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Training in the identification and adaptive control processes using the package ADAPLAB

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Abstract. This paper describes the development of a software for teaching process of the identification and adaptive control. Tree stage of training is proposed: at the beginning the plant structure and coefficients are known, then the plant coefficients are unknown and at last the structure and coefficients of a plant are unknown. The results of a laboratory experiment are given.

Keywords. Teachware, identification, adaptive control, education.

1 Introduction

A number of Computer Aided Instruction (CAI) [1] [2] and Computer Aided Control System Design (CACSD) [3] are developed for learning of the control theory topics such as a classical control theory and optimal control.

Training of identification [4] and adaptive control has a number of particularities that require of the training systems development occupied an intermediate position between CAI and CACSD. A base for building of such intermediate system may be CACSD ADAPLAB [5] that is a specialized package for finding of the identification and adaptive control algorithms parameters by a simulation of the identification and control process.

This paper presents a teachware for the package ADAPLAB provided a training in the identification and adaptive control processes.

2 Features and Capabilities of ADAPLAB

ADAPLAB allows to investigate the control systems that use the following methods of an identification and adaptive control: least square method (LSM) [6], finite-frequency method [7], an adaptive control on the basis of LSM, the direct and indirect finite-frequency methods of an adaptive control [7] and a model reference adaptive control [6]. The identification and adaptation algorithms parameters (sampling period, the amplitudes and frequencies of test signal, convergence adaptation indices etc.) obtained by a simulation in the presence of bounded disturbances are a result of ADAPLAB computation.

This package has two environments: CALC-USER and CALC-EDIT. The former intends for the practical engineers that introduce on a natural language the assumed plant model, external disturbance, directive number (depended on the methods and purposes of an identification and adaptation) the possible parameters of algorithm and then the package works automatic.

CALC-EDIT intends for the researchers that well know control theory and wish to create some own directives using the modules and special language ADAPLAB. This environment has the capabilities near to usual CADSD such as MATLAB, KEDDS [3] and ANDECS [8].

ADAPLAB is designed to run under MS-DOS on an IBM (or compatible) PC/AT, fitted a 640 K Byte memory and 20 M Byte hard disk. The programs has been written in Turbo Pascal 7.0 and MS-Fortran 5.0.

The environment CALC-USER is of interest for the training purposes and it will only be implied under the name ADAPLAB.

3 Teachware for ADAPLAB

To use ADAPLAB for the identification and adaptation training the following modules have been built: *an informative block* and *a plant regimes generator*.

An informative block contains a description of the above mentioned methods of the identification and adaptation. The description is built as "theory for user" in that a main attention is attracted to a algorithms steps sequence and the algorithms proofs are given in an appendix to the block. The theory description is ended by the block-diagrams of algorithms and the program texts written in a simple language ADAPLAB. In addition, the informative block contains the methodical indications of a learning process.

A plant regimes generator intends for forming of plant models unknown for a learner. To explain a generator operation the following example is used.

Let a teacher using a computer screen specify an equation

$$\dot{y} + 10\%70y = 3u + 4\sin 100\%80t. \qquad (3.1)$$

It means that the plant in the first regime is described by the equation

$$\dot{y} + 10y = 3u + 4\sin 100t, \qquad (3.2)$$

where $y(t)$ is the measured output $u(t)$ is a test signal, $\sin 100t$ is the disturbance.

In the second regime the plant is described by the equation

$$\dot{y} + d_0^{(2)}y = 3u + 4\sin\omega^{(2)}t, \qquad (3.3)$$

where $d_0^{(2)}$ and $\omega^{(2)}$ are the random numbers from intervals $3 \leq d_0^{(2)} \leq 17$, $20 \leq \omega^{(2)} \leq$ ≤ 180, whom boundaries are determined by the values 70% and 80%. Let the values $d_0^{(2)} = 15$ and $\omega^{(2)} = 50$ be realized in the second regime then the random parameters boundaries of the third regime is found as $15\%70$ and $50\%80$.

4 Training stages

The training consists of tree stages.

At the first stage the structure (a denominator and numerator degrees of a transfer function) and coefficients of the plant are known (a plant is "a clean box"). On this stage the learner strengthens a theory knowledge by way of the problems and exercises solutions and he/she gets the first customs of a experiment design. A result of this stage is the identification and adaptation algorithm parameters. In addition, a learner is informed about the results of each step of algorithm.

At the second stage a plant structure is known but its coefficients are unknown and they are formed by the regimes generator (a plant is a "gray box"). This stage simulates the conditions of a real experiment and that is why a learner is informed only about such result of the algorithm steps that are accessible in a real experiment. The algorithm parameters obtained at the first stage are corrected on this stage.

At the third stage the plant structure and coefficients are unknown (a plant is a "black-box"). Here the plant is formed by way of complementing so-named "unmodeling-dynamic" to the second stage plant. An influence of this "dynamic" on the plant structure depends on a accuracy requirement of identification and the adaptation purposes.

5 Finite-frequency identification. Laboratory experiment

Consider a plant described by the equation [9]

$$(5\%70s+1)(s^2+6s+25)y=$$

$$=25\%80(1-0.4s)u+25\cdot 0.02\%60\cdot \mathbf{1}(t),$$

$$s=\frac{d}{dt} \qquad (5.1)$$

It is required to identify its coefficients using the finite-frequency method.

During the first stage the parameters (amplitudes and frequencies) of the test signal

$$u(t)=0.001\sin 0.02t+0.01\sin 2t+0.02\sin 4t \qquad (5.2)$$

have been determined.

The plot of the output plant exited by the step disturbance $f(t)=0.02\cdot\mathbf{1}(t)$ and the test signal (5.2) is shown on Fig. 1.

The identification result is the following model of the plant.

$$4.67(5.1s+1)(0.0418s^2+0.244s+1)y=$$

$$=4.736(1-0.407s)(0.007s+1)u \qquad (5.3)$$

The plots of the plant (5.1) output (curve 1) and model (5.3) output (curve 2) under $u(t)=\mathbf{1}(t)$ and $f(t)=0$ are given on Fig. 2. The test signal (5.2) has been used on *the second stage*. The identification result has the view.

$$9.98(2.504s+1)(0.04s^2+0.24s+1)y=$$

$$=15.57(1-0.4s)(1-0.0032s)u \qquad (5.4)$$

The plot of the output plant (curve 1) under this test signal and step disturbance (whose "amplitude" is unknown for the learner) and the modal (5.4) output (curve 2) under same signal of the test are shown on Fig. 3. Comparing these plots it is easily to see that they coincide almost and therefore the model (5.4) is well-grounded.

References

[1] Essenius R. P., Honderd G., Jongkind W. *"Inspection interactive system for pre-examination exercises on control theory"*. *12th World Congress IFAC. Preprints of papers*, vol. **6**, 1993.

[2] Kornefors R., Lenelis M., Haltgren A. *"A hyperbook on automatic control"*. *12th World Congress IFAC. Preprints of papers*, vol. **6**, 1993.

[3] Jamshidi M., Herget C. J. *"Computer-aided Control System Engineering"*. *North-Holland*, 1985.

[4] Szafnicki K., Gentil S. *"Towards a Knowledge-Based Training Tool for Identification with Bench-mark"*. *10th IFAC Symposium on System Identification. Preprints*, vol. **2**, 1994.

[5] Alexandrov A. G., Orlov Yu. F. "*ADAPLAB - Computer Aided Design of frequency adaptive control*". *2th IFAC Symposium on Intelligend Components and Instruments for control application. Preprints*. 1994.

[6] Astrom K. J., Wittenmark B. "*Adaptive Control*". *Addison-Wesley*. 1989.

[7] Alexandrov A. G. "*Toward Finite-Frequency Theory of control*". *12th World Congress IFAC. Preprints of papers*. vol. **9**. 1993.

[8] Grubel G., Joos H D., Otter M., Finsterwalder R. "*The ANDECS Design Environment for Control Engineering*". *12th World Congress IFAC. Preprints of papers*. vol. **6**, 1993.

[9] Graebe S.F. "*Robust and Adaptive Control of Unknown Plant: A Benchmark of New Format*". *12th World Congress IFAC. Preprints of papers*. vol. **3**, 1993.

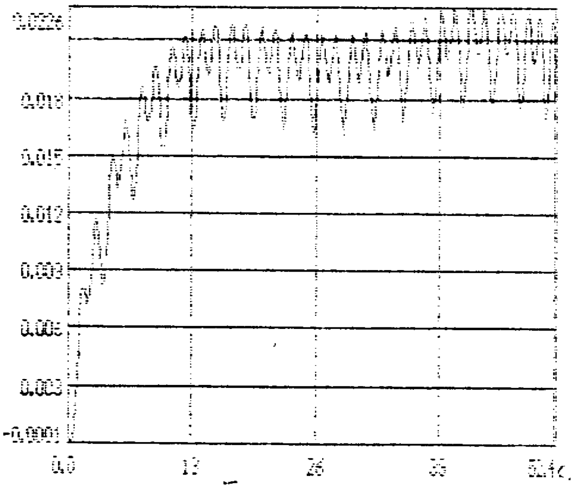

Fig. 1

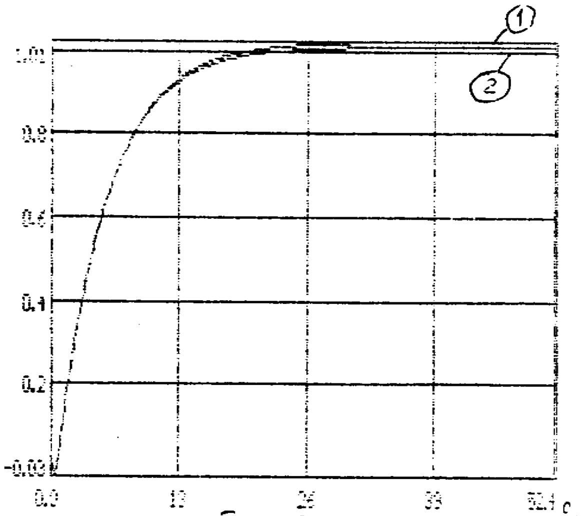

Fig. 2

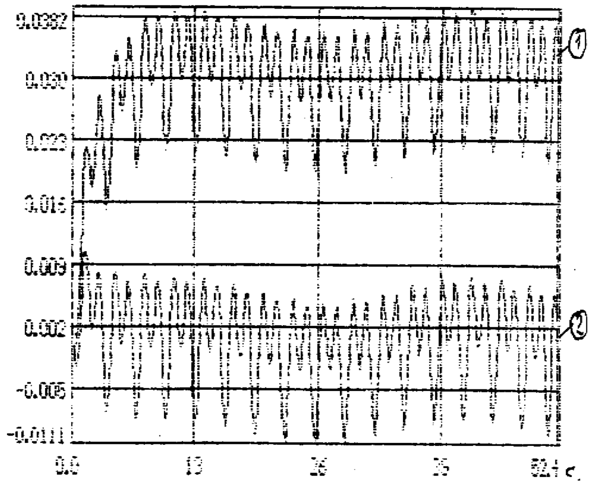

Fig. 3