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Demonstration of a remote control laboratory to support teaching in control engineering subjects

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Abstract: Engineering courses can benefit from using remote laboratories to support teaching activities and online learning. A remote control system can be an effective tool to be used in practical classes and to enhance students' experimental skills. Online experimentation also offers a very important support in engineering teaching, and can be used to improve the students' learning process, for instance in Electrical Engineering courses, particularly on topics related to systems and automatic control. This paper describes an online experiment demonstration, propped up on a remote lab system, aiming at identifying a model of a given nonlinear system and to design and apply controllers based on different methodologies. An experimental setup is used to interact with the remote lab through a Web-based platform, where students can visualize and collect data in real time from the available remote system.

Keywords: Online experimentation; remote laboratory; system identification; automatic control; control engineering.

1. INTRODUCTION

The development and dissemination of Information and Communication Technologies (ICT) represent a significant opportunity to design and develop different kinds of resources to support all components of the educational process, in particular to support teaching and online learning in engineering courses. Especially for these courses, the development of resources of online experimentation is of great importance because the experimentation is mandatory in many engineering subjects, and the availability of remote and virtual laboratories opens the access to infrastructures, which are in many cases not locally accessible or with limited availability, and as such offers the possibility to support teaching and to enhance the students' learning process.

It is well known that higher education institutions have to provide innovative learning experiences that engage and address the needs of society in the twenty-first century (Garrison and Vaughan, 2008). As Swail (2002) points out, the "rules are changing and there is increased pressure on institutions of higher education to evolve, adapt or desist". In this context, the renovation of teaching and learning on higher education is inevitable with the use of web-based communications technology (Newman *et al.*, 2004). Consequently, engineering subjects constitute a noteworthy educational field that should incorporate the technology potential for addressing the teaching challenges, so as to provide high quality of learning experience by using available technological tools. The use of resources of online experimentation, as remote and virtual labs, offers an effective answer to these challenges.

On the other hand, the widespread availability of broadband Internet communications has propelled educators to using innovative ways to support teaching and learning (Edward, 2002), not only in terms of contents, but also in what the available tools and platforms is concerned. A major outcome from this effort is the online laboratory paradigm. Nowadays, experiential individual's learning plays a central role within science and technology curriculum, at all levels of education (Zuperl and Virtic, 2013). Remote and virtual labs provide students with particular engineering experience and allow them to explore systems and their real behaviours similarly to traditional laboratories but with less temporal and space restrictions.

The development of remote and virtual labs can represent a valuable support for teaching and student's learning, enabling a wide and open access to a large number of experiments in several topics and allowing the interaction in real time with the lab system to perform practical experiments, observing and analysing the dynamic behaviour of didactic systems. Identification and control of dynamical systems are one of the most important topics in electrical engineering, because they represent the basis to modelling, simulation and control of different types of dynamical processes.

This paper intends to describe a demonstration of an online experiment supported by a remote lab that designed to be proposed in control engineering subjects, which include topics, such as identification and control of linear and nonlinear dynamical systems, in a blended learning context. The next sections describe the experimental setup, along with the remote lab and some of the experiments that can be performed.

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2. THE EXPERIMENTAL SETUP

The experimental setup considered in this work uses a remote laboratory with and interactive Web-based application that allows, remotely, carrying out experiments using the three-tank system available at the Laboratory of Industrial Informatics and Systems (LIIS) of the Department of Informatics Engineering of the Faculty of Sciences and Technology of the University of Coimbra. The demonstration includes experiments for observing physical variables, for identification of the system's model and to test and apply controllers designed according to different methodologies.

2.1 The lab system

The system considered in this setup is a benchmark three-tank system (Figure 1) manufactured by Amira GmbH (technical information can be obtained in Partner (2004) and Dormido *et al.* (2008)). It is a nonlinear dynamical process (see schematic diagram in Figure 2) with two inputs to control the two pumps (pump P_1 feeds tank T_1 and pump P_2 feeds tank T_2) and three outputs associated with the level sensors in the three tanks (tank T_1 in the left side, tank T_3 in the middle and tank T_2 in the right side). The connections between the three tanks and from each tank to the main tank (tank T_0), at the bottom, are manually controlled and are pre-defined for a given experiment. Thus, the lab system can be used as a MIMO system for identification and control purposes.

Applying the fluidic systems principles, the mass balance of each compartment provides the differential equations for the mathematical model of the overall system. Assuming that $h_1(t)$, $h_2(t)$ and $h_3(t)$ are the tanks' levels, S_i is the cross-sectional area of tank i, $q_i(t)$ is the volumetric flow rates from pump i and $q_{ij}(t)$ the volumetric flow rates between tanks i and j, the following equations are obtained:

$$\begin{aligned} \frac{dh_1(t)}{dt} &= \frac{1}{S_1}\big(q_1(t) - q_{13}(t) - q_{10}(t)\big) \\ \frac{dh_3(t)}{dt} &= \frac{1}{S_3}\big(q_{13}(t) + q_{23}(t) - q_{30}(t)\big). \\ \frac{dh_2(t)}{dt} &= \frac{1}{S_2}\big(q_2(t) - q_{23}(t) - q_{20}(t)\big) \end{aligned} \qquad (1)$$

Considering the Torricelli law, the volumetric flow rates are given by:

$$\begin{gathered} q_{ij}(t) = v_{ij} k_{ij} S_{ij} \operatorname{sgn}\big(h_i(t) - h_j(t)\big)\sqrt{2g|h_i(t) - h_j(t)|} \\ q_{i0}(t) = v_{i0} k_{i0} S_{i0} h_i(t)\sqrt{2gh_i(t)} \\ i, j = 1, 2, 3 \end{gathered} \qquad (2)$$

where v_{ij} represents the dimensionless valve position (a value between 0 and 1) between tanks i and j, k_{ij} is an dimensionless flow coefficient, S_{ij} is the cross-sectional area of the connecting pipes between tanks i and j, in m^2, and g is the acceleration of gravity in $m.s^{-2}$.

This mathematical model of the three-tank system can be used within different experiments as, for example, simulation of the dynamic behaviour of the system, analysis of the system's properties, identification of the system, assuming the system's model is unknown and design of different types of controllers.

Fig. 1. The three-tank system by Amira (Partner, 2004).

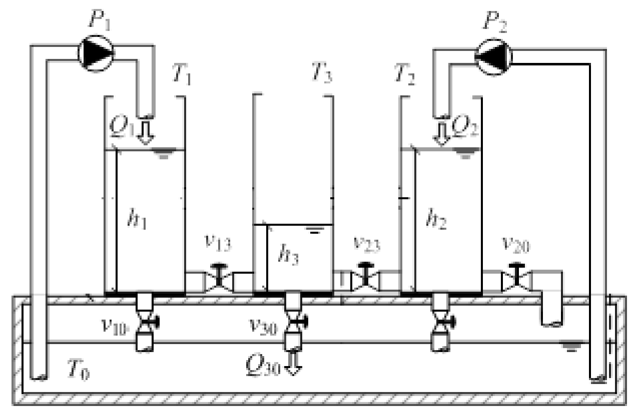
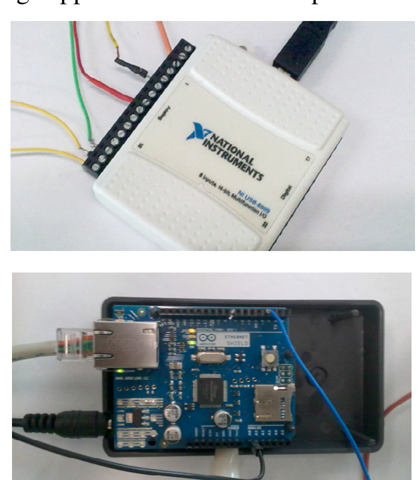


Fig. 2. Schematic diagram of the three-tank system.

2.2 The remote platform

The remote platform follows a Web-based approach, where the connection with the lab system can be implemented through wired or wireless configurations (Fig. 3), using a DAQ board directly connected with the server or a solution based on the Arduino Uno with an Ethernet module for communication purposes, respectively. The Ethernet module includes a micro-controller W5100, which provides an IP stack giving support to TCP and UDP protocols.



(a)

(b)

Fig. 3. Wired (a) and wireless (b) connections for interaction with the remote lab.