USING WEB SERVICES IN REMOTE CONTROL OF LABORATORY-SCALE AND MATLAB SIMULATION MODELS

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Abstract: Internet control of laboratory experiments has lately become a new phenomenon in university education. It brings effective use of the laboratory equipment and comfort to students in performing their laboratory experiments from anywhere. Since a solution for the control-engineering laboratory of the CTU was designed in the framework of a diploma thesis, obtained experience and necessity of establishing a common access to software models especially those created in Matlab/Simulink are the main reasons why a new development has been considered. New features and advantages provided by web services are described and discussed both for existing remote laboratory control and planned introduction of the Matlab/Simulink based simulators into various types of educational courses.

Keywords: Internet, man–experiment interface, simulator, temperature control, power plant, web services, Matlab/Simulink

1. INTRODUCTION

Web services are becoming a standard in application-to-application communication (Haas, 2002). While they bring long awaited unification of the programmatic interface between programs on different platforms, they also help programs to spread to new areas of use, thus bringing many new opportunities. They allow previously unthinkable solutions to emerge. However, they also bring many new challenges.

2. WEB SERVICES IN GENERAL

Web services (previously also known as application services) are services (usually including some combination of programming and data, and possibly including human resources as well) that are made available from a provider's web server for web users or other web-connected programs (TechTarget, 2002). Major advantages of web services are standardized protocols (TCP/IP and HTTP) and data formats (XML), which allow otherwise incompatible programs and platforms to communicate with one another.

The goal of web services is to provide services to other programs or individuals. These services can range from booking a hotel or renting a car to providing the current value of a requested stock quote or forecasting weather for a given area.

2.1. A closer look at web services architecture

In order for the remote party to be able to access the data and understand it correctly, some rules need to be defined describing the format and meaning of data and a way of accessing it. The format for web services data has been set to be Extensible Markup Language (XML). XML is similar to HTML as it uses tags to describe data. Unlike HTML, XML does not have a predefined set of usable tags. Therefore the developer of a web service can define his/her own tags that will be used to describe the data.

Knowing how to access the data provided by the web services is just as important as being able to understand this data. Accessing web service functions is described using Web Services Description Language (WSDL). WSDL is an XML-based language used to describe the services one offers and to provide a way for a remote party to access those services electronically. (TechTarget, 2002)

If one wants to access a certain web service, he/she must know who provides such a service. Information about available web services and the functions that these services provide are contained in the UDDI registries. A UDDI (Universal Description, Discovery and Integration) initiative can be thought of as the yellow pages of web services. They include lists of registered web services. The services are described using WSDL.
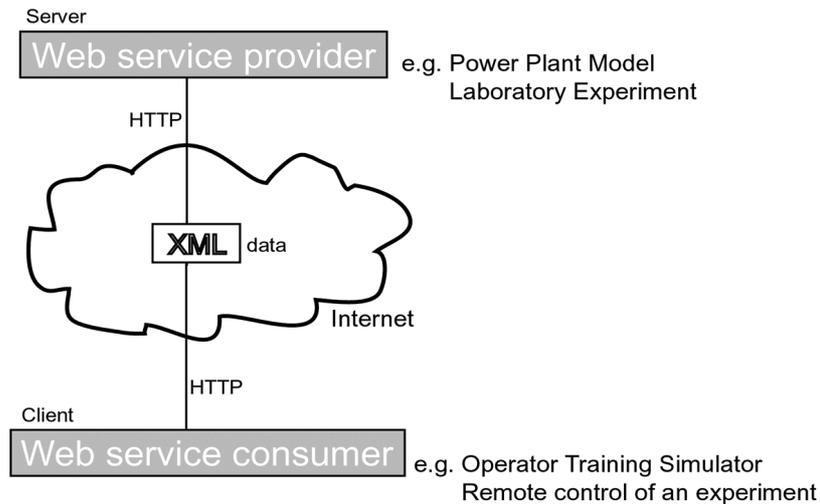
Web Services Architecture

Server
Web service provider   e.g. Power Plant Model
                            Laboratory Experiment

HTTP

XML data

Internet

HTTP

Client
Web service consumer   e.g. Operator Training Simulator
                            Remote control of an experiment

Fig 1. Scheme of a web services architecture

2.2. Advantages of web services over proprietary implementation of remote control

The following are the main advantages of the use of web services:

- Unified cross-platform interface – based on TCP/IP, HTTP, XML and WSDL standards, this solution can be implemented on a variety of platforms

- Scalability - changes to the experiment (server side) can be made without having to change the client software

- Passes through most firewalls – HTTP protocol is used, therefore no changes need to be implemented in the setup of most firewalls, as HTTP traffic is allowed on most networks

- Allows cooperation between on-line users – connection of several users to the experiment at one time is allowed and better management of access rights is provided.

2.3. Matlab approach to remote access

Being a great tool for laboratory experiments as well as system modelling, Matlab software and its remote access capabilities are at the center of attention while developing web service based experiments and models. Recent versions of Matlab software include a web server that allows HTML pages to be generated from within Matlab and served to the clients connecting the Matlab remotely. This approach combines both application server (server generating the data) and web server (server taking care of delivering the generated data to the clients). Recent trends in this area however seem to rather separate these two functions than combine them. This is to allow each server to concentrate on its work and do so more effectively. Further testing is planned to examine the abilities of Matlab web server to withstand heavy load, especially under conditions of simultaneous work of several users.

3. POWER PLANT SIMULATORS AND THE WEB

In recent years, coal-fired power plant simulators of various kinds and for various uses have been developed at the Institute of Instrumentation and Control Engineering in co-operation with Energy Training Centre in Tušimice, Czech Republic. (Neuman P. et al, 2000, Jan, J. A., Šulc B., 2001, 2002). The last development was on an operator-training simulator using Matlab/Simulink as a tool for simulation and Wonderware InTouch as a tool for visualization and manipulation. These purely software realizations are supplemented in the industrial version, by an operator panel. Although the educational version lacks the feeling of working in an operator room, (and this is the specific advantage of the industrial simulator, where the operator uses the real control panels in his/her operator room), it offers a broader range of activities to be performed. Besides providing acquaintance with the work of an operator, this solution allows students to test advanced control algorithms, perform identification experiments and other control engineering tasks otherwise hardly performable in a real environment. In normal operator simulators these functions are not available, as they go beyond the responsibility of the operator. The scope of these tasks cannot be fully estimated in advance and so a well designed interface between the student and the simulator is necessary. Web services will play a key role in the design of such solutions as they provide optimal support for this task. The design of this interface is forming part of a dissertation work currently being undertaken at Czech Technical University.

4. NONLINEAR STEADYING OF LINEAR DYNAMIC RESPONSES

It is critical not only for the models and simulators to be able to accept remote connections, but also to reflect the real conditions as precisely as possible. Therefore importance is also put on the

power plant modelling this is, for example, the case of heat exchangers where compressibility of flue gases can be considered separately from temperature changes when in both phenomena lumped parameters are supposed.
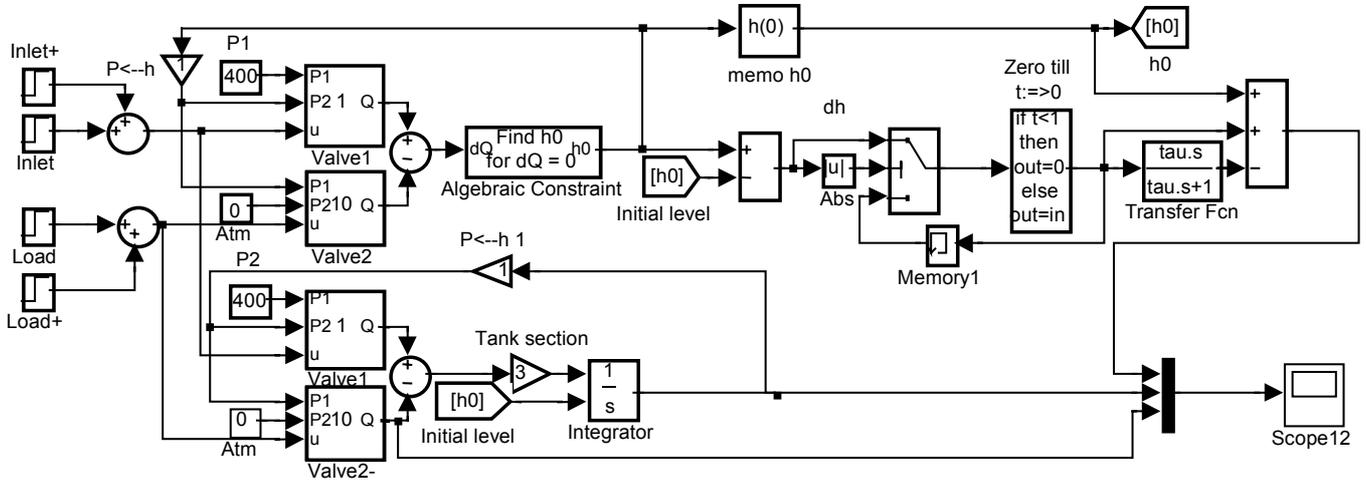

Fig. 2 Simulink block scheme for simulation of level dynamics in a tank modelled by a linear transfer function block with interactively determined non-linear steady state values of level compared with responses on the same changes in both valve opening in a parallel model respecting all significant non-linearities as considered in Eq. (3)

improvement of the currently existing models (including those used for operator training), allowing them to reflect the reality in a more precise way and thus making the simulation experience more realistic.

One of the recently tested ways for a better operator training simulator design offers use of the models whose output steady changes are interactively calculated in an algebraic loop using Simulink block Algebraic Constraint. This calculation uses non-linear relations if they are known inclusive all coefficients or it can be based on experimentally obtained tables replacing hardly determinable parameters. Because calculation of the new steady state is always performed as soon as the new input change is indicated, the dynamic transition can be defined by means of a suitable transfer function guaranteeing that a new steady state is achieved exactly, without any error.

Because the iterative search works even at the simulation start, the initial conditions can be determined relatively precisely and can serve as input data passed to each simulation run.

4.1. Compartment concept

Principles of compartment approach in context of boiler modelling are known and well mathematically formulated. The basic idea can be used independently on the modelling techniques. It consists in the fictive separation of phenomena that influence each other in reality but can be easily described only when separated from one another. In

4.2. Validation testing

As an example for testing the differences between the non-linear modelling based on a non-linear equation of flow rate balance and the linear dynamic modelling with non-linear steadying of water level a water tank has been chosen. The volume flow rate through the inlet and outlet valves is generally described by the equation

$$Q = K_V f(u)\sqrt{\Delta P} \tag{1}$$

where the volume flow rate Q measured in l/min is proportional to the square root of the pressure difference ΔP in kPa on the valve, to the flow coefficient K_V and dimensionless opening characterized by the dependence on u in the form

$$f(u) = \frac{\tanh((u-0,5)v) + \tanh(0,5v)}{2\tanh(0,5v)} \tag{2}$$

where v is an optional coefficient expressing certain measure of valve non-linearity. The values of v may vary from the value one, when the opening characteristics of the valve is practically linear, to the value about 10, when the valve flow characteristics becomes close to a two position switch.

The flow rate balance

$$F\frac{d}{dt}h(t) = K_{V1}f(u_1)\sqrt{P_1 - \rho g h(t)} - K_{V2}f(u_2)\sqrt{\rho g h(t)} \tag{3}$$

determines the dynamics of level changes. The right hand side of (3), if it is put equal to zero, represents the relation for steady state computation. This relation is programmed by means of two generally identical blocks that model the flow through a valve according to formula (1). The inlet valve has the flow coefficient $K_{V1} = 1$ [$dm^3 min^{-1} kPa^{-1/2}$]; the outlet valve $K_{V2} = 20$ [$dm^3 min^{-1} kPa^{-1/2}$] and the parameter v is set equal to four. Outputs of these blocks represent the flow rates through the valves and their equality is achieved by use of the block Algebraic Constraint whose output – height of the steady water level in the tank – is searched by changing its output from a chosen initial value h_0.

Further blocks for processing output of Algebraic Constraint serve for finding out starting value h_0, their changes caused by changes in opening of the valves u_1 and u_2 and their saving. The linear dynamic part is represented by the transfer function

$$\frac{\tau s}{\tau s + 1} \qquad (4)$$

in this case, but it could be replaced by any other transfer function describing reasonable dynamics of transition from one steady state value of the level height to another. Formally, denominator of the transfer function must not involve any term of zero power of s. The time constant τ has been estimated.

5. CONCLUSIONS

Web services approach seems to be suitable for remote access to both laboratory experiments as well as to simulation models. However, only after pilot project testing with the focus on the system load, a final judgement will be possible. Based on the knowledge gained during the recent Advances in Control Education Symposium held in Oulu, Finland, questions arise as to what will be the effect of a significant simultaneous activity of a larger number of students. Focus is also put on the improvement of the models themselves, especially on the promising development of more precise modelling in the area of non-linear systems.

6. ACKNOWLEDGEMENT

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