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INTERNET-MEDIATED PROCESS CONTROL LABORATORY

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Abstract. *E-learning today is very important alternative way of studying, offering many benefits compared to traditional education requiring physical presence of students at certain place and time. The most important characteristics and benefits of distant learning are time and place independence with individual studying pace of learning educational materials. Very important aspect of education especially in engineering and science is practical laboratory work where students gain very important practical experience about real world systems, their behaviour, laboratory and measurement equipment that is necessary for complete education of the future engineer or scientist. While e-learning is very convenient for independent studying of theoretical materials in any educational area, there is a problem how to do the laboratory work at distance. Possible solutions are simulations of the laboratory conditions, and remote access to real laboratory equipment, not simulations. This paper deals with remote access to real laboratory equipment using contemporary computer and network technology for creating the environment that will enable the remote user to perform the required laboratory exercises and control the laboratory equipment. System named WebLab was developed for remote access to laboratory equipment with modular and easily expandable architecture. New experiments or laboratory exercises can be easily added as new hardware and software modules on any physical location equipped with Internet access. Architecture and characteristics of WebLab will be described with special attention to the latest implemented laboratory experiment for control of the coupled water tanks.*

Key words: *Remote laboratory, Automatic control, Controller implementation, Data acquisition, e-learning*

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1. INTRODUCTION

The main goal and significance of the WebLab system [1] is to provide remote access to laboratory equipment and to be as universal as possible for various kinds of laboratory work and experiments. WebLab system is added value to the e-learning system and enables remote laboratory work which is not possible with traditional e-learning systems. The basic precondition for the experiment to be available remotely, through the WebLab, is the use of the programmable equipment that manages all the aspects of the experiment. Experiments can be performed completely unattended on the side of experimental equipment, with full and exclusive control from the remote user. Basic configuration [2, 3, 4, 5] of the WebLab system consists of the web server and one or more PC acquisition servers that control the experiments. Even a simpler configuration is possible with only one PC computer that serves both roles, that of the web server and acquisition servers that controls the experiment. Such simple configuration is limited to cases with small number of experiments where one acquisition server can control all experiments. In general, when there are many experiments, more than one acquisition server is needed. Acquisition servers are PC computers with one or more data acquisition systems (DAS) for measurements of the physical quantities and control of the experimental equipment. Besides DAS, acquisition servers can also have attached other kind of measurement / control equipment, such as digital oscilloscopes for very fast measurements and for laboratory exercises devoted to learning how to use digital oscilloscopes or other kind of programmable equipment.

Data acquisition servers are connected to a web server by means of computer network. Such configuration of the WebLab system enables acquisition servers to be placed in any physical location which is equipped with Internet access for connection with web server. The actual architecture of the WebLab system is distributed, as it is physically situated in different buildings of the institutions [6, 7] that develop the WebLab system.

Users of the WebLab access the system by means of the web browsers as the only required tool on the side of the user. Such distributed configuration of the WebLab system is presented on the UML (Unified Modeling Language) node diagram in Fig 1. Each box in diagram presents one physical piece of equipment. PC 1 is web server, while PC 2, PC 3 and PC 4 are acquisition servers that are connected with web servers using Win Sockets. The structure of the WebLab software is presented with components named Web user interface, Experiment and Programmable devices. Those software components consist of classes for each experiment. Web user interface consists of classes that are used for communication with remote user.

Experiment component consist of classes that control each experiment in the system. Those two components are physically located on the web server. The third software component named Programmable devices consists of classes that are located on acquisition servers and that actually control programmable devices – DAS's and digital oscilloscope. Nodes with names DAS and digital oscilloscope represent programmable equipment used in WebLab system. Nodes on the lowest level that are connected just on one side are specific experimental equipment that is controlled by the DAS and digital oscilloscope. Names of those nodes are equal to names of the existing experiments in the WebLab system – Diodes & Transistors, Analog systems, Electrical signal velocity, Steep plane, Automatic control system.

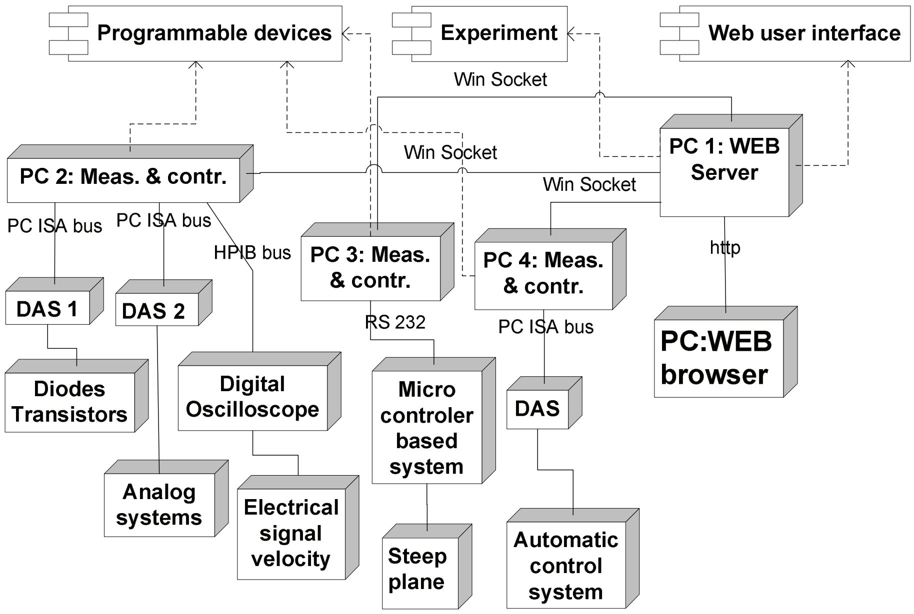

Fig 1 UML node diagram of the WebLab system

The node named PC WEB browser represents remote user of the WebLab system. Although it is only one node in the diagram, it represents all users of the WebLab system. Each experiment can be controlled by only one remote user at a time.

All software components are implemented in C++ and C# programming languages using Microsoft platform. Older DAS where programmed in C++ without .NET, while the new DAS and the web server were programmed in C# .NET. Web server was implemented using Microsoft ASPX.

2. COUPLED WATER TANKS EXPERIMENT

The experiment with coupled water tanks was added as independent hardware/ software module to the existing WebLab structure in Fig 1. It is different from the previous experiments as it was fully developed using NI LabView 8.0 software system [8]. That fact slightly changed the previous general structure of the WebLab given in Fig. 1. As it was developed with LabView software system, integrated LabView web server was used on the acquisition server. No web server programming was required with LabView, as it directly supports web access to experiments. Once the experiment is developed in LabView on the local PC, it is immediately available through the web with simple LabView setup procedure. When using LabView for development of the remote experiments, web server and acquisition server run on the same PC. The role of the central web server is changed in that case, as it serves as the main and central web location that directs the user to other web server running on the acquisition server that controls the selected experiment. In that way, even with the changed configuration, WebLab system remains fully modular and compatible for different implementations with programming languages or LabView software system. Experimental setup for coupled water tanks consists of four water tanks arranged in two levels and two water pumps controlled by DAS. Used DAS is NI USB 6009 [9]. Water level in each tank is measured by the hydrostatic pressure to voltage measurement transducer. Voltages on the output of transducers in each tank are measured by DAS. Diagram with principal schematic arrangement of the coupled water tanks is presented in Fig. 2.

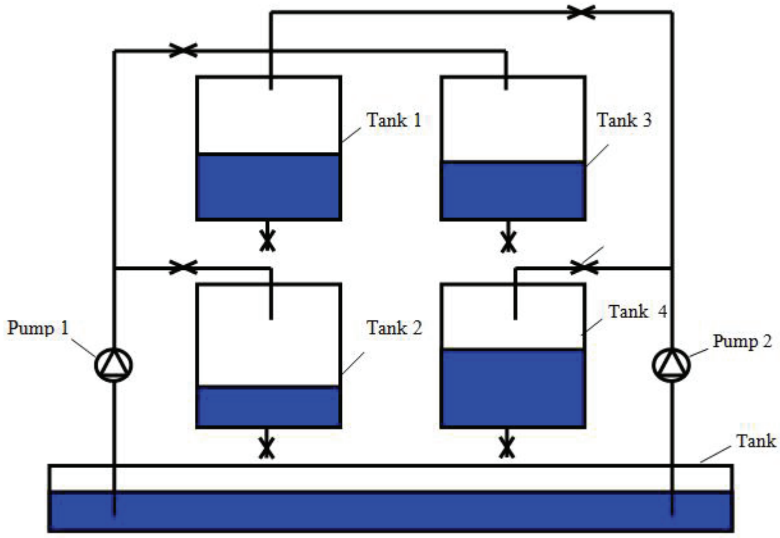

Fig 2 Diagram of coupled water tanks

Experimental setup for coupled water tanks is presented in Fig 3. The control of such coupled tanks system can be quite complex as the tanks are interconnected so that the water from the upper tank goes down in the corresponding lower tank and water pumps simultaneously pump water in diagonal tanks. As the control task for such system of coupled water tanks can be formulated in many different ways starting from the simplest version with only one pump working and controlling water level in only one tank – corresponding lower tank, to cases where both pumps are working and with controlling water levels in more than one water tank, the goal of developing such remote experiment is to make the universal environment in which any control task can be performed.

Fig 3 Coupled water tanks experimental setup

In order to achieve that goal, the design of the experiment with coupled water tanks was divided in two independent tasks. The first task was to develop working environment in LabView software system that will manage all the functions for measurements on the experimental setup and for controlling the water pumps. Also included in that task is development of the complete user interface with many different ways of driving the water pumps, indication of current water levels in tanks, drawing water level/time diagrams, saving measured data and output data in files for offline overview and analysis. Fig. 4 presents the complete UI (User Interface) for coupled water tanks experiment. Before the start of the experiment, duration in seconds and sampling time interval in mS should be set up by writing the values in corresponding text boxes. Experiment can be performed in two working modes, manual and automatic, which are selected with the switch Automatic / Manual. In the manual mode pumps 1 and 2 can be controlled by selection of the continuous manual control from min to max with the rotating knob or one of the periodic functions: rectangular, sinusoidal, triangular, saw tooth and arbitrary function that is defined with array of values. For any of the mentioned periodic functions, frequency in Hz and amplitude in V can be set. Manual mode is used for various purposes such as testing of the experimental setup working condition, setting the initial water levels, identification of the system parameters or demonstration of the system operation. Water level for each tank is measured by the DAS and represented by an indicator in the form of vertical tank where the height of the blue colored column represents water level in the real tank. On the right side of each tank water level indicator, is blue control for setting the water level with white arrow that can be moved vertically. Positions of the white arrows determine maximum water levels in the upper tanks, and besides that, water levels that are to be regulated and maintained in the lower tanks. Water levels are regulated only in the automatic mode of operation, and not in the manual mode. UI in Fig. 4 which is FP (Front Panel) of the main VI (Virtual Instrument) can be accessed locally from the same PC and also remotely from any PC by web browser using the Lab View built in web server. Remote access to any VI by web is very simple to setup, and web pages for VI can be customized in a standard way like any other web page. Fig 5 presents the web page for experiment in web browser. FP of the VI is the same in the browser window as it is on the local computer in Fig. 4. In the lower part of the web page in Fig 5 is live video from the web cam following the experiment. Only one user can control the VI, while others can observe the experiment from the VI and web cam live video.

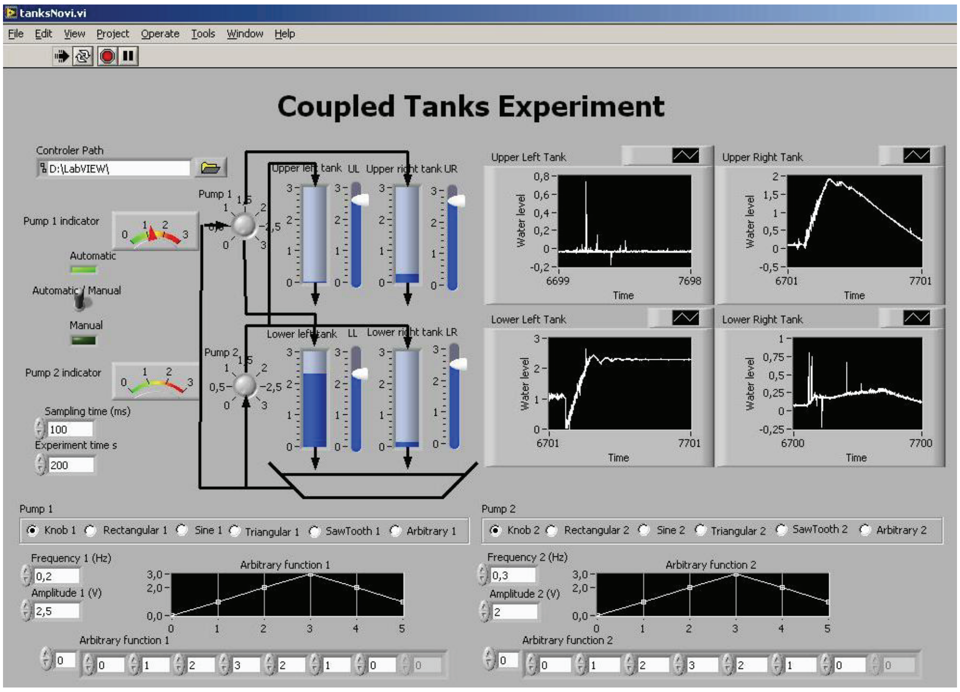

Fig 4 Front panel of the experiment main VI

Second task of the software support for this experiment is design of the system controller template that can be used for implementation of any type of controller. Template controller is designed as separate sub VI that is connected with experiment main VI which FP is given in Fig 4, using a strictly specified interface. That interface is analogous to function templates in C language. Any sub VI serving as the controller that has the same interface, can be inserted and connected with the main VI. Many different controllers in the form of VI can be designed and tested using that same interface. Interface for template controller consists of the current signal and n previously memorized signals from each of the 4 tanks and signals for 2 pumps. While designing controller, attention is devoted strictly to controller, while all technical details concerning DAS, timing, experiment duration, connections with experimental setup and other specifics, are handled by the main VI. Fig 6 presents the FP of the sub VI that implements PID controller. In the upper part of Fig. 6, above T are controls and indicators that serve as interface connections, while T and controls below serve for setting the constants for the controller. Controller in Fig. 6 has two independent sections for each pump. As all constants for the controller for pump 2 are 0, that controller is turned off. Fig 7 presents the water level / time diagram for lower left tank which gets water from the pump 1 directly, and which level is maintained by PID controller with FP in Fig. 6.

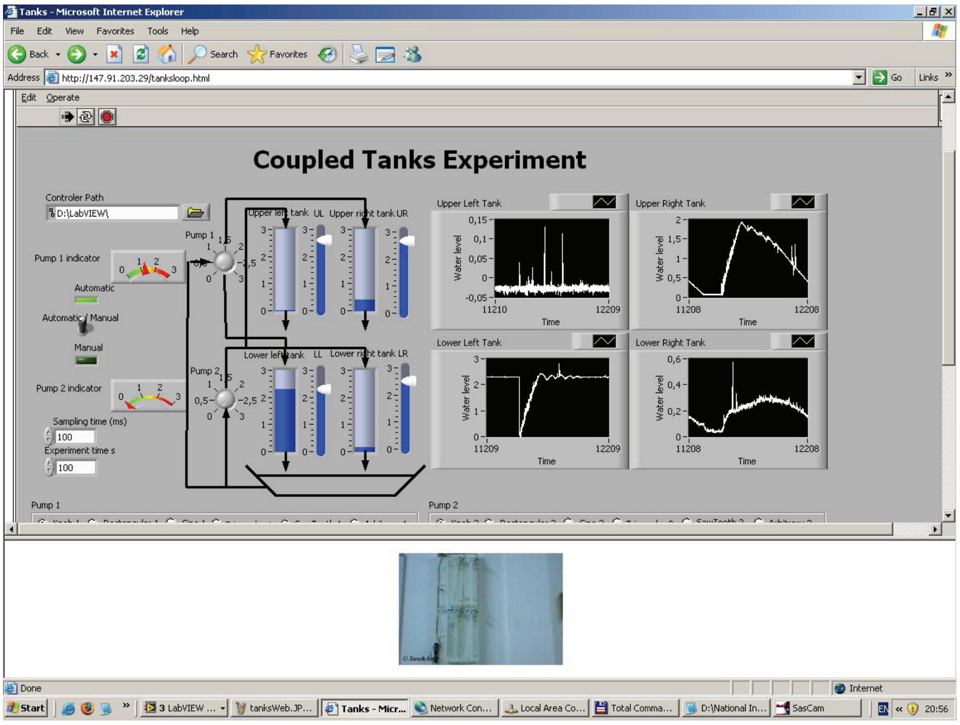

Fig 5 Web page of the Coupled water tanks experiment

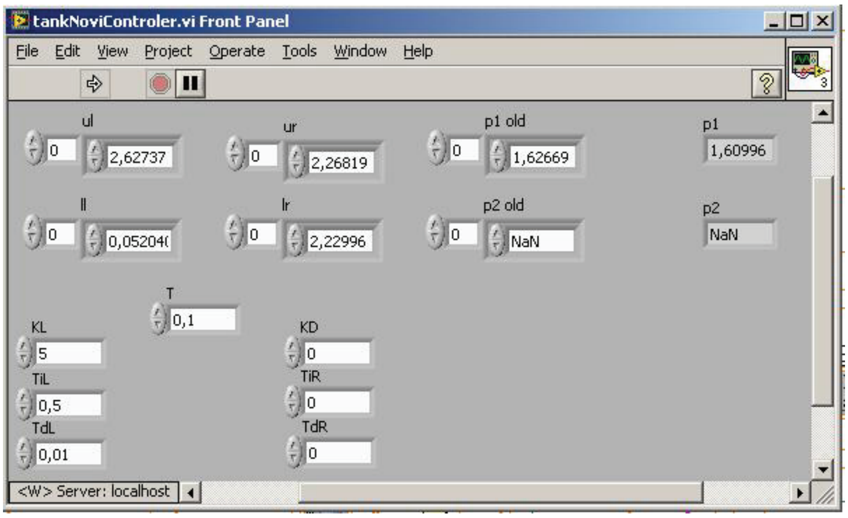

Fig 6 Front panel for implemented PID controller

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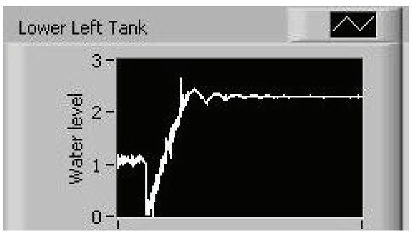

Fig 7 Water level / time diagram of PID controller

3. CONCLUSION

WebLab system was designed and implemented to enable remote access to instruments and experiments for academic education in the domain of sciences and engineering. It is a modular and distributed system that can easily be expanded by adding new hardware and software resources for new experiments. Besides benefits of remote access and 24h /7d availability, students can use it at their own learning pace. Sharing of specific and expensive equipment among various institutions is made much easier, as it can be used from any place with secure and controlled access. WebLab system is combination of two different implementation approaches that are transparent to the user of the WebLab. Implementation based on programming languages and Microsoft platform is quite satisfactory but takes much more time for development comparing to development with LabView system that enables rapid development and excellent visual design using number of ready to use controls and indicators not present elsewhere. LabView is in general better and much more effective alternative to programming when developing measurement and control applications, except for some specific tasks that could require customized software. The most important characteristic of the LabView software support for experiment with Coupled water tanks is design of the universal controller template for implementation of any kind of controller while the designer is free from all implementation details concerning the experimental setup. All implementation details are handled by the main experiment VI which uses controller based on template as sub VI. Once the experiment is developed in LabView, with simple setup it is available on the web for remote users.

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REFERENCES

1. C. C. Ko, Ben M. Chen and Jianping Chen, Creating WEB based laboratories, Springer, 2004
2. Vladimir M Cvjetkovic, Yevgeniya S Sulema, Remote Laboratory for Supporting e-Studies in Electronics, *iJoe* (International Journal of On line Engineering), http://www.i-joe.org Volume 2, No. 1, 2006
3. Vladimir M. Cvjetkovic, On Line Experiments with linear analog systems from the first to nth order, REV 2006 (Remote Engineering and Virtual instruments), 29 - 30 June 2006, Maribor, Slovenia
4. Vladimir M Cvjetkovic, Dragoljub Stevanovic and Milan Matijevic Remote System for Development, Implementation and Testing of Control Algorithms, *iJoe* (International Journal of On line Engineering), http://www.i-joe.org, Vol. 3, No. 1 (2007)
5. V.M. Cvjetković, M. Matijević and M. Stefanović, Remotely controlled experiment for Gantry Crane, REV 2007, 25 – 27 June 2007, Porto, Portugal
6. M. Stefanović, M. Matijević, M. Ravlić, V. Cvjetković, Laboratorijska merenja i upravljanje eksperimentima putem Interneta, Univerzitet u Kragujevcu, 2007
7. M. Matijević, V. Cvjetković, V. Ranković, M. Stefanović, Upravljanje laboratorijskim procesima putem Interneta, Univerzitet u Kragujevcu, 2007
8. http://www.ni.com/labview/
9. http://sine.ni.com/nips/cds/view/p/lang/en/nid/14605.

LABORATORIJA ZA KOTROLU PROCESA POSREDSTVOM INTERNETA

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Elektronsko učenje danas predstavlja veoma važan alternativni način studiranja koji pruža mnoge prednosti u odnosu na klasičnu nastavu koja zahteva fizičko prisustvo studenata na određenom mestu i u određeno vreme. Najvažnije karakteristike i prednosti učenja na daljinu su vremenska i prostorna nezavisnost sa mogućnošću individualnog tempa učenja nastavnih materijala. Veoma važan aspekt obrazovanja, posebno u tehničkim i prirodnim naukama, je praktičan laboratorijski rad gde studenti stiču veoma važno praktično iskustvo o realnim fizičkim sistemima, njihovom ponašanju, zatim o laboratorijskoj i mernoj opremi, što je sve neophodno za kompletno obrazovanje inženjera ili naučnika. Elektronsko učenje je veoma pogodno za individualno učenje teorijskog gradiva u bilo kojoj oblasti, ali postoji problem kako realizovati neophodne laboratorijske vežbe u okviru učenja na daljinu. Moguća rešenja su simulacije laboratorijskih uslova i daljinski pristup stvarnoj laboratorijskoj opremi i eksperimentima. U ovom radu se prikazuje daljinski pristup stvarnoj laboratorijskoj opremi korišćenjem savremenih računarskih i mrežnih tehnologija za kreiranje okruženja koje će omogućiti udaljenom korisniku da izvodi potrebne laboratorijske vežbe i da kontroliše laboratorijsku opremu. Razvijen je sistem pon nazivom WebLab za daljinski pristup laboratorijskoj opremi sa modularnom i skalabilnom arhitekturom. Novi eksperimenti ili laboratorijske vežbe se mogu lako dodati u vidu novih hardverskih i softverskih modula na bilo kojoj lokaciji sa računarskom mrežom. Arhitektura i karakteristike sistema WebLab će biti izložene i opisane sa posebnim osvrtom na zadnje implementiran laboratorijski eksperiment za kontrolu povezanih rezervoara sa tečnošću.

Key words: *Udaljena laboratorija, Automatsko upravljanje, Implementacija kontrolera, Akvizicija podataka, Elektronsko učenje*