Distributed Online Laboratories

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Abstract *¾ Within the Wallenberg Global Learning Network (WGLN) a group of researchers form the University of Stanford (Stanford Learning Lab) and the University of Hannover (Learning Lab Lower Saxony) are working on the development of new learning methods and appropriate equipment needed for distributed experiment-based learning and training.*

This constribution deals with the implementation and subsequent evaluation of our first distance learning experiment as a part of a laboratory of process controll for students of electrical engineering in the main section of their study. In one of our control laboratory experiment students have to design, implement and test a discrete controller for a process engineering plant. Last winter term we have started to investigate students motivation, acceptance and learning results in conjunction with online laboratory access.

Index Terms ¾ Learning network, remote control laboratory, problem based learning, evaluation.

THE WALLENERG GLOBAL LEARNING NETWORK

The Wallenberg Global Learning Network (WGLN) foundet in 1999 by the members of the Swedish Learning Lab (SweLL) with institutions from the Uppsala University, the Royal Institute of Technology (KTH) and the Karolinska Institute and the Stanford Learning Lab (SLL) from the Stanford University. In the year 2000 the Learning Lab Lower Saxony (L3S) with the University of Hannover, the University of Braunschweig and the Braunschweig School of Arts joined the WGLN as the third member.

Research in the WGLN is done in international cooperation between the members in the fields of:

- Learning Spaces
- Innovative Curricula
- Personalized Learning
- Distributed collaboration

The I-Lab project, which is one of the new WGLN projects, deals with the possibility to connect existing experiments to the Internet, so that the experiments can be executed from anywhere in the world.

TYPES OF LABORATORIES

Laboratory exercises are part of many university educational programs. Based on computers and the Internet we come to new types of laboratories which offer greater flexibility and allow access by more students within a given time frame while reducing the total acquisition, operating and maintenance costs [6].

Local Labs

The traditional way of doing experimental or constructive exercises is to go to a university's laboratory. Within that local lab you work in teams with tutorial help from teachers. Engineering education should combine theory and practice. The feeling that students obtain by sitting in the laboratory will not be provided by simulations or remote access. Local labs are still the best way to get a first hands-on experience in operating laboratory devices. That's why Aktan and others have named their remote control engineering environment "Second Best to Being There (SBBT)" [4].

Virtual Labs

Virtual labs are software simulations of physical devices (e.g. measurement instruments) or other real life systems (e.g. economic systems). Computer animation and visualization can help to illustrate complex relationships during classroom teaching as well as in individual learning at home.

It is very expensive and time consuming to implement simulations which come close to reality, because you need to take account of far too many parameters and dependencies. If the behavior of the real system cannot be formalized by mathematical functions or precise rules, a simulation can by used to show general principles only.

Simulations are artificial and do not represent reality. If the lab experiment needs to show very specific effects, one has to use local or online labs.

Online Labs

In our definition, online laboratories do offer remote access to laboratory equipment, workbenches and all types of experiments via the Internet.

Online labs try to combine the prerequisites of local labs with the flexibility of simulations. Additionally online experimentation will develop engineering skills like remote

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operation, diagnosis and maintenance, which could be important for the students in the near future.

ONLINE LAB SCENARIOS

These online labs are important in several learning situations. The first of these is the distance learning scenario. In this situation, learners execute a laboratory-oriented course or exercise from their homes or places of employment. Individual learners are remote from each other so that *collaboration is distributed.* There are currently an increasingly large number of efforts to provide the online analog of the university classroom. However, there are comparatively few efforts to provide the online analog of the university laboratory, as lectures are simpler to implement in the Internet environment. Yet, laboratory learning is a key part of a well designed curriculum. As the numbers of distance learners and distance learning programs increase, the demand for online laboratory experiences will also increase.

The second important scenario for online labs is the ed-to-ed application. In this situation, learners at one educational institution execute a laboratory course or exercise hosted by a second institution. Although remote from the lab, the learners are collocated with each other so that collaboration is local. This offers the opportunity for universities, departments, or individual instructors to maintain and execute experiments in laboratory environments that are too costly, too time consuming, or too difficult to maintain and execute individually. This could for example, make available to a community college or trade school laboratory-based learning experiences that traditionally have been possible only at research universities.

A final scenario of interest is integration of reality into live lectures and seminars. In this situation, learners observe a live (but remote) experiment or demonstration controlled by the instructor. In this scenario, the lab is brought online to the classroom.

Economic, space, and cost issues are extremely important and must be considered in any distance as well as conventional learning environment. Online Laboratories hold promise of being up to two orders of magnitude cheaper than conventional laboratories.

EDUCATION CONCEPTION

Early computer-based learning systems (CBT) followed a behaviouristic theory of learning that regards learning as a passive alteration of the individual. In this process, the organism of the individual is only an intervening variable in the stimulus-and-response model.

Cognitive learning theories, take learning to be a structured cerebral activity. The individual, however, doesn't only use his head. Learning could be explained as the result of active contacts to nature and society. Additionally, learning theories based on performance theories see learning as a deliberately planned process of action.

In contrast to current purely receptive uses of the Internet for obtaining information, in a distance-learning experiment the Internet becomes a constructivist medium where knowledge is build up by the student in the learning situation (learning by doing). On the condition that the experiments include exercises with a high degree of interactivity real learning spaces are formed [1]. Examples of these lab exercises are the graphical design and construction of programs or the planning and conducting of a systematic sequence of measurements.

The notion of learning behind the conception of our Internet assisted laboratories approach is based on the model of the reflexive subject [5]. In line with the constructivist paradigm, students dealing with the teaching and learning environment are confronted with a demanding experiment or problematic situation (process engineering plant with a technical fault). The distance-learning experiment creates for the learner a greater proximity to reality due to its concreteness as an object, which is inherent in the system, in contrast to pure software simulation. This concreteness also serves to greatly increase the learners' motivation, since they see directly the physical effects of their actions and they are given responsibility for a materially represented process.

In our remote lab purely instructional sequences based on a course of lectures (e.g. the learning materials in our course "Design of Discrete Controllers") will alternate with example sequences based on exercises. Together with a problem statement and the actual distance-learning experiment as well as metacognitive sequences they will form the pedagogical articulation scheme of a complete action.

IMPLEMENTATION OF AN ONLINE LAB

Based on conventional technologies (HTML, Java etc.), it is thus possible to observe and control our distance-learning experiments from the institute as well as from anywhere in the world. In our online lab (see the structure of prototype version in Figure 1) the laboratory devices can be observed through one or two pan tilt zoom web cameras and can be operated by a remote controller connected to the Internet. The control program is designed, implemented and tested interactively by small teams during the lab exercises. To do that they use a graphical editor (e.g. Petri net) and some other software tools which were developed at our institute. All tools will be programmed in Java.

The graphical Petri net editor on the client side (the learner side) stores the Petri net structure data in a SQL Database hosted at our institute. To control the process the client builds up a TCP/IP Socket connection to an I/O Server which sends the output signals to the controller, read the input signals and send them back to the client (see Figure 1).

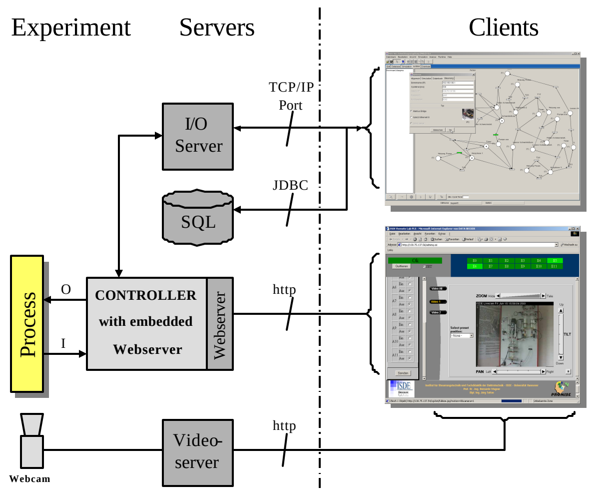

FIGURE. 1
STRUCTURE OF AN ONLINE LABORATORIE

The necessary information regarding the lab experiment (theoretical background, user manuals, etc.) is provided on web pages using a Web-CT server (see Figure 2).

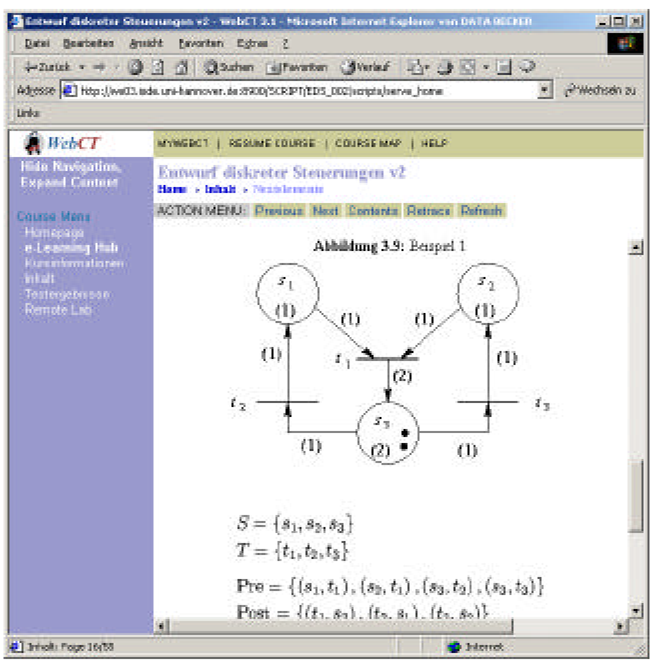

FIGURE. 2
BACKGROUNDINFORMATION PRSENTED BY THE WEB-CT SERVER

THE EXPERIMENT

This winter term twenty students in electrical engineering have taken part on the lab course in discrete control. The complete course consists of eight individual experiments. Themes dealt with are Petri net and state machine modeling, PLC and robot programming and distributed control using field busses. Currently, only one experiment is connected to the Internet. Others will follow in the near future. Two or three students have formed a lab team which ones collaborated during the whole lab course. Four teams have worked remotely on the Petri net experiment (see Figure 3) via Internet. We call this teams the online teams. The other four teams worked in the traditional way with direct, local connection to the lab devices. Our small database will not deliver valid statements. Nevertheless this first evaluation brings up interesting results.

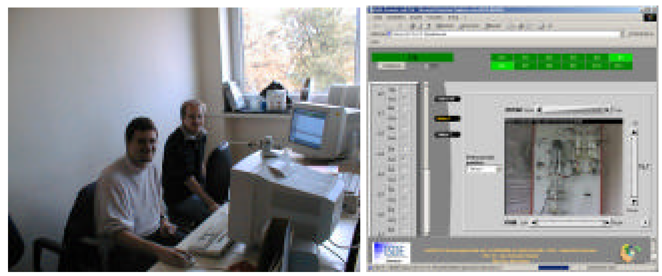

FIGURE. 3
REMOTE TEAM (LEFT); REMOTE SCREEN (RIGHT)

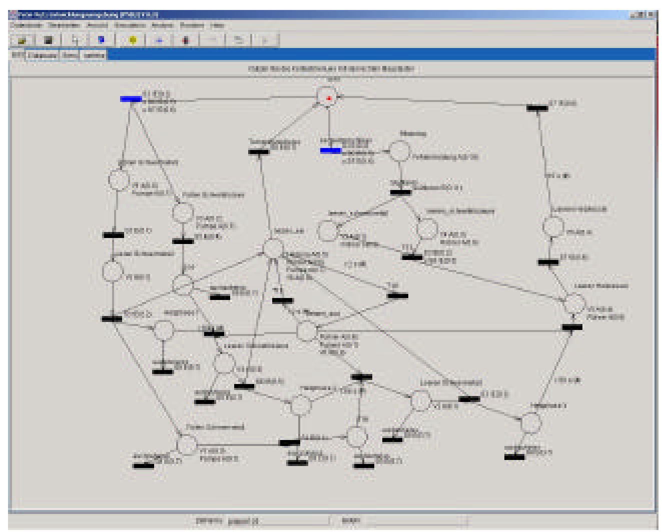

FIGURE. 4
PETRI NET EDITOR WITH AN INTERNET RUNTIME SYSTEM

The resulting Petri net of one team is shown in Figure 4. A medium sized Petri net has been implemented interactively on screen.

EVALUATION

A process of evaluation accompanying the process of designing the teaching/learning environment is intended to contribute to continuous improvement. The subject of the evaluation is the optimisation of the teaching/learning environment. It is evaluated with regard to the learning effect (acquisition of knowledge, knowledge transfer, changes in behaviour, changes in motivation) as well as with regard to cost-benefit effects both in terms of educational policy and in organisational and economic terms.

Evaluation approach

As success in learning is dependent both on situational as well as constituted parameters, the intention is to carry out the evaluation of the distance-learning experiment using a theory-based holistic approach. UCIT (Universal Constructive Instructional Theory) [2], developed since 1991, provides a suitable, subtle and systematic theoretical framework. According to UCIT, the teaching and learning system is divided into four components (learner, learning task, learning environment and reference framework) and three processes (knowledge use, knowledge acquisition and knowledge storage).

Within the evaluation, suitable methods are used to examine the learning requirements with respect to the professional, method and social competencies of the learners. In addition to this, it documents their motivation and acceptance with regard to the distance-learning experiment.

A suitable way of evaluating a distance-learning experiment is a comparative investigation of the process which varies of the reference framework. Three scenarios are conceivable (see Table I). In our first evaluation we focused on Scenarion One and Two.

TABLE I
TEAM LEARNING SCENARIOS

Scenarion One	Scenario Two	Scenario Three
Scenario 1 is a conventional scenario of a laboratory experiment. Tutor, learners and the test object (in this case the process which is to be controlled) are in one room. Although the technological basis is identical with scenarios 2 and 3 (the process is controlled via an Internet connection), learners can see the result of their actions directly in front of them.	In contrast to scenario 1, the learners are now in a different room, at a distance to the actual object. They receive visual impressions by a video transmission as well as some software tools (images of process states, graphic process visualization). Tutorial supervision is direct here too.	The idea is altered here to the extent that the groups, the experiment and the tutorial supervision are spread out over different rooms. This scenario will probably be carried out in winter term 2001/2002.

Levels of evaluation

After a formative evaluation by an expert, a summary evaluation followed which is intended to provide information as to the suitability of distance-learning experiments in professional education. This will allow us to discuss questions of whether distance-learning experiments in contrast to pure simulations or other computer-based learning arrangements are more suited to the promotion of professional competence.

Based on Kirkpatrick's levels approach [3], our first evaluation focused on the level 2 (reaction level) and level 3 (learning level). Central evaluation questions on these levels are: How do learners react to the online lab experience? What was learned? Was the learning transferable to the job or other life activities

Evaluation methods

The following evaluation methods have been used in our first experiment.

- subjective impressions in terms of the three dimensions of acceptance, learning success and transfer
- audio and video recording
- screen capturing
- interviews and ratings (online/offline)

Results

The online and the local teams have slight difference in existing knowledge. 25% of all students have taken the corresponding course of lectures in "Design of Discrete Controllers", 40% of them belong to the local group. This course of lectures introduces to the theoretical foundations of Petri nets and their application in automatic control. All teams from both groups have finished successfully the lab experiment within the given four hours. No difference in the achieved results has been observed between local and online teams.

Most students had prepared the lab exercises in working groups. In average they spent two hours for preparing themselves. Main focus of preparation was on understanding the problem statements and how to operate the laboratory tools and devices (75%) and to work on additional exercises given in the lab description to prepare the students (70%). Almost all students (95%) have used the delivered hypertext-based information system (delivered on CD-ROM). 25% used the course materials and 15% other reading books for additional reference.

The remote group has given the lab experiment a significant better grade (average 1.7 in comparison to 2.1) [3]. Both groups graded the technology value of the Petri net experiment similarly (2.3 and 2.4) [4].

The most significant result was that the remote teams graded the whole lab experiment much better than the local group (1.7 and 2.6) [5].

As a result of our experiment one could see that possibly remote lab experiments will have a positive impact on acceptance and motivation. Almost all students could imagine to accept further remote laboratories (95%).

[3] 1=very important ... 6=no value
[4] 1=very important ... 6=no value
[5] 1=EXCELLENT ... 6=VERY BAD

CONCLUSION

In this paper we explained our implementation of an Internet-assisted online lab. This online lab is a part of our laboratory course program for discrete controllers done the first time by students of electrical engineering last winter term.

Despite the small database our evaluation shows that distance-learning experiments can lead to the same learning results than traditional local lab experiments. We have investigated two scenarios. In both cases teams have shown that they are able to transfer theoretical knowledge to concrete problem situations. Additionally the online teams have noticed that remote diagnosis and maintenance could be important for them in the near future.

Because of limited perception (computer screen) the online teams have to plan and operate more carefully the lab experiments than the local teams. It is indicated that online experiments could possibly be used to teach planning and analyzing competencies in a more effective and inherent way.

Almost all students do accept online lab experimenting and understand that net-based forms of learning have several advantages in comparison to presence teaching. As with most new ways of teaching and learning students motivation is increased at first. This has been measured by asking the students to grade the whole experiment. It is plainly visible the online teams have been more satisfied than the local teams.

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