International collaboration in education and research: active noise and vibration control example

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Abstract *— The paper concerns th e possibilities of international collaboration in education and research based on tele -laboratories and virtual laboratories. The author of this paper participated in the methodology development and implementation of active noise and vibration control tele -laboratory at the Silesian University of Technology (SUT). The Industrial Control Group at SUT is involved in the active noise control research based on the theory of systems and adaptive control concepts for several years. Successful results have been ob tained with respect to the problems of noise attenuation in acoustic ducts, personal noise attenuators, as well as the creation of zones of silence. The active noise and vibration control problems are also present in education at Silesian University of Tec hnology – there are non -obligatory courses concerning the theoretical and implementational issues in these fields. The lectures are accompanied by the laboratory exercises which are also used with other courses, including Adaptive Control, Digital Signal P rocessing and Microprocessor Techniques. The equipment used for active noise and vibration control laboratory exercises is rather unique and of high cost, the laboratory room is typically filled with many microphones, loud -speakers and other equipment. The refore it was decided to enable the access to the active noise laboratory at SUT in the form of tele -laboratory by means of computer network. At the same time the author of the paper has successfully applied with 9 other universities for the international collaboration project called LABLINK focusing on building tele -laboratories and virtual laboratories at the participating institutions and cross-accessing them by the students from the project partners institutions. The tele - and virtual laboratories built as part of LABLINK project covered several important areas of engineering education, especially with respect to electrical and mechanical engineering. .*

Index Terms *— Distance learning, remote laboratories, active noise control, advanced control, digital signal processing .*

INTRODUCTION

The paper presents the results of international collaboration in the field of tele-laboratories and virtual laboratories called LABLINK. The presentation is focused on the participation of the Institute of Automatic Control team, Silesian University of Technology, Gliwice, Poland. The LABLINK project resulted in the set of laboratories with the possibility of Internet based access, the methodological guidelines concerning the usage of such laboratories in education, and – what is probably the most important result – the examples of virtual international exchange of students by means of using the tele-laboratories via Internet, typically with some help from local tutor. On the other hand the tele-laboratory platform can be easily used to build the international research-oriented contacts, e.g. by enabling the collaborating scientists from other universities access to the active noise control laboratory at Silesian University of Technology. Thus the LABLINK project could be viewed as the successful example of enhancing the possibilities of international collaboration in education and research by using the concept of tele-laboratories and virtual laboratories

At the very beginning of the LABLINK project there was a strong feeling of the project originators that the high tech labs, which are expensive and often require specialized trainers are difficult to build and maintain at numerous European universities. As a result it seemed obvious that not many universities and institutes have advanced laboratories in all engineering specializations, it is rather so that each university specializes in some research and laboratory oriented area whereas it lacks the sufficiently modern equipment in several other. It is also typical that many universities are not capable of hiring the enough competent staff members in all important fields of engineering. In addition the number of staff depends on the student population and as the number of students has decreased significantly in several European countries recently, some universities became too small to compete with other in the research and education fields. To even more complicate the technical and human resources problems, some universities in various European countries have very well qualified staff but very limited financial resources to buy equipment. All of the above mentioned arguments brought the LABLINK project originators to the conclusion that it would be of great importance to exchange laboratory experiments between universities. This could be realized by offering them a suitable technical means and methodology to present the local well-established and

modern lab to the outside students and researchers: distant students should have access to advanced laboratory experiments. Such hardware/education concept are usually called tele-laboratories. The LABLINK project covered also the topic of faithful computer simulations of lab experiments, which is usually related to the concept of virtual laboratories.

It was obvious from the very beginning of the LABLINK project activities that the vigorous development of computer networks and internets makes it practically evident to implement the tele-laboratories and virtual laboratories on the basis of global Internet. The virtual and tele-laboratories should be simultaneously accompanied by the matching data (text) modules, preferably in the multimedia-rich format. In addition, the possibility of interactive work with the "human" tutor – preferably locally – would also enhance the possibilities and amplify the advantages of the access to tele-laboratory or virtual laboratory. The overall objective of the LABLINK project was therefore to improve the quality of higher education in technical universities, especially with the engineering education and high-tech topics in mind. Giving students access to laboratory experiments done elsewhere, and to web-based laboratory simulations will broaden the spectrum of topics taught. As a result the universities and teams participating in the LABLINK project would increase the quality of engineering education at their sites and also make their schools more popular among local students and international students' exchange participants.

Many of the above mentioned reasons justifying the participation in the collaboration of LABLINK project kind fit perfectly to the situation and possibilities of Silesian University of Technology, especially with respect to the Institute of Automatic Control. As a specific area of specialization, the Adaptive Control, Digital Signal Processing and System Identification courses have been chosen for the IAC/SUT team participation in LABLINK project. All these courses from the basis for active noise and vibration control problems and laboratory exercises that are developed at the Institute of Automatic Control in Gliwice. As a result the local objective of the LABLINK pilot project in Gliwice was to develop the methodology to ease distant students' access to academic laboratory activities with respect to the active noise and vibration laboratory exercises as well as to workout the technical means of easy access of students and researchers to the instrumentation and software in this engineering field.

The topics quoted below were considered as the LABLINK project outputs in the project application as well as in the various reports and dissemination activities:

- A survey of existing know-how in the partnership on virtual labs. A synthesis of related open and distance learning projects, searched in European and other databases of information society building projects. 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 tele-control, tele-operating and tele-visualisation, in order to train students to communicate and give support in troubleshooting of automated manufacturing-systems, process-optimization.
- For each tele-laboratory and virtual laboratory developed, the outputs 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.

LABLINK ACTIVITIES AT SILESIAN UNIVERSITY OF TECHNOLOGY

The proposed virtual laboratory experiments to be developed at the Institute of Automatic Control, Silesian University of Technology, included some specific control experiments in the field of adaptive control and active noise and vibration attenuation. As it was mentioned above, one of the most challenging laboratory experiment at the Institute of Automatic Control is the active noise and vibration control problem. There are several highest level control theory specialists employed at the IAC who work in the field of optimum, adaptive, hierarchical, nonlinear and intelligent control. The active noise and vibration control problems seem sufficiently challenging for such richly composed group of researchers. The control related tasks appearing in the active noise and vibration control problems are definitely theoretically and numerically involved and include rather sophisticated hardware problems concerning the noise and vibration measurement and anti-noise/vibration generation. The major strands of IAC staff effort of attacking the active noise and vibration control problems appeared to be the noise attenuation in acoustic ducts, personal noise attenuators, the creation of 3-dimensional zones of quiet and vibration control in bearings. The first laboratory to be included in the LABLNK project based collaboration covered the problem of the 3D quiet zone generation, which at the same time 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
ACTIVE NOISE CONTROL LABORATORY WITH REMOTE ACCESS CAPABILITIES.

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.

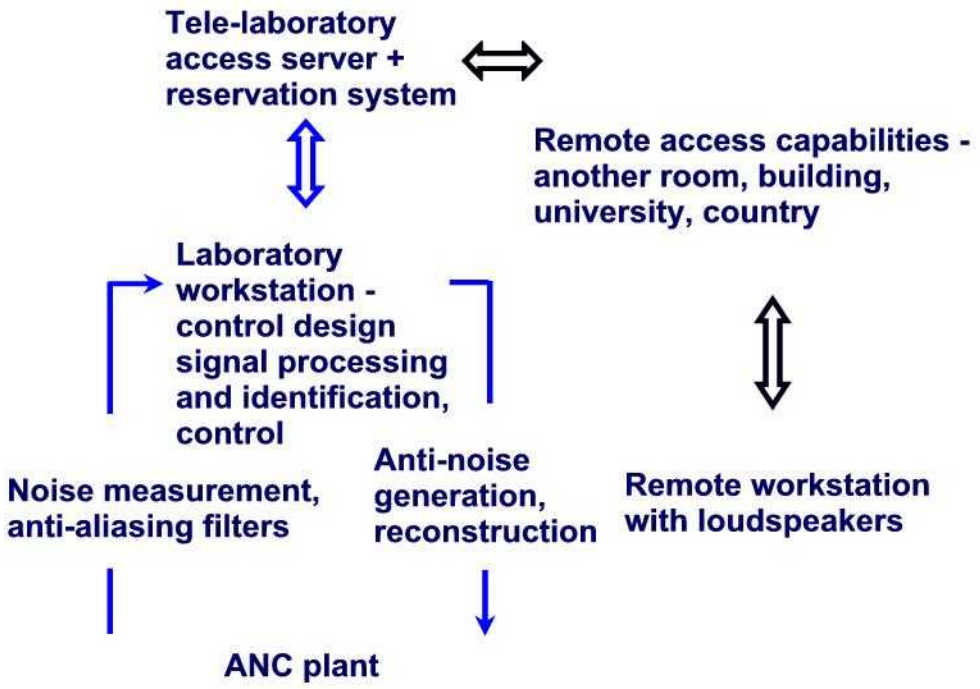

FIGURE 1
BLOCK DIAGRAM OF REMOTELY DRIVEN ACTIVE NOISE CONTROL LABORATORY.

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. Exactly this concept was developed in the Institute of Automatic Control, 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.

ACTIVE VIBRATION CONTROL EXPERIMENTS

Active vibration control became one of the most exciting research topics of the control area in the last few years. The research problems examined at the Institute of Automatic Control, Silesian University of Technology, focus on vibration attenuation with respect to bearings systems and in general in the full active suspension systems. There are many specialized technological solutions available with respect to the problem of magnetic levitation. It is however worth mentioning that in

many cases the research work is concentrated on the technical possibilities of such systems realization, whereas the quality of control concerning such systems – which includes the vibration attenuation – is often underestimated. This may be also the result of the fact that such magnetic suspension system is rather difficult with respect to its modeling, analysis and control design and implementation, also due to open-loop instability, non-linearity and nonstationarity.

At the Institute of Automatic Control the problem of optimizing the quality of control of such difficult systems has been attacked. It is sometimes suggested to use well known standard PID controllers for such systems – which usually ensure stable control but the quality of transient responses is not sufficient. The control quality could be substantially improved e.g. by means of advanced methods of control system design including predictive control with nonlinear modeling, which is one of the priority research topics at the Institute of Automatic Control.

Some other control concepts, structures and algorithms with respect to the suspension systems and active vibration control are examined at the IAC, e.g. modal controllers, adaptive systems with direct disturbance measurement, adaptive compensators and several other adaptive control schemes, including gain scheduling as well as identification/parameter estimation based systems. The algorithms are being tested using the model of magnetic bearings - MBC 500, Magnetic Moments – extended with pneumatic system of rotary speed measurement and control. The laboratory rig is currently being adapted to the tele-laboratory paradigm in order to enable the remote and safe access to the active vibration control system for researchers and students from the Silesian University of Technology and possibly from any other university in the world.

CONCLUSIONS

The paper presented the results of work on implementing Internet technologies to Adaptive Control teaching at Silesian University of Technology, Poland, also as part of the author's involvement in the realization of the LABLINK and LINK international collaboration projects. The course on Adaptive Control includes elements of Control Theory, Identification and Estimation, Signal Processing and Computer Controlled Systems. The lecture on Adaptive Control usually refers to several simulation and real-time experiments which serve as exemplary material on advanced control and estimation algorithms performance. Laboratory experiments accompanying the lecture are usually quite complex and an expensive and rare equipment is used to conduct the experiment. The above mentioned characteristics of the course justifies the usage of modern tools – like Internet technologies – in the Adaptive Control.

The SUT/IAC has chosen the laboratories for Active Noise/Vibration Control, as well as Adaptive Control laboratories to be included in the LABLINK project collaboration. The general field of study was Electrical Engineering, Automation and Robotics and specialization was Computer Controlled Systems. The target group was composed of students from the 4th and 5th year of studying. The target laboratory experiment included the active noise control with producing local zones of silence as well as the active vibration control with magnetic bearings system. Both experiments include elements of adaptive control theory and non-trivial 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 LABLINK project was 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. Future work concerning the incorporation of Internet technologies in the Adaptive Control and similar courses could include among the following:

- revised versions of multimedia interactive courses for tele-learning platforms;
- tools for semi-automatic translation of HTML based lectures to various partners countries languages;
- other partner language versions of several produced multimedia interactive lectures and laboratory exercises introductory materials as well as software interface.

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