

AC 2007-2118: COLLABORATIVE LEARNING IN LABORATORY-ORIENTED COURSES USING WEB CONFERENCING FOR SHARED CONTROL OF PHYSICAL LABORATORY EXPERIMENTS

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Collaborative Learning in Laboratory Oriented Courses Using Web Conferencing for Shared Control of Physical Laboratory Experiments

Abstract

The Electrical and Computer Engineering Department at the University of Minnesota has embarked on an innovative method to conduct the laboratory component for its Electric Drives course. The method involves exploiting the versatility of the Adobe Breeze 5.1 package, which can create a computer interface for users to actively participate from remote computers in ongoing experiments. Apart from the instructor being able to demonstrate the experiment to students, she can also actively involve the students by giving them remote control of the experiment. So the experiment can be performed in a collaborative manner by giving control to each group of students or individual students with all students having viewing privileges. The students can get a real-time experience using this new method. The cost of laboratory setups can be greatly reduced using this method. The method allows a large number of students to perform experiments using just one physical laboratory setup. Hence the university can reduce its investments on laboratory apparatuses and invest on the software, which is much more cost effective.

Motivation

In traditional laboratory courses students follow a laboratory manual to perform experiments. In the typical two hour laboratory session the students are required to set up and perform the experiment, take the necessary readings and obtain the results. The laboratory instructor helps the students with any trouble they face with the apparatus or the procedure.

Students generally have difficulty in laboratory courses even though the corresponding theory has been extensively covered in lecture sessions and detailed laboratory manuals describing the laboratory facilities and the procedures are handed to them well in advance. One reason for their difficulties is that they are not familiar with the laboratory environment that contains machines and relatively complex measurement methods and devices. Time constraints during the laboratory experiments add to the difficulties. Because of these time limitations, students often rush through the experiments in order to finish them on time, which unfortunately prevents them from appreciating what has been accomplished in the laboratory practice¹.

To address these difficulties, the Electrical and Computer Engineering Department at the University of Minnesota has implemented a new method of conducting the laboratory component of its Electric Drives course. This method addresses the student's difficulties by creating a collaborative, group working environment where students can share and build off of each other's efforts. The method is based on integrated use of computer and computational tools. These tools include the Adobe Breeze 5.1 package, Matlab Simulink and Real Time Workshop, dSPACE and Control Desk.

The computational tools also enhance the laboratory experience by providing students with the opportunity to verify the results of the laboratory experiments and compare them with those

obtained by computer simulations. Such a comparison opportunity helps students realize the limitations of hardware experiments and, as a counterpoint, appreciate that computer models cannot substitute for actual hardware experiments. Those simulations might not exactly represent the operation of the machines because of incorrect or incomplete modeling assumptions.

Moreover an undergraduate electric drives course that integrates up-to-date computer hardware and software tools meets the expectations of today's students (and employers) who want to use computer and simulation tools in every aspect of a course and thus the improved laboratory methods will attract more students¹.

Background

The addition of computer-based collaboration to the Electric Drives laboratory course is an enhancement and continuation of work done at the University of Minnesota to improve its entire power curriculum. This work has spanned over a decade with support from the National Science Foundation (NSF) and the Office of Naval Research (ONR)² and has included numerous faculty workshops and on-line courses³ to disseminate the new teaching methods to Universities across the United States and abroad. In this time, enrollment in power courses at the University of Minnesota has increased several fold. Four new electric power textbooks have come from this effort⁴⁻⁷, as well as completely redesigned laboratories for the Power Electronics course and the Electric Drives course⁸. The hardware for the Electric Drives laboratory was designed specifically for the laboratory and includes active loads that can be controlled and modified by the students.

Software Used to Implement the New Teaching Method

Computational tools are vital teaching tools in the classroom and the teaching laboratory. Let us discuss the use of these tools in our Electric Drives laboratory course.

The Adobe Breeze 5.1 package is used for Web conferencing to facilitate real time communication, collaboration, teaching and learning over the web⁹. Breeze Meeting Rooms are used for real-time meetings and seminars that everyone can access instantly. All students in our electric drives laboratory are connected through a Breeze Meeting Room.

Matlab Simulink is universally used to build real time models. Simulink is a tool for modeling, analyzing and simulating an extraordinarily wide variety of physical and mathematical systems, including those with non-linear elements and those which make use of continuous and discrete time. Matlab Real Time Workshop supports the execution of dynamic system models. Real Time Workshop quickly generates the C-code for discrete time and hybrid systems¹⁰.

The dSPACE setup helps in testing and verification of motor control algorithms which is very demanding and time consuming. The dSPACE real time platform allows simulations and verification environments to be created from Simulink models. This way the model can be used throughout the whole development cycle of the control algorithm. dSPACE allows simulations to be performed in several phases of the design, from a single module to the system level¹¹.

The Control Desk module is a very convenient way to manage and measure the experiments. Control Desk creates a complete experiment environment with virtual instrument panels, and it is easy to use. We can design the experiment interface by drag and drop.

The transition from Simulink to the dSPACE real time world and back is transparent as we use the same virtual instrument parameter sets and automated test loops¹⁰. Matlab, with its toolboxes, is selected because it is the main software package used in many undergraduate courses in our university. Therefore students can easily access Matlab, and most of them already have the basic programming skills needed to use the given Simulink models and to write computer programs when required before coming to the electric drives laboratory class.

Description of Collaborative Learning Method Implemented in the Electric Drives Laboratory

The following is a step-by-step description of the computer-based collaborative laboratory course.

A detailed laboratory procedure is posted on the course web page, in our case Web CT is used, at least one week before the experiment is scheduled. Simulation models are included to serve as useful preparatory exercises before students come to the laboratory. The students are expected to have a fair understanding of the procedure and the simulation models before they come to the laboratory.

Our laboratory environment has six terminals. One is the master setup with the entire apparatus and all the machines. The other five terminals have all the required software installed but no machine hardware.

At the time of the laboratory class or even before, the instructor can create a Breeze Meeting. To create the Breeze Meeting the instructor just logs into her breeze account using her University ID. Once the meeting is created she invites the students for that particular laboratory using the students' University ID. She can also create groups and just invite the group after creating the meeting.

Once the meeting is created and the students are invited by the instructor, known as the "Host", she and the students, known as the "Participants", log in to the Breeze accounts and enter the Meeting Room. Now the Host of the meeting starts the experiment and manages the entire meeting session. She passes control of the meeting by granting the role of the Presenter to different students inside the Breeze Meeting Room. There are three roles in Breeze Meeting Rooms - Host, Presenter, and Participant. The Host, as explained, creates, manages and invites the students for the meeting. She is always in control of the meeting. The role of the Presenter is to present via audio and video when the Host grants that role. The Presenter then acts as though they have control of the meeting. The role of the Participant is just to participate in the meeting. The List of attendees is displayed in the Meeting Room. The Host can easily grant the role of Presenter to anyone of the attendees inside the meeting room. The rest of the students are Participants of the meeting. The Host shares the master terminal desktop using the Breeze

feature of screen and application sharing. Now the Presenter or the selected student performs a part of the experiment.

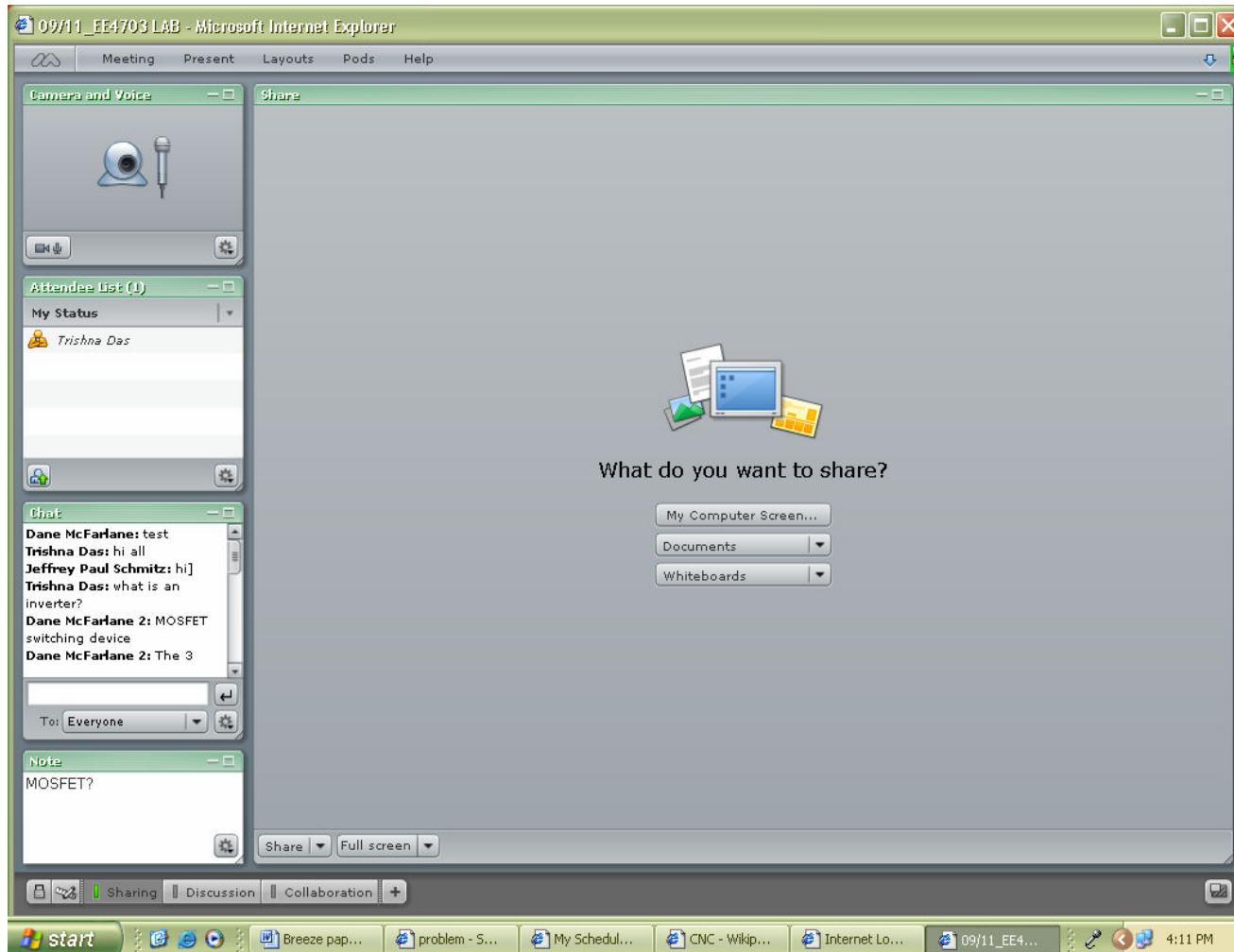


Fig. 1 Breeze Meeting Room

Typically there are ten students in the laboratory section forming five teams. The experiment starts with a few Matlab Simulink models that selected student Presenters simulate. The hardware part of the experiment begins by first creating the Matlab Simulink models using the dSPACE toolbars. Then the models are built in real time using the Matlab Real Time Workshop that generates the C-code of the dSPACE model. The students then create the layout using the Control Desk toolbars which gives them the required measurements and readings from the machines. Though there is just one physical machine setup the experiment is collaboratively performed by all students.

Students submit a report one week after the laboratory class that must combine the results from both simulations and experiments from the Control Desk outputs. The emphasis is that the report should compare simulations results with the experimentally recorded data, mainly focusing on

the differences and similarities. One might assume that results obtained from the Simulink simulations and the Control Desk reading would be the same. However, this equivalency is not the case, and non-negligible errors are observed. Students are encouraged to provide explanations for these errors in their reports. These errors might be the result of machine modeling errors or shortcomings in the Simulink simulations, or measurements errors from the Control Desk layouts. Nevertheless, the students realize the need for hardware experiments. They realize that software simulations can never completely replace hardware experiments. They understand that a true sense of performing an experiment is achieved only when they are able to do the experiment on the hardware setup.

The students can help each other in building the various blocks using the chat window in the Breeze Meeting room. The students can also post questions regarding the procedure or any difficulty faced during the laboratory session. Currently the laboratory uses the Breeze Meeting Room without the audio and video features, as the classroom doesn't require the use of these features. But with the use of a web camera and microphone the laboratory teaching can be more effective. The hardware setup can be monitored not just by the Host, i.e. the instructor, but also by all the Participants in the meeting.

In this collaborative learning environment, a student interacts in an efficient way with her instructor and peers. Every group can perform different parts of an experiment (or even completely different experiments) simultaneously and learn from each other. Hence by sharing knowledge a student can learn more in a quicker and more effective way. This allows a complete revamping of laboratory instruction techniques, methods, and philosophy.

Experiments can also be performed such that the students work independently on their own terminals using their own Matlab and dSPACE and then screen-share the simulation results using the Breeze Meeting Rooms. Only for the hardware part, after the dSPACE models are built, will the instructor share her terminal desktop and allow students to perform the experiment using Control Desk. The students can then take the required measurements from the master setup using the Breeze screen sharing feature.

Laboratory courses conducted with the Breeze interface could have future extensions such as virtual experiments, providing opportunities for inquiry, higher levels of thinking, and a sense of accomplishment for students through independent discovery. This is an innovative approach to integrating technology into the teaching/learning process for laboratory oriented courses and can change our fundamental approach to laboratory environments.

Redesigning the Laboratory Courses

This was an introduction for both the students and the faculty to this method. But this method has the potential to completely revolutionize the laboratory courses. We are redesigning and rewriting the experiments such that each group of students can perform a separate module of the experiment independently. For example, we are planning to include an experiment that aims to design the load for a motor. This is possible because the physical machine hardware in this laboratory uses an active load which can be modified or programmed by the students. General load characteristics will be given to the students, such as torque vs. speed curves, time or

position dependent load variations, or stiction. Using these characteristics the students will design loads that would be difficult to operate to stringent parameters. Each group would then try to run the load designed by other groups. Thus there is a constructive thinking environment developed and new challenges posed to the students. For such an experiment the students can design the loads independently, or discuss with other groups in the Meeting Room using the Breeze feature of discussion rooms. After each group has designed the load they can demonstrate the load using the screen sharing feature of the Breeze Meeting Room.

The laboratory classes can include pre-lab tests using Breeze quizzes and polling features. Thus students would be comfortable with the procedure and the theory before performing the experiment. This would help them to develop a better understanding of the experiment.

Benefits of Adopting the New Teaching Method

This technology enables us to offer the laboratory courses to students for whom attending university laboratory classes is not feasible. As stated, we just have one master setup in our laboratory. Thus the laboratory classes could be conducted virtually over the web. And students need not be physically present inside the laboratory class. Now, having been freed from the constraint of physical attendance, the students can attend the laboratory class from anywhere. All they need is a terminal with an Internet connection (56 kbps) and Macromedia Flash Player 6.0.79 or higher. Thus, laboratory courses can be offered for distant learning students, and this method of conducting laboratory courses opens up whole new possibilities for students from urban as well as rural communities to get an experience with real machines!

Some experimental set-ups are very expensive. For example, a High Voltage laboratory will require a large capital investment, strict detail to safety, and will use up valuable space. In such cases a centralized laboratory with remote users could be a good solution benefiting students in different parts of the world, urban and rural.

A very evident advantage of this new method of conducting the laboratory classes is that the money invested by the universities into laboratory apparatus can be reduced drastically. This method requires just one working hardware setup. Maybe the universities would have another back-up apparatus. That's it! Universities no longer need to purchase large numbers of apparatus or restrict the number of students registering for the laboratory courses due to lack of sufficient apparatuses. This method completely relieves universities of such heavy expenditures on the hardware apparatus. The universities can simply invest money on the license of the softwares required. Thus the investment required to set up laboratory classes would be more reasonable.

Now that we know we need no more than one setup to actually conduct the laboratory we can think of offering laboratory courses for subjects such as High Voltage Engineering, Computer Numerical Control Laboratory or other specialized subjects. Thus laboratory courses can have just one satellite terminal at the universities or the place of hardware setup and the students can participate in the laboratory by remote access using the Breeze Technology. So now students can have real time experience with apparatus that are expensive and have strict detail to safety.

Thus many more courses can include laboratory components into their undergraduate curriculum, enriching the learning experience.

The Breeze meetings can be recorded for asynchronous access or review. Students can review what they have learned in the laboratory sessions and recapitulate the entire experiment at their free time. Even if a student is unable to log into the laboratory session on a particular day, he can always revisit the recording and get a feel of the experiment. The Breeze meeting recordings can be used for content tracking. The major difficulty that students face in perceiving the concepts of courses such as Electric Drives and Machines is that they are unable to visualize the machine functioning in real life. Thus, making these laboratory session recordings available to students taking the theory courses would help them to analyze as well as visualize the machines. This would further aid them to get a stronger grasp of the concepts learned in the classroom.

Computer-based laboratory collaboration also increases the integrity of the course, making more accurate assessment of student contributions possible. The Breeze platform provides a complete, rapid and robust system of communication and learning including archive capability and course content tracking.

When the students graduate and enter their respective professional field, they are usually overwhelmed by the technology used in the workplaces. They take time to adjust to the environment of virtual meetings and at times even virtual employees! This method of teaching helps them to prepare themselves for the challenges that await them after school. They have firsthand experience communicating effectively using communication tools such as Breeze. Similar softwares are used in work places as mediums of communications. This helps students to use the technology to their advantage and thus shine in their field of work.

Challenges Using Breeze

The Breeze technology, just as all technologies, has its own share of shortcomings. When the screens are shared among the students and the experiment is performed by a remote user on the master setup terminal desktop to build models using Matlab Simulink, they experience a fraction of a second delay or lag. While this seems insignificant when working with a few Simulink components, the students often get annoyed when the models require a large number of components. But the students slowly get used to this lag. We tried resolving this issue but the Breeze support had no particular reason as to why there was this lag when trying to share screens and build models using Matlab Simulink. Breeze is very efficient with all other softwares such as Control Desk with no complaints of delays.

Future Possibilities

This method can be expanded in many ways that can help in sparking new interest among students for the laboratory courses. This method can renovate the laboratory aspect of the courses and give way to infinite possibilities to conduct the laboratory component.

A logical extension of this method is that using Breeze, the instructor can record the entire experiment with all its modules from the simulations to the Control Desk. Then this recording

can be made available as a url link to all students. So when the students come for the laboratory sessions they can perform the experiment without having to read the laboratory manual but just sit through the experiment recording. They can also play the recording while performing the experiment like an online guide. Once each group finishes one module of the experiment the student can screen share their simulations using the meeting room. This way of conducting the laboratory experiments helps students to explore the experiment at their pace and develop their own learning pace. They can have a true feeling of the experiment performed. This is a more individualistic approach of conducting the laboratory course.

Conclusion

In this paper we have put forth a method of teaching that would completely change our approach towards the way laboratory courses are conducted. This is a successful integration of simulation tools with the hardware setup in the electric drives course laboratory that complements the classroom lecture. The students benefit with better understanding of the experiment. They develop the quest to learn the subject matter meticulously. Thus the students can achieve much more using this technology than what has been accomplished currently using the traditional method of conducting laboratory courses. This method of conducting the laboratory courses provides numerous opportunities of inquiry, higher levels of thinking, and a sense of accomplishment for students through independent discovery.

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