Building Remote Laboratories for Education (Workshop)

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Abstract — *Remotely controlled laboratories have been developed in pilot projects for some years now. Many university teachers are considering to make their local experiments available over the internet as remote labs. There are a number of technical challenges that have to be solved in remote lab developments. In this workshop, we want to share our experience in building remote labs and provide technical insights. Recent issues have been to make our remote labs ready to support virtual student teams and to increase the joy of use. We believe that students should work in teams to raise motivation and prepare them for team work in the workplace. Remote labs should thus allow remote synchronous collaboration, so students at different places can work together at the same time. We also expect that remote labs with high interactivity, visual feedback and authentic views of the experiment will give students a motivating and rewarding learning experience.*

Index Terms — *remote laboratories, technology, workshop*

EXECUTIVE SUMMARY

We demonstrate student usage of our labs and then describe their implementation. This includes system architectures, programming languages, protocols and technical details in the following areas:

- Video, audio and symbolic diagrams of the experiment
- Control software allowing users to perform experiments or program lab devices
- Support of multiple simultaneous users: synchronizing views and managing access rights
- Teleconferencing equipment for collaboration among students and tutor
- Lab scheduling for reserving time to use the lab
- Repository of tutorial background information on the experiment and work assignments for students
- Facilities for student´s note taking
- Recording and download of experiment data and pictures

Different technical solutions for building a remote laboratory are presented. We demonstrate examples of remote laboratories for electrical, mechanical, chemical and computer engineering. We work out differences and similarities and discuss the advantages and disadvantages of the particular solutions:

- Is the solution platform independent? Is it based on a proprietary system?
- Is it easy to develop new labs based on the technology?
- Which costs have to budget for different hardware elements like web cams?
- Is the solution reusable for other remote labs?
- Is the performance high? Which bandwidth must be available?
- What about security?

Although technical aspects of remote labs are the focus of this workshop, an evaluation of technical solutions for remote labs has to consider pedagogical aspects. For example, a synchronous communication and collaboration environment is only necessary if team learning or synchronous support by a remote tutor is preferred. And the system requirements for a remote programming lab are different from those for a remote measurement lab.

The combined consideration of technical and pedagogical aspects will help us to identify suitable technical tools for certain educational scenarios.

PRESENTERS

Dr. Nils Faltin, Dipl-Berufspäd. Andreas Böhne, Dipl.-Ing. Jörg Tuttas

We develop remotely controlled laboratories for engineering education and vocational training in automation technology. With these, remote maintenance and remote programming of technical devices are learned. Devices are operated and programmed from a remote location through a web browser and watched through several video cameras. In an automatic control lab valves, pumps, motors and sensors of a process engineering plant are controlled to move and mix liquids. In a second lab ("laser experiment") pictures and animations are drawn with a laser beam. We test our labs with university and vocational students. We evaluate the influence of reduced optical perception of the device [7] [8] and reduced communication opportunities with tele-tutors [1].

We use videoservers from AXIS to broadcast the video pictures from our experiments. A browser plugin allows students to observe the experiment in a normal web browser. "PTZ-Cams" allow users to pan, tilt and zoom in on details. The compression rate of the video pictures can be adapted to the available bandwidth. In the laser experiment we also transmit the sound of the lab devices via an audio server from AXIS to support the feeling of being in a real laboratory.

The learning target of the automatic control lab is to get to know the programming language Instruction List (IL). The remote lab environment is a distributed client/server architecture. We selected JAVA as a platform independent programming language for this lab. The client is a JAVA applet that was integrated in the remote lab web page. This JAVA applet uses the object communication protocol RMI to communicate with the server components. The server components are JAVA applications that provide the services for observing and manipulating the learning object. We have developed a reservation system, a runtime system and an I/O system as server components. An "Opto 22 Ethernet I/O Module" with integrated web browser serves as hardware interface to the process engineering plant.

In the laser experiment students write java programs in a web based programming environment. The programming environment is implemented as JAVA server page (JSP). The Java server page communicates with a programming server on a Linux lab server developed with Java Beans. The students can compile their programs on the lab server and then execute their JAVA programs on an embedded system (PC 104 single board computer) as runtime environment. For the hardware interface in this experiment we use an I/O-Card with PC/104 ISA-Bus connector.

In the laser experiment, a web based communication environment allows students and tutor to communicate with each other. They can communicate via audio, video and text chat after logging in with a username. The client side of the communication environment was realized with "Macromedia Flash MX". The communication server is based on the "Macromedia Flash Communication Server MX". Application sharing is provided by an external tool (VNC).

Prof. Denis Gillet

The main domain of competencies and interest of the EPFL is in Virtual/Remote Laboratory facilities with application to flexible learning in traditional academic institutions. Most of the research activities have been inspired by the pedagogical and technical requirements related with virtual/remote laboratory facilities and their integration in curricula.

The Automatic Control Laboratory (LA) is chartered within the Institute for Systems Engineering of the EPFL to teach automatic control to students specialized in various disciplines such as electrical, mechanical, micro, chemical and computer engineering. The course work is designed on the base of a highly interdisciplinary approach. It aims at suiting the students' different backgrounds and needs. Education, which is considered the EPFL's prime product, goes hand in hand with research. As a consequence both aspects are tightly linked. The research activities of the LA address modern crossdisciplinary modelling, control and real-time man-machine interaction issues. In 1995, Dr. Denis Gillet formed within the LA the Sustainable Interaction Systems Group working on Real-time Internet applications, including remote experimentation and Web-mediated collaboration. This research group is carries out important developments in the field of real-time prototyping and motion control in collaboration with National Instruments (the LabVIEW company). It has also initiated and it carries out numerous E-Learning projects. One can point out for example (1) a 4-years project supported by the Swiss National Science Foundation called Sharing of unique or expensive equipment for research and education: The remote manipulation paradigm, (2) the eMersion Project, which aims at developing hands-on resources for flexible learning in engineering education focusing on the teaching of automatic control, fluid mechanics, and biomechanics, (3) the CoHandLE Project, concerned with the development of a collaborative environment for remote hands-on laboratory experimentation, (4) the SCOPES Project, aimed at developing advanced educational technologies for automatic control in collaboration with Romanian Universities, (5) the ReLAX Project, funded by the EU in its 5th framework programme, which established a unique Web portal to distributed laboratory facilities provided by a network of universities to students for carrying out meaningful experimental sessions, and (6) the Mentors Project, concerned with the tutoring of students in flexible learning environments.

Prof. Lambertus Hesselink

Our research group at Stanford University has built a remotely controlled laboratory that consists of a fully self-contained system where students can reserve and remotely access optics and physics experiments. We have developed new technology for securely accessing the experiments behind firewalls without IT intervention, easily and quickly in a matter of minutes, while providing a complete remotely controllable laboratory environment with an electronic notebook, new collaboration tools and unprecedented reliability over the Internet. These tools allow students in dispersed locations to collaborate with each other and with the equipment as if they were all located in the same room. This technology allows teachers to bring experiments into the classroom via the Internet in a quick and easy plug-and-play manner, providing additional resources for experimental demonstrations of theoretical concepts and theories. The tools are generic and can be applied to labs in physics, engineering, biology, chemistry, economics, geology, and medicine. We have applied the developed online laboratory system to a microscopic optics, thermodynamics and telecommunication laboratory.

One overall goal of our research is to extend the existing technology to include tiny devices. The challenge is to determine how to scale the experiment down in physical size while still maintaining the desired properties for use in distributed online teaching and learning. The motivation is the reduction in cost of an online lab while still providing a meaningful collaborative learning experience for participating students.

M.Sc. Nalin Navarathna

At the Division of Heat and Power Technology at the Royal Institute of Technology (KTH) we develop a remote lab that will allow students from all around the world to gain practical experience relating to fluid dynamics in a turbo-machinery. This is done by enhancing a traditional laboratory with internet technology.

Currently, the students at the Division of Heat and Power Technology have the opportunity to acquire understanding about specific topics like turbomachinery aerodynamics. This is accomplished by means of lectures given as a part of the course "Thermal Turbomachines" and by related laboratory exercises. For example, in the laboratory exercise "Flow Losses in a Linear Cascade" students are given the opportunity to experience realistic experiments with high mass flow rates and to use appropriate instrumentation for studying the characteristics of airfoils. Students more clearly understand the influence of the turbine cascade on the flow and the resulting pressure losses due to this. In addition, the students performing this laboratory exercise can see the blades of the stator of the turbine cascade, their shape and orientation first hand and they can realize the influence of these factors on the fluid dynamics in turbomachinery. In other words, these students obtain all the knowledge and practical experience that a traditional laboratory exercise like this one offers. Capturing this experience for remote users involves many challenges, both technical and pedagogical.

As stated above, the linear cascade facility is a fully functional traditional lab exercise, thus the most essential components are already in place. Web cameras are placed at strategic locations around the facility in order to visualize the immediate surroundings and the proper functioning of the exercise. Aside from web cameras, stepper motors are installed on the pressure probe assembly, which are in turn integrated with a PC to allow for the students to remotely control the experiment. For safety reasons, a technician will initially be required to be on site to activate the fan, open valves, etc. The PC also includes a data acquisition system for the pressure, temperature and flow mass measurements. On-site users can also use this PC to communicate with the remote on-line users.

As for traditional laboratory exercises the students need to get a good theoretical and practical introduction to the basic theory. This exists already for the turbomachinery lab, but a remote user needs significantly more detailed instructions to the laboratory. Thus, the complete laboratory exercise is also prepared in a "virtual" mode in which the students can go through the lab exercise during the self-study preparations. This integration into the CompEduHPT-platform (an interactive learning platform for electronic learning of gas turbine technology) also allows a direct connection to the turbomachinery-theory and the access to existing and new self-assessment questions. This "virtual" laboratory ensures that the remote students have the necessary background before they are allowed to start the (large and expensive) equipment and ensures also that the students do not use more running time than needed for the efficient learning process (the electricity and maintenance cost for running turbomachinery laboratory exercises can be substantial, and unnecessary running time should thus be avoided.).

Workshop Summary Recommendations

After the conference, all documents presented at the workshop will be made available over the internet. We will establish a shared workspace for all workshop participants.

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