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A CONTRIBUTION TO REMOTE CONTROL OF THERMO-OPTICAL PLANT

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Abstract: The paper is devoted to the remote control of a thermo-optical plant that is used for experimental work at Faculty of Electrical Engineering and Information Technology STU in Bratislava. The presented approach is based on the created Java client-server application that enables to connect the graphical user interface with the Matlab engine running on the server.

Keywords: remote control, thermo-optical plant, server and client application.

1 INTRODUCTION

Experimental work is inseparable part of everyday life at technical universities. Experiments enable students to understand basic theorems, principles and physical relations and to develop their practical skills. Students usually start with simulations on local PC and only after they can approach real devices. Using simulations they can learn on errors, they can make mistakes without any consequences. Then, after starting real experiments they are already more or less prepared on the behavior of the presented real plant. Of course, this procedure doesn't have to be a rule. Sometimes it is more convenient firstly to measure a property of the material, a value of the signal or other required output and on the base of experimental results to deduce a theoretical conclusion. In both cases real experiments have their unsubstitutable place in the educational process. The problem usually consists in the fact that experiments are available only in certain time of the day and only for the group of people that according to the timetable can enter to the room with laboratory equipment. This approach cannot respect individual requirements of all students. Actually, it is not enough only to accomplish all measurements. Much more important is to understand all relations and dependencies. Therefore performing experiments is required. Sometimes it is necessary to accomplish still some additional

measurements that confirm or exclude previous conclusions.

Expansion of Internet brought new possibilities on the field of education, too. Except of other achievements that are not focused in this paper it also enables to experiment on real devices without a necessity to visit a laboratory personally. Building of remote laboratories is one of aims at many universities over the world. The advantage is that remote laboratories are usually opened 24 hours per day and 7 days in week.

The paper demonstrates one way how to use remote control for a thermo-optical plant. It is an example of nonlinear system that is very suitable for laboratory exercises.

2 PLANT

The introduced thermo-optical laboratory plant uDAQ28/LT (Fig.1) presents a system that enables to control two physical variables – the temperature inside a plastic cylinder and a light intensity.

The plant [Huba, 2008] has three inputs – the bulb voltage (the heat & light source), the ventilator voltage (system cooling) and a light diode voltage (the second possible light source). Except of these 3 input voltages there exist still two parameter inputs for adjusting the sampling period and the time constant

of the built in derivative filter. The user can use eight measured outputs: the system temperature measured by PT100 sensor, the light intensity (both measured directly, or with a preliminary filtration by the filter of the 1st order) and its derivative, the ambient temperature, the current and the speed of the ventilator rotation.



Fig. 1. The combined thermo-optical laboratory plant

In spite of the fact that one can measure 8 variables, students usually do not use all of them. They control the temperature inside the plastic cylinder that is influenced by the bulb heating and the ventilator cooling. In spite of the fact that both these variables can be used for control in the same time together, the plant is very often controlled only by the bulb voltage whereby the voltage on the ventilator is considered as a disturbance variable. Another possibility is to control the light intensity that can be influenced by the voltage on the light diode.

As it is possible to see to see the introduced plant offers a big variability of experiments that can be accomplished. In addition, except of control students have to solve tasks that are connected with plant identification, input-output data manipulation and communication with outer computer environment.

3 REQUIREMENTS

The basic problem that has to be solved is to find a way for communication between remote client and technological equipment (Fig.2). For simplicity we can consider that the remote client is a typical Internet user with Internet browser and the technological equipment is the controlled plant – in our case the thermo-optical plant.



Fig. 2. Communication between remote and technological plant

Actually, for accomplishing the remote control of experiment it is necessary to create two applications: application for the server and application for the client.

The choice of programming tools for the preparation of the server side of experiment is usually influenced by several requirements:

- Expansibility of the experiment – the experiment should be easily spread without need for long study of the source code.
- Maximal use of system tools.
- Accessible hardware and software – it is necessary to take into account the most used systems and software environments at the universities and their accessibility for users.

The realization of the client side also requires considering various aspects of its design. It is needed to adjust requests of users, programmers and possible technical limits of application. The chosen tool should

- enable simple Internet communication.
- create a multi-platform application – the platform independence is important because the application is presented to users via Internet.

In the following section we will devote our attention to one possible solution.

4 REALIZATION

Considering simulation environment we can say that at universities students very often use Matlab with Simulink. There they can easily test various control approaches. Therefore the natural question is how to control the introduced thermo-optical plant remotely but via well known environment of Matlab/Simulink.

4.1 Server Side

The server part can be solved by several ways. One approach comes out from the fact that interaction with Matlab is accomplished via built-in API libraries that can be exploited by means of Java programming language. This object oriented language can be easily integrated into the web server. In addition, it supports multi-thread communication that enables to run several Matlab applications. Stefan Müller introduced JMatLink library that can be used for remote control of Matlab applications. JMatLink enables to use MATLAB's computational engine inside our own Java applications, applets or servlets. This dll library is programmed in C language that using ActiveX tool approaches data and services of Matlab. The library is implemented in the class of Java language that has the same name (JMatLink.class). In the case that Java is used for development of an own application

one has available all methods of the mentioned class. JMatLink uses a multi-threading approach to improve performance and handle multiple Matlab sessions at a time.

As it was already mentioned the JMatLink library enables the connection to Matlab from Java servlets. These so called JMatServlets can be later approached from the web browser via HTTP. The servlet functionality can open and initialize Matlab engine, start all simulations, get results and send them to the client application. Of course, finally it enables to close the connection with Matlab application.

The created Java based server application was tested on PC with Matlab v.6.5 and Matlab v.7.0. The server that takes care for communication with Matlab has to be supplemented with the web server where the client application is placed. We decided to use Apache Tomcat 6.0 server with the support of PHP programming language.

4.2 Client Side

The client application is dynamically generated by the web server. It serves for the user interaction with the remote system. Except of PHP we also used AJAX approach that enables asynchronous modification of the web page.

The whole application is divided into two parts. The first one is devoted to the remote control by itself and the second one enables to change the control structure for the remote control of the plant.

The remote control of the plant consists in the ini-

tialization of the connection with Matlab, initialization and starting the simulation, getting results and closing the session. The user can see results using the dynamic graph and after simulation he or she can download experimental results to the local file.

The created graphical user interface is shown in Fig.3. In the illustrated example we controlled the temperature inside of the plastic cylinder whereby we used a classical PID controller. However, the interested user is also offered by the possibility to change the predefined control algorithm.

The modification of the control structure can be accomplished by the change of Simulink block scheme. The remote user can upload to the server 2 files: one for the modified block scheme with predefined inputs and outputs (mdl file) and one for the numerical values of parameters (mat file) (Fig.4).

For interactive visualization of results it was necessary to choose a suitable graphical data format. It has to be standardized and supported by web browsers. We decided to use very promising SVG format because it is a vector format and thanks to its XML structure it can be easily modified, zoomed, animated, etc.

4.3 Security

Since the remote user has the full access to the Matlab (using Simulink block scheme) and in this way to the whole set of commands that could make harm to the system, we also have to deal with big security issue. Matlab is not prepared for remote access, so it

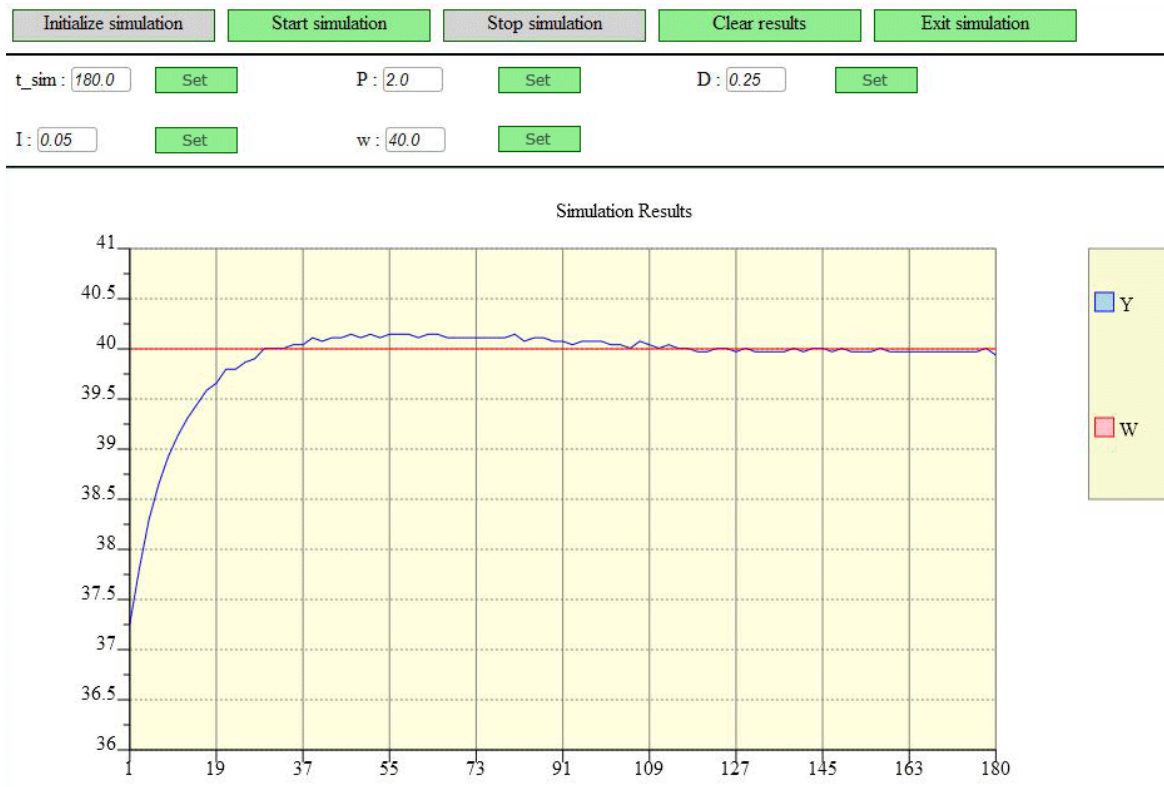


Fig. 3. Client application

is our task to solve how to protect the server side from destructive commands. We considered three ways:

The first one is to prepare a black list of functions that are not very secure because functions and variables could be overridden by dangerous code. Therefore the use of these functions is prohibited.

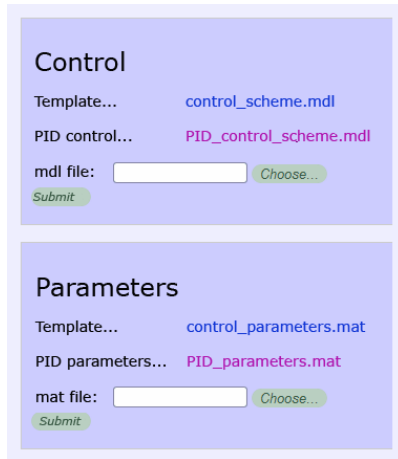


Fig. 4. Modification of control algorithm

Second way is to summarize a so called white list of Matlab functions, i.e. list of functions that only can be used. This way is much more secure but it is a very restrictive to the user.

The third approach consists in the use of the secure server on the level of operating system. The used Apache web server can run under the restricted user that has only minimal permissions necessary for interaction with Matlab, PHP and our application. In this case if user tries to run dangerous code, like deleting something important, this action is invoked, but denied by the operating system. It means that in the case of correct system permission settings remote user cannot accomplish any harm. The only damage can be done on the level of workspace that cannot be fatal for the whole application.

The third choice seems to be the most appropriate. However, in some situation it is not possible to have the installation with limited rights. Therefore we decided to eliminate using “Matlab Function” and “S-function” blocks from that part of the Simulink block scheme that can be modified by an user.

5 CONCLUSIONS

Many approaches to remote control use the engine of very popular Matlab simulation software package. It facilitates the whole design procedure because it is necessary to take care only about the communication via Internet and not about computations and tasks that could be accomplished by Matlab, e.g. the numerical methods needed for simulations.

Matlab is usually used for computations that are accomplished on the computer locally. However, the increased expansion of Internet together with the growing support of online education raised a question how to exploit capabilities of Matlab for these purposes, too. In such a case, one installation of Matlab placed on the remote server can serve for several clients whereby the client can be represented by a person or an application.

The MathWorks, Inc. brings some standard solutions how to exploit Matlab over Internet. However, there also exist some alternative ways. One of them was introduced in this paper. The advantage consists in the fact that we can better influence the functionality of the developed application.

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