CLIENT – SERVER VIRTUAL LABORATORY MODEL OF COUPLED TANK SYSTEM

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Abstract: In this paper, level regulation in coupled tank system is used to show simulation software written for educational purposes, for courses related to modelling, measurement and control. It is virtual experimental setup that provides animation and simulation of real physical process, and allows its user some level of creativity in choosing virtual experiment conditions.

Keywords: Virtual laboratories, Education, Coupled devices, Level control, Digital systems.

1. INTRODUCTION

Quality education in technical science is always connected with two levels of knowledge – theoretical and practical. While theoretical knowledge can easily be transferred to students in classical schoolrooms, engineering way of thinking and problem solving can be accepted by students only after hours of laboratory work.

At the beginning of XXI century, real laboratory work is often replaced with computer simulations, which offers the same studying possibilities to future engineers, with lower cost and grater possibility for experimenting and independent work of students. Through graphical user interfaces, students can directly manipulate graphical representations of system and get instant feedback on effects. (Johansson, *at al.,* 1998)

Many universities have recently developed virtual laboratories in control that provide improved accessibility to students and reduce laboratory setup and maintenance cost (Johnston and Argawal, 1995; Sheng, *at al.,* 2000; Peric and Petrovic, 2000). Video or audio feedback is available for students through internet/intranet. Students can specify the control parameters, and the server performs actual control and sends back the results when the experiment session is over. There is also a possibility for controller to be implemented at the client side, while the server transmits the system response. Problem with this approach is that it often suffers from delays caused by traffic on the net.

At The University of Kragujevac, two versions of same educational tool are developed. Training version (Stevanovic, *at al.,* 2004), uses *all in one* principle, and it is designed for work on one PC. All tank parameters are known, and by using preset control options, students can prepare themselves for higher-level experiment presented in this paper.

Educational tool presented in this paper consists of two parts. One part presents plant, and it is located on server PC at The University of Kragujevac. The other part is located on user's PC at home, in the office or classroom, and it presents controller. Students can use graphical interface that is part of this program to set control parameters, and to connect controller with server. All calculations are done in real time, and the user should notice no difference between accessing this simulation and real tank experiment.

Users can experiment with already implemented PID, but they also have possibility to design their own control algorithm. In this case, plant parameters are unknown, so some kind of identification is expected before implementing control algorithm.

This simulation presents only the first step in creating virtual laboratory for automatic control on University of Kragujevac. Ultimate goal for authors of this paper is to replace simulation with real coupled tank system, while keeping user interface described below.

2. COUPLED TANK SYSTEM

In this paper, simulation tools designed for student's practice for the course Digital Control Systems, which is the course taught at mechanical and electronic faculties, particularly within the group for automatic control are described.

System (shown on figure 1), consists of a basin, a pump, and two reservoirs which are placed one above the other (*Quanser Consulting Inc*). Using the pump, water is injected from the basin into the upper reservoir (1), out of which water flows into lower reservoir (2) through the valve 1 which is controlled. From the lower reservoir, water flows through the valve 2 into the basin, thus completing the cycle.

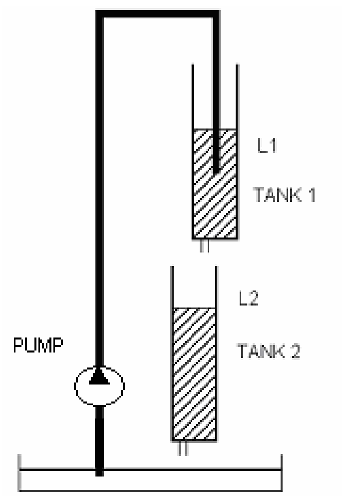

Figure 1. Coupled tank system

Reservoir volumes, as well as pump flow are random, and they change every time the server restarts.

The aim of this program is water level maintenance at the required levels.

System is described by the following equations:

$$L_{k+1} = L_k + \begin{bmatrix} -\dfrac{g_1\alpha_1}{A_1} & 0 \\ \dfrac{g_1\alpha_1}{A_1} & -\dfrac{g_2\alpha_2}{A_2} \end{bmatrix} \sqrt{L_k} + \begin{bmatrix} T_n\dfrac{K_m}{A_1} \\ 0 \end{bmatrix} V_P$$

$$L_k = \begin{Bmatrix} l_{1k} \\ l_{2k} \end{Bmatrix}, \begin{cases} l_1, t = k \cdot T_n \\ l_2, t = k \cdot T_n \end{cases} \quad (1)$$

Where:

$$g_1 = \mathrm{T_n}\,\mathrm{a_1}\sqrt{2g}, \qquad g_2 = \mathrm{T_n}\,\mathrm{a_2}\sqrt{2g} \quad (2)$$

l_1, l_2 are water level in tanks 1 and 2,

α_1, α_2 are values of opened valve 1 & 2 (0-100%),

a_1, a_2 are measurements of valve 1 & 2,

A_1, A_2 are measurements of tanks 1 &2,

K_m is pump constant,

V_P is voltage on pump,

T_n is nominal time 10ms, and

$g = 981 \left[{cm}/{s^2} \right]$ gravity constant,

Block scheme of this system is given on figure 2.

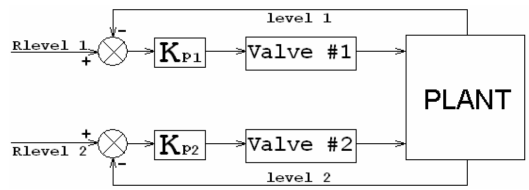

Figure 2. Block scheme of coupled tanks

3. THE USER INTERFACE

User interface for the program, which simulates the operation of the coupled tank system is shown on figure 3. It is divided into four parts.

The graphic representation of this system is given on the left. At the graph, the wanted and the real levels in reservoirs, as well as the valve opens are shown in two ways – numerically and graphically. Required level in tanks can be entered through the slider located to the left of their graphical presentations, or as the time function, which can be found in menu bar.

The central part of the interface is reserved for the graphic representation of this process. From the graphic we can read the real, wanted and measured level in both tanks, as well as the change in the valve openness.

Above the graphic is a button (ON/OFF) by which user can decide whether the system will be influenced by disturbance or not.

The tools for the process control are located under the graphic. The manual control is enabled as well as two different automatic types of control.

Taster <u>Time sample</u> (for control), can be chosen as multiplexer of 10ms.

Push button <u>Reset Time</u> clears previous values and starts measuring the time from 0, but this does not influence time function, which measures the time from the beginning of function.

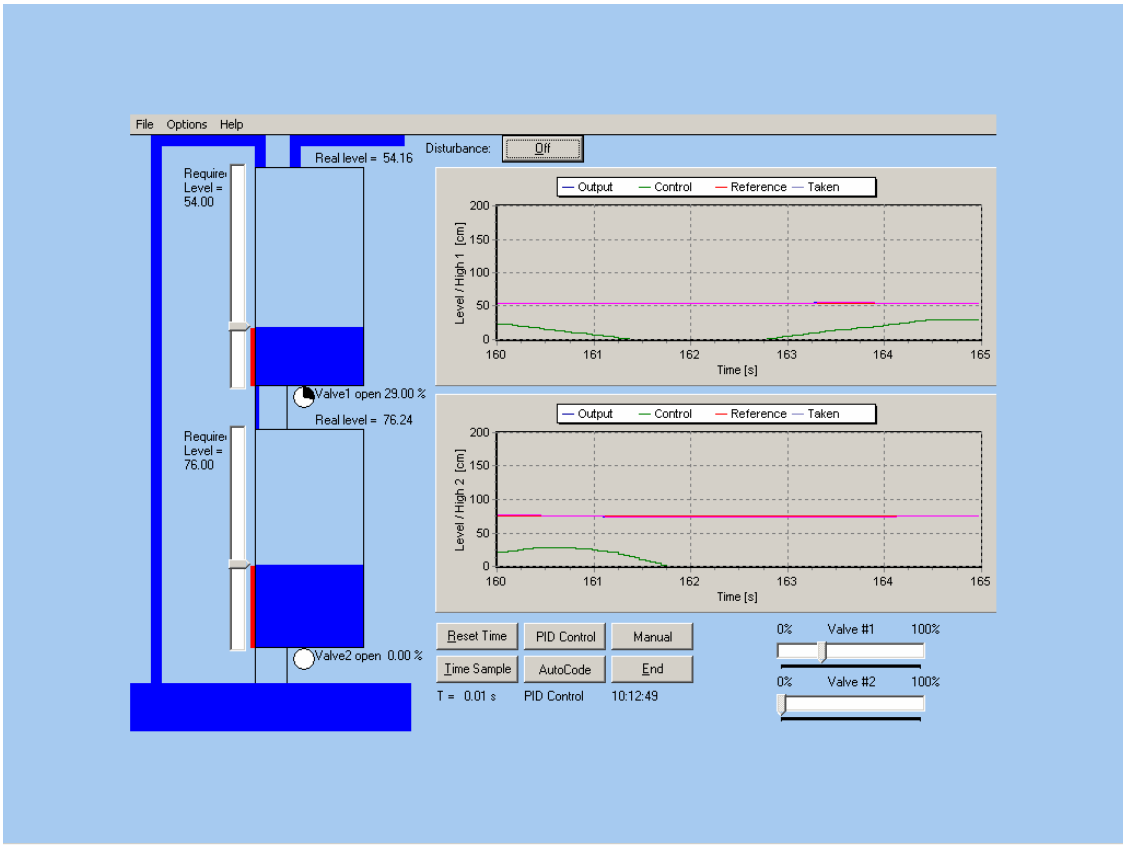

Figure 3. Graphical user interface

Push button Manual enables the manual control. Control is done by using the sliders: upper slider controls the valve of the upper tank, and the lower slider controls the valve of the lower tank.

Push button PID Control enables classical PID control, as in equation:

$$U_i = U_i + \left(K_{Pi} e_i + K_{Ii} e_i \Delta T + K_{Di} \frac{e_i - e_{iold}}{\Delta T} \right) \quad (3)$$

$$e_i = L_{zi} - L_i$$

Where:

- Ui – control signal for i-th valve
- Kpi – proportional reinforcement constant
- Kii – integral reinforcement constant
- Kdi – differential reinforcement constant
- ei – signal error
- Lzi – wanted level
- Li – real level in i-th tank
- deltaT – time between the two times of choosing

Standard values for gain constant (Kp) is 10, integral constant (Ki) and D constant (Kd) are 0, but it can be modified in any other value, for each valve independently uses the option in menu bar.

If during control process, valve should be open less than 0, it is set to 0, but if it should be greater than 1 (100%), then it is set to 1 (100%).

Push button Auto Code enables automatic control by user code, which is placed within **userscode.dll**. This file must be located in the same directory as **tank.exe**. Example project for ON/OFF control is given with user interface. Using any compiler capable of creating .dll files, users can create their own control algorithms.

Push button End stops the simulation and enables saving of the graphic together with data. Example of saved graphic is shown on figure 4.

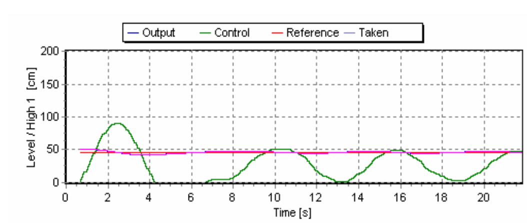

Figure 4. Example for saved graphic

Program possess the menu bar where, together with the standard options, changing of measurement resolution, valve resolution as well as the value of the reinforcement values for proportional control is possible. Also, there is option Connection that allows adjustment of the IP address which contains (plant)-program server.exe

In Options section we have following possibilities:

Graphics – graphic representation selection

Measurement Resolution – choice of fluids and water level measures

Valve Resolution – valve precision choice

Reference Time Function – maintenance of the desired water level due to time function

PID parameters P, I, and D control parameters selection

Disturbance – selection of amount of disturbance flow

Connect (Ctrl+C) – connection to the server and beginning of the simulation

Disconnect (Ctrl+D) – disconnect, and the termination of the simulation.

4. CONCLUSION

Software presented in this paper was widely accepted at The University of Kragujevac.

This program turned out to be extremely useful in student training, as well as in the process of their examining and grading.

By using this simulation, students are able to see advantages of different ways of automatic control over manual level correction. Also, they can experiment on their own and see the influence that valve resolution, measurement resolution, PID parameters or disturbance flow have on the automatic control.

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