots, to which they could not all have access, due to its cost and the limitations of their schedules.

In developing these types of systems, an important aspect to consider is that, at the present time, the uses of the Internet is not expanding as much as before. In fact, we should emphasize that, in our study, less than 63% of the students have internet access at home. However, the great acceptance of the system as a support to teaching encourages us to continue working to extend the uses of the virtual laboratory to remote control tasks, increasing the capacity of the system. Also, improvements in the interface are being implemented, based on the use of low-cost haptic devices.

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