COURSE DESCRIPTION CARD - SYLLABUS

Course name

Adaptive control

Course

Field of study	Year/Semester
Automatic Control and Robotics	1 / 1
Area of study (specialization)	Profile of study
Control and Robotics Systems	general academic
Level of study	Course offered in
Second-cycle studies	Polish
Form of study	Requirements
full-time	compulsory

Number of hours

Lecture	Laboratory classes	Other (e.g. online)
30	30	0
Tutorials	Projects/seminars	
0	0	

Number of credit points

4

Lecturers

Responsible for the course/lecturer:

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Responsible for the course/lecturer:

Prerequisites

A student should know fundamentals on statistics and theory of systems and control (state-space description of systems, input-output description of systems in the continuous and discrete time domains, Laplace and Laurent transformations, Lyapunov stability analysis, linearization and linear approximation of dynamics). Moreover, a student should have basic design skills in control systems for linear plants, skills in Matlab and ANSI C programming, in implementing and simulating of block schemes in the Simulink environment; should have skills to acquire knowledge from indicated sources, and should be ready to cooperate in a team.

Course objective

Extension of student's knowledge on designing and validation of experimental models for static and dynamic systems build based on measurement data taken from a plant; familiarization of students with selected identification techniques and methods, and shaping skills in implementation and practical utilization of identified models; presentation, explanation, and analysis of selected adaptive control methods and techniques used in automatic control systems; shaping skills in practical implementing of basic adaptive control systems and shaping skills needed for cooperation in a small team.

Course-related learning outcomes

Knowledge

1. Deepen knowledge on selected computational techniques and mathematical methods needed for solving specialized tasks of system identification. [K2_W1]

2. Knowledge of underlying model structures used for description and identification of models for dynamical systems in the continuous and discrete time domains; extended knowledge on identification methods for static and dynamic systems (linear and nonlinear) defined in the continuous and discrete time domains. [K2_W5]

3. Theoretical and practical knowledge on selected algorithms and techniques of adaptive control for linear and nonlinear systems; knowledge of applicability conditions for adaptive control methods. [K2_W9]

4. Basic knowledge on applying the supervision and safety nets in adaptive control systems; knowledge of exemplary commercial systems utilizing adaptive control techniques. [K2_W9]

5. Awareness of the need for supervisory and protection circuits in adaptive systems; knowledge of practical examples of adaptive systems and knowledge of examples of commercial systems using adaptive techniques. [K_W9]

Skills

1. Conducting an identification procedure of a system using either synthetic data or data recorded from a real plant. [K2_U15]

2. Development and validation of experimental models of single-input (SISO/MISO) systems and their utilization for adaptive control purposes. [K2_U10]

3. Selection of appropriate methods and tools for solving design tasks in the areas of system identification and adaptive control. [K2_U22]

4. Implementation and testing of selected types of adaptive control systems in a simulation environment and in a fast-prototyping testbed. [K2_U9]

5. Preparation and presentation of laboratory results. [K2_U8]

Social competences

1. Ability to cooperate in a team with a responsibility for a common task. [K2_K3]

2. Consciousness of neccessity to professionally approch to technical tasks. [K2_K4]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

A) For lectures: Verification of the teaching results in the form of a final selection test written by students. The test includes 30 questions, every one with A,B,C,D answers, where two of them are correct and other two are false. A student earns maximally 1 point for a question if he/she selects two correct answers. One correct answer and one answer left empty results on 0.5 point. Other possibilities result in 0 points for a question. A positive mark from the test needs earning more than a half of a maximal possible number of points. The result determines the mark OT which, together with a mark OL from laboratory classes, determine (after rounding) the final mark OK computed as follows: OK = OT*0.7 + OL*0.3. The result OK < 3.0 leads to a negative mark from the course.

B) For laboratory classes: Verification of the teaching results is performed upon assessment and 'defending' of a final written report prepared by the students teams from a second part of laboratory classes; three ingredients are assessed: quality of obtained results, quality of the report, and answers to questions formulated by an instructor with relation to the reported task.

Programme content

The course addresses the following topics:

- definition of a model, types and roles of models, identification as an alternative approach to modeling, pragmatic approach to empirical modeling, a general scheme of an identification procedure, modeling errors, properties of experimental models,

- structures of static models, universal structures of input-output models in the continuous and discrete time domains, linearity of the models with respect to parameters, model linearization with respect to parameters,

- predicting a response of a plant: the optimal one-step-ahead predictor vs. simulation model,

- non-parametric identification methods for transfer-function models (time response approach, correlation analysis, frequency analysis),

- properties and general identification schemes for models in the continuous and discrete time domains,

- equation error and output error, selected stochastic parametric identification methods: least squares of equation errors method (LS), weighted LS method, instrumental variable method (IV); statistical properties of selected identification methods,

- selected stochastic recursive identification methods: recursive LS (RLS), extended recursive LS (RELS), recursive IV method (RIV); constructions of instrumental variables; discussion of selected problems on implementation of recursive methods,

- adaptive recursive identification for systems with time-varying parameters (forgetting factor, covariance matrix resetting),

- remarks on designing an identification experiment (planning an experiment, initial data processing, SVF filtration, selection of a sampling frequency, selection and shaping excitation signals, persistency excitation order),

- identification in a closed-loop control system,

- model quality assessment methods (flexibility and parsimony of models); model reduction, final model selection,

- the concept of adaptation and adaptive control, definition of an adaptive control system, objectives of adaptive control; properties of the ideal and practical adaptive control systems; general scheme of an adaptive control system; remarks on practical applicability of adaptive control and a decision scheme of adaptive control application,

- application of identification in adaptive control and in tunning of controllers,

- the main adaptive control techniques/schemes: MIAC-STR (Model Identification Adaptive Control – Self Tuning Regulator), MMAC (Multi-Model Adaptive Control), AT (Autotuning), MRAC (Model Reference Adaptive Control), P/GS (parameters/gains scheduling), ADRC (Active/Adaptive Disturbance Rejection Control),

- selected issues on practical implementations of adaptive control systems (supervision and safety nets),

- discussion of exemplary commercial adaptive control systems.

Laboratory classes are organized as fifteen 2-hour meetings in a laboratory room. In the first part of classes, all students (divided into teams of 2-4 persons) perform the same set of simulation tasks:

- analysis of deterministic signals and stochastic processes in the time and frequency domains (stationary stochastic process and its mean and variance, white and colored noise, correlation function of signals, periodogram, power spectrum of a signal),

- non-parametric identification of SISO systems (time-response methods, correlation analysis, frequency-domain analysis),

- batch versions of LS and IV parametric estimation methods for the static and dynamical systems

- recursive versions of LS and IV identification methods (RLS, RIV, adaptive recursive identification – forgetting factor and covariance resetting).

In the second part of classes, every team of students chooses one design task among a set of prescribed tasks. Every task is devoted to a topic adaptive control design, implementation (Code Composer Studio, VisSim, Matlab-Simulink Real Time Workshop), and testing on a fast-prototyping testbed equipped with a real plant (PMxR, ZB2, HILSys, 3DCrane, TRAS, PME1R). The teams prepare a final report which presents the results obtained during realization of the task.

Teaching methods

A) Lectures: Presentation of slides illustrated by additional examples provided and analyzed on a blackboard.

B) Laboratory classes: Organized as fifteen 2-hour meetings in a laboratory room. Tasks are performed in teams of 2-4 students. In the first part of a semester – programming-computing and simulation excercises (Matlab-Simulink environment). In the second part of a semester – practical control design tasks assigned separately to every team (design, implementation and testing of a selected adaptive control system on a fast-prototyping testbed).

Bibliography

Basic

[1] System identification, T. Soderstrom, P. Stoica, Prentice Hall Int. 1989 [2] Adaptive control. Second edition, K. J. Astrom, B. Wittenmark, Addison Wesley, 1995

Additional

[3] Adaptive control tutorial, P. Ioannou, B. Fidan, SIAM, Philadelphia 2006

[4] Adaptive control. Algorithms, analysis and applications. Second edition, I. D. Landau, R. Lozano, M. M'Saad, A. Karimi, Springer, London, 2011

[5] Robust and adaptive control with aerospace applications, E. Lavretsky, K. A. Wise, Springer, London, 2012

[6] Advanced PID control, K. J. Astrom, T. Hagglund, ISA, 2006

[7] Multivariable system identification for process control, Y. Zhu, Pergamon Elsevier Science, 2001

[8] Identyfikacja obiektów sterowania. Metody dyskretne, A. Królikowski, D. Horla, WPP, Poznań, 2005

[9] Cyfrowe przetwarzanie sygnałów. Od teorii do zastosowań, T. P. Zieliński, WKŁ, Warszawa, 2007

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,0
Classes requiring direct contact with the teacher	60	2,5
Student's own work (literature studies, preparation for laboratory classes, testing the programs after classes, preparation of a final report from laboratory classes, preparation to a credit for classes, preparation for a final test [1]	40	1,5

[1] delete or add other activities as appropriate