REMOTE LABORATORY METHODOLOGY FOR ACTIVE NOISE AND VIBRATION CONTROL VIA INTERNATIONAL COLLABORATION IN LABLINK

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Abstract *¾ LABLINK is an international collaboration project in the SOCRATES/ERASMUS programme framework. It is proposed in the project that laboratory experiments will be exchanged between universities in a virtual way. By using the internet, distant students are going to have access to laboratory experiments which could be called tele-laboratories. The experiments could include image and sound transmission. The main goal of the first phase of the project is to develop the methodology of organizing remote laboratory experiments and simulations. The target group consists of undergraduate university students in a technical study programme. The project dissemination phase would include the methods developed can be transposed to postgraduate students or doctoral students, and even to adults who are trained on-the-job (in companies).*

Index Terms ¾ Virtual laboratories, distance learning, control and identification, international collaboration in education.

INTRODUCTION

Nowadays, many popular multimedia productions (on CDROM) such as encyclopaedia, commercial software training packages, dictionaries, glossaries… reach large audiences. There is however a growing need for excellent course material for interest groups such as academic students in engineering. Their study topics have a more specialized level than the average of the materials available on the market.

Moreover, technically oriented students must acquire laboratory practice in advanced laboratories. In this age of speeding technological evolution, laboratory training is extremely important. Making use of well equipped labs will always increase the quality of education.

High tech labs are expensive, and they require specialized trainers. Not all institutes have advanced laboratories in all engineering specializations, and each university has its own strengths and weaknesses. Moreover, not all of them have competent staff members in all fields (automation, welding, material processing, image processing, waste water treatment, biochemistry. During the last decade the number of engineering students has been decreasing dramatically in many European countries. As the number of staff depends on the student population, some universities became too small to compete with other in the research and education fields. Universities in several European countries have very well qualified staff but very limited financial resources to buy equipment. Nowadays, there is also a huge brain drain of ICT specialists from universities to industry.

For all these reasons, it would be of great importance to exchange laboratory experiments between universities. This could be realized by offering them a suitable medium to show their well-established lab to the "world": distant students should have access to advanced laboratory experiments. Such hardware/education concept could be called "tele-laboratories". A second issue is the implementation of faithful computer simulations of lab experiments. This concept could be in turn called "virtual laboratories".

The recent internet explosion opens possibilities for implementing IP (Internet Protocol) based virtual laboratories. The virtual and tele-laboratories must be supported by corresponding text modules in multimedia format, and by interactivity with a local tutor

The overall aim of this project is to improve the quality of higher education in technical universities. As mentioned before, not all institutes have advanced laboratories in all engineering specializations. Giving students access to laboratory experiments done elsewhere, and to web-based laboratory simulations will broaden the spectrum of topics taught. This will increase the educational level of the universities in the partnership.

The aim of the LABLINK pilot project is to develop the methodology to ease distant students' access to academic laboratory activities. Only some universities in (and also outside) this partnership have done some isolated virtual laboratory experiments before. The LABLINK project will bring together their technical and didactical know-how and will start developments at a higher level.

An important objective is to agree on a uniform system. The partnership (8 participants) is quite broad, and the system must be applicable to all. It is thus important that all universities in the partnership agree on the hardware, the software tools and standards. Therefore, the idea was not aim at developing the tools from scratch, but try to adapt existing software packages to the participants' needs. Before working out the standards, the partnership will look at previous and still running projects (by exploring the Socrates ODL compendium and other ICT databases) in order to find

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synergy with LABLINK project. Then the partnership will work out and define the technical system. The threshold to get acquainted with it should be put as low as possible. The partnership must agree on didactical aspects as well. Eventually, the worked out methodology must facilitate co-operation in a large European user group.

The partners were aware that there was a risk of a disappointing project outcome. To minimize this chance, the LABLINK partners agreed to:

- not focus exclusively the efforts on tele-laboratories, but on computer simulations (virtual labs) as well,
- unite laboratories in specific fields only: control engineering and automation, electromechanical and manufacturing engineering,
- develop all tele- and virtual laboratories in English only,
- work in a partnership consisting of universities with many similarities.

Virtual laboratories are not common yet in universities. Isolated virtual lab experiments have been done in some universities before, but we estimate this percentage as marginal. This project is innovative in a technical sense and in a pedagogical sense: technical developments in hard- and software are required to make virtual experiments work; a teaching, learning and evaluating methodology must be worked out.

The LABLINK project was supposed to work out the pedagogical approach of teaching remote laboratory experiments to students, including the tutoring before and after the virtual sessions. Below some concepts concerning the structure of the teaching events is explained.

At agreed time slots, each university will open a virtual laboratory tier. The sessions will be attended in at least two foreign countries, where pilot groups of students with a tutor have been selected. Students will attend the tele-laboratory sessions in the PC classes of their institute. They don't have to invest in high speed (i.e. expensive) internet access themselves.

Before the start of the session, the system will be introduced to students by a local tutor. The students are supposed to actively take part in the laboratory session. Afterwards, the students should discuss questions with their local tutor. The interaction with a tutor will make the sessions more understandable, and will broaden students' insight in the matter. Thus a virtual laboratory cannot be a passive video flow of information, it has to be a flexible process, with student interactions. The partnership must create a basic teaching and learning frame, basic rules, including schedule, time slots

Students learn how to communicate with distant professors and other students without having human contact before. They learn to use IP (internet protocol) based tools. They learn to participate at laboratory experiments from a physical distance. Students are trained to use tele-control, tele-operating and tele-visualisation.

For the simulations (virtual laboratories), there are less time constraints. Students can have access to such laboratory experiments at the institute or at home.

A virtual laboratory tier will have ECTS credits. The assessment of students' knowledge will mainly be done by the local tutor, a kind of permanent evaluation of his activity and progress. Where possible, an internet based system capable of issuing tasks and quizzes can be used. The precise evaluation system still has to be decided by the partnership. One possibility is the use of the tele-learning platform introduced in a previous Socrates/Minerva project LINK.

The categories of persons who will directly use the results or implement the outputs from the project are undergraduate university students in a technical study programme, and their professors, laboratory assistants, heads of fields of study and other staff members.

The introduction of virtual laboratories is supposed to have some impact on the educational system. The professor at the remote site doesn't have to invent all experiments himself, his task will shift from researcher towards tutor, teacher.

If the virtual laboratories are succesful, decision makers can make more agreements with other universities for new virtual laboratories. This will eventually have impact on the kind of academic staff engaged.

In the dissemination phase, the methods developed can be transposed to postgraduate students or doctoral students, even to adults who are trained on-the-job (in companies). Thus employers and their technical staff will be involved as well in the LABLINK project.

The target group for the virtual laboratories are undergraduate university students in a technical study programme. During this project, we will involve mainly students in mechanical and control engineering.

Special potential users are:

- learners in less industrialized countries, in which little equipment is available,
- handicapped people who have difficulties to enter laboratories,
- learners in remote areas attending at home; this is possible as the tele- and virtual laboratories are internet based.

In the dissemination phase, the methods developed can be transposed to postgraduate students or doctoral students, even to adults who are trained on-the-job (in companies).

LABLINK PROJECT OUTPUTS

The following topics could be considered as the LABLINK project outputs:

- A survey of existing know-how in the partnership on virtual labs. A synthesis of related ODL projects, searched in EU databases of ICT projects, which are synergetic. An overview of experiments already carried by some partners before the project start.

- A report of technical meeting, including a motivation for the technical system chosen.
- A technical training manual: how to use the tele-laboratory system and the software tools.
- A survey of the didactic outputs. As explained before, the partnership will produce two types of lab modules: Laboratories or processes, which exist in reality at a partner institution or don't exist, presented as computer animations, as recorded video and sound material, or as a combination of the two media (virtual laboratories). Existing laboratories or machinery made available to the other partners via the world wide web, by use of telecontrol, teleoperating and televisualisation, in order to train students to communicate and give support in trouble shooting of automatizated manufacturing-systems, process-optimization, plants-control, ... (tele-laboratories).
  For each tele-laboratory and virtual laboratory developed, the outputs will be descriptions on paper or in multimedia format (CDROM), including a description of the required hardware equipment and the tutorial sessions. A description of all virtual laboratories on the websites of the universities, ECTS credits for each virtual laboratory tier.
- A manual of good practice: the overall teaching, learning and evaluating methodology.
- Reports of the four general meetings. A project website containing all reports and studies, and links to the partner universities.

EVALUATION STRATEGIES

In each partner institution, the local co-ordinator has a specific mission of evaluation and follow-up in his own university. The project manager assistant will be in charge of an integral quality audit of the project. We think there is no need to ask an external evaluator.

For the evaluation of the main output - the lab modules - two levels of feedback are implemented:

The tutors of user group institutes will attend the lab sessions and will learn the modules well. The tutors will send back suggestions to the creator, and possibly add contributions. In this way, the newly developed lab courses are discussed and evaluated by the different partners.

Also students will give permanent feedback during the laboratory sessions. After having attended all virtual/tele-laboratory modules, the students will evaluate the learning method by filling in a questionnaire. The local co-ordinator will organize and process the students enquiries. The co-ordinator will co-operate with the local tutor(s).

During and at the end of the semester, the students will be assessed by their local tutor (he is their normal teacher) by means of permanent evaluation and/or examination a traditional way. The results of this examination will provide information on the quality of the lab courses as well.

EXPERIENCES DISSEMINATION

The experiences and outputs of the project will be distributed internally in the partner institutes via heads of fields of study and heads of department.

All the project partners are involved in other existing European projects. Their integration in other networks will facilitate dissemination to other universities.

There will be dissemination towards the Thematic Network THEIERE ("Thematic Harmonisation in Electrical and Information Engineering in Europe").

PEDAGOGICAL ASPECTS

It was supposed that the LABLINK project laboratory should not be only a passive video flow of information for the students, it should be flexible process with a great amount of students' interaction. what's more, LABLINK laboratory experiments should include several items concerning the teachers/tutors work, the students work and their interaction.

The following elements of teachers/students work with respect to virtual laboratory experiment could be distinguished:

- Students prepare at home to the laboratory experiment.
  Manual , CD ROM – pictures, video, photo show etc. of real measurement (from active LABLINK session)
  Manual covers: general rules how to use the LABLINK session, task description e.g.: theoretical background, standards (if any), limits modeling (can also be as independent virtual LABLINK session), measurement, goal of the measurement, method of measurement, standards (if any), instrumentation, safety rules, possible hazards, ecology viewpoint etc., process of measurement, results of the measurement and its data evaluation, evaluation of the used method, summary, comments, suggestions, example of the evaluation stage, data processing, testing, questions, answers of frequent questions concern to the passed session
  Student prepares his first set of general questions (if any) and sends them via Internet to the teacher (laboratory) before the real active LABLINK task session.
  Teacher answers those questions whose can be generalized, the others can explain in the beginning or during the real active LABLINK task session. Different technical possibilities are for such answers: web page, chat (time slot needed by plan), video conference (time slot needed by plan)
- Students take part in the LABLINK laboratory experiment session.

Teacher and group of his students measure in the lab – distant student can follow via internet. Distant students first are going to get the information:
teacher will introduce the measurement, goals, methods, teacher will answer some questions;
visual from measurement via internet (web) camera(s), gathering data from the measurement process;
For this part it is necessary to create the time schedule very carefully - with brakes / slots for repetitions, for summary of individual parts, comments of used methods and measurement instruments as well as for student replies and feedback.
Students are supposed to ask questions during the session, send them or to use chat. Teachers are supposed to answer – it is probable that the second teacher is needed, or by individual time slots.
Finally the teacher will conclude the measurement (comparison to the theory, model and modeling) and can open the evaluation stage.

- Students' work is evaluated, at this point there are no tests and credits allocation
  This evaluation should help teachers to evaluate the level of understanding of the laboratory material by the students. This evaluation serves as feedback concerning the performed laboratory experiment. It is not evaluation for awarding of credits.
  The purposes of running the experiment and its evaluation is to create basic frame of virtual labs including schedule, time slots concerning short introduction to the theory – background – link to the other (input) project tasks, modeling, measurement – instrumentation - tools, measurement - testing methods, measurement – processing – to show other links, results, background, results and data evaluating, evaluation – teacher summary – comparison to the theory, conclusions, evaluation – student summary / reply, final summary – link to the other (output) project tasks.
- Students work at home after performing the laboratory experiment, students prepare the report on the work that they have done, prepare for evaluation and tests.
- Students take part in the final LABLINK laboratory experiment session
  Teacher will send his questions and notes to the students, such as rules for testing, credits awarding, to calculate the results of measurement, evaluate the data and method of measurement, ask about the method of measurement and measurement process.
  Each student will finish technical report / protocol of measurement.
  Each student gets individual set of tasks based on LABLINK session (methods).
- Students' work is evaluated concerning the results obtained during the laboratory session as well as the report developed after the session.
  The evaluation is based on results of measurements and experiences from work at home. The teacher will answer all the questions from the work at home, summarized results, express his experiences from the other phases of the experiment. The conclusion will be oriented towards the level of understanding and individual ability to apply the results of measurement and method in practice. Teacher can repeat some parts of the measurement, introduce the technical report, protocol, (re)calculate the results which was asked.
- Appropriate amount of credits is allocated to the students.
  Each student is supposed to receive his results in the form of evaluation of individual items from the test, protocol and calculation.

CONTROL AND IDENTIFICATION TASK

The proposed virtual laboratory experiments to be developed at Silesian University of Technology include some specific control experiments in the field of adaptive control and active noise and vibration attenuation. At the Institute of Automation, Silesian Technical University, one of the most challenging laboratory experiment include the active noise and vibration control problems. These tasks are theoretically and numerically involved and include by far nontrivial hardware problems concerning the noise measurement and anti-noise generation. In particular the creation of 3-dimensional zones of quiet is the filed of current interest and is one of the more difficult tasks from the point of view of the adaptive control algorithm design and implementation. On the other hand the creation of such zones is of great potential application as it could concern the vehicles interior but also offices, shops, industrial buildings as well as concert halls.

FIGURE. 1
CONTROL AND COMPUTATION FACILITIES IN THE ACTIVE NOISE AND VIBRATION LABORATORY.

The creation of 3-dimensional zones of quiet is investigated in the Laboratory of Active Noise and Vibration Control which is equipped with basic hardware concerning noise measurement and anti-noise generation including measurement microphones, sound-level meters, signal analyzers and generators, amplifiers, mixers and loud-speakers. Additional and very important hardware components include special anti-aliasing filters as well as forming filters used for precise anti-noise signal generation. Obviously the laboratory is heavily computerized and the laboratory sites under discussion include fast computers equipped with specialized signal processing cards and input/output interfaces as well as additional sound measurement equipment. The noise is generated by means of loud-speakers driven by sound generators and is measured by means of several measurement microphones placed in a special way in the 3-dimensional measurement space. On the basis of this multidimensional measurement process the anti-noise signal is on-line calculated and generated by means of precise signal generators and several loud-speakers specially placed in the 3-dimensional anti-noise generation space. However, the basic problems attacked in the laboratory concern the algorithms used for identification, recursive estimation, filtering and adaptive control of the zone of quiet control task. These problems are difficult because the acoustic object is very difficult to model, it is impossible to bound the control scene, several signals have to be involved in the control scenario calculation and all this has to be performed on-line and very fast which usually leads to simplified control identification algorithms and much trouble with the most possible efficient coding of such algorithms.

The control and identification algorithms are calculated mainly by means of specialized DSP hardware plugged into PC computer used also for data input, resulting data analysis and control and identification results visualization. The equipment used for calculation has to ensure the satisfactory computation speed because of the natural demand to work with short sampling period in such control system. One should realize that in the adaptive control system – such as the generation of the 3-dimensional zones of quiet – it is necessary to realize both identification/estimation and control calculation which heavily increases the needed computation power. The control algorithms proposed for the zone of quiet generation control task include several modern and advanced control, filtering and identification algorithms like poles/zeros placement control approach, adaptive feed-forward filters, phase-shifts algorithms, minimum-variance control and adaptation in the frequency domain. The identification/optimization task includes non-trivial performance index to be minimized and good identification algorithms is of much importance. Therefore the work towards more efficient identification/optimization algorithms like the multiple cluster one described in this paper is important for the efficient run of the algorithms in the active noise/vibration control systems.

Another aspect of running the active noise and vibration control experiment concerns the setup of laboratory site to be used in virtual manner by students from possibly other universities, and countries. This concept was developed in the Institute of Automation, Silesian University of Technology as part of the international collaboration based on the participation in Socrates/Minerva programme in the framework of LABLINK project. Within LABLINK project framework it is proposed that laboratory experiments will be exchanged between universities in a virtual way. By using the internet, distant students are going to have access to laboratory experiments which could be called tele-laboratories. The experiments could include image and sound transmission which is especially well suited to the active noise and vibration control experiments described above.

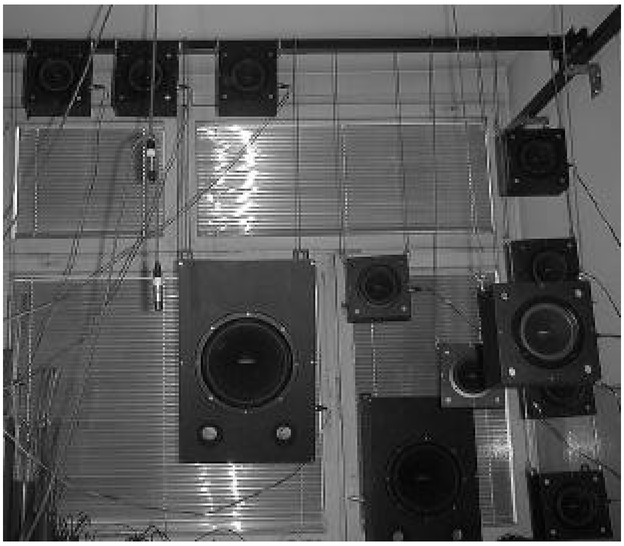

FIGURE. 2
MEASUREMENT MICROPHONES AND LOUD-SPEAKERS FOR THE 3-DIMENSIONAL ZONE OF QUIET GENERATION.

CONCLUSIONS

The author of this paper works at Silesian University of Technology, Gliwice, Poland – Institute of Automatic Control which is one of 8 partners in the LABLINK project. The SUT/IAC has chosen the laboratories for Active Noise/Vibration Control, as well as Adaptive Control laboratories to be included in LABLINK. The general field of study is Electrical Engineering, the direction is Automation and Robotics and specialization is Computer Controlled Systems. The target group is composed of students from the 4th and 5th year of studying. The target laboratory experiment included the active vibration control with magnetic bearings system as well as active noise control with producing local zones of silence. Both experiments include elements of adaptive control theory and important implementational issues. The general laboratory concept included the computer assisted experiments with real and simulated plants that could be accessed from outside by means of computer internetworks and IP protocol. Such experiments may be accompanied by some kind of tele-control as mentioned in the project proposal. The possible implementation could be started with fairly standard environment including standard PC, Apache webserver, Webcam software, CGI for telecontrol, servlets and Java applets.

The overall aim of this project is to improve the quality of higher education in technical universities. Giving students access to lab experiments done elsewhere, and to web-based lab simulations will broaden the spectrum of topics taught. This will increase the educational level of the universities in the partnership.

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