Work In Progress - A Remote e-Laboratory for Student Investigation, Manipulation and Learning

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Abstract - **The development and evaluation of a remote laboratory for student manipulation and learning is reported in this work in progress paper. The laboratory allows students to observe and control a physical setup of a multi-pipe fluid flow experiment through the internet and to predict and analyze the results. The laboratory learning environment interface was developed using LabVIEW™ and structured to enhance students understanding of basic engineering concepts, problem solving, experimental error, data analysis and curve fitting. It further provides students with the opportunity to use engineering software to develop their own algorithm to predict the results. A key aspect of the remote experimentation design is that it allows students to manipulate flow paths on a test bed section of the pipe flow network to obtain parameters they require for the prediction of the results. This allows the use of creativity in experimentation, a feature available in physical experimentation but often restricted in web-based remote laboratories. The remote environment provides increased individual access to equipment during and outside of regular hours from any web-enabled location. The overall architecture of the remote laboratory presented here can be easily applied to other technical fields.**

Index Terms – Multi-pipe experiment, LabVIEW™, Remote laboratory, and Student manipulation.

INTRODUCTION

The integration of computer technology in education has seen significant progress over the years, meeting growth in numbers and diversity of the student population by providing increased access from any location. The 2003 Sloan survey of online learning reported that online education delivered by higher education institutions in the United States is perceived to be critical to the long term strategy of a majority of schools. In addition, academic leaders expect the quality of online learning to surpass that of traditional methods in the future [1].

This evolution is evident in engineering education, where online delivery of laboratory experiments was initiated with the virtual simulation environment and eventually the active remote laboratory environment was introduced involving remote control of physical equipment. In a one-year study on the potential contribution of virtual and remote laboratories to the development of a shared virtual learning environment [2], the University of Hull reported the advantages of the remote laboratory over the virtual laboratory environment. Student feedback has revealed that although computer simulated experiments are acknowledged as tools in learning to control equipment and explore scenarios, they cannot replace the physical laboratory environment [3]-[6]. With adequate complexity and interaction, remote laboratories have the potential to achieve this. Hence, the logical progression of the online effort was to develop the remote laboratory and include virtual reality representations to reinforce the pedagogical effectiveness [7].

The development of remote experimentation facilities is motivated by several factors such as time savings, sharing resources of expensive equipment and individual access to experimentation [8]. The positive contribution of the remote laboratory in a distance learning environment has been verified by the MIT Microelectronics Weblab which is based on a transistor characterization experiment. The experiment has been used by students in distance courses taught in Chalmers University of Technology in Sweden and courses under the Singapore-MIT alliance. Several educational experiments using this laboratory yielded positive testimonials from the students [9]. Another iLab experiment under the MIT initiative involves a heat exchanger laboratory designed to demonstrate the principles of heat transfer [10]. The remote use of this setup in a process control experiment by the Chemical Engineering Department at Cambridge University [11] has demonstrated successful sharing of experimental resources among universities. Similarly, the joint development of jet thrust laboratory by faculty at Rutgers University and the University of Illinois at Urbana-Champaign culminated in the Integrated Remote Laboratory Environment (IRLE), where both universities host remote control laboratories that are then made available to their students [12].

While the emergence of high-speed network connections has unleashed numerous such implementations of remote laboratories [13]-[19], they are generally limited to guided control of equipment with emphasis on recording measurement data or viewing responses. There is a need to investigate more complex experimental setups that encourage increased interaction, creativity and initiative on the part of the student to design the experiment and greater autonomy to manipulate equipment and apply the concepts.

The experimental setup presented in this paper was designed to implement technology in remote experimentation, while retaining the exploratory aspect of a physical laboratory

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environment, by allowing increased user-interaction. The laboratory allows students to observe and control a physical setup of a multi-pipe fluid flow experiment through the internet and to predict and analyze the results. In order to fully exploit the presence of physical equipment in the remote laboratory setup, students are given the opportunity to manipulate the flow path in the test-bed section of the network, thus providing the ability to investigate even from a remote setting. As part of an effort to upgrade the mechanical engineering laboratory by integrating state of the art measurement and instrumentation techniques, the University of Texas at San Antonio has renovated a pipe flow test station with a LabVIEW™ based data acquisition and control system so that the experimental process can be performed manually or electronically in the laboratory environment [20]. Apart from this restricted physical laboratory environment, LabVIEW™, has been used successfully to provide multidisciplinary engineering solutions in several virtual and remote experimentation applications [21] and was therefore chosen as the control software in this experiment.

A framework for the evaluation of the remote laboratory experience is critical to ensure that the effectiveness of the implementation is measured suitably and to assist in the design of the remote laboratory. The Sloan Consortium has defined five key areas for achieving quality in online education which include the learning effectiveness, cost effectiveness, access as well as faculty and student satisfaction [22]. Examples of evaluation methods used to satisfy this framework include pre and post knowledge tests to measure the learning effect as well as student surveys and faculty feedback on quality indicators of the online experience [23]-[26]. Studies on such quality indicators and their importance, as perceived by students and faculty in measuring the success of the online experience, indicate that the level and speed of interaction, clear articulation of expectations, timeliness of feedback and access are some factors of importance that should be considered in the design and assessed during evaluation [27] [28]. A tutoring scheme that provides different levels of support in web-based experimentation is presented in the collaborative work of the Swiss Federal Institute of Technology and the University of Florida [29]. It is with these quality indicators in mind that the design of the complex and interactive remote experimentation described here was developed to achieve a significant step towards improving the standard of online engineering education.

THE REMOTE LABORATORY

Pipe Network Structure

The structure of the pipe network was required to achieve goals in terms of providing unique fluid paths for a sizeable number of students, an interactive set-up for user-flexibility and automation to operate in a remote setting. The hardware setup, which has been designed and completed (schematic shown in Fig 1), includes an experiment section, where 4 pipes of varying diameters are connected in a configuration to provide 60 different fluid paths through 21 valves. The test section emulates the pressure loss sections of the experiment section, and will enable the required pressure loss measurements to be ascertained and obtained by the students. The test section thereby offers the exploratory aspect of the experiment, allowing for students to design the experiments and obtain the necessary information, with the aim of reliably predicting pressures at any point in the experiment section at a given flowrate measured by the flowmeter.

Software Structure

LabVIEW™ was chosen as the software for implementation of the remote control of the equipment through the data acquisition interface. A Matlab interface is provided so that the students are given the opportunity to write their own Matlab codes for the theoretical validation of their measurements. The software code has been written and validated for a prototype system consisting of a simplified pipe network. This code will be extended to cater for the network shown in Fig 1 and will include a user-friendly interface assisting the students to successfully conduct the experiment.

COMPLETION AND EVALUATION PLAN

The following are the various components of the completion and evaluation plan for the project.

1) The software implementation will be carried out to effectively control the equipment for the different configurations of the fluid network.

2) This will include an effective user-interface to guide the students to perform and understand the theory surrounding the experiment.

3) The remote laboratory environment will be set up using the internet for communication with streaming video for real-time observation of the experiment.

4) Student assessments will be performed to determine the effectiveness of the remote laboratory environment as compared to the conventional laboratory setting with manual controls.

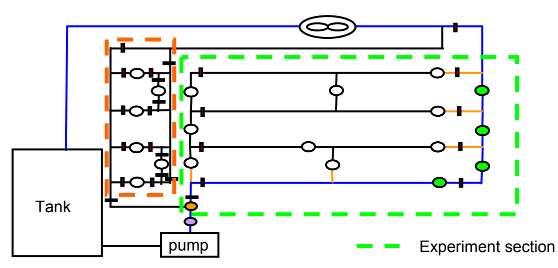

FIGURE 1
SCHEMATIC OF PIPE NETWORK

REFERENCES

[1] Allen, E., Seaman, J., “Sizing the Opportunity, the Quality and Extent of Online Education in the United States, 2002 and 2003”, Sloan Center for Online Education at Olin and Babson Colleges, September 2003.

[2] Stimson, G., Tompsett, B., “The potential contribution of virtual and remote laboratories to the development of a shared virtual learning environment”, A Report for the Joint Information Systems Committee Technology Applications Programme, University of Hull, October 1997.

[3] T. F., Wiesner, W., Lan, “Comparison of Student Learning in Physical and Simulated Unit Operation Experiments,” Journal of Engineering Education, vol. 93, pp. 129-138, 2004.

[4] D. G., Alexander, R. E., Smelser, “Delivering an Engineering Laboratory Course Using the Internet, the Post Office and a Campus Visit,” Journal of Engineering Education, vol. 92 (1), pp. 79-84, 2003.

[5] Foss, B.A., Eikaas, T.I., Hovd, M., ”Merging Physical Experiments back into the Learning Arena”, American Control Conference, 2000. Proceedings of the 2000 , Volume:4, 28-30 June 2000 Pages:2944 - 2948 vol.4.

[6] Burrell, B., Wiggins, R., J., Sonwalkar, N., Kutney, M., C., Dalzell, W., Colton, C., K., “A Comparison of Web-Based and Laboratory Learning Environments”, ASEE 2000-2433, Proceedings of the 2000 ASEE Annual Conference& Exposition.

[7] D., Gillet, H. A., Latchman, Ch., Salzmann, O. D., Crisaille, “Hands-On Laboratory Experiments in Flexible and Distance Learning,” Journal of Engineering Education, vol. 90 (2), pp. 187-191, 2001.

[8] Salzmann Ch., Gillet, D., Hugeuenin, P., “Introduction to Real-time Control using LabVIEWTM with an Application to Distance Learning”, International Journal of Engineering Education, Volume 16, Number 3.

[9] Microelectronics Weblab, MIT News Office, March 2001, http://web.mit.edu/newsoffice/2001/weblabcomment.html

[10] Colton, C., K., Knight, M., Khan, R., A., Ibrahim, S., West, R., “A Web-accessible Heat Exchanger Experiment”, International Conference on Engineering Education, Valencia, Spain, July 21-25, 2003.

[11] Web Based Teaching: Cambridge Students Perform Experiment at MIT over the internet - a CMI funded initiative, Department of Chemical Engineering, University of Cambridge, July 2004. **http://www.cheng.cam.ac.uk/research/groups/como/proj.wbt.news.html**

[12] Ogot, M., Elliot, G., Glumac, N., “Hands-On Laboratory Experience via Remote Control: Jet Thrust Laboratory”, ASEE 2002-2666, Proceedings of the 2002 ASEE Annual Conference& Exposition.

[13] Wong, H., Kapil, V., and Tzes, A., "Mechatronics/Process Control Remote Laboratory", ASEE 2001-1526, Proceedings of the 2001 ASEE Annual Conference& Exposition, June 24-27.

[14] Azad, A., B., K., Otieno, A., Ghrayeb, O., Anand, N., “Internet Based Experiments for Physical Laboratory Setup”, ASEE 2003-2158, Proceedings of the 2003 ASEE Annual Conference& Exposition.

[15] Henry, J., “7 Years Experience with Web Laboratories”, International Conference on Engineering Education, Valencia, Spain, July 21-25, 2003.

[16] Watson, J., L., Bibel, G., Ebeling, K., Erjave, J., Salehfar, H., Zahui, M., “On-line Laboratories for Undergraduate Distance Engineering Students”, Proceedings of the Frontiers in Education 34th Annual Conference, October 2004, Savannah, Georgia.

[17] Tan, K., K., Lee, T., H., Leu, F., M., “Development of a Distant Laboratory using LabVIEW”, International Journal of Engineering Education, Volume 16, Number 3.

[18] Chen, S., H., Chen, R., Ramakrishnan, V., Hu, S., Y., Zhuang, Y., Ko, C., C., Chen, B., M., “Development of Remote Laboratory Experimentation through Internet”, Proceedings of the 1999 IEEE Hong Kong Symposium on Robotics and Control, Hong Kong, pp. 756-760, July 1999.

[19] Ko, C., C., Chen, B., M., Chen, J. Zhuang, Y., Tan, K., C., “Development of a Web-Based Laboratory for Control Experiments on a Coupled Tank Apparatus”, IEEE Transactions on Education, vol. 44, pp. 76-86, 2001.

[20] Karimi, A., Rogers, A., C., Connolly, T., J., Frazer, J., W., “Automated Laboratory Experience in an Undergraduate Mechanical Engineering Program”, ASEE 2003-2433, Proceedings of the 2003 ASEE Annual Conference& Exposition.

[21] Ertugrul, N., “Towards Virtual Laboratories: A Survey of LabVIEW-based Teaching/ Learning Tools and Future Trends”, International Journal of Engineering Education, Volume 16, Number 3.

[22] Moore, J., C., “A Synthesis of Sloan Effective Practices, July 2004”, The Sloan Consortium, July 2004.

[23] Lang, D., Mengelkamp, C., ReinholdJ., S., Geoffreoy, D., Billaud, M., Zimmer, T., “Pedagogical Evaluation of Remote Laboratories in emerge Project”, International Conference on Engineering Education, Valencia, Spain, July 21-25, 2003.

[24] Tuttas, J., Rutters, K., Wagner, B., “ Telepresent vs Traditional Learning Environments-A Field Study”, International Conference on Engineering Education, Valencia, Spain, July 21-25, 2003.

[25] M., Ogot, G. Elliot., N. Glumac, “An Assessment of In-Person and Remotely Operated Laboratories,” Journal of Engineering Education, vol. 92 (1), pp. 57-63, 2003.

[26] D. W., Dearholt, K. J., Alt, R. J., Halpin, R. L., Oliver, “Foundational Aspects of Student-Controlled Learning: A Paradigm for Design, Development, and Assessment Appropriate for Web-Based Instruction,” Journal of Engineering Education, vol. 93, pp. 129-138, 2004

[27] M. S. Cohen and T. J. Ellis, "Developing Criteria for an On-Line Learning Environment: From Student and Faculty Perspectives," Journal of Engineering Education, vol. 93, pp. 161-167, 2004.

[28] Gillet, D., Salzmann Ch., Latchman H., A., Crisalle, O., D., “Recent Advances in Remote Experimentation”, Proceedings of the American Control Conference, Chicago, Illinois, June 2000.

[29] Gillet, D., Crisalle, O., D., Latchman H., A., “Web-based Experimentation Integration in Engineering Curricula”, System Theory, 2002. Proceedings of the Thirty-Fourth Southeastern Symposium on, 18-19 March 2002 Pages: 66 – 70.