Integration of a Remote and Virtual Control Lab in an Intelligent Tutoring System

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Abstract— This paper intends to describe the functionalities offered by the remote and virtual control laboratory available in the Department of Informatics Engineering of the University of Coimbra (Portugal) that allows users to perform experiments in an intelligent tutoring system context. The platform and some remote and virtual real-time control experiments, basically in the area of Systems and Control, are described. The relevance of a remote and virtual laboratory is discussed in a tutoring system context with requirements of adaptation to different students/trainees of engineering courses or lifelong learning programs.

Index Terms — Remote and virtual labs; system and control experiments; Engineering education; lifelong learning; intelligent tutoring systems.

I. INTRODUCTION

In the last few decades there have been considerable and consistent efforts to develop remote and virtual labs as web-based education tools [1], [2], [3] and platforms of tutoring systems for students and trainees in lifelong learning programs, where the inherent flexibility and adaptability of such systems are greatly welcome [4].

This new paradigm of learning and training creates a system rich in educational contents that are practical, flexible and easy to access, breaking down spatial and temporal barriers of the traditional approaches. Students and trainees may accomplish their own experiments from her/his laptop just requiring the availability of an Internet connection to have access to different kinds of virtual or real plants and experiments not only in a b- or e-learning context but also enriching the class room activities [5].

A tutoring system adapted to different users should be able to define contents and propose experiments according to the specific needs and backgrounds of each user. In particular, students of engineering courses and trainees from industries have different profiles and the system should be developed taking into account their specific characteristics.

In general, the use of an intelligent tutoring system (ITS) can provide advantages in the student’s and trainee’s exploration and interaction by creating adequate sequences of experiments and following up the user’s performance in real time, using, for example, task planning to enhance the user’s learning and providing feedback, help and guidance to address the user’s immediate problems and needs [6].

The technological acceleration and advances in several areas as adaptive computation, neuroscience, psychology and cognitive science have made significant changes and promises in the computer based tutoring realm.

To assist learning in an intelligent manner, research has focused on addressing computer perception, the representation of the domain, the representation of the user’s mental/cognitive status and the adaptability and sequence of responses (e.g. activities, evaluation tests and feedback).

Engineering courses along with lifelong learning programs are currently taking advantage of all the potential of Information Technologies, namely, the Internet infrastructure and web technologies, to develop and implement distant teaching and learning paradigms.

For example in Systems and Control area, students or trainees use a web-based virtual control laboratory and the Internet or an Ethernet local area network (LAN) to perform experiments on hypothetical setups expressed in the form of plants’ models [7], being the virtual system’s time response emulated by simulation on a fast processor server [8], [9]. The outcomes of simulations, i.e. the system time response and control actions, are subsequently retrieved and analyzed by the user.

In the case of remote control laboratories users, instead of testing remotely identification or control methodologies on virtual plants, they can implement and test algorithms on real pilot plants, connected via data acquisition boards to a computer. This kind of laboratories can operate either in batch or online.

The Remote and Virtual Lab available in the Department of Informatics Engineering of the University of Coimbra (RLV@DEI-UC) is a laboratory with interactive computer applications that allows users to carry out remote and/or virtual experiments (examples are: systems identification, digital control of dynamic systems, networked control systems or fault diagnosis systems) using physical systems that can be remotely or locally controlled through a web browser. The experiments provided to each user in the tutoring system are selected according to its profile, background and the characteristics of the course.

Next sections outline the main characteristics of the RVL, present some experiments in the area of Systems and Control and sketch the relevance of the use of remote and virtual labs in intelligent tutoring environments.

II. THE REMOTE AND VIRTUAL LAB ARCHITECTURE

The RLV@DEI-UC is a hybrid laboratory based on a client-server architecture that allows users to carry out remote and virtual experiments using various physical systems that can be remotely or locally accessed and controlled using the web platform (figure 1).
The server application provides an interface between either the real setup or the virtual plant representation and the client application, located on a remote computer. It is implemented in JAVA and makes use of MATLAB functions, for instance, for I/O communication with DAQ cards or to evaluate the sequence of control actions taking into account previous inputs and outputs, as well as the reference trajectories. In case the platform is configured as Virtual Laboratory the computed sequence of control actions is provided to the virtual plant environment, and used in the plant’s simulation by calling the MATLAB computational engine.

The client application is launched by a user logged in on a remote computer, connected to the server via an Ethernet local area network or the Internet. After the authentication, the client application gets from the server a list of experimental setups and virtual plants that are available. Students have to choose one of these setups to use in their own experiments.

For example, in a control experiment (figure 2), the remote user should select and initialize a given controller by loading to the MATLAB workplace all the variables and parameters needed to run the controller’s m-file functions. These functions are executed on the server, in case of batch operation or, alternatively, on the remote computer, for online control. In this case, the computed sequence of control actions is sent to the server using a TCP connection. The user should also define the sampling time, the overall time for the experiment, the reference trajectories and the type of control cycle.

While the experiment is in progress, the remote user can follow up the closed loop control performance in dedicated windows, displaying numerically and graphically references trajectories, process’s outputs and the computed control actions (figures 3a and 3b) and showing a 3D virtual representation of the experiment and related values (figure 3c) and video and audio streaming (figure 3d).
Additionally, the user may have access to a number of monitoring statistics regarding the running experiment (Figure 4, above). These statistics include, the updated number of timeouts, server-client and client-server latencies and other statistics concerning the average, minima and maxima of the monitoring parameters.

III. EXPERIMENTS

Several real-time experiments can be carried out using the RVL@DEI-UC interacting with different laboratory systems, allowing to acquire knowledge, for example, in the topics of systems identification, digital control of dynamic systems, networked control systems and distributed control systems in the context of engineering courses, just to name out a few.

A. Experiments for identification and control of systems

Two of those experiments include the identification of a transfer function and the synthesis of controllers for real laboratory systems (example in Figure 5). A non-recursive identification method is applied to a real bench process represented by a deterministic ARX model. The achieved transfer function is simulated and compared with the real process in order to validate the identification procedure.

Considering that the laboratory system is represented by a linear time-invariant ARX deterministic model, a PID controller, for example, could be tuned by pole placement techniques and applied on the real time environment.

B. Experiments for networked and distributed control systems

The next two experiments offer the possibility to develop and test networked and distributed control systems (example in Figure 6).

In the first case, the experiment considers a non-dedicated communication network between the controller and the system to build a networked environment. Using the Internet to remotely control a real system, it is possible to analyze the robustness of the overall system to delays and faults in the communication channels.

The user can implement and test a remote controller (on the platform’s client side) that receives the process’ outputs and sends the control action to the process’ inputs through an Internet connection. It is possible, for example, to implement a predictive controller that generates and sends actual and future control actions to support contingency plans in case of faulty situations, especially when the communication network fails.

The experiment concerning the Supervision of Distributed Control System (DCS) integrates a Wireless Sensor and Actuator Network (WSAN) to interact with sensors and actuators. Several aspects concerning supervisory systems and wireless networks communication protocols are studied and, given the distributed characteristic of the system, the user can analyze several aspects of the WSAN and implement local or remote controllers and supervisory control systems.

Considering the distributed system represented in Figure 6, several temperatures and levels signals are acquired using sensors connected to the nodes of the WSAN. The actuators are also associated with other nodes in order to allow the control of the distributed system.

The nodes are connected with the server computer through a gateway that establishes the communication between the wireless network and the platform.

The user can choose to implement the controller inside the network in the actuator node or outside considering a remote controller that interacts with the system using the platform.

![Figure 5. The two-tank process (PCT9) that can be used in experiments for system’s identification and control of systems.](image1)

![Figure 6. The diagram of the Distributed Control System based on the two-tank process (PCT9) and a Wireless Sensor Network that can be used in experiments for Networked and Distributed Control Systems.](image2)
IV. INTEGRATION OF THE RVL IN A ITS

The interaction with the laboratory plants could be defined in function of the user’s profile or preconfigured according to a scheduled learning process. For instance, depending on the user’s ability, the control system can be established using a remote controller, developed and implemented by the user on the client side, or considering a local controller with a predefined structure but in which some parameters can be defined remotely by the user. The set of experiments that can be performed through the RVL involves various processes with different levels of complexity that are chosen in an adaptive way in order to accomplish the objectives and the characteristics of each learning program.

The integration of remote and virtual laboratories in intelligent tutoring systems is of great relevance to the learning process because the user has the opportunity to complement the theory and practice, which considers usually only simulators, developing and implementing control systems to interact with real or virtual laboratory processes. Moreover, building courses with requirements of adaptability to different profiles of students/trainees of engineering courses or lifelong learning programs, the learning process can be improved by motivating the users and giving them conditions to the knowledge acquisition with good results.

The tutoring system under development in the DEI-UC seeks to incorporate intelligent agents that implement mechanisms of identification, monitoring and supervision of the user behavior and performance, namely in terms of the performance and the accomplishment of the tasks proposed in each course’s module. The ITS is supported on a Moodle platform and is being developed using the freeware CourseLab authoring tool. Figure 7 presents an example of a slide where the user can interact with the remote and virtual lab and run an experiment, for example, to control the three-tank system in the context of a course in Systems and Control.

Whenever the ITS identify the necessity to make suggestions, warnings or indications to the user, an intelligent agent shows a virtual teacher that interacts or writes a message on the slide. The methodology and intelligence of the agents is in process of research, knowing that the quality of the system depends deeply on the agents’ ability to interpret the behavior and progress of each user and to react accordingly.

![Figure 7. Systems and Control course interacting with the RVL to carry out an experiment to control the three-tank system.](image)

V. CONCLUSIONS

This paper describes the remote and virtual control laboratory RVL@DEI-UC and their integration in an intelligent tutoring system, showing the adaptability and potentialities of the experiments that can be carried out, for example, in the thematic of Systems and Control, in the context of engineering courses or in life-long learning programs.

The main characteristics of the remote and virtual lab and some experiments have been presented. Although the intelligent tutoring system is at an early stage of development, it was highlighted the relevance of the integration of remote and virtual labs in intelligent tutoring environments promoting the improvement and the adaptability of the learning process to different users’ profiles.

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