

# Automation and Control Learning Environment with Mixed Reality Remote Experiments Architecture

F. M. Schaf and C. E. Pereira

Universidade Federal do Rio Grande do Sul/Electrical Eng. Department Porto Alegre, Brazil

**Abstract** — This work aims to the use of remotely web-based experiments to improve the learning process of automation and control systems theory courses. An architecture combining virtual learning environments, remote experiments, students guide and experiments analysis is proposed based on a wide state of art study. The validation of the architecture uses state of art technologies and new simple developed programs to implement the case studies presented. All implementations presented use an internet accessible virtual learning environment providing educational resources, guides and learning material to create a distance learning course associated with the remote mixed reality experiment. This work is part of the RExNet consortium, supported by the European Alfa project.

**Index Terms** — Remote Experiments, Web-based Laboratories, Distance Learning, Mixed-Reality Experiments, Collaborative Learning Environments.

## I. INTRODUCTION

Remote experimentation allows the application and test beds of theoretical knowledge in practical situations [1]. Control and automation system engineering courses demands knowledge of real practical situations in order to improve the learning process of his students. The use of laboratories gives students active learning [2, 3], distributed learning [1] and team learning [4] skills. These skills are the very essence of remote experimentation learning since teachers are not always present.

With the growth of Internet, and the technologies involved in this service, the web accessible laboratories with his remote experiments gains space and importance to attend the demand of more laboratories According to [5] the remote experimentation has become an attractive economical solution for the increasing number of students. The remote experimentation has become the “second best of being there” (SBBT) [6] solution for students and laboratories with expensive equipments. Remote experiments are increasing the accessibility of laboratory equipment and also providing space and time flexibility, i.e. the student can be anywhere anytime performing his experiments through Internet. Remote laboratories are not necessarily followed or assisted by learning materials.

To improve the knowledge transfer some remote experiments [7, 8, 9] are assisted by virtual a learning environment that manages and provide learning materials to the students to help in the experimentation process. In order to canalize the learning skills of students to a single

environment an architecture that integrates virtual learning environments and remote experiments is proposed.

Mixed reality experiments, as in [10], are the keys to achieve more flexibility to experiments scenarios. These scenarios can illustrate different learning situations according to the level of knowledge of the remote students, i.e., simulated components (experiment equipments) can be combined to real equipment to provide more practical situations without the need to purchase real equipment.

This work is part of the results of the RExNet Consortium, supported by the European Alfa project. The RExNet [11] – Remote Experimentation Network – members collaborate to build a common network to integrate different educational institutions in Latin America and Europe.

In the following sections the proposed architecture and his case studies will be presented and described.

## II. PROPOSED ARCHITECTURE OF ENVIRONMENT

With the goal to reach more students and to provide a common environment to learn automation and control system theory a proposed architecture for learning environments with support of remote experimentation and mixed reality is presented. This architecture integrates virtual learning environments (VLEs), educational material, remote experimentation, mixed reality, interchangeable components [7], post-experiment analysis [12] and simple student guide [12].

The Figure 1. depicts the integrated “modules” and his simple interactions. Note that if the experiment interface is web accessible the integration is very simple. The students can only access the remote experiment through the VLE, which has also support to experiment analysis (post) and a student guide.

### A. Virtual Learning Environment Integration

Following the technologies used in the web-accessible experiments the VLE integration is very simple since a given link (Internet address) in the VLE can supply connection with the experiment. A few improvements in this integration were proposed to make the interaction between the VLE and remote experiment more reusable and efficient.

The VLE controls the user access and configures the remote experiment according to the user (student) learning level, i.e., students with no previously recorded interaction with the experiment should perform the most simple

experiment (usually the one with only simulated equipments) whether other students can choose the type of experiment. The communication channel between VLE and remote experiment is the central database which both have interfaces. This way, the VLE can setup experiments writing database parameters that are read by the experiment manager/interface. Given the experiment setup parameters the manager “links” (provide the connections) the selected components (plants and controllers) to form the desired experiment (scenario).

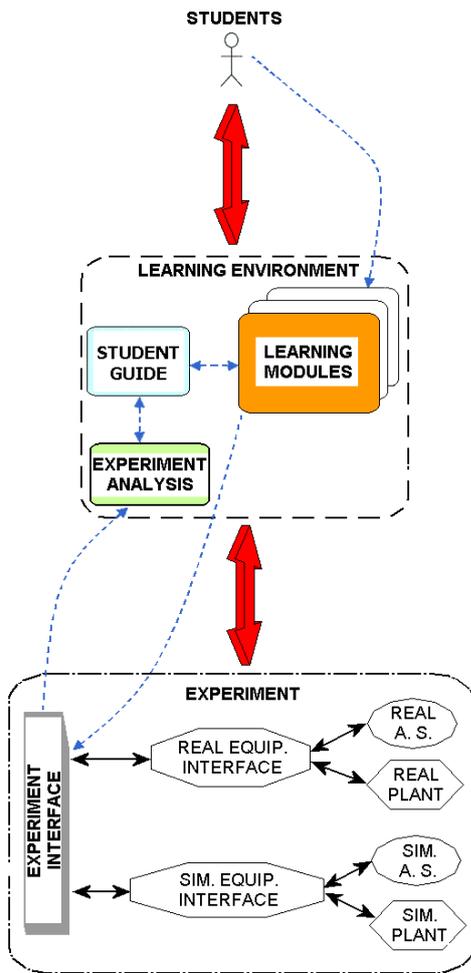


Figure 1. Proposed Architecture

The experiment analysis is a tool to identify problems or errors in the performed experiment. This tool reads experiment reports (text files generated by the experiment manager) and calculates characteristics metrics of control systems theory like: maximal overshoot, rise time and settling time. These metrics point out the performance of the conducted student remote experiment. Based on the metrics the student guide suggests learning materials to be revised by the student if the experiment goal was not reached.

The Figure 2. illustrate how the different modules communicate through the central database in the server. Note that the experiment manager supplies a Java Applet interface that can be viewed by the client (student) with a simple JRE compliant web browser (thin-client computing [13]).

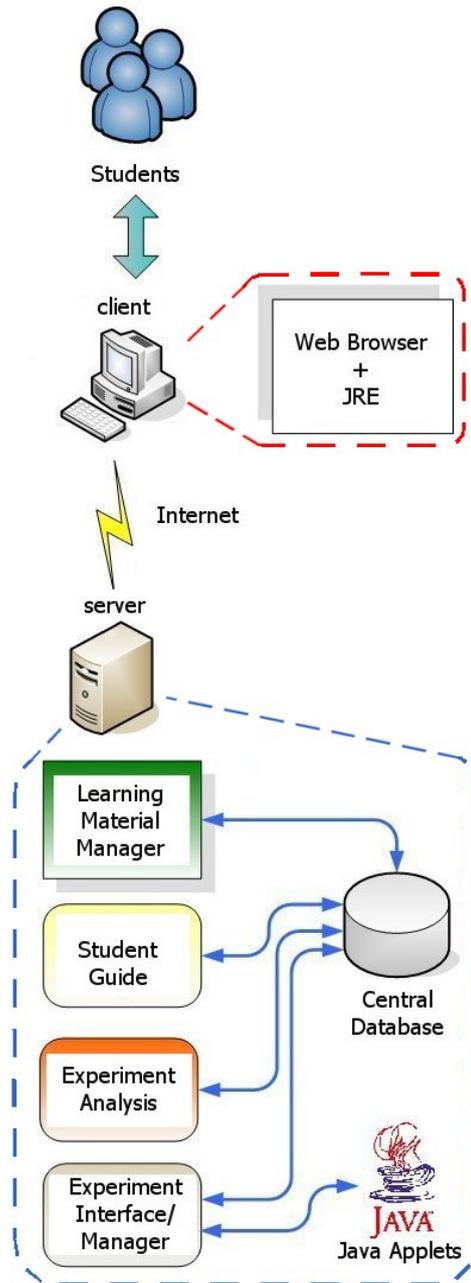


Figure 2. Proposed Architecture Interfaces

B. Mixed Reality with Interchangeable Components

In order to increase the range of possible scenarios of the mixed reality experiment a strategy is used, the interchangeable components.

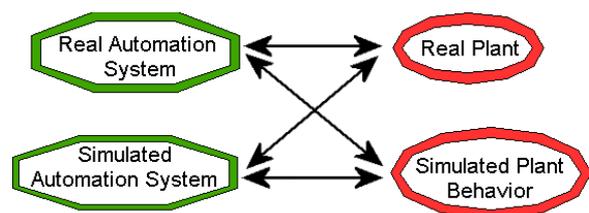


Figure 3. Interchangeable Components

The interchangeable components strategy (see Figure 3) [7] enables the execution of distinct learning scenarios. For instance, simulated plants can be used to evaluate robustness of control algorithms when the technical plant presents unexpected behaviour; simulated automation systems can be useful to show step-by-step execution of industrial controllers. All this combinations are useful in the education of student to differentiate real and simulated equipments as well as bringing more flexibility to the remote experiment.

The communication between the components follows a common interface, i.e., the experiment manager, which held all interfaces with all experiment components.

### III. CASE STUDIES – IMPLEMENTATION

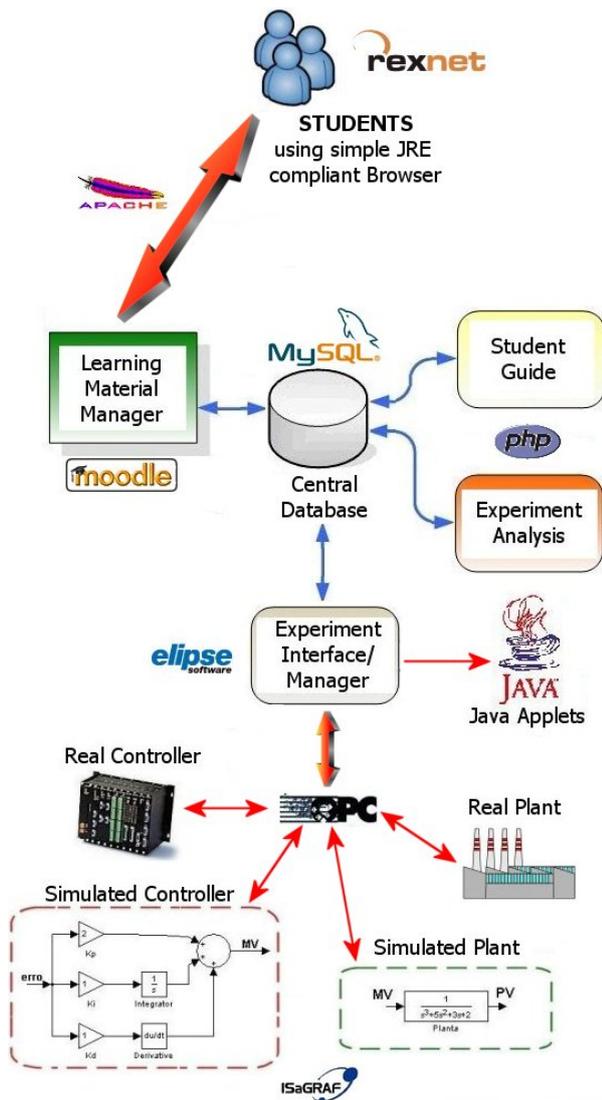


Figure 4. Case studies basic implementation.

The case studies works as validation of the proposed architecture. Different plants and technologies were used to build the case study “framework”. MOODLE [14] was chosen among a large number of software implementations of learning materials managers, also known as learning management systems (LMSs), course management systems (CMSs) and VLEs. The MOODLE installation resembles the work presented in [8], were all

courses and learning materials are organized to provide maximum intuitive perceptions, simplicity and knowledge transfer to the student. MOODLE have a simple to use MySQL interface witch is used as database manager.

The student guide and experiment analysis “modules” of the architecture are written in PHP code to simplify the integration and the interactivity with the MOODLE software. The simple SCADA software, named Elyse SCADA [14], is used as experiment manager and is responsible to provide connections with the real/simulated equipment and to supply a Java Applets as interface. Elyse SCADA also have interfaces to deal with ODBC (with MySQL connector) and with OPC [15] servers. The OPC-DA is as interface to connect with real equipments and with simulators.

The simulated equipments can be executed in any simulator that has OPC server support. In the presented case study the ISaGRAF [16] simulator is used to simulate dynamic as well as discrete components. Figure 4. illustrate all software and technologies used in all case studies implementations.

The prototypes, built as case studies, use common remote experiments used within the scope of the REXNet Project.

The first prototype was built using a Foundation Fieldbus Pilot Plant [17, 7] in use for many years at UFRGS. This experiment provides PID controlling techniques to control the water level in two tanks. The VLE (MOODLE) contains learning materials within PID tuning techniques organized as courses. Integrated in the VLE tools for identifying experiment metrics and a student guide based on feedbacks from the experiment and also form the tracked (from logs) visited learning materials were developed. Other courses related to the experiment such as “how the experiment works?” and “how to run the experiment?” was also developed as well as a course of the Foundation Fieldbus industrial communication protocol.

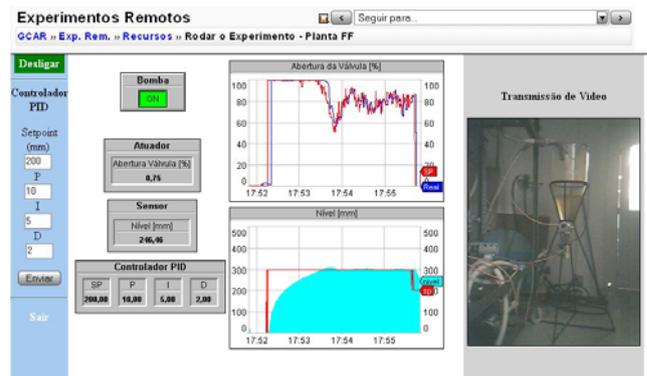


Figure 5. Foundation Fieldbus Pilot Plant Remote Interface.

The second prototype uses a simple thermal plant [18] built with a PID industrial controller and simple electronic equipment to illustrate the temperature control techniques. Again special courses were developed and the same student guide and experiment analyzer were used (see Figure 6).

The third prototype uses the system developed by [10]. The system provides a full mixed reality workbench for teaching mechatronics (electro pneumatics). This system

is more flexible and has more interactivity with the user. Enhancements in this system were made to be more robust and reliable to be used in technical education [9]. In [9] is also described the project which enhanced the former system to interact with OPC servers, providing this way a mean to work as case study of the proposed architecture (see Figure 7).



Figure 6. Experiment Analyzer

The final prototype is a simulated bottle production plant [12] (without any automation) used in electrical engineering courses. This simulation is executed in the ISaGRAF providing a very didactical and reusable experiment. This prototype can be combined to other prototypes to form a complete combined experiment, i.e., interactions with the mechatronics workbench produce a flexible way to control the experiment and also to integrate with other external OPC servers (other simulations). This prototype has a built-in analysis experiment tool in his model to identify problems in the simulation. The main goal of the experiment is to design an automation system based on I/Os provided by the simulated model.

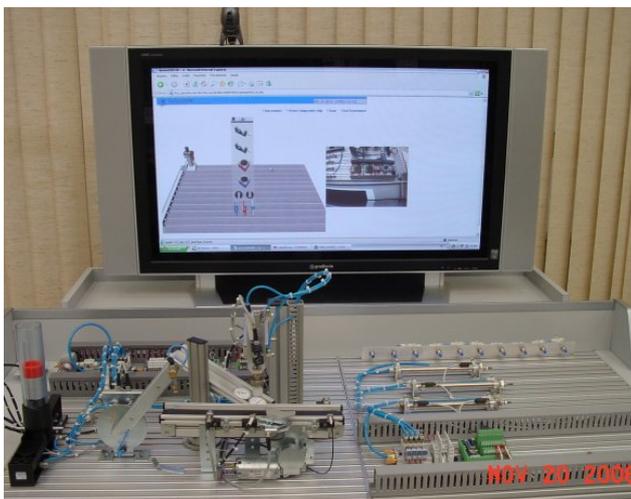


Figure 7. Electro Pneumatics (Mechatronics) Experiment.

#### IV. CONCLUSIONS

The proposed architecture supplies the need for educational backup to remote experiments providing also experiment feedback. The feedback and the theory background is the key to achieve more learning results from students. The flexibility caused by the use of mixed reality associated with the interchangeable strategy switch static remote experiments in fully dynamic created remote experiments.

Although the basic case studies implementation employs several commercial softwares the architecture does not hang on the usage of these specific softwares. The standardized OPC is a very common interface built-in in several simulation softwares available in the market. OPC complaint softwares are also very simple to integrate in the system making the creation of different scenarios easy.

The VLE integration is very important to unify: student guide, experiment analysis, learning materials, experiment booking systems, remote experiments, collaboration tools, user access control, etc. in a single environment responsible for collaborative, active and distributed learning.

#### V. FUTURE WORKS

The basic architecture is now finished, as future works remains the enhancements of the integrated “modules”. The student guide requires more parameters and more development to be a reliable tool to identify learning problems. For this purpose a student model research and implementation is in progress. The main idea is to have a student guide as in [18], were a probabilistic model based on several user interactions was developed. A future improvement of the third and last prototype is also planned. All prototypes implementations will be tested in electrical engineering courses at the UFRGS.

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## AUTHORS

**F. M. Schaf** is a PhD student at the Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil (e-mail: [fredms@ece.ufrgs.br](mailto:fredms@ece.ufrgs.br)).

**C. E. Pereira** is a senior Professor at the Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil (e-mail: [fredms@ece.ufrgs.br](mailto:fredms@ece.ufrgs.br)).

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