TEACHING ADAPTIVE CONTROL WITH DS1102 DSP CONTROLLER BOARD

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Abstract: The paper describes the experimental setup for teaching adaptive control to undergraduate students. This has been built using the standard Pentium III – based PC, DS1102 DSP Controller Board and software both standard and purpose written. The experimental results to show the capabilities of the lab are presented. This presents how the students can prepare their own experiments with different adaptive control schema. The laboratory presented has been applied in teaching modern control to the third year students of Electrical Engineering.

Keywords: adaptive control, DSP controller, control education

1. INTRODUCTION

There is a growing need to teach the undergraduate students more advanced topics in control theory and engineering. This includes robust control, optimal control, nonlinear control and adaptive control. This paper describes the effort undertaken at Warsaw University of Technology in order to introduce the basic laboratory setup for undergraduate students to learn fundamentals of adaptive control. The aim of this effort was to prepare a laboratory equipment composed of a Pentium III based PC with a DS1102 DSP controller board, electronic external plant model and software to implement different adaptive control algorithms. The algorithms implemented were uploaded to the DSP board internal memory and this allowed the hardware-in-the-loop configuration. This way a flavour of real-time adaptive control was given to the students.

2. EXPERIMENT DESCRIPTION

In our laboratory setup, a DS1102 Controller Board by dSPACE GmbH and a Pentium III - based PC are used. The board is designed as an ISA card and is based on the Texas Instruments TS320C31 floating-point processor. This card contain also:

- SRAM memory for loaded programs
- 4 A/C converters (two 16-bits and two 12-bits) and 4 12-bits C/A converters, which allow to connect the real object.
- Slave signal processor 320P14, which is responsible for binary input/output, PWM output, encoder input,
- ISA interface,
- serial connector,

The ISA interface allows us to adjust the loaded program variables. It means that we can change the control system parameters on-line without having to stop the execution of the loaded control algorithm. It also allows us to track the system variables and parameters, also those being estimated throughout the adaptive control process. The block diagram of the board is given in Figure **??** (?) (?)

This control system environment enables the demonstration of several basic adaptive control algorithms, (?) like:

1. deterministic self-tuning regulator (STR) – direct and indirect
2. minimum variance regulator (self-tuning) (MVR) (?)
3. Model Reference Adaprive Control (MRAC)

Adaptive control algorithms were implemented in C/C++ language (?) (?) .

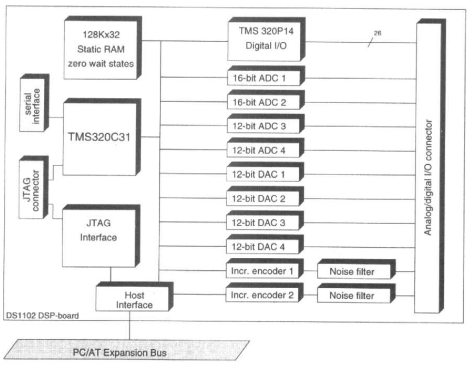

Figure 1. DS1102 Controller Board block diagram

As a model we used "I or II degree electronic model board" which was based on operational amplifiers.

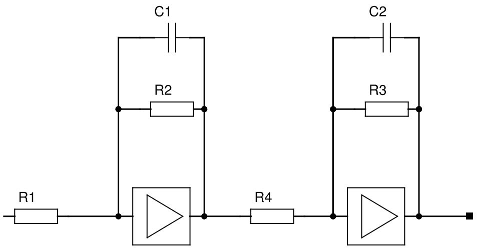

Figure 2. I or II degree electronic model board scheme.

The model's transfer function is given by

$$G(s) = \frac{\frac{R_1}{R_2}}{\frac{C_1}{R_2}s + 1} \frac{\frac{R_3}{R_4}}{\frac{C_2}{R_4}s + 1}. \qquad (1)$$

This board allows us to change the model parameters, that makes it possible to better explain and understand how adaptive algorithms cope with the changing plant parameters. In examples which are shown below, we will consider two groups of parameters describing two objects.These parameters are:

I) $R_1 = R_2 = R_3 = 10k\Omega$,
$C_1 = 0.1\mu F$, $C_2 = 0.7\mu F$
II) $R_1 = R_2 = R_3 = 10k\Omega$,
$C_1 = 0.1\mu F$, $C_2 = 0.9\mu F$,

giving two transfer function:

$$T_I(s) = \frac{1}{7 * 10^{-22}s^2 + 8^{-11}s + 1} \qquad \text{(I)}$$

$$T_{II}(s) = \frac{1}{9 * 10^{-22}s^2 + 10^{-11}s + 1}. \qquad \text{(II)}$$

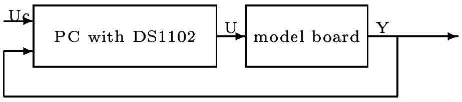

Figure 3. General control scheme.

Estimation model is given by the following discrete transfer function

$$T(z) = \frac{b_0 z + b_1}{z^2 + a_1 z + a_2}, \qquad (2)$$

with sampling time Ts=0.001s.

Control law used in all the algorithms is given by the equation (?)

$$Ru(t) = Tu_c(t) - Sy(t) \qquad (3)$$

The figure 3 shows object response (upper waveform) and reference (lower waveform). Because reference signal will be the same in all examples in next pictures instead of this signal we will use a control signal. It allows also to show regulator adaptation to the different objects more clearly.

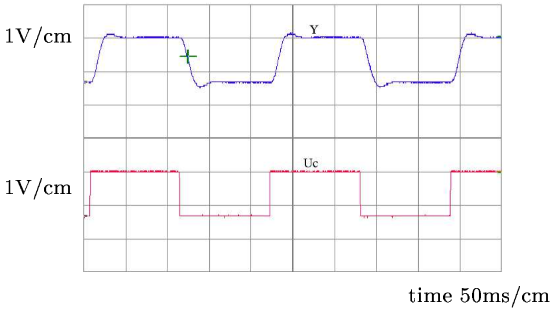

Figure 4. Response (Y) and reference (U_c) from object with indirect STR with zero cancellation

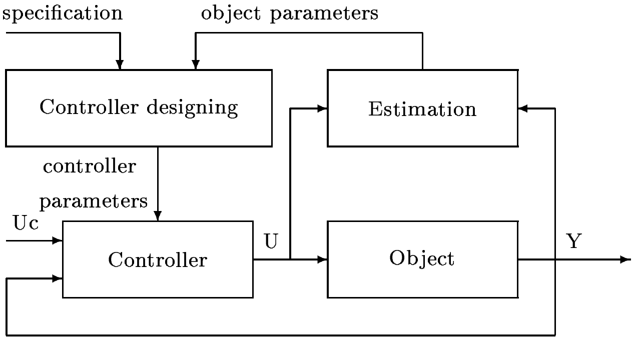

Figure 5. General indirect adaptive control algorithms block diagram.

In figure 4 we may see the general idea of adaptive control setup. Parameters of the object are estimated and the estimates are passed to an algorithm which calculates parameters of the controller. These parameters are used in feedback control loop and are adjusted on-line using DS1102 board.

Now we will present experimental results of the selected adaptive control algorithms.

2.1 Deterministic indirect STR with zero cancel

Estimated parameters for:

object I

$$\hat{b}_0 = 0.06510 \qquad \hat{b}_1 = 0.02614$$
$$\hat{a}_1 = -0.81179 \qquad \hat{a}_2 = -0.04758$$

object II

$$\hat{b}_0 = 0.052412 \qquad \hat{b}_1 = 0.03074$$
$$\hat{a}_1 = -0.611700 \qquad \hat{a}_2 = -0.25741$$

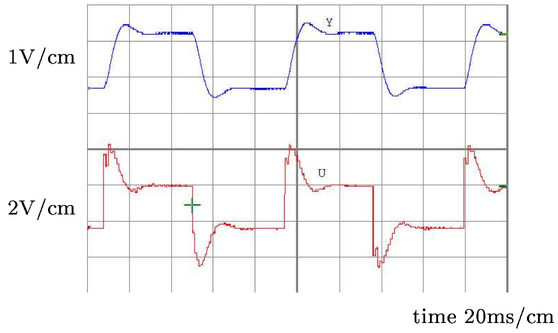

Figure 6. Object I with indirect STR with zero cancellation.

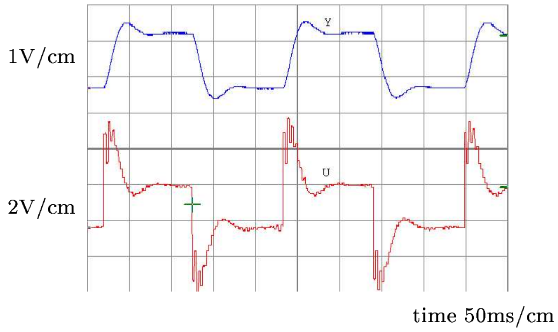

Figure 7. Object II with indirect STR with zero cancellation.

Picture 7 shows output and control signal for object I. Picture 8 shows the same for object II. In this pictures we can see that despite changes of objects parameters output is nearly the same. Different control signal better explains adaptation of regulator parameters.

2.2 Deterministic indirect STR without zero cancel

Object's parameters estimates:

for object I

$$\hat{b}_0 = 0.06490 \qquad \hat{b}_1 = -0.00803$$
$$\hat{a}_1 = -1.16142 \qquad \hat{a}_2 = 0.26039$$

for object II

$$\hat{b}_0 = 0.11730 \qquad \hat{b}_1 = -0.03601$$
$$\hat{a}_1 = -0.57607 \qquad \hat{a}_2 = -0.29338$$

2.3 Deterministic direct STR

Estimated parameters

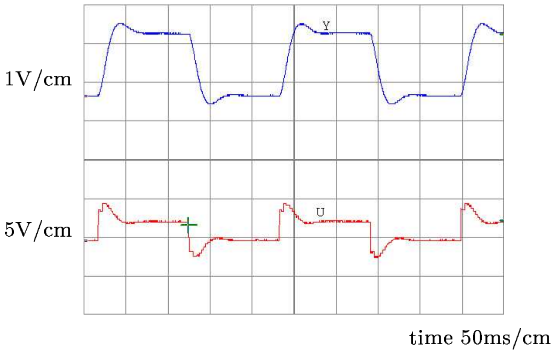

Figure 8. Response (Y) and control signal (U) from object I with direct STR without zeros cancellations.

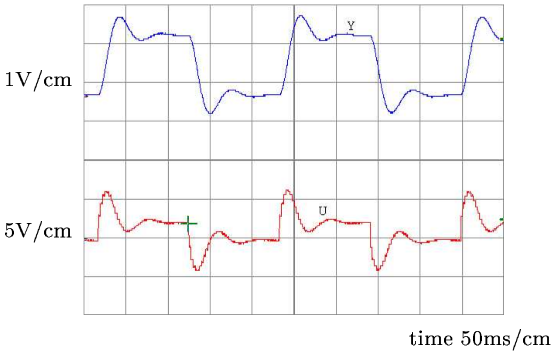

Figure 9. Response (Y) and control signal (U) from object II with direct STR without zeros cancellation.

for object I

$$\hat{r}_0 = 0.041 \qquad \hat{r}_1 = 0.0229$$
$$\hat{s}_0 = 0.0296 \qquad \hat{s}_1 = -0.124$$
$$\hat{t}_0 = -0.228$$

for object II

$$\hat{r}_0 = 0.0306 \qquad \hat{r}_1 = 0.0156$$
$$\hat{s}_0 = 0.0297 \qquad \hat{s}_1 = -0.105$$
$$\hat{t}_0 = -0.228$$

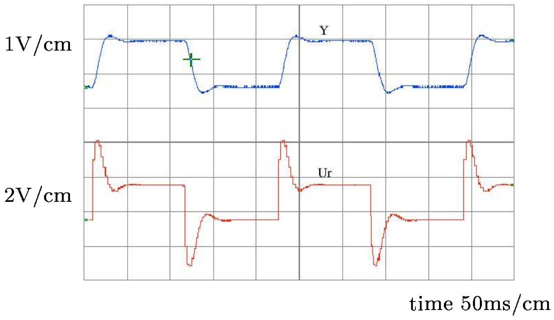

Figure 10. Object I with direct STR.

3. CONCLUSIONS

The results presented show the capabilities for the laboratory setup for teaching the adaptive control for undergraduate students at Warsaw University of Technology. The aim of the laboratory

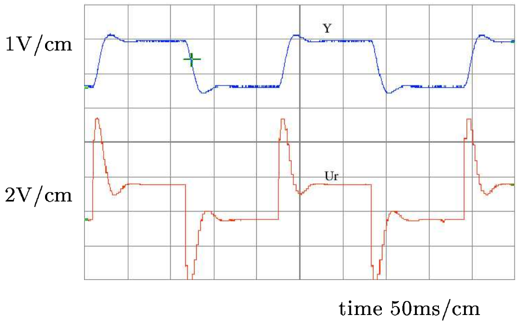

Figure 11. Object II with direct STR.

is to show the students the basics of adaptive control using standard PC and DSP controller board attached to the control plant. This setup allows us to introduce the fairly advanced control concepts to the third year Electrical Engineering students without the need of introducing some dedicated control, modeling and simulation tools. The software used is a standard MS Windows, user friendly environment augmented with adaptive control algorithms prepared at our group. The experimental results presented in the paper show the examples of the students laboratory exercise with deterministic STR. These exercises were aimed at demonstrating the capabilities of adaptive control and expose the very ideas of it. For this purpose different control algorithms were presented, both direct and indirect, with and without the zeros cancellations. The plant changes used are just example and the parameters changes of 20% presented can be increased. The laboratory setup described in the paper is easy to use and easy to explain to the undergraduates. It assumes only the basic knowledge of classical control plus fundamental knowledge of linear algebra, calculus and probability. There is also an option of remote access to the experimental PC via local area network (Gigabit Ethernet) and also using Internet. This is still the subject of further research.

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