Remote Labs versus Virtual Labs for Teaching Digital System Design

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Abstract: *Online laboratories became a very useful support for practical aspects of teaching methods since the time their technical basis got available world wide. There are two main classes of such online labs: Remote Labs and Virtual Labs. In this paper we give an overview about actual developments in this field, discuss selected examples and compare them with a collection of criteria we consider as important. In a second part of the paper we suggest a solution for a Remote Laboratory, dealing with the design of digital control systems and describe the goals of our actual research in that field.*
Key words: *Web based Laboratories, Educational Aspects of Computer Systems and Technologies .*

INTRODUCTION

As mentioned in many papers (for instance [1]-[3]), Online Labs can open possibilities for an experimental approach to a wide audience and are independent of opening hours. We can distinguish them by location and experimental equipment (see Table 1).

Table 1: Concepts of Laboratories

		Access to Laboratory	
		Local	Remote
Experimental Equipment	Virtual	Local Simulation	Virtual Laboratory
	Real	Traditional Laboratory	Remote Laboratory

A lot of Online Laboratories are available via the Internet. They support different teaching scenarios

- Live experiments during lectures
- Distance learning courses (Students work at home)
- Ed-to-ed scenarios (Students work at an institute and access an Online Lab at another institute to save costs for expensive equipment)

To classify them, we have analysed the laboratories which are listed in Table 2. We found out that none of the laboratories fits all the criteria we have explored. To produce an ideal Online Laboratory the best solutions and experiences of the labs have to be mixed. In the next section we describe the evaluation method and compare five examples with our criteria.

Table 2: Inspected Laboratories

Engineer Sciences	Humanist and Business Sciences	Natural Sciences
▪ Telerobot - Western Australia ▪ **iLabs Hannover** ▪ Internetio ▪ University of Ulster ▪ University of Tennessee ▪ Stevens Institute ▪ Polytechnic University, NY ▪ **NetLab** ▪ JBIT ▪ IsiLab Italy ▪ National University of Singapore ▪ AIM-Lab ▪ Lab on Web, Norway ▪ WebLab ▪ Verbund Virtuelles Labor ▪ LearNet ▪ CMOS Demonstration Uni Hamburg ▪ **Control-Net**	▪ Fachhochschule für Wirtschaft Berlin ▪ Fachhochschule Darmstadt, Fachbereich Informations- und Wissensmanagement ▪ Fachhochschule Hildesheim ▪ Hochschule Bremen ▪ Justus-Liebig-Universität Gießen ▪ Universität Trier ▪ Technische Universität Berlin ▪ **ElatNet** ▪ OLAT	Uni Kaiserslautern Museum München NGL, Norway Royal Institute of Technology, Sweden Heat Exchanger Project **INGMedia** V-Lab, Uni Konstanz Central Force Solar System, UCLA Diffusion Applet Fermi Function Applet Hysteresis Applet Virtual Photosynthesis Experiment NTNU, Taiwan University of Guelph, Canada

EVALUATION

The evaluation [4] started with an Internet search for Online Laboratories. The results where classified by aspects of subjects (see table 2) and technology. Main technologies, used by the laboratories, are

- Download of software 6 %
- Applet technology 58 %
- Learn management system 36 %

The subjects of the inspected laboratories are classified by engineering (18), humanists, business sciences (9) and by natural sciences (15) as well. In Table 2 these laboratories are listed.

To evaluate the laboratories we check them versus the following 7 criteria

- **Registration (2)**
  (How many steps in the registration process, time between first registration and first opportunity to use the lab)
- **System requirements (2)**
  (Available information about requirements, need for special hardware or software)
- **Introduction (3)**
  (Information about the lab environment, the subject and the theory)

- **Technology** **(3)**
  (Implementation of modern web technologies, consideration of standards)
- **Booking** **(2)**
  (Online opportunities to book time slices, availability)
- **Management Support** **(3)**
  (Integration in a learning management system or comparable system and in the curriculum)
- **Usability** **(5)**
  (Concept, layout, navigation, system stability, robustness)

The number in brackets gives the maximum of reachable points. In sum a maximum of 20 points can be reached. We have chosen at least 5 laboratories (see Table 3) for a deeper analysis and we will discuss the results following.

Table 3: Evaluation results

	iLabs[11]	ControlNet[17]	NetLab[18]	INGMedia[19]	ELATnet[21]
Registration	2	2	2	1	1
System Requirements	2	2	1	2	1
Introduction	1	3	3	3	3
Technology	2	2	2	1	3
Booking	2	1	2	0	2
Management	0	2	1	1	3
Usability	3	1	3	4	3
Sum	12	13	14	12	16

- **Registration**
  Mostly good solutions, password via email, quick access possible.
- **System requirements**
  Not all labs have available information, some need the newest browser version.
- **Introduction**
  ControlNet offers the best information.
- **Technology**
  Only ELATnet
- **Booking**
  iLabs and NetLab open possibilities to book free slices in the actual time table.
- **Management Support**
  Only ELATnet offers an integration in the learning process and possibilities for an individual assessment.
- **Usability**
  IngMedia has the best uncomplicated structure, uniform layout and navigation, and offers communication possibilities.

The evaluation shows that none of the laboratories fits all criteria. The best system reaches 16 points. In the next section we describe the concept of a Remote Lab that is realised at our department.

Remote Lab IHS

At the chair of Integrated Hardware and Software Systems (IHS) of the Technical University of Ilmenau we have 7 years of experience in the field of digital systems design using Internet supported teaching [5], [6]. We have developed a new teaching concept, called "Living Pictures" that we use in several phases of the learning process. "Living Pictures" are highly interactive applets that can be used for demonstration as well as for experimental purposes and serve as tools in certain steps of the design process of digital systems too.

To complete the teaching concept by own experiences, the students have to pass a practical examination in a laboratory. One task during this examination is to design a digital control system that controls one of different mechanical models, for instance a model of a traffic light, a lift, a positioning table and the like. Actually these models can be used in a special lab during the opening hours of the lab only. Last year we have started to work on a solution for a Remote Laboratory that can be accessed via the Internet. To make the use of this Remote Lab interesting for students in their spare time also, we are working on concepts for a "game-like" usage. /9/

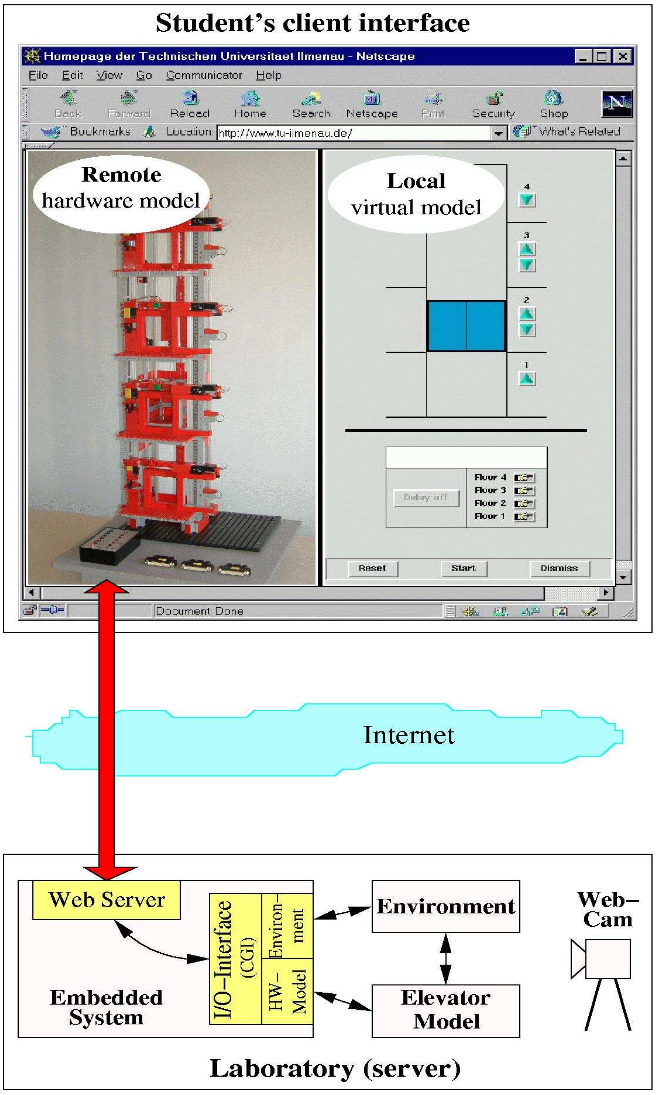

Figure 1: Concept of the Remote Laboratory IHS

Figure 1 gives an overview about the architecture of the system. In the laboratory room the following components are necessary to guarantee the server functionality:

1. An *embedded system* (a Single Chip PC manufactured by the company Beck (Beck-IPC) [5] is used, providing its own "Mini Web server".)
    a. realizing the communication with the client through the integrated Web server,
    b. exchanging all available model and environmental variables through the I/O interface (using CGI scripts),
2. the *hardware model* to be controlled as well as
3. a *WebCam* offering the observation of the whole hardware setup (model and environment).

Usage of Web based embedded systems demonstrates the advantages of Single Chip PCs for such ranges of application simultaneously. It gives a cost efficient and space saving alternative to a complete PC.

For supervising the laboratory procedure the students can use two information paths:

- Supervision
  By supervising, the signals of the designed control (input/output variables) and its environment can be transferred to the client. These variables are interactively changeable.
- Observation
  Additional information (not available through the input/output interfaces) will be retrieved and transferred using a WebCam to provide assertions in case of faulty behaviour.

In doing so almost real laboratory conditions are available at the student's home via the Internet.

Web supervising is not obligatorily necessary for fault free designed control algorithms and ideal environmental behaviour. Because in the project "Remote Laboratory IHS" a selected or accidental manipulation of environmental variables is planned from the start, an observation of the whole hardware setup is required urgently. This is important e.g. to create different initial conditions or to preset a real malfunctioned condition. Not all information can be provided by the WebCam in a sufficient manner (e.g. values of the limit switches or internal signal levels). Therefore it is necessary to supervise those information using an I/O monitor additionally. That way redundant information contributes to the improvement of the understanding.

CONCLUSIONS AND FUTURE WORK

The inspection of online laboratories shows that actual available solutions can be improved by a better use of available web technologies, increasing the usability and embedding the labs in the educational process. Future work of our group are concentrated on a holistic approach to design an online laboratory for design of digital control systems.

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