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Development of a Global Web-Based Industrial Process Control Laboratory for Undergraduate and Graduate Engineering Technology Education

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Abstract

Web technology provides powerful, online, educational tools for teaching and demonstration of automated processes. This paper describes a fundamental global initiative to establish laboratory cooperation based upon integrated web-based process control for engineering technology education. This initiative is a collaboration between Midwestern State University in Wichita Falls, Texas, USA and AlBalqa' Applied University in Amman, Jordan. This treatment outlines the motivation and the need for this initiative and the approaches taken to develop the process. A case study of multi-variable coupled tanks level control process is proposed and the application of networking and control methods to allow remotely situated students from both universities to control and monitor the process parameters is described. Future steps are also discussed with the motivation of using this technology in real industrial applications for better industrial engagement with engineering education and to facilitate the sharing of expensive and inaccessible instruments and equipment, which is an essential step in remote distance engineering study.

Introduction

Industrial automation and control has witnessed significant advancement and innovation in recent years. New applications and technological advances have accordingly proliferated in diverse fields that were hardly realized before. This has influenced staff and decision makers at the managerial level to provide suitable strategic planning and future expansion efforts for their systems to comply with the market demands and associated constraints. But due to the costs associated with this technology, insufficient progress has been made in the introduction of engineering students around the globe to modern industrial technology. Therefore the necessity of instruction modernization has risen to develop new communication and training channels between engineering education and industrial partners to provide tools and paradigms that accommodate rapidly changing industrial environments. Execution of these paradigms, creates challenges to academia to modify their curriculum and provide hands-on skills their graduates need to compete in the job market. These efforts are worthwhile as industry/academe partnerships would be solidified and the undergraduate and graduate curriculum would be expanded to cover state of the art industrial applications.

Coordinated efforts establishing new concepts for industrial control courses and laboratories have been addressed in the literature [1,2]. It is evident that faculty at higher institutions strive to adopt new systems and equipment which provide better exposure for students to relevant automation and industrial applications. Students gain expertise in advanced industrial applications and faculty acquire dynamic projects for curriculum improvement and research studies. Based on these factors, a fundamental collaboration between AlBalqa' Applied University and Midwestern State University has been launched.

Laboratory Design

The first objective targets the design of the physical experimental. Undergraduate students are expected to follow the design procedure and analysis using simulation tools to verify the process controllability. Next, students will explore the versatile experimental settings to cover the principles of I/O interfacing and data acquisition programming techniques to achieve different control operations for analog and digital applications. Finally, graduate students are involved to investigate the application of SCADA (Supervisory Control and Data Acquisition) principles, DCS (Distributed Control Systems), industrial Ethernet, and web-based control concepts. Afterwards, those subsystems are assembled and various control schemes are remotely implemented through the application of web-based network.

The last designated purpose for undergraduate and graduate students is to play a fundamental role in the improvement of implemented techniques by having them utilize the facilities available in the laboratory in the aspects of experiment development, precise control algorithms and advanced SCADA system applications. This will also contribute to some revenue for the faculty and staff involved, which accordingly will build tight relationships between both sides and eventually graduates will be more attracted to pursue their careers with international engineering corporations.

System Architecture

The applied experiments in our project are run remotely via a web interface, and are well suited to distance learning courses where students need not be physically present on campus but can monitor and control different experimental parameters to support their theoretical background. The project development consists of the following modules:

1. Process Set-up Preparation

Our work presents the implementation of a remote laboratory for control of different practical industrial processes. In this paper, a case study of level and flow control in a

“Multi-Variable Coupled Tanks Level” process is demonstrated for the applied procedure. This process is introduced for implementation of multi-variable control algorithms for the level in a double tank using the liquid flow. As shown in figure 1, this process composed of coupled tanks and set of sensors and actuators to control level, flow, and temperature, it also contains an interface circuits for the sensor and actuators. The input to the system is via a water pump which feeds water to the tanks. The flow rate is controlled by speed of a direct current motor that drives the pump using input from a digital computer running an appropriate feedback control algorithm for various water level control tasks.

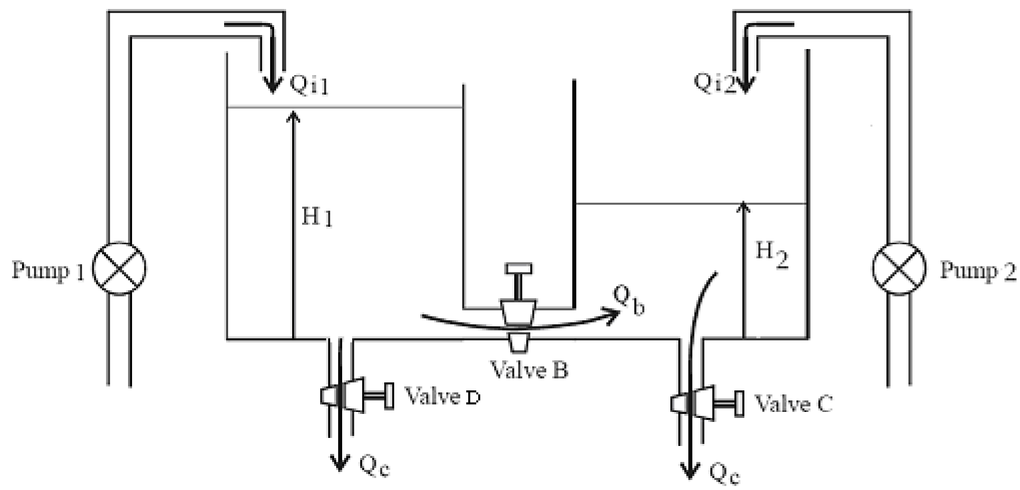

Figure 1: Coupled Tanks Level schematic diagram. Q: Flow rate, H: Head level.

2. Physical Laboratory Design

The physical laboratory has the main server/controller computer workstations connected to the network. This workstation is equipped with LabVIEW hardware and software components from National Instruments™ (NI), to allow real-time data acquisition to LabVIEW. A simple diagram of system interface is shown in figure 2.

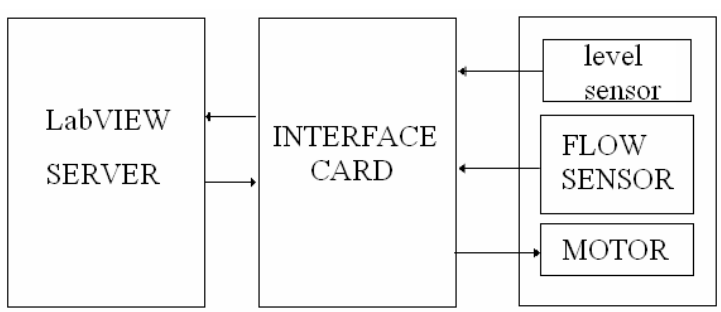

Figure 2: System connection block diagram.

The transferred data from and to the computer must be adjusted according to sensors calibration curves.

A key step in this educational process is to allow students to learn the basic components of virtual instrument programming tools and environments. The emphasis is concentrated around the functional and control elements that can be constructed in the interface front panel and the underlying connectivity among components. Simulation modes of different simple application programs are to be implemented and to examine the generated results and graphics. One of advantages of LabVIEW is the compatibility with Java language where the pages of the program and the data can be shown on the internet easily using Java language [3].

The students practice with simple and medium level device and channel configurations in the main panel interface and block diagram and then examine the related signals being communicated externally. Figure 3 shows the process wired to the server station via DAQ system.

Figure 3: Process set-up and server system.

To allow the distant user to monitor the system behavior under several manual or automatic control adjustments, a camera and a microphone is connected to the video server to send image and sound to the client, figure 4. The camera also must be connected to the LabVIEW server in order to control the movable platform where the camera is mounted on, so that the user can control both the zooming and viewing angle.

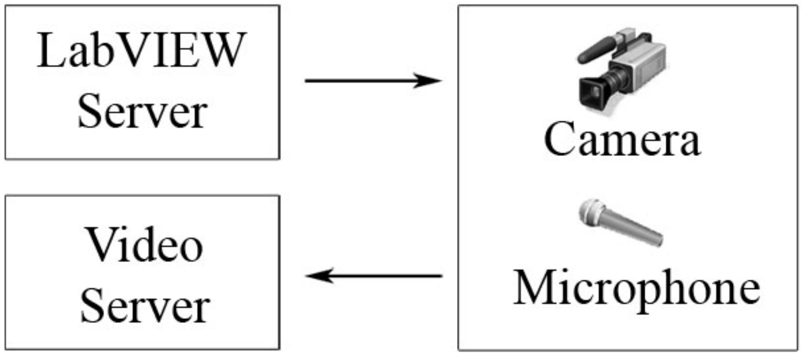

Figure 4: Monitoring system of the process.

3. Industrial Network and Internet Requirements

The main component is the software to provide a wide range of flexibility in designing the relevant web pages that correspond to the automated application such as WinCC and SIMATIC.NET™ which are trademarks of Siemens industrial communication standard [4, 5, 6]. Management level operators are thus benefited out of such scheme since the process layer can be connected to the WinCC application server via proper PROFIBUS-FMS channel. Students will get a wide exposure about all of these modern industrial concepts and hence can build up further skills into different directions.

To connect the LabVIEW server to the client through the internet, figure 5, TCP (Transmission Control Protocol) is used as a basic reliable tool for network communication between the client and the server. LabVIEW supports TCP, in other words LabVIEW includes TCP VIs and functions in order to create a client or server VIs.

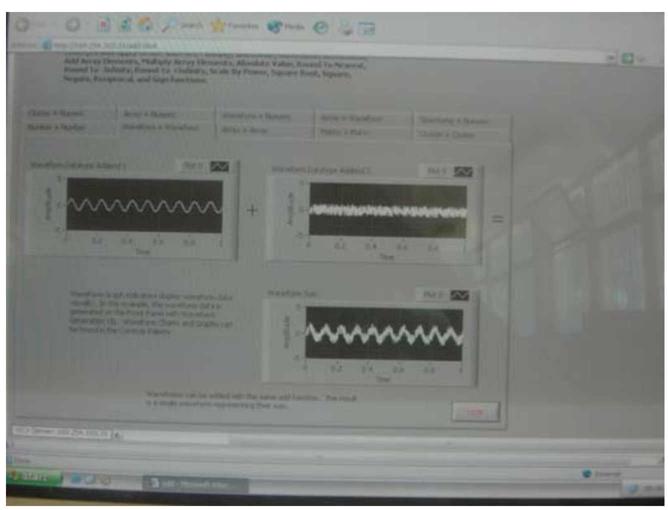

Figure 5: Client Monitor with server IP: 169.254.103.31.

This server has a unique IP Address which can be used to communicate with this computer remotely. When this server is called using this IP address, it gets connected to the user and the user will have the access to the LabVIEW control panel, this access can be protected via a password to limit the user interference with the system. It would then accept the control commands from the operator's computer and send to process, figure 6.

Figure 6: Students working at the server station.

4. Undergraduate Engagement in Active Learning and Applied Research

A fundamental issue addressed by this research is student access, at primarily undergraduate institutions, to leading-edge industrial applications. A significant goal of this global collaboration is to leverage the teaching and research strengths of each university to address this issue of access. Students witin the McCoy School of Engineering at Midwestern State University will have the opportunity to design and implement process control solutions for the "Multi-Variable Coupled Tanks Level" problem, even though the system is not physically located on campus. The only alternative method to provide the students with this educational experience is to purchase and develop a physical system on site. However, the costs and time associated with the purchase of such equipment are often prohibitive.

4.1 Current Undergraduate Learning and Research Objectives

Based upon the physical system housed at AlBalqa' Applied University, the students at Midwestern State University will first develop a mathematical model of the system to derive governing equations. This derivation will allow the students to apply fundamental concepts of dynamics and differential equations to a physical system with which they will be interacting. Following this, topics introduced in "Computer Aided Engineering" and

"Mechanical Engineering Analysis" to develop a Matlab code for simulation of the systems behavior. The results of this simulation are vital for two reasons: 1) The students will be able to compare the behavior of the simulated system with the physical system itself, and 2) After validation/agreement between the simulated and physical system, the students will develop a control law which may be tested first through simulation, before implementation on site. Informal polling of student opinions throughout the intial stages of this research project reveal that active learning strategies, where students link the theory to the application, are well received and important for student success in theory driven classes such as in a control systems course.

The control methodology we will employ first is Proportional-Integral-Derivative (PID) control. PID control is a well known industry standard; employment in any process control industry dictates that an entry level mechanical engineer be comfortable with this control methodology. Participation in this research means that the students will be exposed to PID control earlier in the curriculum, improving chances for success in a linear control systems course which is typically offered during the semester just prior to graduation. The control of system characteristics such as level, flow, and temperature are particularly relevant for mechanical engineering students. These characteristics are present in numerous engineering applications both applied and theoretical. Exposure will give these students an advantage on the job market.

The above mentioned internet protocol and LabVIEW software capabilities will allow our students to control a LabVIEW virtual instrument which dictates system parameters on site at AlBalqa' Applied University. Students at Midwestern State University will be able to monitor in real-time the response of the system to the control commands. The virtual instrument panel allows for a visual observation of the system response and video allows for a visual observation of the system response; each are then compared to the simulation results. A numerical comparion can be made as data is uploaded from the site to the dedicated PC at Midwestern State University.

5. Future Prospective

Based on the case study described in this paper, a proposed methodology for teaching different tracks could be easily adjusted to meet the requirements of different engineering fields by having fundamental and advanced concepts exercised in a predetermined manner. In all of the above experimentation efforts different process systems could be considered such as batch (coupled) tanks, pressure, sorting, assembling or Robotics systems. This laboratory will be improved by including fieldbus setups to form an industrial network to control and monitor more advanced discrete control systems. From the beginning of the implementation phase of this project, a numerous number of students showed their interest in working with this project from both universities. This project is expected to attract more students in the forthcoming semesters and also to bring people from the industry for training.

A significant contribution of the proposed process control laboratory will be realized in the area of engineering technology education. For the undergraduate students at Midwestern

State University, this benefit is achieved through access to industrial process control equipment. A fundamental goal of the proposed laboratory is to provide the undergraduate students with a complete industrial process control experience using this equipment. One that includes mathematical analysis and simulation of a candidate control algorithm for the tank level problem problem, followed by implementation on the physical system, and finally by process manipulation and monitoring. The engineering education literature reports the benefits of establishing theory, design, and implementation based pedagogical control methodologies that improve student understanding of concepts both theoretical and practical. For example, in [7] it is noted that in typical control systems courses theory and analysis are presented, but the implementation and monitoring of the design phases are not. In [8] it is noted that the inclusion of the physical component of control system design, resulting in the complete theory, analysis, and implementation phases of system design are happily received by students, which is reflected in student performance in the course.

In this work, we propose to adapt the theory, analysis, design, and implementation pedagogical methodology and apply it to a research group setting. That is, the educational benefits are not limited to a single course; the students involved in this project are participating in the Global Process Control Group of their own choosing. Success has been reported in the literature (for example in [9]) by structuring research group experiences around a strong pedagogical framework initially developed for use in the classroom. From the undergraduate perspective (students of Midwestern State University) the complete design experience will be achieved by leveraging the benefits of both Midwestern State University and AlBalqa' Applied University. The theory and analysis (control design and simulation) will be carried out on site, under the supervision of the faculty sponsor. Implementation and monitoring of the industrial control process, using the designed control law, is carried out via the global collaboration. That is the physical hardware for the two tanks experiment is located on the campus of AlBalqa' Applied University. It is through the Siemens technology, via LabVIEW, that the undergraduate students interact with the physical system.

As this research effort evolves, creation of a physical process control laboratory on the campus of Midwestern State University is planned. The McCoy School of Engineering possesses five PLC trainers with dedicated electric motor control capability. Establishment of a global motor control laboratory would allow the learning benefits detailed above to be fully realized by students at each university. Implementation would allow the undergraduate students at Midwestern State University to use knowledge from “Measurements and Instrumentation” and “Mechanisms” courses to design the system and select the appropriate sensors and transducers needed for system control. Additionally, coordination and implementation of the server technology which allows for remote access to the equipment provides an educational experience not typically realized in a mechanical engineering curriculum. Ultimately, students from each university will have full access to on-site industrial process control equipment for close interaction, but also the ability to remotely control the process from virtually any location.

Conclusion

This paper briefly described development of a joint laboratory for process control systems educations. It also presented an effective proposal for the development and establishment of an industrial control and communication laboratory at the global level. The main outcome behind this effort is to reduce the gap between engineering students from different universities and real world industry by having modern equipments and technologies to be shared. Students of undergraduate and postgraduate will feature this laboratory when participating either to the physical or web-based laboratory development.

This treatment details the evolution of new learning technology derived from the global laboratory development collaboration. This is centered on teaching the monitoring and control techniques such that students may control remotely any process environment worldwide. Such high-tech education offers students a unique career pathway in advanced industrial applications. This global collaboration leverages the teaching and research strengths of each university to support our ongoing initiatives to revitalize the global industrial sector by providing highly skilled graduates to meet the demands of new advanced technologies.

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