



A multi-user remote academic laboratory system

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ARTICLE INFO

Article history:

Received 28 April 2012

Accepted 17 October 2012

Keywords:

Remote labs

E-learning

Learning management systems

Control processes

Software architecture

ABSTRACT

This article describes the development, implementation and preliminary operation assessment of Multiuser Network Architecture to integrate a number of Remote Academic Laboratories for educational purposes on automatic control. Through the Internet, real processes or physical experiments conducted at the control engineering laboratories of four universities are remotely operated. Through an internet connection to the Manager Administration Server, a remote experiment to design and test a modeling and control algorithm can be performed.

The suggested Network Architecture is based on the Singlet-Server model and uses a database server to record important information that helps create a new remote experiment, including a Graphical User Interface (Applet) developed with Easy Java Simulation, which allows the simple integration of new processes to the Manager Administrator. Results of a real-physical-process remote manipulation through the proposed network architecture are presented as well as results of an academic pilot test conducted to measure functional aspects related to the operation of the remote system when carrying out remote-laboratory work.

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1. Introduction

Nowadays, the importance of practical experiences for the development of competences in engineering is of common knowledge. Suggesting a solution to real situations in the context of automatic control is no exception. On the other hand, Information Technologies (IT) have provided great support for learning and teaching academic processes, enabling the development of activities which were previously restricted to attended environments. In this sense, remote laboratories that use this kind of IT, and apply remote operation to real processes, extend their teaching capabilities beyond the scope of conventional laboratories when teaching a specific subject, which are often limited in time and in the number of physical experiments available.

Alternative proposals on this topic suggest the remote operation of physical processes, which often lack a structured didactic-and-pedagogical framework that is essential to adequately conduct remote experiments on automatic control. Another proposal is to replace lab-experiments with simulations, which by definition are reduced models of reality, and as such, reduce the possibility to confront students with the complexity that arises when real physical systems are analyzed.

The present paper describes a collaborative project between four Universities, namely *de los Andes*, *Tecnológica de Bolívar*, *Nacional de Colombia* and *École des Mines de Nantes*, where the development of Remote Academic Laboratories using Information Technologies is proposed. The project is intended to share lab resources as well as evaluating the knowledge acquisition levels achieved by a specific student when compared to the learning process at a conventional laboratory. Via Internet, the proposal allows users to access several control processes located in different campus or in other universities. Different kinds of experiments provide support and enable other academic institutions to link up with the management system in order to use these resources directly.

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A variety of remarkable technologies is discussed to help found our proposed Network System Architecture. Firstly, the most appropriate technologies to develop a Single-Server Administrator structure are defined so as to provide the different universities with an easy-to-use, secure management system of real control processes. In this respect, the proposed Multiuser Network Architecture, structured as a three-independent-level system, allows user-client applications such as Moodle and Blackboard to access a diversity of remote experiments and carry out work-labs that are part of control courses at different universities; at the same time, these resources are managed with time scheduling and secure access to conduct the experimental practices. On the other hand, Academic Pilot Tests are conducted to measure the functional aspects of the remote operation interface and so develop remote experimental practices. To conduct the tests, a remote laboratory is designed and implemented with a selected group of control students, where the conditions of *Acceptance*, *Usability* and *Usefulness* are evaluated through a Survey.

This article is structured as follows: Section 2 is a survey of different kinds of network architectures, which are analyzed according to the IT techniques used to integrate remote academic laboratories; thus the final structural design for our proposed network system is defined. Section 3 is a description of the proposed Network Architecture to integrate Remote Academic Laboratories together with the functionalities of each constituent network-system level. In Section 4, the proposed Academic Pilot Test is explained, whose purpose is to measure functional conditions over the remote system used to carry out a remote experimental practice with a selected group of control students. Finally, in Sections 5 and 6, we present the results and conclusions from the implemented multi-user network architecture, which serves to manipulate a real plant, as well as the results from the academic pilot tests conducted to measure functional aspects of the remote system.

2. A survey of remarkable technologies

In this section we study the different approaches to remote laboratory architectures and the tools used to create them. Even though there are many works related to the architecture and construction of remote laboratories, it is possible to categorize most of the studies into four groups according to their technologies.

2.1. Remote desktop connection

This technology is widely used in virtual-lab systems. The idea is to connect to a computer, which controls practice assignments by using applications such as Virtual Network Computing (VNC) (Kahoraho Bukubiye & Larrauri Villamor, 2002). The purpose of VNC (Richardson, Stafford-Fraser, Wood, & Hopper, 1998) is to supply an entire desktop environment that can be accessed from any Internet-connected machine using the required software. Vicente, Muñoz, Galilea, and Del Toro (2010) created a remote laboratory for industrial automation comprising different programmable logic controller (PLC) manufacturers and allowed clients to access the system by using either VNC or ActiveX. Hu and Meinel (2004) implemented a security laboratory on the Internet using well-managed virtual machines which allow students to gain experiences of security technologies and tools in a reliable and secure way. The user interface of the platform employs VNC and a remote frame buffer protocol (RFB).

The main problem of this approach was the lack of security due various types of attacks such as man-in-the-middle, brute force and sniffing. Moreover, the delay of the application operation made it difficult to control the teleoperated plants and the installation of software such as TightVNC or other applications that were necessary to access the platforms. Therefore, architectures based on Remote Desktop Connection were rejected. The architecture proposed focused on resource management, restriction of the IPs that can connect to the platform and communication through TCP/IP protocol. These considerations and technologies decreased latency and increased security.

2.2. Web tools for LABVIEW/MATLAB

The second approach is based on web tools that use MATLAB® and LABVIEW® as platforms, allowing the use of some characteristics of these platforms through a webpage. Dixon, Dawson, Costic, and de Quiroz (2002) proposed a flexible architecture for operating real processes using MATLAB® software, the Simulink toolbox and the Real Time Workshop toolbox to develop software tools running over a platform called CACSD (Computer Aided Control System Design). Manchón, Jiménez García, García, and Peris (2002) presented a general architecture to control physical processes in real time using ®Web Server and PHP. On the other hand, Moudgalya and Arora (2010) implemented a Virtual Laboratory that enables clients to design and implement algorithms by using the LABVIEW® networking capabilities. The virtual lab uses the LABVIEW® Data socket technology for communication and the Web Publishing tools to display the experiments.

The main disadvantages of this approach are the mandatory use of MATLAB® or LABVIEW®, depending on the license obtained by universities, and the installation of different plug-ins for the end-clients of the platform. In contrast, the architecture proposed here is independent of the technology used to locally teleoperate the plant. Thus, some processes at universities can be controlled regardless of whether applications run on MATLAB® or LabVIEW®, being transparent to the user or student that remotely operates the plant.

2.3. Easy Java Simulation-software control connection

Easy Java Simulation (EJS) is a free software tool that allows creating scientific simulations in Java. The simulations are structured in the model and the view, and it is not necessary to know how to write Java programs due to its “Drag-and-Drop” characteristic. Therefore EJS is an excellent tool for developing virtual and control laboratories. EJS has been widely used to develop Remote Laboratories for Automatic Control. For example (Dormido et al., 2007) used this tool to teleoperate three processes, namely a three-tank system (Dormido et al., 2008), a heat-flow apparatus and an electrical drive servo motor. Additionally, Sánchez et al. (2005) discussed a new way of teaching by using interacting and dynamic simulations and also how to develop the corresponding interfaces with Easy Java Simulation. Finally, Delgado and Lopez (2009) developed a virtual laboratory of intelligent control for a level process; the interfaces were developed in EJS and control was performed by using fuzzy logic, neural networks and PID strategies.

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