Benefits of Using Remote Labs in Intelligent Control Teaching

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Abstract. The use of remote and virtual labs in teaching and learning activities can be very useful in different high education courses, especially in engineering courses. This paper presents the use of a remote experiment in a laboratory work of Intelligent Control subject of an engineering course. A remote lab system can represent an important tool to be used in practical classes, complementing the experiments in the lab and contributing to the enhancement of the students' experimental skills. For this purposes, a remote setup was considered to provide the interaction with the remote lab through the Internet, where students can visualize the lab using a Web camera and observe data in real time from the remote system and download it. Different type of experiments can be accomplished using this setup. This work includes some preliminary results about the assessment of the use of the remote lab by students of an engineering subject. The results are encouraging to continue to use this kind of online experimentation resource for teaching activities in different areas of engineering courses.

Keywords: Remote laboratories · Intelligent control · Teaching
Online experimentation · Assessment

1 Introduction

In the era of the Internet of (Every)Thing, where the interconnection between things and people is promoted and supported, online experimentation represents a great opportunity to support teaching and learning activities in several contexts of higher education courses. In particular, resources like remote and virtual experiments can contribute to the improvement of teaching activities, to the extension of the laboratory activities and to motivate students to perform practical works, understanding the concepts and achieving experimental skills.

Teachers and higher education institutions should be committed with the use of online resources to provide learning conditions that engage and address the current challenges of society [1]. Thus, it is very significant to make all the efforts to provide students with high quality learning experiences, by taking advantage of different

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technological supports, interfaces and resources, namely of online experiments based on remote and virtual labs [2].

In this context, the assessment of this kind of resources, involving teachers and students, is very important to consolidate and improve their quality. Therefore, the students' opinion is fundamental to understand their perspectives about learning methodologies supported by online experimentation, to find effective ways to call their attention for the benefits of this approach and to make successive improvements in order to reinforce the use of these resources in a valuable manner.

This paper describes and evaluates the use of a remote laboratory in a topic of intelligent control of an Electrical Engineering M.Sc. course.

2 Intelligent Control Subject

Automatic control has become an important field in almost every engineering subject. Over the years, the control teaching/learning approaches have become more motivating and interactive with the use of virtual/remote laboratories [3–6].

The resource presented here was considered in the subject "Intelligent Control" of the 4th year (1st semester) of the Electrical Engineering Master course at the New University of Lisbon, Portugal. This subject is intended to develop the students' skills on System Identification and Control techniques, using computational tools. It is focused on the design of control systems based on intelligent control techniques, such as artificial neural networks and fuzzy systems. In addition, linear systems identification and adaptive control are also studied.

The main goal is to study intelligent control techniques, both theoretically and applied. Starting by introducing concepts on linear dynamic systems identification and adaptive pole placement control, follows the use of artificial neural networks and fuzzy logics as a means to approximate nonlinear system dynamics. Therefore, the core of this subject is the development of neural and fuzzy controllers.

The program of the "Intelligent Control" subject includes the following topics:

- Linear Systems Identification: Problem; The identification process; Linear time invariant models; Parameter estimation: least squares; Model validation; RLS.
- Adaptive Control: Functional models; Pole placement.
- Artificial Neural Networks: The neuron; Activation functions; Feedforward neural networks; Approximation properties; Supervised training in multi-layer networks; Generalization and validation; Neural control architectures.
- Fuzzy Control: Fuzzy systems fundamentals; Fuzzification of variables; Inference with linguistic variables; Defuzzification of linguistic variables; Fuzzy control design.

The teaching activities comprise theoretical and practical classes, in which students have to carry out various practical works. Some of them involve solving theoretical-practical problems and carrying out simulation exercises and others include experimental tasks, namely through the interaction with lab systems.

In one of these practical works, students should interact with a remote lab, available online at the Laboratory of Industrial Informatics and Systems of the Department of Informatics Engineering of the University of Coimbra, to configure the experiment and obtain data from the real setup. Thus, they can identify, for example, the model of the system and to apply different controllers and evaluate their performance, comparing its behavior with the simulation results.

2.1 The Practical Work

The practical work, entitled "Fuzzy Control", is intended to use a strategy based on fuzzy logic for the purpose of designing a fuzzy Mamdani type PI controller. The process to control, whose dynamics is unknown, is located in Laboratory of Industrial Informatics and Systems of the Department of Informatics Engineering of the University of Coimbra. The communication with the process to be controlled is based on an Internet connection between the client, where the controller runs and the server, located remotely, and between the server and the process, through a wireless sensor network of type 802.15.4 (see Fig. 1).

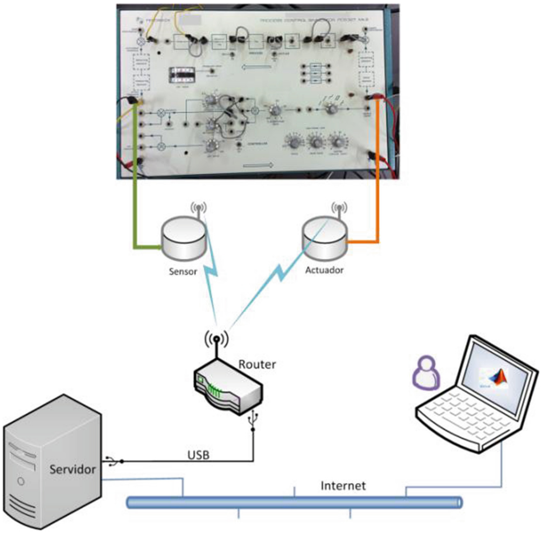

Fig. 1. Architecture of the communication model between the client and the remote setup.

This practical work comprises two main parts: Part A - Analysis and design of fuzzy controllers; Part B - Synthesis of a fuzzy controller for the remote system.

In Part A, students should analyze the system, to design fuzzy controllers considering a fuzzy structure with three fundamental modules, common to any fuzzy system, namely, the fuzzification, the inference engine and the defuzzification, and to determine the universe of discourse and fuzzy partitions associated with each linguistic variable.

Part B starts by training a neural network to approximate the nonlinear system dynamics subsequently tuning a fuzzy PI controller, using the neural model of the remote system, and performing the follow-up control of the remote system in real time, using a step reference signal. By collecting the output from the remote system, students can evaluate the performance of controllers.

3 The Remote Lab

As previously mentioned, the teaching of engineering can benefit from the presence of a strong practical component. Thus, the online experiments are, because of their availability, important enablers to a greater teaching quality, being essential to the remote lab.

One example of such an experiment is the nonlinear electrical system, namely the FEEDBACK PCS 327 (Fig. 2). It is of much utility, for instance to obtain a model of the system and to control it using different methodologies.

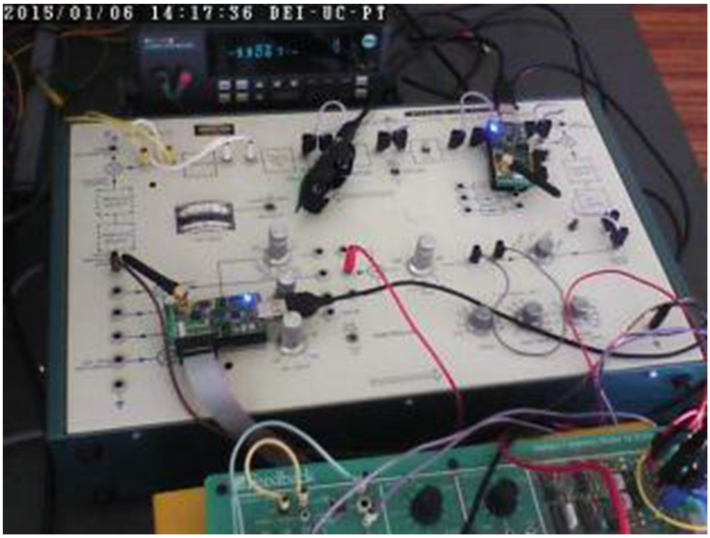

Fig. 2. Web camera image of the remote lab using a nonlinear electrical system for the online experiment.

It must be stressed that this system is remotely operable, allowing the user to change the inputs in an online interface and to observe the evolution and response of the system through images returned by a webcam located in the laboratory. Besides, it is also possible to test the experiment in a designed simulator, allowing to comparing the results.

This online experiment can be used for monitoring systems observing physics variables, systems identification, digital control of dynamic systems, networked control systems and distributed control systems, considering remote controllers in a shared communication network [7].

The remote monitoring and control of the systems can be implemented using a Wireless Sensor and Actuator Network (WSAN) within a distributed framework, where different sensors and actuators are spatially distributed and connected through nodes of the wireless network to a gateway, which provides the data to the main platform or to a local computer. The remote lab is based on a client-server architecture where the connection with the pilot plants is implemented through the WSAN [8].

4 Assessment Results

To assess students' perception and benefits regarding the use of the remote lab to perform a practical work, 34 students (in the first semester of the scholar year 2016/2017) were asked to complete a questionnaire.

A synthesis of the results of the questionnaire is presented in Table 1.

Table 1. Questionary results.

#	Item	Median	Mode	Factor	Cronbach α
1	It was easy to perform this activity	4	5	Ease of use	0.81
2	I thought it was easy to analyze and project the diffuse controller	4	4		
3	I became familiar quickly with using the remote system	4	5		
4	I consider this activity as being very useful to train necessary skills in this course	5	5	Intrinsic value	0.77
5	I consider this activity of using a diffuse controller to control a remote system as very interesting	4	4		
6	This activity was useful to learn how to project a diffuse controller	4	5		
7	It is a good idea to use this remote system in the Intelligent Control course	5	5	Attitude	0.90
8	I feel it is very positive to use this remote system	4	5		
9	I'm motivated to use other remote systems in the future	4	4		
10	It is advisable to use the remote controller to learn about control	4	4		

The questionnaire aims at assessing three latent variables: Intrinsic Value [9], Ease of Use and Attitude [10].

Intrinsic Value represents how interesting and important students regard the activity with the fuzzy controller implementation. Ease of Use measures how easy to use students consider the controller to be. Attitude reflects how positive the students are towards using the remote controller to improve their skills. In order to estimate the reliability of the questionnaire, internal consistency was checked by computing the Cronbach's alpha. It is a measure of how well the items group in a factor.

As can be seen in Table 1, all of the values exceed 0.7, the accepted minimum for internal consistency. To determine how well a set of items load in the corresponding factor, Factor Analysis should be performed. This has not been done due to a relatively small sample size.

The median and mode for all items are 4 or 5, indicating that students consider the remote controller Easy to Use, Valuable and their Attitude is very positive towards using such a learning tool.

One limitation of this study is the small size of the sample (34 answers). More data should be gathered in order to establish this type of remote experiment as a motivational learning tool. Moreover, it would be important to combine the assessment of students' reaction with an assessment of students' performance in the related topics. However, in view of these preliminary results, the authors are encouraged to continue to use this kind of learning resources in their teaching activities.

5 Conclusion

This paper described the use of a remote lab in teaching and learning activities of a "Intelligent Control" subject and presented the analysis of the results of a questionnaire, which aimed at assessing three latent variables: Intrinsic Value, Ease of Use and Attitude.

The use of remote labs can represent an important tool in practical classes, complementing the laboratory experiments and contributing for the enhancement of the students' experimental skills. Therefore, a remote experimental setup was considered in this work, providing the interaction with the remote lab through the Web, where students can visualize the system using a Web camera and observe data in real time from the remote system and download it.

The preliminary results are encouraging to continue to use this kind of online experimentation resources for teaching activities in different areas of engineering courses and to enhance the students' learning process.

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