PRACTICAL STUDENT TEACHING THROUGH INTEGRATED TRUE, VIRTUAL AND REMOTE LABORATORIES

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Abstract: Currently data acquisition cards are being widely used by process control engineers. In this paper an integrated tool supporting work on a true, virtual and remote laboratory is described. The presented techniques provide different levels of independence from the direct access to the real system through a remote access to it or interacting with a virtual system based on simulation. One significant contribution, apart from the integrated approach, is its simple use by the students since the students can move from real lab to virtual with no changes in their work.

1 INTRODUCTION

Nowadays the programs of many engineering degrees include subjects that provide the students with the knowledge required to analyze control systems hardware architecture. That is, how to signals coming from a process to be controlled have to be connected to the processor responsible for executing the control algorithms. In this framework, these subjects devote a significant amount of class time to describe data acquisition cards as one of the most widely used alternative to interface processes and personal computers.

It is important to note that the laboratories used to teach the students in measurement and control systems require specific purpose hardware apart from a personal computer, i.e. a data acquisition card and some process (or an emulator) capable of being monitored or controlled.

Hence, the specific needs of such subjects prevent the students from working on their own computer at home or even in general purpose computer laboratories. This restriction significantly limits student interaction with very important aspects of real world applications very common in their professional career as engineers. Only during the time dedicated to laboratory sessions the students have the opportunity to work using equipment close to that used in real applications. Moreover, the high cost of specialized laboratories further deepens this problem.

The above limitations, which have been highlighted by several authors during the past years, are traditionally solved, or at least compensated, by means of the use of simulators (also known as virtual laboratories) and remote laboratories (Stonick, 1993), (Shaheen et al., 1998). Also, computer use in experiments greatly simplifies the normally routine and tedious task of gathering data and facilitates the analysis, creativity and development of scientific and engineering skills (Barton and Rogers, 1991).

As mentioned, previous work on this field focuses on two different approaches: 1) virtual laboratories, where the process under control is simulated by a computer; and 2) remote laboratories, where a physical implementation of the process can be accessed remotely through the Internet.

Virtual laboratory is a very powerful tool that allows students to develop and check their own understanding of processes and experiments autonomously before working on the real system. In addition, simulation is a common technique in the design process of many commercial products and, hence, a useful background for their work once graduated. Nevertheless, an intensive use of simulation is not recommended since spaces out students from the real world.

Also, when asking students, they prefer to work in a real laboratory, considering virtual tools a good

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complement (Torres et al., 2006). That is the reason why remote laboratories find interesting benefits: costly resources sharing with remote 24/7 access, and, at the same time, students feel remote laboratory like the real one (P.Lundgren et al., 2006). Finally, significant contributions in this field are the use of real processes with direct alumni observation such as the integration of a true laboratory with a virtual one (Kocijancic and OSullivan, 2002) or the integration of a remote and virtual labs (Saliah et al., 1999).

In this work an step further is provided, integrating true, virtual and remote laboratories using unified tools, making switching from lab sessions in one particular form to another one extremely easy. The result is a learning process composed of different phases where the student firstly simulates and secondly performs a real experiment on a real system.

As an improvement over previous reported tools, where the interaction with the remote laboratories is reduced to data gathering or visualization (Imbrie and Raghavan, 2005), our tools allow the student to act on the processes not only in the control actions but in process conditions.

These features encourage autonomous learning, which is a process that allows the student to choose paths, strategies, tools and times to learn and practice with what has been learned.

The rest of the paper is organized as follows. Section 2, 3 and 4 describe the organization of the true lab sessions, the virtual laboratory and the remote laboratory, respectively. Finally, some conclusions are drawn in Section 5.

2 TRUE LABORATORY

The real laboratories used to teach control systems and industrial computer-based automation are equipped with personal computers and data acquisition cards, to provide signal conditioning and monitoring and control hardware. Once the students are given with the basic concepts to program the data acquisition cards they can use them, together with the computers, to control real processes specially devised to be used in the laboratory. The set of available processes to be controlled are: a printed circuit board to provide basic analog and digital inputs and outputs, an articulate arm (Figure 1), a model of a room with temperature and light control, and a model of a bridge crane with a clam (Figure 2). The limitation is students cannot work in advance to design their data acquisition programs, verify the implementation of their control systems nor debug their software. They have the limited time slot provided by the subject and laboratory schedules, greatly conditioning what they can do and what they can be asked to do.

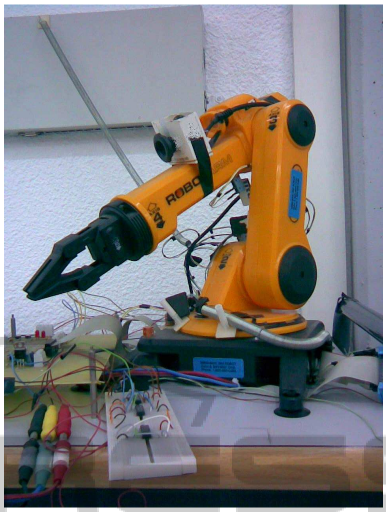

Figure 1: Laboratory equipment: articulate arm.

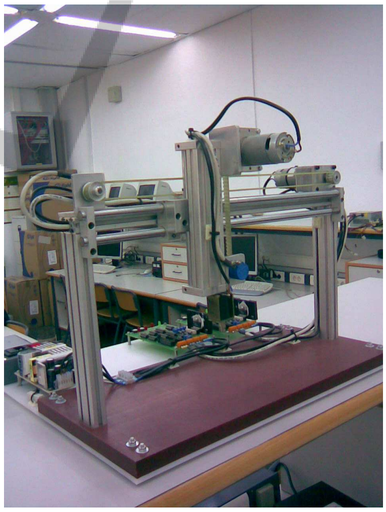

Figure 2: Laboratory equipment: bridge.

3 VIRTUAL LABORATORY

As stated in Section 1, the virtual laboratory allows students to work on every lab experiment from any computer, either at the university or at home without requiring a data acquisition card or the physical processes. It is based on a software tool that simulates the different system building blocks, their interfaces and the connectivity between them and with students application programs. The structure of the proposed tool is shown in Figure 3.

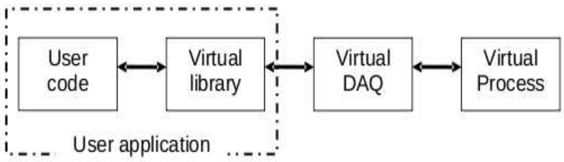

Figure 3: Virtual laboratory tool building blocks.

- **Virtual Library (VL).**

This library provides a set of functions that replicates the original ones used on the real data acquisition used in the real lab. These functions can be used on user applications with the only difference that their execution will operate on a virtual card. The communication is performed through TCP/IP using sockets (Walton, 2001), (Comer, 1997).

- **Virtual DAQ (VD).**

The virtual data acquisition card (Figure 4) is responsible for emulating the real card operation. It provides two socket-based access interfaces, one to the VL and the other one to the Virtual Process (VP). From the VL side, the VD receives requests to perform write or read operations in registers, and replies according the internal DAQ state. Data exchanged between the Virtual DAQ and the Virtual Library is always digital, that is, for analog inputs or outputs their value is converted to digital according the converters included in the real DAQ. From the VP side, VD sends values of outputs when internal registers change, and receives, asynchronously, input values as they change in the Virtual Process. This emulates the real behavior of a true daq. Data exchanged between the Virtual DAQ and the Virtual Process is always in volts (or amperes) because this is the outdoor side of the DAQ, that is, the real, analog world. This allow to design virtual processes with no knowledge about bit resolution of converters, for example, and allowing its use with several different cards.

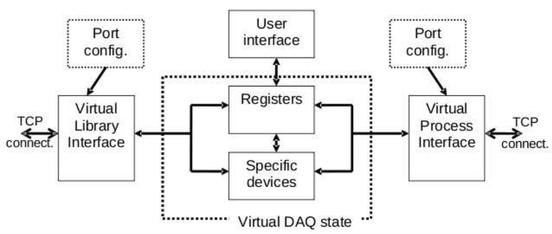

Figure 4: Virtual data acquisition card.

- **Virtual Process (VP).**

The objective of this building block is the simulation of processes to be controlled by a user application executing a control program. The VP simulates the process, the transducers responsible for measuring the magnitudes of interest and the operation of the actuators used to interact with the process. The virtual process provides a graphical interface that allows the student to change process parameters, introduce perturbations, modify the transducer being used or the signal conditioning element. For each real process presented in Section 2, which are available in our laboratory, we have designed a virtual process. As an example, the virtual process simulating room temperature and light, whose graphical interface is shown in Figure 5, allows settings of: external ambient temperature, external light received through the window whereas the student must develop and test the control algorithms for room temperature and light.

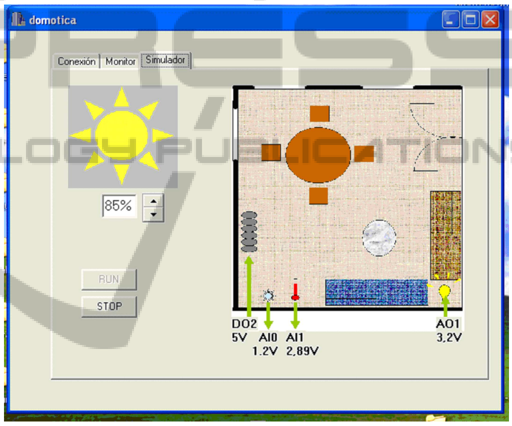

Figure 5: Domotic system virtual process.

4 REMOTE LABORATORY

The remote laboratory is based on a set of tools that complement the Virtual Laboratory. The goal is making it possible for the student to have access to the real system through an Internet connection. Remote laboratory can be accessed in two different ways, either on-line or off-line. The block diagram of the complete set applications developed for the Remote Laboratory is shown in Figure 6.

- **On-line Acces.**

In this case the students write, compile and execute monitoring and control programs on their local computer. During the user program execution all the data acquisition card operations are sent using a TCP connection to a real card located at the laboratory and connected to a real process. The library the student must use to write their programs using the data acquisition card is exactly the same one used for the Vir-

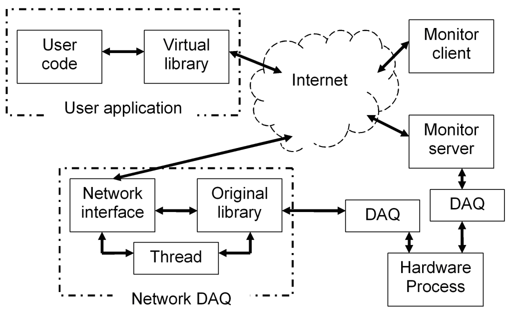

Figure 6: Remote laboratory building blocks.

tual Laboratory (Section 3). The difference now is that the communication is performed through the Internet with the Network DAQ element (ND), running on a remote computer located in the real laboratory. The Network DAQ block directly operates on the real card.

A significant contribution we included in our software tool box for the Remote Laboratory is a mechanism for the student to check the operation of a program by directly analyzing the behavior of the real system as he was working in a real lab. This mechanism is based on two blocks based on a client-server called Monitor. Monitor Server runs on the real lab computer, and uses a second DAQ to monitor system's state. This state, and a video stream, are sent to Monitor Client. Monitor Client receives video and data gathered by Monitor Server, and allows student to interact with the real process enviroment, like in simulation.

- **Off-line Access.**

In order to avoid the communication delays when located remotely the students can send their source code through the Monitor client. The source code is then compiled and linked with the original data acquisition card library and run afterwards. Apart from looking at the process behavior through the video sent by the monitor the process evolution is stored in a log file with time stamps that allows for an off-line analysis.

5 CONCLUSIONS

During the past two years the proposed system has been tested with students. Before finishing the semester the students fulfill a survey used as feedback path. Their opinion has been taken into account to improve the platform. In general, the students consider very useful and easy to use the set of tools.

The job presented in this paper integrates on a single platform three experimental: true, virtual and remote laboratories. The system relies on a virtual data acquisition card that provides a virtual operation very close to the original operation with a real card. The user only has to introduce very simple changes in the application program to follow one approach or another.

It could have been possible to integrate all the applications into a single one. Nevertheless independent units have been preferred because of the following reasons:

- Keeping closer to the real system structure makes the students easily understand the system operation and how it has been designed.
- It has the adequate modularity for selecting a different data acquisition card or process.

With respect to the students methodology, they always know what version of the system they are working on, but they do not need to generate different application programs depending on their location: virtual, remote or off-line.

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