Architecture for Remote Laboratories based on REST Web Services

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Abstract - **In this paper, a new architecture for remote laboratories based on REST (Representational State Transfer) web services is proposed. The proposed platform use languages such as HTML, AJAX (asynchronous Javascript and XML) and Labview. A web browser is the client interface and on the server side runs an application based on Labview 8.6 with REST web resources. The main contributions are: a) the proposed architecture; b) a "thin client" based on a browser requiring a low bandwidth. Experimental tests, using an analog process simulator, were done and the obtained results show a good performance.**

I. INTRODUCTION

In the last years, the computers and telecommunication networks technologies improvements allow a great evolution of remote systems, not only for industrial applications but also for e-learning activities.

Industrial remote systems allow not only performing remote and distributed control but also supervision with fault diagnosis and fault-tolerance. Fault-tolerant systems must guarantee that faults do not cause drastic failures, and also permit increasing plant reliability, safety and economy.

E-learning environments are supported on virtual and/or remote laboratories [1, 2, 3]. Different architectures can be used to support these environments [1, 2, 4, 7, 12]; some are based on proprietary software solutions such as Labview, while others are supported by open-source software such as PHP, Javascript, Java, Pyhon, AJAX, etc, [17]. Particular attention is paid to the Web Services technology that proves to be a general solution, suitable for each type of application [10, 17]. Accordingly to W3C (world wide web consortium, www.w3.org) a web service is "a software system designed to support interoperable machine-to-machine interaction over a network".

The solution proposed in this paper runs the Labview 8.6 software on the server side and on the client side only a browser is needed. AJAX and REST web services are used for communications between the server application and the client.

The main contributions are the proposed architecture and a "thin client" based on a browser. This "thin client" is an alternative to the classical solution using a run-time Labview plug-in installed on the client's browser.

II. REMOTE LABORATORIES

The Internet and World Wide Web allow the effective support for collaborative work in real-time. Currently, most universities have e-learning environments ready to be remotely accessed through the Web [1].

In the engineering education activities, the role of experimentation is a key concept. In most of the topics, physical experimentation is a better approach than simulation, since permit students to fully understand the physical laws, disturbances and restrictions, and to get acquainted with design procedures.

Due to different goals and constraints, simulation and physical experimentation can be incorporated within the same e-learning platform.

Remote laboratories allow students to access experiments without time and location restrictions, allowing avoid dangerous failure situations. The remote lab concept also provides a tool to shift towards a student-centric teaching approach as suggested by the Bologna Process [20].

In literature, numerous definitions of remote lab environments can be found (e. g. [5]). But nevertheless, a universally accepted definition and mutual understanding of what exactly is meant when talking about a remote laboratory does not exist. In some publications the terms remote-lab, web-lab, virtual lab, on-line lab, etc, are often used synonymously. Muller & Erbe, [3], proposed the following classification of laboratory environments (Tab. 1), following criteria based on nature of equipment and user access. A similar table was proposed early by Dormido Bencomo [6].

Tab. 1 – Classification of laboratory environments [3].

user access / nature of equipment	local	distant
physical (real)	hands-on lab	remote lab
virtual (modelled)	virtual lab	distributed virtual lab

A simplified general architecture for a typical remote laboratory, inspired in the architecture presented by Alves & al. [8], is depicted in Fig. 1. The access server prevents unauthorized users from accessing the remote experiment, by requiring a login and a password. The user clients can control the experimental setup via a web browser.

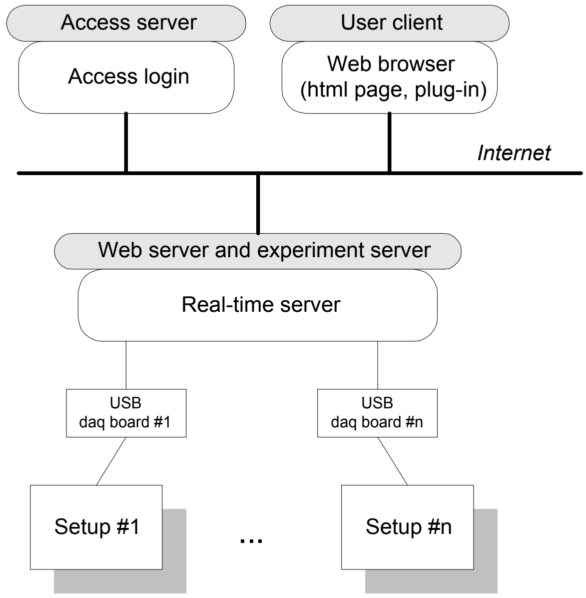

Fig. 1. Simplified general architecture for a typical remote laboratory.

In Table 2 are presented some approaches used for implementing remote laboratories.

On the server side, in the past, efforts were done to apply technologies based on Java, Matlab and Virtualization techniques. The new trends are focused on languages such as Python, Labview and also on Webservices. Labview has been choosen in many projects since it's used in many professional environments (industry, research and development, etc).

On the client side, technologies such as HTML, Java applets, Labview plug-ins, and others, were used in the early years. Now, the new trends are focused on HTML and AJAX.

The communication between the client and the server does not need to open additional holes in the security since the HTTP protocol is used in the communication, namely port 80 (HTTP) and port 443 (HTTPS), both usually open in firewalls [11].

AJAX (asynchronous Javascript and XML, [22, 23]) is a new technology for dynamic and interactive web based clients. There is no need to install any software on the client machine, since the web browser is already there. The other software needed, typically a mixture of Javascript, XML and CSS, is downloaded from the server.

Some authors argue that AJAX is the only technology that can provide a unique solution for a wide range of platforms, including mobile devices [17, 18, 19].

Using AJAX there is no need to install any software on a client computer apart from an operating system and a browser. One key aspect that must be kept in mind while using AJAX is the Web browser compatibility issues. Different Web browsers like Firefox and Internet Explorer can behave differently for the same piece of Javascript code.

The focus of the presented work is on the technology used for implementing a thin-client which does not require the installation of plug-ins.

In this paper, a new approach is proposed for a thin-client using Web RESTful services [9, 21] and AJAX (Asynchronous JavaScript and XML) [11, 22, 23].

A RESTful web service is a simple web service implemented using HTTP and the principles of REST (Representational State Transfer), [9, 21]. Such a web service can be thought about as a collection of resources. The definition of such a web service can be thought of as comprising three aspects: a) the URL for the web service; b) the MIME type of the data supported by the web service; this is often XML, JSON, or YAML but can be any other valid MIME type; c) the set of operations supported by the web service using HTTP methods (e.g. POST, GET, PUT or DELETE).

Tab. 2 – Comparison of different approaches for remote laboratories. Note: Only the main technologies are presented, not considering the booking systems.

	Web based	Mobile devices	Server side	Client Side
(Marín, et.al., 2005)	•		Java + Corba	HTML + Java applets
(Casini, et.al., 2004)	•		Matlab + Php + Exe	HTML + Java applets
(Costas-Pérez, et.al., 2008)	•		Labview	Labview plug-in or HTML + Java applets
(Lasky, et.al., 2005)			Windows NT server + Virtualization	Remote Desktop terminal
(Robson, et.al., 2007)	•		Matlab + Control server	HTML + AJAX
(Garcia-Zubia, et.al., 2007)	•		Java + Python	HTML + AJAX
(Garcia-Zubia, et.al., 2008)	•	•	Python	HTML + AJAX
(Cmuk et.al., 2008)	•	•	Labview	DHTML + AJAX
Proposed approach (this paper)	•		Labview + REST webservices	HTML + AJAX

III. ARCHITECTURE FOR REMOTE LABORATORY BASED ON RESTFUL WEB SERVICES

The proposed general architecture for the remote laboratory is depicted in Fig .2.

Labview 8.6 uses the REST paradigm for Web services, making easier the access to the available services since an URL address is assigned to each service; this approach facilitates the interaction with the user.

In the proposed architecture can be observed that the main communication protocol is the HTTP protocol. Both the interfaces AJAX and Labview REST service are server-side applications.

The user sends requests for data via the AJAX interface; this interface is a HTML page eventually with dynamic elements. The AJAX interface communicates with the server using an object XMLhttpRequest, allowing an asynchronous data change. The server response can be an XML, TXT or HTML document.

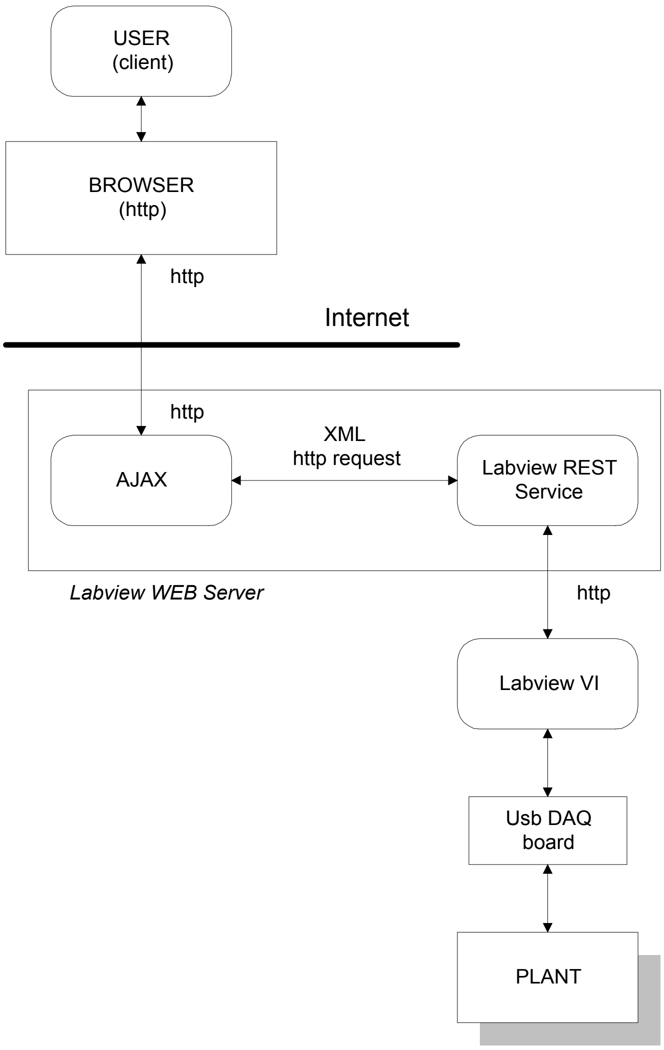

Fig. 2. Proposed architecture for a remote laboratory based on RESTful webservices.

The XMLhttpRequest object can support and deal with different data types (XML, TXT or HTML).

The HTTP protocol is also used in the communications between the server and the REST web service.

Web methods VI's are used to communicate between the Labview VI application and the REST web service.

The Web methods VI's share variables with other applications through the internet using the HTTP protocol; these special VI's are the source files used in the Labview to configure Web REST Services.

The software architecture, relating the three main components (AJAX interface, Web method VI and main VI), can be observed in Fig. 3. There are REST resources (input and output variables) that can be accessible via the AJAX interface.

In Fig. 3, without loss of generality only one input signal and one output signal of the plant are represented; the magnitude is represented in Volt. Assuming a control system, in closed loop, input variables can be reference signals, controller gains, etc, while output variables are, typically, process output variables, fault and failure signals and alarms, etc.

The communication between the server and the plant is done using an usb data acquisition board (National NI USB-6009).

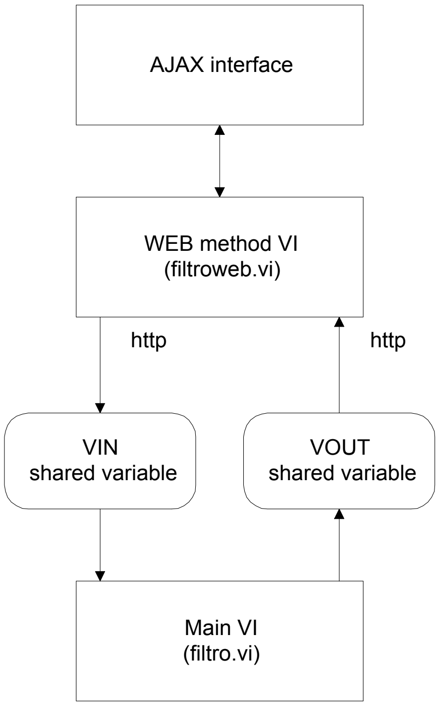

Fig. 3. Software architecture relating the three main components (AJAX interface, Web method VI and main VI).

IV. EXPERIMENTAL RESULTS

Some experimental results, obtained with the proposed architecture, are described in this section.

In order to test the architecture and the algorithms, a first-order analog filter was built with electronic components to model a first-order plant.

The schematic diagram of the filter can be observed in Fig. 4. The references of the components are: ampops A1 and A2 (LM358N), diodes D1 and D2 (1N4148), resistors R1 (820 KΩ) and R2 (180 KΩ) and a capacitor C1 (0.1 μF). The supply voltage is 5 V obtained from the DAQ board (National NI USB-6009).

A first-order model can represent the dynamic behavior of some real systems such as heating systems, liquid level systems, etc.

In Fig. 5, the front panel of the main Labview VI running on the server side can be observed. The steady-state behavior of the first-order system is depicted in this figure, assuming a unitary reference signal and a classical PI controller.

The inputs signals, namely reference signal (VIN), proportional controller gain (Kp), and integral controller gain Ki=1/Ti) are received by the AJAX interface and send to the Labview server via a REST web service, implemented using a XMLhttpRequest object. The output signal (process output signal) is received by the AJAX interface also via a XMLhttpRequest object.

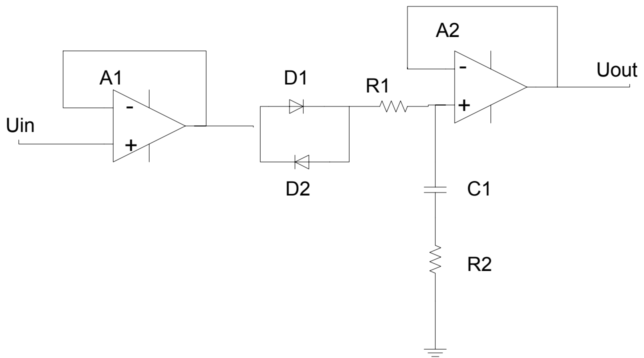

Fig. 4. Schematic diagram of first-order active filter used in the experiments.

The current available webpage on the client side, at this project stage, can be observed in Fig 6. Tests were performed using a Firefox browser, since it supports well the AJAX technology. One key aspect that must be kept in mind while using AJAX is the Web browser compatibility issues.

At this project stage, the remote laboratory proposed in this paper can be accessed via the following webpage: http://193.136.127.198/filtrowebservice/static/index.html.

The interface and algorithms are in a development stage, in order to improve the functionally and the performance.

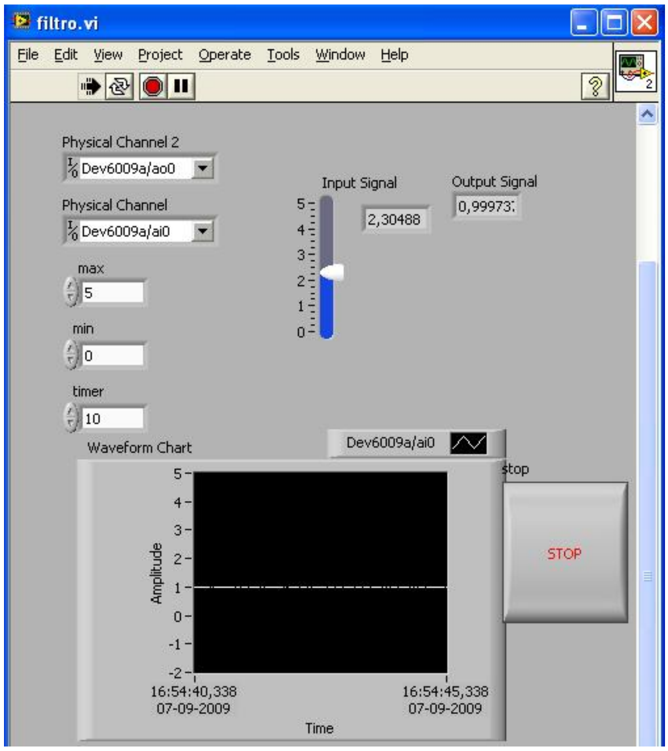

Fig. 5. Front panel of the main VI running on the server.

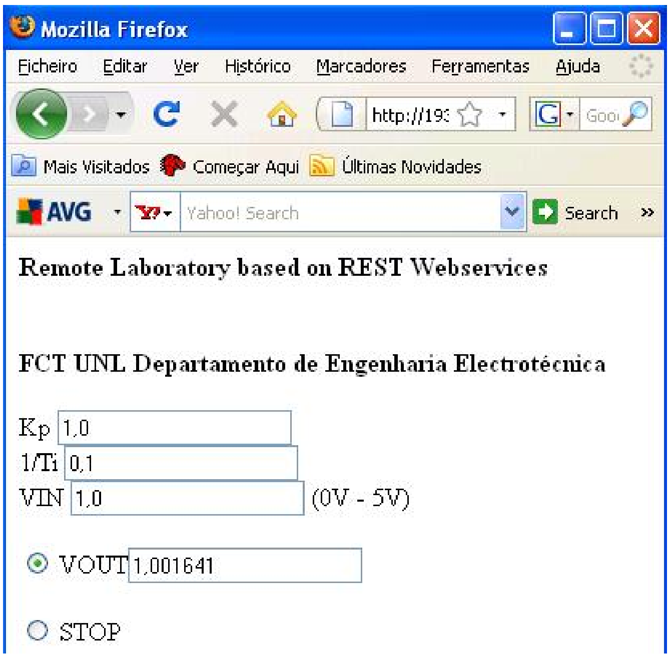

Fig. 6. Client's webpage, with input-output plant signals, in real-time operation.

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AJAX receives the values sent by Labview REST service and presents them in a HTML webpage. The response comes in the XML format, so it is necessary to perform the parse with Javascript code, and after show periodically the values; the sampling time must be within the range [0.2; 1.0] s, in order to do not block the browser.

The XMLhttpRequest is a standard object in most of the actual browsers, allowing avoid the need of installation of a browser plug-in on the client side.

In this approach, only a part of the webpage is asynchronously updated, so browser's performance is not significantly affected.

The general closed-loop control architecture used in the experiments, running on the server side, can be observed in Fig. 7.

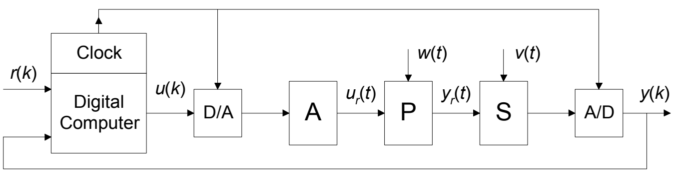

Fig. 7. Closed-loop control architecture.

Assuming a SISO system without loss of generality, the process plant is represented by the block P, and the blocks A and S represent, respectively, the actuator and the sensor; in this work, the first order filter depicted in Fig. 4 models the dynamics of cascaded blocks A, P and S. The blocks A/D and D/A are the analog-to-digital and the digital-to-analog converters, embedded in the DAQ board. The digital computer implements the control algorithm. The digital signals are also represented in the figure: the reference signal, $r(k)$, and the input and output signals, $u(k)$ and $y(k)$, respectively. The other signals are analog signals: the real process input, $u_r(t)$, and the real process output, $y_r(t)$. The signals, $w(t)$ and $v(t)$, are, respectively, the disturbance input to the plant, and the disturbance or noise in the sensor.

A classical PI controller based on the transfer function (Eq. 1) was implemented in Labview. The controller gains, proportional gain K_p and the inverse of the integral time $1/T_i$, can be adjutsed by the user via the client's browser, as depicted in Fig. 6. The user can also adjust the reference value (VIN).

Figures 5 and 6 show the situation of steady-state operation, for a set-point (VIN = 1). The gains $K_p = 1$ and $1/T_i = 0.1$ guarantee approximately a zero steady-state error, since the plant output (VOUT) is approximately one (Fig. 6).

$$C(s) = K_p(1 + \frac{1}{T_i s}) \qquad (1)$$

V. BRIEF DISCUSSION

It must be emphasized that the main contribution of the paper is the proposed architecture based on REST web services, using a "thin client" that does not require a Labview plug-in to be installed on the client's browser. At the present project stage, Labview runs on the server side.

The "thin client" running on the client's browser interacts with a Labview server using Ajax and web services, do not requiring a high bandwidth internet connection. This is a great advantage comparing to other architectures and approaches using a Labview plug-in installed on the client's browser, which present typically a high computational load.

Currently, some results presenting a good performance have been obtained. In a near future, the improvement of the graphic user interface and new functionalities will permit the use of this remote laboratory based on web services as a valuable pedagogical tool.

The authors believe that a remote laboratory based on the proposed architecture will be a valuable pedagogical instrument in courses in the electrical engineering area (Control Theory, Intelligent Control, Automation, Digital Systems, etc) and on other education areas.

This kind of remote laboratory has features allowing its use as an autonomous tool or integrated in courses following a blended learning approach.

From the authors point of view, blended learning is a combination of multiple approaches (on-class, e-teaching, e learning) to achieve the learning goal. New teaching paradigms are required. For the development of such paradigms one needs to understand the factors that have impact on the learning process. In the past few years, for many engineering courses, the trend has been in towards a blended learning approach: traditional teaching methods combined with e teaching and e-learning. This is the approach followed in our department, has it was found to be the most consensual and efficient.

The e-learning process based on remote laboratories can play a crucial role in the interaction between theory and practice. Theory is the best tool for the practice, and practice is the best tool to validate a theory.

It should be noticed that constructivists' theories highlight the importance of practical work, shifting the focus to the "learning by doing" paradigm.

In case of engineering education, this means that additional stress is shifted towards laboratories, as some "social pressure" – mostly from employers – tends also to increase experimentation.

VI. CONCLUSIONS

A new architecture to support remote laboratories using a thin client, Labview on the server side, RESTful web services and AJAX technology, was proposed in this paper. The main contribution is a thin client based on HTML and AJAX able to communicate with the Labview server using RESTful web services, avoiding the need of an additional plug-in installed on the client's browser, and increasing the performance of the overall system. Both goals were achieved and the obtained results are promising.

Software solutions based on Web services and AJAX technology are new paradigms, allowing dynamic and interactive web based clients. There are more and more new WEB applications based on these technologies.

In the e-learning area related to electrical engineering, this kind of remote applications can be applied not only for control, but also for monitoring, fault diagnosis, supervision, among other areas.

It is expectable that this new remote laboratory architecture be a valuable pedagogical instrument, as an autonomous tool or integrated in courses offered at Universidade Nova de Lisboa following a blended learning approach.

Some pointers for further work under investigation are:

a) the development of a graphic running on the browser's client, to monitoring the input-output signals in the plant, in on-line operation, with some inherent time delay;

b) the analysis of system performance in terms of inherent time delays;

c) a login and authentication service based on Javascript and session variables using Web services pallete blocks;

d) the adaptation of the system architecture to deal also with mobile devices.

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