New Educational Tool for Control Engineering

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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 modeling, 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. Educational tool presented in this paper is client - server based, which means that user can access it through internet or LAN connection. Users can experiment with already implemented control algorithms, but they also have possibility to design their own. Also, results achieved with different implemented control algorithms are being compared.*

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

I. 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. [1]

Many universities have recently developed virtual laboratories in control that provide improved accessibility to students and reduce laboratory setup and maintenance cost [2], [3], [4]. 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 [5], 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, ON/OFF or manual control algorithm, but they also have possibility to design their own. 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.

II 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 consists of a basin, a pump, and two reservoirs which are placed one above the other [6]. Using the pump, water is injected from the basin into the upper reservoir, out of which water flows into lower reservoir through the valve which is controlled. From the lower reservoir, water flows through the valve into the basin, thus completing the cycle.

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:

$$L_{k+1} = L_k + \begin{bmatrix} -\dfrac{g_1\,\alpha_1}{A_1} & 0 \\[2mm] \dfrac{g_1\,\alpha_1}{A_1} & -\dfrac{g_2\,\alpha_2}{A_2} \end{bmatrix} \sqrt{L_k} + \begin{bmatrix} T_n\dfrac{K_m}{A_1} \\[2mm] 0 \end{bmatrix} V_P$$

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

Where:

$$g_1 = T_n\, a_1\, \sqrt{2\,g}\,, \qquad\qquad g_2 = T_n\, a_2\, \sqrt{2\,g} \tag{2}$$

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

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

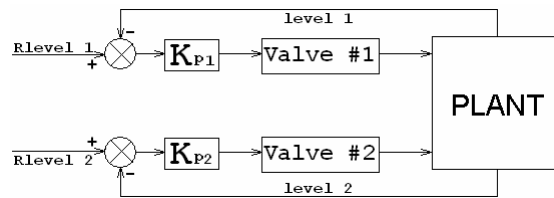Block scheme of this system is given on figure 1.

Figure 1. Block scheme of coupled tanks

III THE USER INTERFACE

User interface for the program, which simulates the operation of the coupled tank system, is shown on figure 2. 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 dis-

turbance 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 [7].
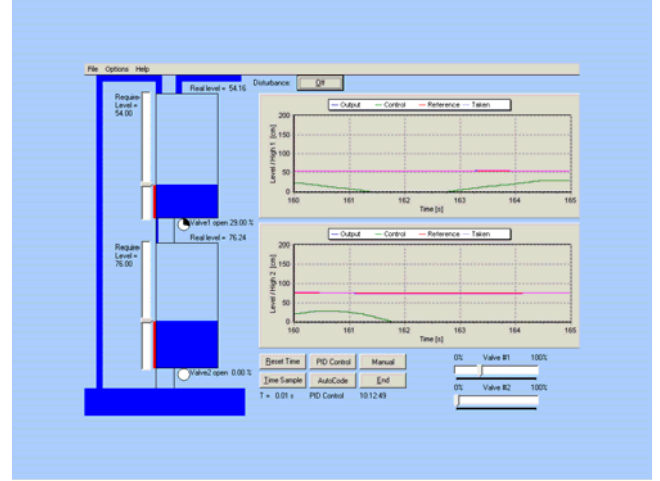

Figure 2. Graphical user interface

IV. IMPLEMENTED CONTROL ALGORITHMS

A. Experiment

In this chapter, differences between methods of automatic control are shown. Goal of experiment is to rise level from 50cm to 70cm in first, and from 50cm to 60cm in second tank, with all other conditions unchanged, using ON/OFF, PID and manual control.

B. ON/OFF control

One of the control algorithms implemented in software described in this paper is perfect ON/OF control. It is implemented under the AutoCode button, and can be changed by user. Results achieved using ON/OFF control are shown on figure 3.
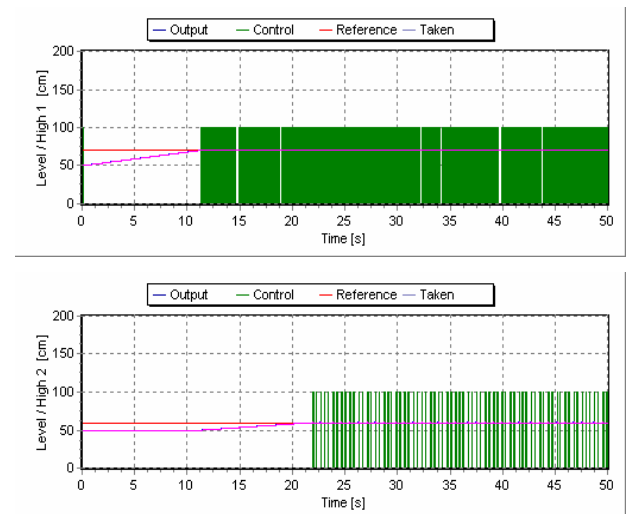

Figure 3. Graphical presentation of results for ON/OF control

B. PID control

Software explained in this paper, has implemented 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%).

Values for gain, integral and differential constants in example used for this paper are calculated using Zeigler-Nichols procedure. Achieved results are shown on figure 4.
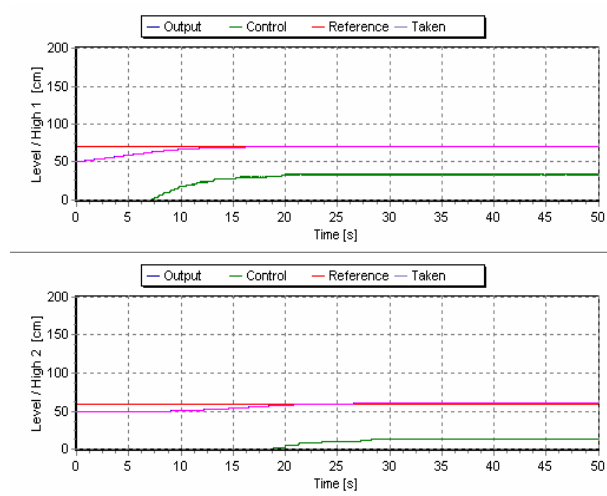

Figure 4. Graphical presentation of results for PID control

C. Manual control

Using PC mouse and sliders at the bottom of the user interface, users of this software are able to manually control levels in tanks. Example for results achieved using manual control by trained user, are shown on figure 5.
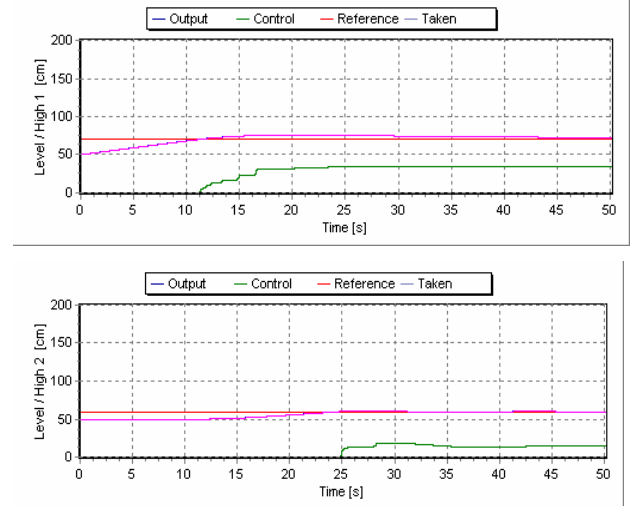

Figure 5. Graphical presentation of results for manual control

D. Comparing control algorithms

Figures 3, 4 and 5 shows that best results are achieved using perfect ON/OFF control, which has shortest response time and lowest steady state error. Unfortunately, perfect ON/OFF control, that shows best results in this simulation, can not be used in real systems, because of great mechanical pressure applied on valves, and because in perfect ON/OFF control momentary transfer between completely opened and completely closed valve is needed. Adding to perfect ON/OFF control linear function to transfer valve from full opened to full closed state, users can create real ON/OFF control.

Results achieved with PID control are also very good. Response time is only few seconds longer than with ON/OFF control, and steady state error is small. Considering that control signal needed for PID algorithm can be easily achieved, it is obvious that PID control is the best solution for practical problems, if one has to chose between algorithms already implemented in this software.

Manual control leads to highest response time and steady state error. Also, it acquires constant attention of the user. It should be used only when it is necessary, or for comparing results with any of the implemented or user defined control algorithms.

V. 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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