J3eA, Journal sur l'enseignement des sciences et technologies de l'information et des systèmes,
Volume 4, Hors-Série 4, 13 (2005)
DOI : http://dx.doi.org/10.1051/bib-j3ea:2005863

Virtual Labs in the Engineering Education : a Standardization Approach for Tele-Control

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COMMUNICATION DANS LES JOURNEES DU CLUB EEA

« Diagnostic en Electronique, Electrotechnique et Automatique »

17-18 Mars 2005

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Abstract
Distance education systems based on new technologies can provide learning process for individualistic Learning or Cooperative Learning. With Networked systems (providing by communication channels among the different agents of the learning process), we can use the appropriate tools to turn computer networks into a real virtual classroom. In the study of engineering education, presently a change of learning and teaching happens through the use of new media. The reason for this is the implementation of tele-laboratories into the curricula of automatic control engineering and mechatronics education. Real existing laboratories can get controlled remotely over the Internet with a web browser by the student. An accompanying usage of these lab experiments during the lectures as well as an independent use is considered with theoretical teaching units and tutorials.

1 Introduction

The expanding roles of electrical engineers, computer engineers, and computer scientists in today's society reflect the variety and scope of these important professions. In recognition of the distinct qualifications required of engineers and scientists entering these fields, the various Electrical Engineering and Information Engineering curricula offers Virtual Labs in order to be able to bring these courses to international students. With the building of Europe, more and more students share their studies between their host university or institution and another one, chosen in one of the European countries. This situation has been strongly promoted by the different education programmes offered by the Commission of the European Union **[1]**; ERASMUS programme, for example, has supported the mobility of several thousands of students. But the mobility is bringing a cost overrun for the student and then it may be interesting to develop distance learning. Virtual Lab training offers the capability by using Internet technology to bring students the access to experimental courses located in a central laboratory. This convenient, economical training alternative enhances learner access to costly technology. It reduces the capital equipment, development, and training costs and it eliminates the need for expensive travel cost.

2 Virtual Labs construction

In the Virtual Labs construction it is necessary to see four basic areas (figure 1):

- resource preparation,
- communication with student,
- examination,
- Organizational part.

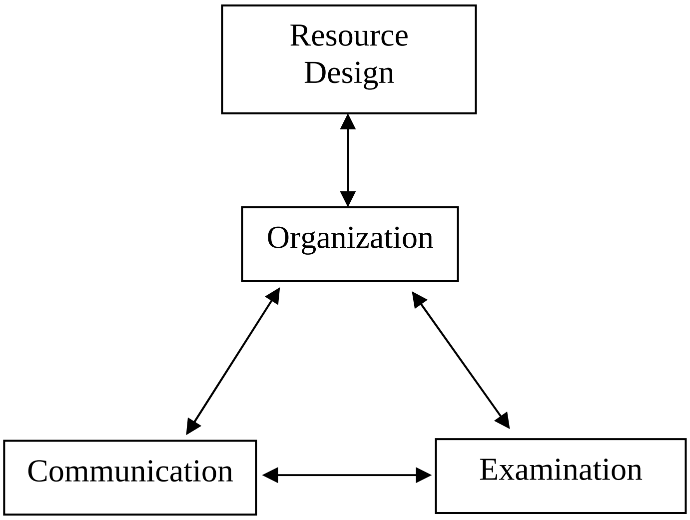

Figure 1, four fundamentals of Virtual Labs.

Resource fundamental is responsible for virtual labs creation and presentation. It involves domain experts to prepare material and some tools required for presentation or distribution. Virtual Lab training must be fully automated and interactivity must be the principle rule for the design process. The final structure is typically composed by objectives, prerequisites, contents, references, activities and questionnaires. The second fundamental is communication. It can be assured by usage of new technologies such as e-mail, voice mail, videoconference, and discussion lists. They are used by student between them and supervised by teacher.

The third fundamental is examination, Knowledge exam is necessary when we want to document qualification within graduate curricula. The last fundamental is organization, provides support for previous two fundamentals.

3 Example of Virtual labs resource in Germany in electrical Engineering:

The University of Siegen is involved in different national and international projects, which deal with the development of remote laboratory experimentation via Internet. These experiments are all based in the field of automatic control engineering and mechatronics. The national participating projects are LearNet (learning and experimenting on real technical plants, www.learnet.de) and Learn2Control (project oriented multimedia learn environment for control engineering, www.learn2control.de), the international projects are IECAT (Innovative Educational Concept for Autonomous and Teleoperated Systems, http://www.ars.fh-weingarten.de/iecat) and TEAM (Tele-Education in Aerospace and Mechatronics Using a Virtual International Laboratory, http://www.ars.fh-weingarten.de/team). Developed pedagogical concepts and course units offer innovative laboratory experiments with hardware controllable via Internet. By including a wide audience of students at the partner universities, the exchange of student and faculty members is guaranteed. Thus students profit from this transatlantic tele-education approach by training in advanced technology in an international environment.
In this paper, the national project LearNet will be introduced, which consists of seven technical and one pedagogical university. Each technical university developed one remote controllable experiment, combined with teaching units, multiple choice questions and tutorial material. An overview about the developed experiments from the partners will be given.

3.1 Control of Flexible Structures

In the design of spacecraft, aircraft, and even buildings, the flexibility of structural elements is of concern. This is especially pronounced in space structures and aircraft where large sizes coupled with lightweight materials emphasizes structural flexibility. The control of such structures becomes problematic due to this behaviour. For rigid structures, accurate theoretical models can be obtained. However, for flexible structures, modelling, simulation, and controller design is difficult at best. To familiarize students with these control techniques, an experiment dealing with the control of flexible structures has been developed at the Automatic Control Engineering Department at the University of Siegen. The focus of this experiment is an aluminium rod, suspended on a motor called the "Swinging Rod". Its sensors and actuators can be controlled via the Internet. The rod's length coupled with its small cross section makes the system quite flexible. The purpose of this lab is to provide a test platform for students to analyze structural vibrations, model system behaviour and design controllers. They can implement their work on an actual physical system via the Internet or locally in the laboratory.

3.2 Test Facility Hardware

The main feature of the "Swinging Rod" test facility is shown in Figure 2. It uses a 1.6 meter long aluminium rod with a small cross section (4x10 mm) as the flexible component **0**. An excitement of the rod is possible in one orthogonal direction at the upper end of the rod. The system is equipped with a DC-Motor as an actuator, used for disturbing and afterwards to control the rods movement. An Encoder inside the motor and a position sensitive detector (PSD) is used to measure the movement of the rod, as shown in Figure 2.

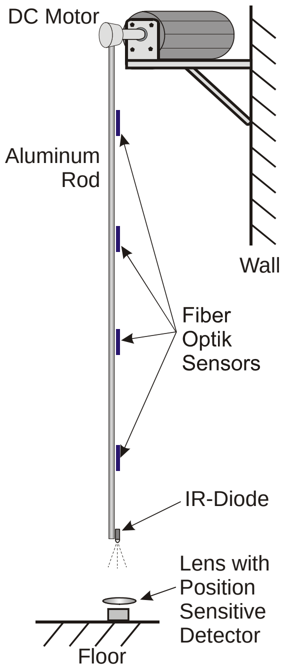

Figure 2. Schematic Drawing of the “Swinging Rod”

3.3 Software Structure

The software is divided into two main parts, one part is to communicate directly with the hardware over a data acquisition board, and the other program part establishes the remote control over the Internet **0**.
The remote control software is implemented in Java **0**. On the server-side a Java application and on the client (student) side a Java-Applet was developed. The Java-Applet is integrated into a web page and is accessible inside a web browser. No special software is needed on the client side, except a web browser which allows Java-Applets. The communication between the client and the server over Internet is managed by socket communication. The control signals form the client to the server and the feedback information backwards get transferred over this connection **0**,**0**. The sensor data get displayed inside the web browser to the student after the particular real-time process is finished. Due to the fact that this is a fast vibrating system, the sensor signals get transferred after the real-time process is finished. The movement of the rod is also observed by a web camera to get a better expression of the oscillating rod and to see how well the controller works.

3.4 The LearNet Project

The project "LearNet (figure 3)- learning and experimenting on real technical plants" consists of seven technical and one pedagogical university. Each technical university established one experiment, consisting of the real existing online experiment, didactically prepared theoretical teaching units and some tutorials for users with some lack in knowledge. The following list shows the participants and their experiments:

- Brandenburg Technische Universität Cottbus – couplet signage telecontrol system
- Universität Würzburg – telebased control of a mobile robot
- FernUni Hagen – remote control of a gantry crane
- Pädagogische Universität Weingarten – project evaluation
- Ruhr-Universität Bochum – hydraulic cylinder infeed
- Technische Universität Dresden – industrial automation

- Technische Universität München – tele-floating with a haptic device
- Universität Siegen – test-platform for vibration damping and high-precision positioning of a flexible system

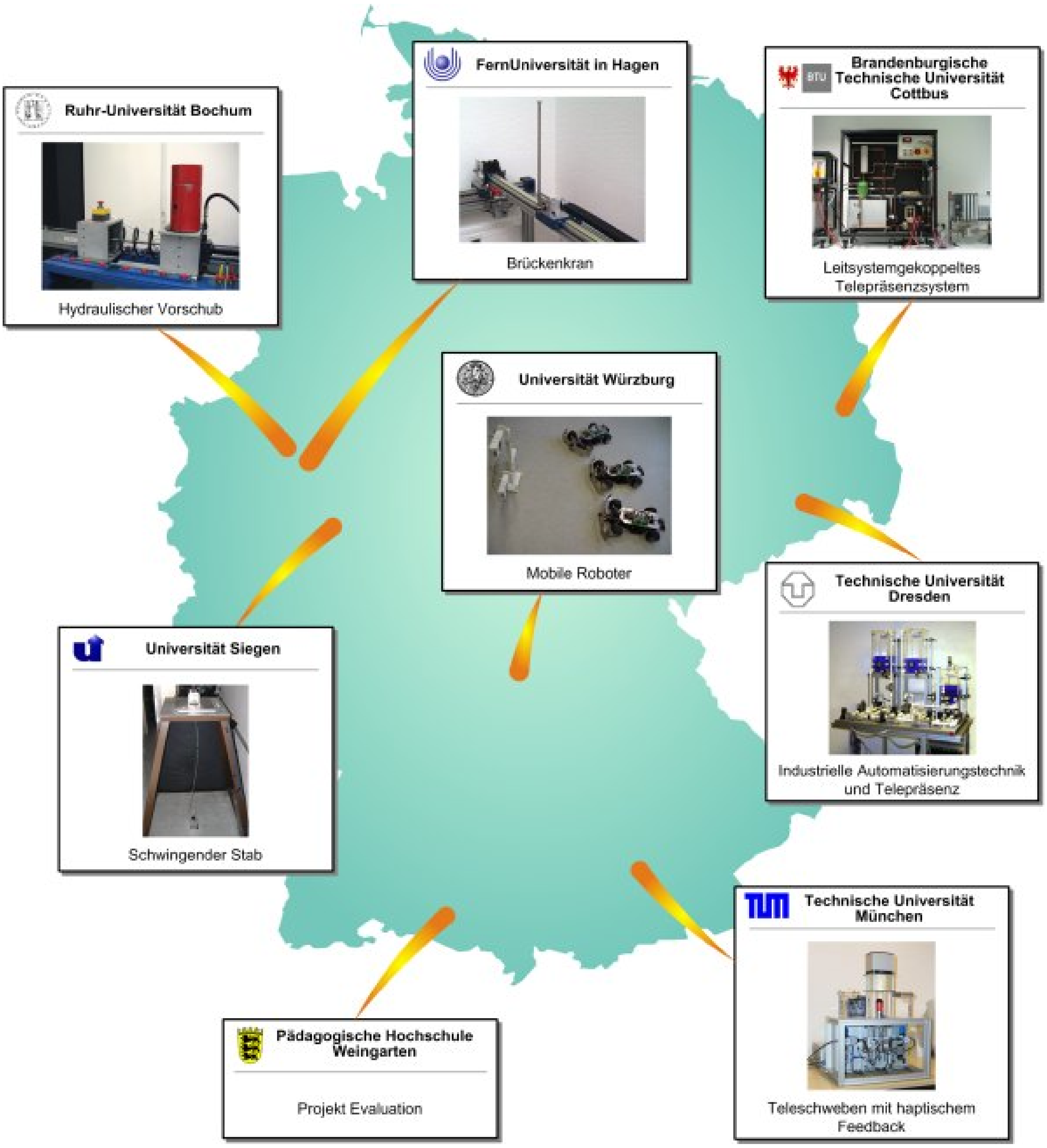

Figure 3 The project "LearNet

The Pedagogical University in Weingarten accompanied the work done during the preparation of teaching units, questionnaires and during experiment setup and remote control programming. By this an iterative improvement of the eLearning experiment was possible.

4 Conclusions

This article has introduced the key development of Virtual Labs design and gives us an example of one national project. By sharing physically real remote controllable experiments by many universities, a huge financial benefit is achieved. One main platform for accessing such online experiments is available, which offers physically real eLearning experiments to a wide audience. All experiments inside this portal can be accessed from anywhere in the world. An implemented time reservation system handles the complete access to the experiments for the users (students). This extensive booking system provides a secure administration of users and resources.
The example of Experiments describe in this paper is online since 2003 with about 45 Students per year. The principal benefic from the point of view of the students are:

- Free time schedule,
- No pressure from a tutor (with tough questions)
- Difficulty to use it but manageable with more time
- Time limitation

For tutors Difficulty was:

- Cheating not really controllable
- Students have problems which we did not expect

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