

## Internet-based interactive remote laboratory for educational experiments

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### Introduction

The present changing world leads to a new century in which chemical engineers should face unforeseen challenges. New capacities and proficiency do not grow spontaneously in the students but require training. In particular, the advances in information technologies have induced a fundamental change in both, contents and methods of the teaching+learning process. Education researchers involved at every level and in every discipline have developed new methods, tools and environments for instruction. The educational use of computers has advanced beyond word processing and numerical calculations to include integrated data acquisition and analysis, intelligent tutorials, interactive video and virtual instrumentation. Novel methods in Computer Aided Process Engineering (CAPE) education make extensive use of all the aforementioned techniques to achieve efficient education [1,2].

In order to expand their knowledge, students must access different sources of information throughout different approaches. Since course notes had a low long-time efficiency, measurements, simulations and illustrations contribute to the teaching+learning process, we consider "learning by doing" as a fundamental part of engineering education. However, it demands great resources. Designing and constructing state-of-the-art experiments is time-consuming and requires money and effort. Sharing experiments locally and remotely allows unique laboratory equipment to be utilized more efficiently, brings down the cost per student, and makes more experiments available to students. The application described in this work presents a method of usage and exploitation of the facilities given by the computer and the Internet.

Two applications were developed to introduce the telelaboratory paradigm in different chemical engineering courses, using LabVIEW (National Instruments, USA) and Visual Basic software. The applications allow the users to access a distillation column pilot plant in order to execute experiments locally or remotely. Some of the lecture materials are developed using Macromedia Flash software and embedded in HTML environment, hence being easily accessible using standard Internet browsers. The experiments are being introduced in chemical engineering curriculum in courses such as Chemical Process Control, Chemical Process Modeling, Transfer Phenomena, Data Acquisition and Monitoring Systems in Chemical Engineering. Tests are conducted to develop a center of chemical engineering experiments at "Babeş-Bolyai" University to be used at the University Rovira i Virgili and ETH Zurich.

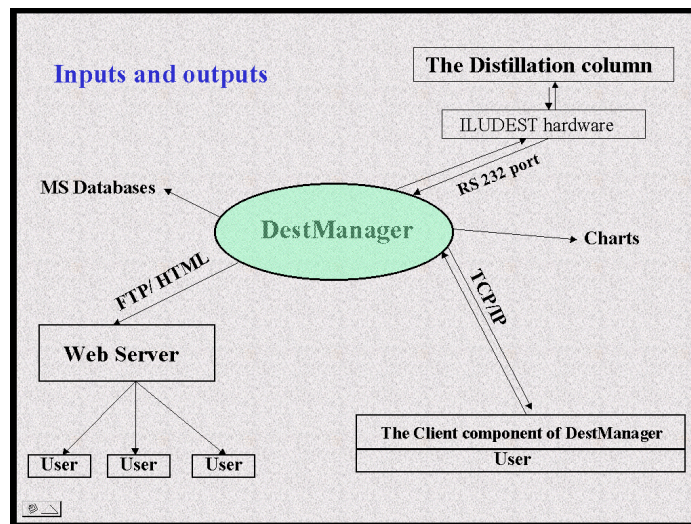


Figure 1. The Input-Output map of the software

The scopes of the experiments are, to study the dynamic and steady state behavior of the distillation process, understand the basics of data acquisition, and to study the performances of different control algorithms. The application provides a detailed description of the equipment and the theoretical background of the distillation process, distillation control, basics of data acquisition, and tuning algorithms. The lessons are illustrated with different interactive simulations, videodocuments, and experiments, which can be performed remotely in real-time, thus the application strongly supports active learning. The software provides an audio and video transmission from the remote equipment, to create the sense of being present ("telepresence") at the information source.

In the following part of this paper we are going to give a short description of the DAQ system and further focus will be put on the Data Acquisition tutorial the Data Acquisition CyberCourse.

### Description of DestManager 2002

The software interface is a Microsoft Windows platform software and is developed in Microsoft Visual Basic 6.0, with ActiveX Control and ActiveX DLL design. DestManager 2002 allows data acquisition, monitoring and control of the distillation column. In the development of the software interface the following key issues were of particular attention:

- Possibility of remote access of the data
- The actual communication with the distillation plant is realized through the ILUDEST-MOS unit on the first level. In this way a hierarchical control structure with tasks distributed on two levels was implemented. This is necessary to ensure the safety operation of the plant in case of computer failure or interruption of Internet connection.
- The most important criterion is: SAFETY OPERATION. For this, besides the hierarchical control structure, additional safety functions were implemented in the software.
- Simple operation through menu control and extensive help system enhanced by video documents and animations.
- Flexible software architecture for easy future development.

The input-output map of the software is presented in Figure 1. One software variant is designed as a MDI (Multi-Document Interface) environment, which contains the two main windows. These are the “Plant” and the “Chart” windows, presented on Figures 2 and 3, respectively.

Of particular attention in the development of the DestManager 2002 software packages was the implementation of the telelaboratory paradigm.

In order to implement the remote lab there are two approaches. The first approach is to embed the active code in a NET browser, like Internet Explorer. The second approach is to design two software packages, which communicates via TCP/IP protocol, using the specific communication libraries (ActiveX Control or ActiveX DLL for the Microsoft protocol). An example on the first approach is described in Shin et al. [3], the remote systems are developed using plug-in programs in Visual Basic\ASP (Active Server Pages), C++, and Java. These are embedded in NET browsers. A similar approach can be found in Arpaia et al. [4]. In this work a remote application was developed using the HTML and CGI (Common Gateway Interface) programming techniques. The active code was embedded in NET browsers. The disadvantage of this approach is that the Internet Browser embedded applications running on the Server Side and the Client Side are complex and need advanced programming skills to be developed.

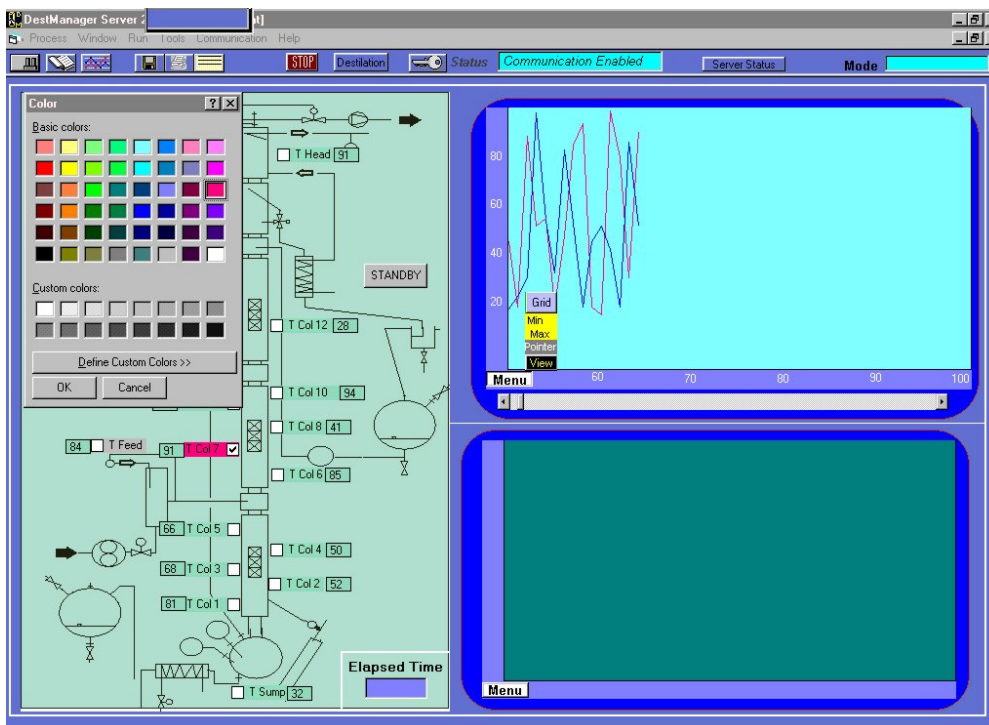


Figure 2. The 'Plant' window of application DestManager 2002

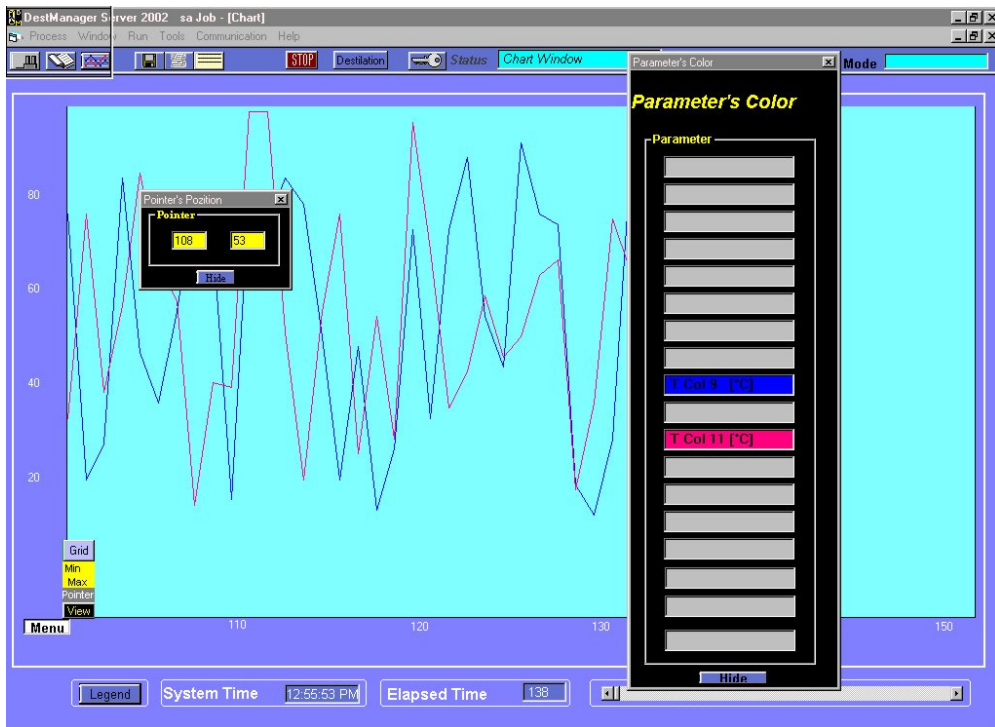


Figure 3. The 'Chart' window of application DestManager 2002

In order to have the maximum benefit of the TCP/IP communication and the worldwide network, we designed two software packages (Server-Client), which communicate using the specific ActiveX Control. In order to benefit of the advantages of this type of structure we developed our alternative to this approach. The main idea of the structure is that the Server application, which is result of a programming language compilation, generates a web page, which is uploaded on the web-server on a certain time basis. This page can be viewed using a regular web-browser. It must be stressed out, that each approach has its own advantages and disadvantages, outlined in Figure 4.

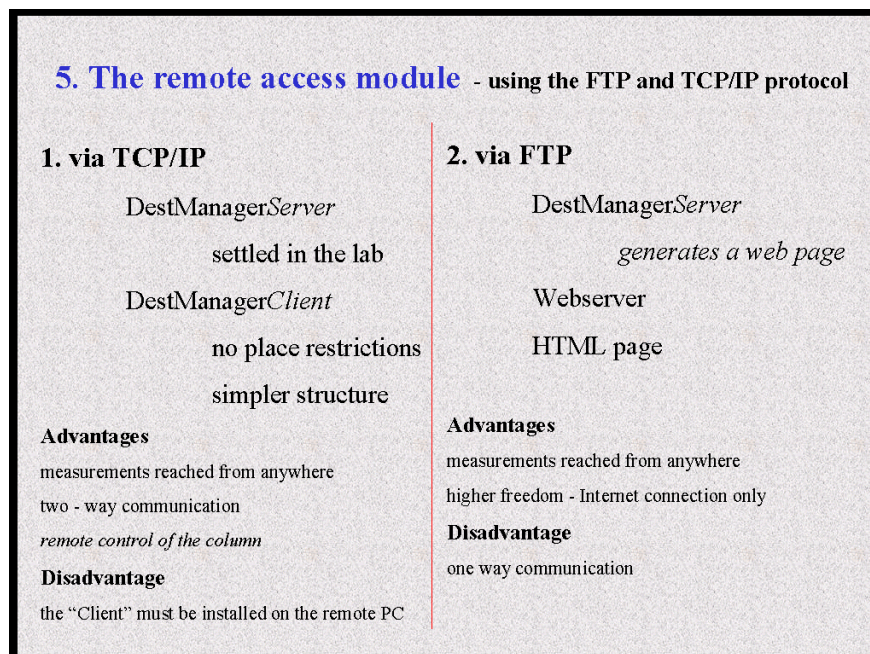


Figure 4. Advantages and disadvantages of the communication strategies

In order to provide a modern and flexible data storage capability to the software, the measurement data is stored as Microsoft Data-Base files too. In order to retrieve the data we designed a search engine based on the SQL syntax. (Structured Query Language). This data storage module is available on both, the Server side and Client side of the application thus the data access is easy. Besides the easy retrieving of values from database using the SQL syntax this approach provides the advantage of compatibility with web-based applications (ASP).

### **The Data Acquisition CyberCourse**

This electronic data acquisition course is designed for those who make the first steps into the DAQ field. The level of this course is not difficult, the approach to the DAQ systems is based on the previous skills of the students attending the Computer Aided Chemical Engineering section at the "Babes-Bolyai" University of Cluj, Romania. This DAQ CyberCourse is powered by the DestManager 2002 software, a dedicated DAQ and control application. As a support to the learning process, the DestManager software has the "Telelaboratory" features.

The Data Acquisition CyberCourse has been designed in the Macromdia Flash software package and embedded in the HTML environment. Macromedia Flash development environment, is a professional standard for producing high-impact web experiences, and is the industry standard for interactive vector graphics and animations for the Web.

The Macromedia Flash development environment, through its features, has proven to be the best choice for the design of the DAQ CyberCourse.

The DAQ CyberCourse can be integrated in a web explorer application like Internet Explorer. This feature makes it suitable for the using over an Internet or Intranet connection. Naturally, software installation, setup or maintenance is not necessary in order to benefit from the DAQ CyberCourse, which is an important aspect.

This electronic Data Acquisition course is meant to extend the possibilities offered by the DestManager 2002 package. By the aid of this course the students, have a short theoretical approach of the DAQ systems in general. The particularities and the implementation in the Visual Basic programming language of the serial communication protocol are also discussed. Students at the end of the course will be able to solve simple DAQ tasks required in a chemical engineering laboratory. Examples illustrated with the distillation column are provided. The main window and several windows of the DAQ CyberCourse are presented in Figures 5, 6, 7 respectively.

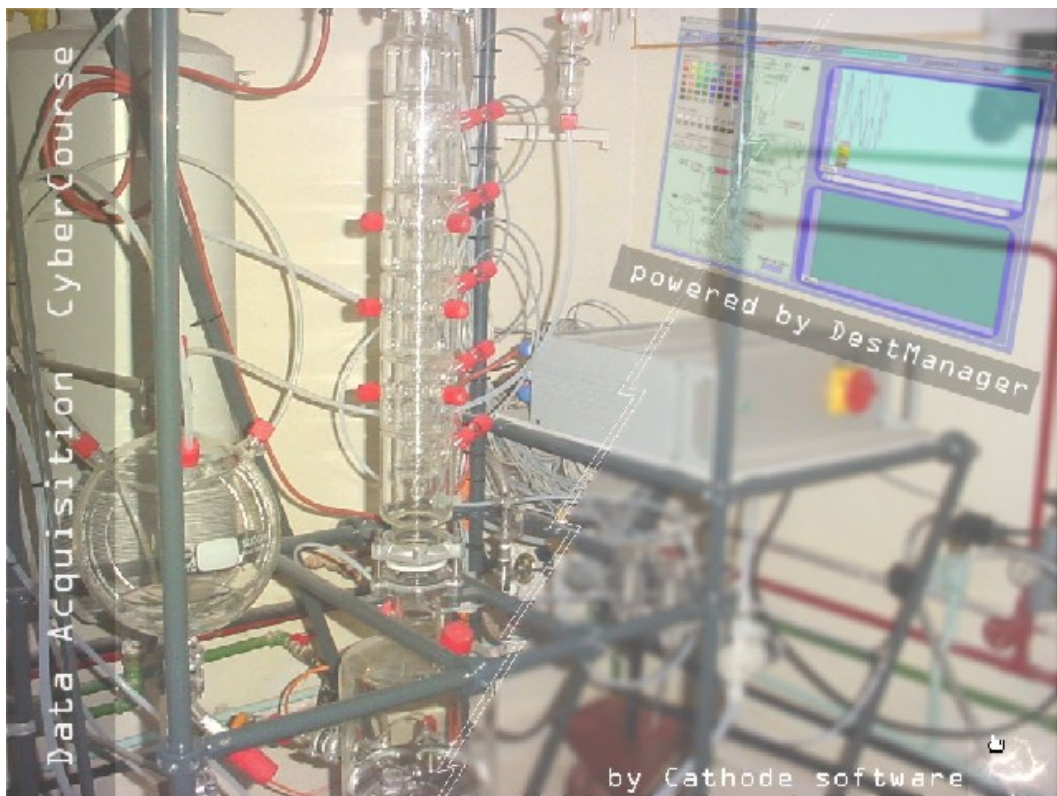


Figure 5. The first page of the CyberCourse

**Data Acquisition CyberCourse** by Cathode Software

**1. Introduction to a Data Acquisition system**  
The serial port and the serial protocol

The diagram illustrates the flow of data from transducers through signal conditioning and DAQ hardware to a personal computer running DAQ software.

**What is a DAQ system?**

Today, most scientists and engineers use personal computers (PCs) with PCI, PCMCIA (interface for laptops), USB, ISA, or parallel or serial ports for data acquisition in laboratory research, test and measurement, and industrial automation.

Many applications use plug-in devices to acquire data and transfer it directly to computer memory. Others use data acquisition (DAQ) hardware remote from the PC that is coupled via parallel or serial port. Obtaining proper results from a PC-based DAQ system depends on each of the following system elements:

1. Transducers
2. Actuators
3. DAQ Hardware
4. The Personal Computer
5. The DAQ Software

PREVIOUS | NEXT

Figure 6. Answer to the question: What is a DAQ system?

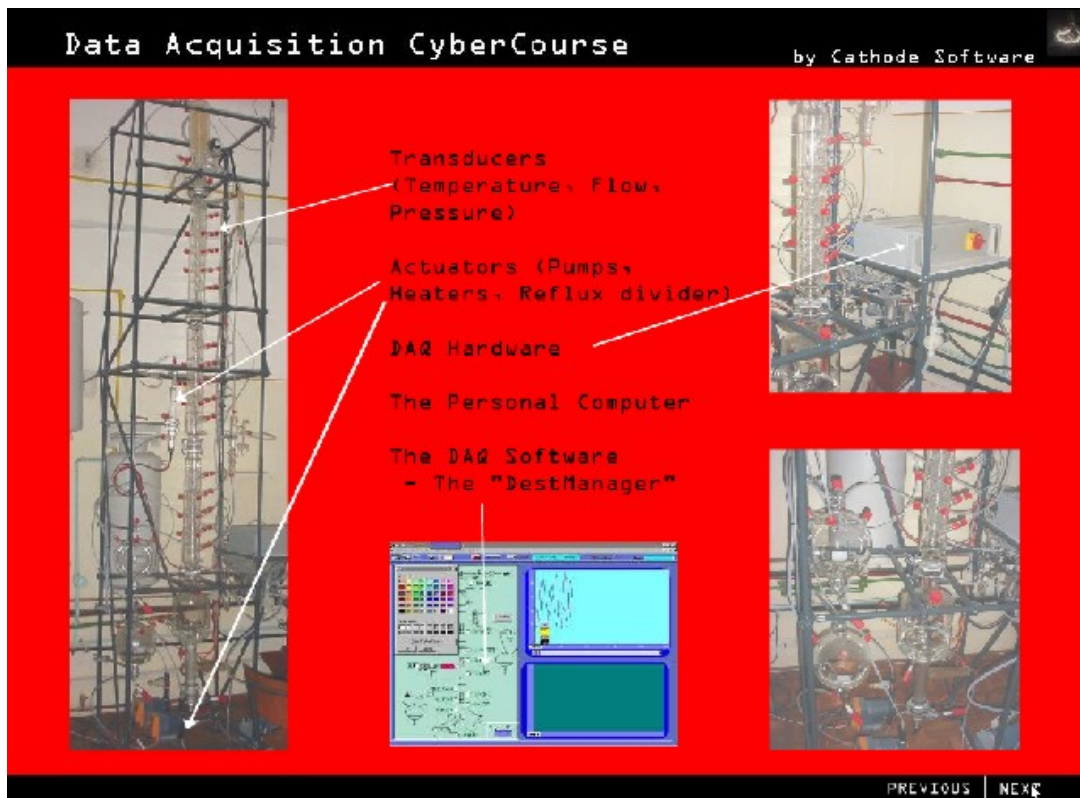


Figure 7. The main components of a DAQ system.

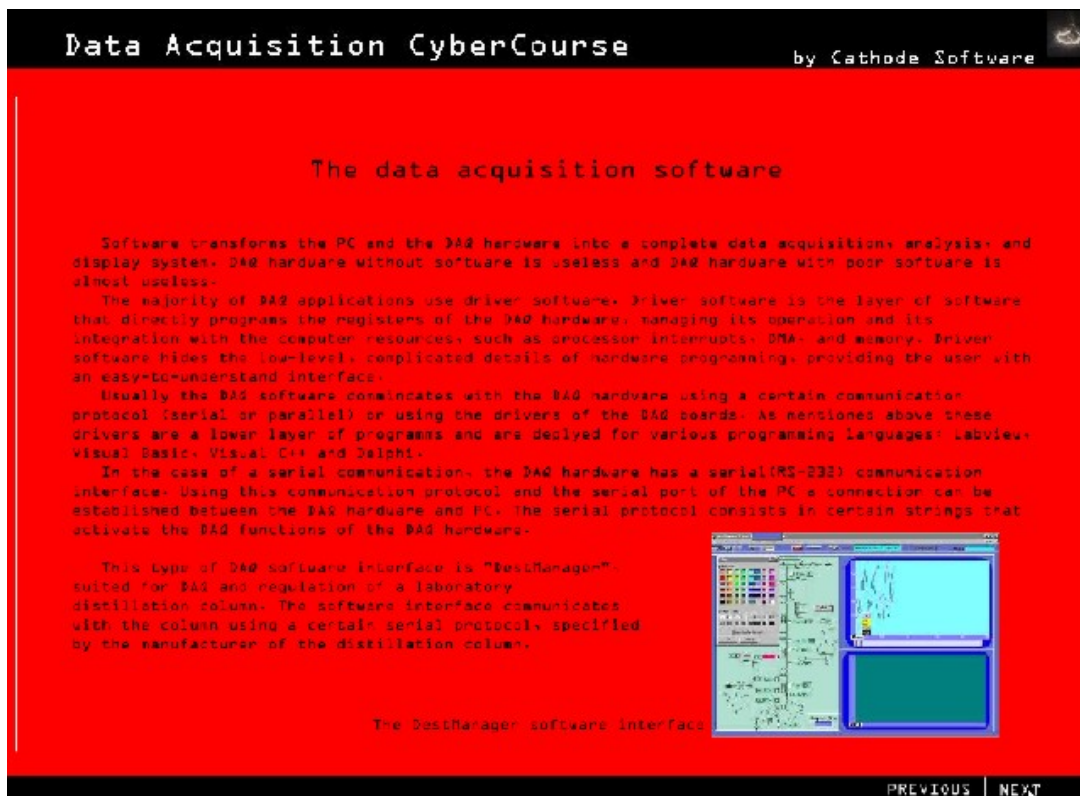


Figure 8. Short presentation of a DAQ software – DestManager 2002.

## **The remote Control laboratory**

The application is coupled with several remote experiments, which are used in the Process Control, Mathematical Modeling of Chemical Processes, and Advanced Control of Chemical Systems courses. Students prefer projects related to the remote experiments since this decreases significantly the problems related to the scheduling of working groups. Experiments can be performed even from their dormitory. This remote experiments module has been developed in the Server/Client architecture using the advanced features of Labview (National Instruments, USA), which provides fast means to develop the required network security module and user-friendly interface. When an experiment is in process or it is not activated by the authorized person it will not be available remotely. In the development of the experiments the user friendly and “fun” operation were the major objectives to support active learning. Simulations, exercises, extensive help systems, including video documents and glossary are built in the application to provide help and efficient learning. The network security kernel of the application allows the connection of authorized clients to the DAQ server application. Remote video and sound transfer is realized using microphone and internet QuickCam. The CUSeeMe videoconference software is integrated into the application. The software creates the sense of being present at the information source, which is planned to be enhanced with the acquisition of a more performant video camera that will be possible to control remotely.

The student are guided through the steps of the remote experiments by a “speaking genie” video help systems. Genie provides an extensive and interactive help and a fun operation. It appears automatically whenever a situation of evident need of help is detected, or whenever the student request contextual help. In our experience students like this feature so much that they keep using genie making it to repeat information several times, hence hearing and learning it even unwillingly. Although in initial version this feature meant to fulfill the role of an interesting help system only, in future version it is intended to upgrade it to the role of an “educator” this voice help system. This is on one hand the result of the students’ reaction to this feature, but on the other hand future version of the remote lab application will also have the objective to provide a more accessible way to do experiments for students with disabilities. The help system is already can be activated by voice, it is intended that experiments with voice command will be developed. Figure 9 shows the main window of the application showing that only the “PID tuning” experiment is active. The main features of the application, including the network security settings, glossary and videoconference window are also shown.

## **Conclusions**

The main advantages of the application are:

- Savings in lab time, experiments can be repeated accurately.
- The experiments can be performed from anywhere at any time with PC connected to the Web. This feature is enhanced by the Server-generated web page.
- It can be used to collect data and to perform remote-analysis. Measurement data can be saved locally, on different PC stations, via the Client component. The measurement values are available using the application interface and the MS Access Database editor.
- It helps students to become familiar with computers, data collection, and data retrieval. This function is enhanced by the Data Acquisition CyberCourse, which provides information about how the parts of the system work together.



- Real world applications are often remote we ought to get used to them.
- Data is presented in a clear manner, can be used in other software.
- Only authorized persons are able to use the equipment.
- If the "Remote Server" kernel of the software is activated the application will act as a server and will allow the remote access via the TCP/IP protocol. An access control check is implemented, thus, only authorized computers can establish data connection and perform experiments.

Disadvantages:

- One disadvantage consists in the lack of the advantages of "being present" at the experiment, which is very important to acquire practical skills. This drawback is compensated in the Labview version of the telelab, which provides support for visual and audio connection to the plant using a web-camera giving thus the possibility of seeing what is physically happening during the experiment in real-time.

The ultimate goal of the application is to develop a center of engineering education where the location of the instructor or student is no longer an impediment. Instructors from one university will be able to guide experiments using equipment in another part of the world and students from all over the world will be able to participate. Tests are conducted to develop such center at the "Babes-Bolyai" University to be used in collaboration with the University Rovira i Virgili and ETH Zurich.

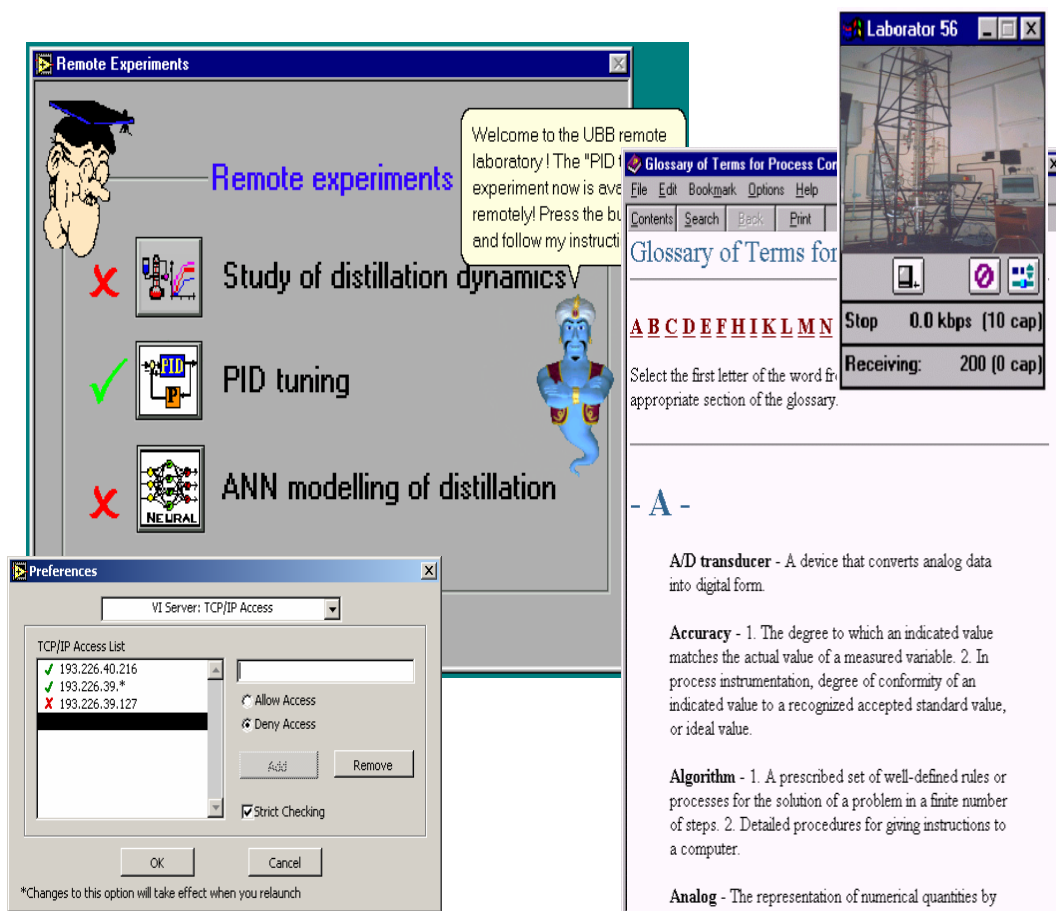


Figure 9. Main features of the Control "Telelab" application.

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