Development and Integration of Project-Centered Modules into RLab Remote Laboratory System Environment

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Abstract

Applied approaches to learning enhance the traditional theoretical approaches in many engineering education aspects while also contributing to the manufacturing and machine sciences facets of the curriculum in order to respond to the needs industry. A hands-on approach continues to be integrated into the engineering curriculum through industrial collaborations as well as physical system experimentation. Extending regional efforts into an effort of international cooperation between the University of North Florida (UNF) and Cologne University of Applied Sciences (CUAS) gains the synergy of international engineering education through collaborative projects in precision automatic control engineering. The collaboration involves learning, using, developing, and enhancing the RLab Remote Laboratory System developed at CUAS, porting the RLab capability to UNF, and expanding the scope of experiments. The premise for the Remote Laboratory, or RLab, is to allow a user from any location to access and perform tests on different experimental electromechanical systems, or plants. The user may access RLab from anywhere in the world with the only requirement needed is an internet browser. RLab, developed using National Instruments LabVIEW, has been used successfully at CUAS with three electromechanical plants and is now being integrated with four different types of electromechanical plants at UNF. The project-centered modules in place at UNF use high-quality hardware and software. The laboratory equipment comprising a large set of project-centered modules for experimentations uses ECP Systems. This paper describes initial development and integration of the ECP electromechanical plants into RLab.

Introduction

Informatics in control and automation with advances in communications technologies accelerates the development of applied experiential learning in system dynamics and control. Applied approaches to learning enhance the traditional theoretical approaches in many engineering education aspects while also contributing to the manufacturing and machine sciences facets of the curriculum in order to respond to the needs industry.

Hands-on approaches continue to be integrated into engineering curricula through industrial collaborations [1] as well as physical system experimentation [2]. The concept of a remote laboratory has been used for instructional purposes in many instances and many examples exist. With the ability of the internet to allow users to connect and share common interest and resources, remote laboratories may be designed and implemented to produce a system which functions as a teaching method and/or a remote control via the internet. A remote laboratory may be used for instructional purposes in a variety of educational laboratory and remote control domains; for example, in power conversion laboratory [3], and in control engineering courses [4]. Remote laboratories have been developed for motion control in mechatronics [5], DSP control, electric drives [7], and control of DC motors [8].
Extending regional efforts into an effort of international cooperation between the University of North Florida (UNF) and Cologne University of Applied Sciences (CUAS) gains the synergy of international engineering education through collaborative projects in precision automatic control engineering [9]. One motivation is to allow users at various sites, with differing hardware resources, to connect and share resources with colleagues via remote access. With this motivation a Remote Laboratory, or RLab [10-13] has been developed using LabVIEW [14]. Remote laboratories can be designed and implemented to produce a system which functions as a teaching method for control

theory via the internet [10,13] in a project-oriented context. Further collaboration involves learning, using, developing, and enhancing the RLab Remote Laboratory System developed at CUAS [10-13], porting the RLab capability to UNF, and expanding the scope of experiments [9,15].

The premise for the Remote Laboratory, or RLab, is to allow a user from any location to access and perform tests on different experimental electromechanical systems, or plants. The user may access RLab from anywhere in the world with the only requirement needed is an internet browser. RLab, developed using National Instruments LabVIEW [14], has been used successfully at CUAS with three electromechanical plants and is now being integrated with four different types of electromechanical plants at UNF. The project-centered modules in place at UNF use high-quality hardware and software [2,9,14,15]. The laboratory equipment comprising a large set of project-centered modules for experimentations [2,9] uses ECP Systems [15]. This paper describes initial development and integration of the ECP electromechanical plants into RLab. Similar in concept to the project-oriented approach, project-centered modules allow an instructional approach using multiple hardware instances to be used in a variety of contexts spanning several engineering courses [2]. Development of additional project-centered modules may then include additional electromechanical plants [15] and comprise collaborative research projects [9]. Educational modules are used for courses in system dynamics and control and offer a platform for collaborative research projects.

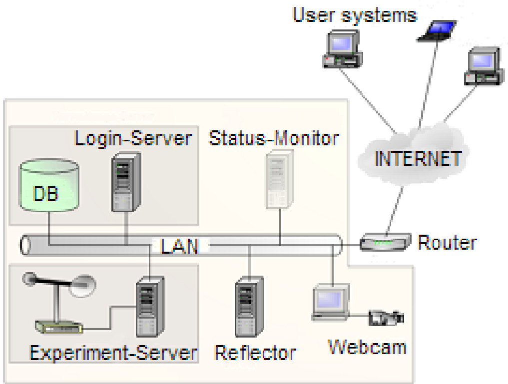
RLab Overview

The initial version of RLab [10-13] has been developed to enable a set of experimental plants to be controlled remotely among partnering institutions. The additional capability of the RLab system is the ability to be solely run over the internet and thus allow it to be remotely accessed with the only requirement is that the user has a web browser. The development of RLab requires connecting the user to the experimental electromechanical systems. The website interface initiates the experimental system plant, records the data from the plant, and displays the results. LabVIEW software is used as the infrastructure largely due to its data acquisition capabilities and its internet connectivity options. Also a database is needed to monitor user activity and other experiment support functions. Microsoft Access is used to store the experimental data and other data. Some of the data include information for the login system that requires the user to sign up for RLab, login and logout times for the different users, and administrator information. The overall interoperability of the infrastructure is described below. Later releases of LabVIEW enable new features of the underpinning software, LabVIEW, to be incorporated into system enhancements while also allowing the introduction of new electromechanical plants.

The structure of RLab currently consists of seven independent servers, all of which run LabVIEW. The initial RLab implementation [10-13] made use of LabVIEW 6.1 [14]. Enhanced versions use the later 8.x versions of LabVIEW. The architecture of RLab is illustrated in Figure 1. RLab allows a user from any location to access and perform tests on different experimental electromechanical systems, or plants. The user may access RLab from anywhere in the world with the only requirement needed is an internet browser. The initial RLab configuration consists of servers that are used to control three existing plants. Figure 1 schematically depicts the RLab system with one of the physical plants.

There are two servers which are required for RLab to function, the login server and one experiment server. The login server handles creating the majority of the html code, the user interface, and the interaction with the database. The login server controls the flow of information and is the connection between the user and the experiment server. The experiment server is the connection between the login server and a specific electromechanical plant. It contains the device drivers to run the given plant and handles the flow of information back to the login server as well as interaction with the remote user.

Figure 1: RLab architecture overview.



Each physical plant requires a corresponding experiment server. The initial RLab system has three experimental plants, the heater fan plant, the twin rotor plant, and the inverted pendulum plant. A given experiment server also contains the ability to implement different controllers for the various plants using LabVIEW. The software needed for the webcam server is also resident with the experiment server. There are other support servers that serve additional extraneous functions but not essential for RLab to operate. The first is a reflector server, which streams live data acquisition. The second is a client server, which is used to test the system for possible errors. The final server is a status monitor server, which displays which servers are being used and which ones are open. This structure permits the ability to customize RLab for different situations. Because the servers operate independently, they may be upgraded independently. For example, if a given experiment server needs to be upgraded to a later version of LabVIEW, the login server would be unaffected. The login server handles creating the majority of the html code and interaction with the database. Therefore, the login server is the initial connection between the user and the experiment server.

The experiment servers are the connection between the login server and the respective plant. Each contains the device drivers to run the given plant and handles the flow of information back to the login server as well as interaction with the user. The experiment server also contains the ability to implement various controllers into its code by creating LabVIEW programs. In the initial RLab, three basic controllers for the three plants were included for students to perform experiments in basic control theory. The extensibility using LabVIEW allows development and facilitates integration of more complex experiments in control theory. With the partitioning of RLab into the various servers, it may be upgraded and enhanced [16]. Also in order to clone RLab and port it elsewhere, a new RLab is constructed with minimal need to modify the current system. Also new electromechanical plants and experiments may be added to an existing RLab with the addition of LabVIEW virtual instrument (vi) programs.

The initial RLab as a functional system has provided a useful system for remote control and access for electromechanical plants used in teaching of basic control theory. However the are possibilities for continuous improvement as the underpinning platform is LabVIEW. One reason to upgrade RLab to a new version of LabVIEW is to gain access to newer toolboxes, better performance, and more ease of customization. The LabVIEW toolkits have been updated and upgraded, currently at versions 8.x. LabVIEW has undergone significant changes in its SQL and Internet Toolkits since the version of LabVIEW 6.1 used in the initial implementation of RLab. Two significant areas of attention during the LabVIEW upgrade have been accomplished [16], one regarding the former SQL Toolkit and the other regarding the Internet Toolkit. Another reason to upgrade to LabVIEW 8.x is the new products being released that link the electromechanical ECP plants [15] the LabVIEW 8.x software. The ECP plants at the UNF expansion site for RLab include two ECP 205 torsional plants, two ECP 210 rectilinear plants, three ECP 220 industrial plants, and an ECP 750 gyroscope.

RLab Experimental Plants

The original version of RLab has three experimental plants, each from a different vendor. The ported version of RLab had four plants available, all from the same vendor. Since there are three types of experimental plants at CUAS, in the original RLab system there are three distinct experiment servers in the RLab system at CUAS to support the experimental plants. The first server corresponds to the twin rotor plant as shown in Figure 2. The twin rotor is a multi-input multi-output (MIMO) plant that has two rotors, one for a horizontal axis and one for a vertical axis. The horizontal axis may be disabled to make the system a single-input single-output (SISO) system. For more advanced experiments, the horizontal axis should not be disabled; however instructional control experiment may still be run on the SISO system configuration.

Figure 2: Twin rotor plant at CUAS.

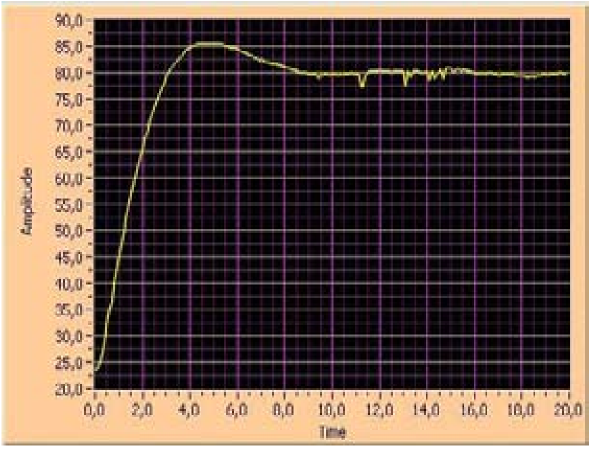
In the original RLab system, the twin rotor experiment server has three experiments in basic control theory. The first is a set point experiment, in which a voltage is given to the plant and the uncontrolled response is recorded. The second is a step response, in which the customization of the step responses length and magnitude is created, and the plot for the trajectory response of the plant is generated. The third experiment is the Proportional-Integral-Derivative (PID) controller. This experiment places a PID controller into the feedback loop of the system and allows the user to choose different controller gains.

The second experiment server corresponds to the heater fan experiment server. This plant consists of a variable speed fan and a heat generating wire. The fan blows ambient air over the wire cooling it. A current is passed through the wire heating it. Both the voltage to the fan and the current to the wire can be controlled. The plant can output the temperature of the wire and the fan speed. The experiments on this server are in the same form as the twin rotor. There is a set point experiment, a step response, and a PID controller. However, this system is a MIMO system; the existing PID experiments control each input independently as in the twin rotor plant.

The third experiment server corresponds to the inverted pendulum experiment server. The inverted pendulum consists of a cart that is able to slide on a single axis. The pendulum is attached to the cart with full rotational freedom of motion. The input to the system is a voltage to the cart which displaces it along the axis. There is a single remote laboratory experiment on this server, in which a disturbance is induced onto the cart and the position of the pendulum is recorded. Although more experiments exist in a stand alone mode as with any of the plants, the inverted pendulum may undergo further development to make more features available in the RLab environment.

Each experiment server performs several operations to be successfully integrated into the RLab environment. The interface is through a webpage that corresponds to each experiment, and varies for each experiment. For example, the set point experiment needs a webpage that allows the user to input a voltage and a duration, while the PID experiment must allow the user to input different controller gains, a time constant, a voltage, and a duration. The experiment server stores these parameters in the database. Depending on the experiment selected, the corresponding vi program retrieves parameters from the database, manipulates the data, sends out an input voltage to the plant, reads and stores the output of the plant, and creates the response graph, for example as shown in Figure 3.

Figure 3: RLab PID experiment response graph.



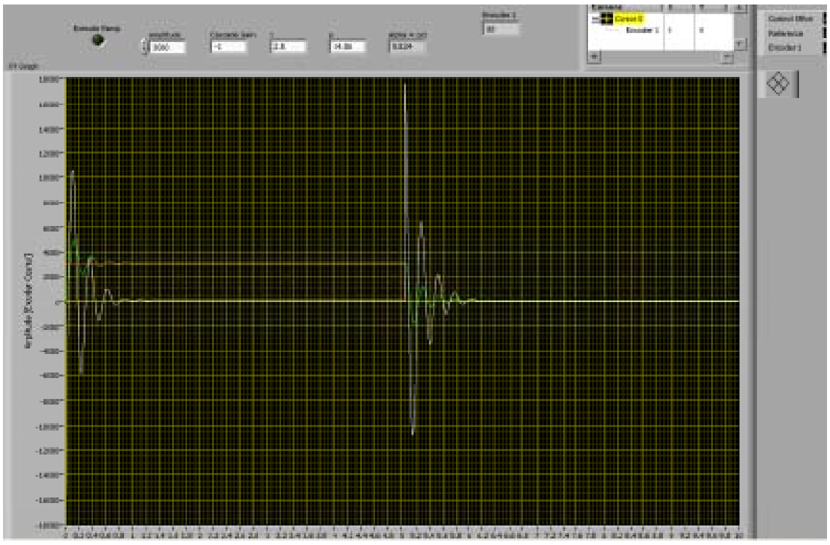
There are four types of experimental plants at UNF [9] as mentioned above. These are the torsional plants, the rectilinear plants, the industrial plants and the gyroscope [15]. Figure 4 illustrates one of these plants, the ECP 205 torsional plant.

Figure 4: Three degree-of-Freedom torsional plant at UNF.

The capabilities of the ECP plants form the basis of Project-Centered Modules, or PCMs in courses of system dynamics and control [2,9]. There are multiple replicas of these plants at UNF, but because the experimental plants are from the same vendor, uniform issues for interfacing for all the plants helps to facilitate the migration into the RLab environment. The integration is also facilitated by the ECP-RIO interface features [16] made available through the LabVIEW and National instruments. This hardware and software architecture permits a configurable interface with customization tools featured within the LabVIEW system.

The port of RLab to UNF has first involved the development of the experiment server for the torsional plant. A suite of stand-alone experiments exist for each of the ECP plants [15]. The first experiment ported to the new experiment server has involved Proportional-Derivative (PD) controller experiments. One of these is to perform pole and zero placement for a digital cascading filter in series with the PD controller. Among the user inputs is the location for the zero and the pole of the filter for the experiment. Figure 5 shows an output from this experiment for the ECP experiment server. The display provided shows the step input, along with the position and velocity response output plots on the graph as the result of the controller configured by the user through the RLab environment.

Figure 5: Plot of response from torsional plant.



Conclusion and Future Work

The RLab environment gives remote users the possibility to control a real world physical plant, observe its behavior, and download measured data of the machine system for further analysis. The initial RLab as a functional system has provided remote control and access for electromechanical plants used in teaching basic control theory. The architecture and underlying infrastructure of RLab provides for extensibility and expandability. Experiments in the RLab environment have been for use in instruction of basic control theory and the initial set of experiments on the three initial plants is extensible by adding new experiments to the plants existing at the site of the initial RLab implementation at CUAS.

In a collaborative project, a new site at UNF has been developed and RLab has been successfully ported. An enhanced RLab environment is created and updated allow for new experiments. The enhanced version also exploits the newer features of LabVIEW. One motivation is to allow users at various sites, with differing hardware resources, to connect and share resources with colleagues via remote access.

The upgraded and enhanced implementation of RLab facilitates the opportunity to create a broader set of control theory experiments using the ECP electromechanical plants. The upgrade process continues as new releases of LabVIEW achieve improved capabilities. New experiments with the ECP plants are being introduced into the RLab environment. One of these initial experiments is described above and the set of experiments will continue to expand beyond basic control theory experiments.

New experiments in the RLab environment enable the Project-Centered Modules (PCMs) to be delivered remotely as components in curricula around the globe. Similar in concept to the project-oriented approach, project-centered modules allow an instructional approach using multiple hardware instances to be used in a variety of contexts. With the ability of the internet to allow users to connect and share common interest and resources, remote laboratories may be designed and implemented to produce a system which functions as a teaching method and/or a remote control via the internet. A remote laboratory may be used for instructional purposes in a variety of educational laboratory and remote control domains. Only needed by the user is an internet browser. With collaborative opportunities curricula and research projects can make use of the platform. Development of additional project-centered modules may then include additional electromechanical plants, comprise collaborative research projects, and facilitate the development of shared educational modules. Clearly this is an obvious benefit of the RLab environment. Plants and experiments not available at a given location become accessible to users at remote sites with the only requirement being an internet browser, a key benefit of the RLab system.

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