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
Smart Aerospace and Autonomous Systems	general academic
Level of study	Course offered in
Second-cycle studies	English
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:

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Prerequisites

Before taking this course, each student should poses basic knowledge in mathematical statistics as well as in control and systems theory (state-space representation, input-output description in continuous and discrete time-domains, Lyapunov stability analysis, Taylor-approximation of nonlinear systems). A student should also possess the ability to solve basic problems of feedback control design for linear systems, should possess basic programming skills in Matlab-Simulink environment, as well as the ability to acquire additional information from various sources. Moreover, a prospective student should be able to practically use the basic communication-information technologies, and should be ready for team work activities during the course.

Course objective

Extension of the students' knowledge in the scope of design and application of mathematical models of plants/processes based on experimental data by introduction to various parametric identification techniques and their implementation and practical utilization. Presentation and explanation/analysis of various adaptive control methods with their exemplification in automation and robotics. Teaching the implementation skills of selected adaptive control algorithms in a simulation environment.

Course-related learning outcomes

Knowledge

1. Extended knowledge in the scope of parametric identification methods (batch-type and recursive-type estimators) for static and dynamic, linear and nonlinear plants/processes described in continuous-time and discrete-time domains. Knowledge on selected model structures, basic methods of model validation, basic problems and their solutions related to practical applications of identification methods (also in a closed-loop system). Knowledge how to utilize the empirical models of a plant/process in the selected schemes of adaptive control; knowledge on basic techniques of adaptive recursive identification for parameter-varying plants/processes. [K2_W5]

2. Knowledge and understanding of such terms as adaptation and adaptive control. Knowledge on the main objectives of adaptive control and properties of an ideal and a real adaptive control systems; knowledge on a decision scheme of application of the adaptive control schemes. [K2_W7],[K2_W9]

3. Basic theoretical and practical knowledge in the scope of selected adaptive control techniques. [K2_W7],[K2_W9]

4. Awareness of a necessity of supervision and safety nets application in the practical adaptive control systems. [K2_W7],[K2_W9]

Skills

1. Construction and validation of simple empirical models for single-input single-output (SISO) systems, and their practical utilization in adaptive control systems. [K2_U10]

2. Ability to select a proper adaptive control algorithm to the stated control problem; ability to implement and commission the algorithm in a simulation environment. [K2_U9],[K2_U22]

3. Multi-criteria evaluation of control quality for selected adaptive control methods. [K2_U19]

4. Preparation and presentation of the results obtained during the laboratory classes. [K2_U8]

Social competences

1. Ability to work in a small team taking responsibility for a given task. [K2_K3]

2. Awareness of a necessity to professionally approach the technical problems presented during the course. [K2_K4]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

A) Lectures: Rating is decided upon the exam in the form of a selection test. The test comprises 30 technical questions. Four different answers (A, B, C, and D) are provided for every question, where two of them are correct and the other two - incorrect. Selection of two correct answers gives 1 point for a question. Selection of a single correct answer and leaving the second answer unselected gives 0.5 point for a question. Selection of a single correct answer and a single incorrect one implies zero points for a question. Other types of selections (or their lack) imply zero points for a question. Positive rating TR from the test requires collecting at least 15.5 points. A final rating FR from the course is obtained according to the rule: FR = TR*0.7 + LR*0.3, where TR is a rating received from the selection test, and LR is a final rating received from the laboratory classes (note: FR < 3.0 implies negative final mark from the course).

B) Laboratory classes: Final rating results from the overall quality assessment of the tasks realized by the students; the assessment concerns: (a) technical quality of the obtained results, (b) quality of the implementation details, and (c) a 'defense' of the tasks in the form of answers to detailed questions related to topics covered by the laboratory classes.

Programme content

The course covers the following topics:

- introduction to system identification and selected parametric identification techniques: model definition, types of models, identification as an alternative pragmatic approach to system modeling, properties of experimental models, selected structures of static and dynamic input-output models (in continuous-time and discrete-time domains), linearity of models with respect to parameters (linear regression), linearization of models with respect to parameters, simulator vs. one-step ahead predictor, general schemes of parametric identification for continuous-time and discrete-time model structures, selected stochastic estimation methods (Least Squares, Recursive Least Squares, Extended Recursive Least Squares), comments on implementation of recursive estimation methods, adaptive recursive identification for systems with time-varying parameters (forgetting factor, covariance resetting), selected practical issues concerning the system identification (the State Variable Filters method, sampling time selection, persistent excitation property of input signals, problems of identification in a closed-loop system),

- introduction to adaptive control: a concept of adaptation and adaptive control, objectives of adaptive control, properties of an ideal and a real adaptive control system, a general scheme of an adaptive control system, remarks on applicability of adaptive systems, a decision-making scheme for the adaptive control application,

- selected schemes of adaptive control systems: Model-Identification Adaptive Control - Self-Tuning Regulator (MIAC-STR), Multi-Model Adaptive Control with supervised switching (MMAC), Model-Reference Adaptive Control (MRAC) in the direct approach, Parameters/Gains Scheduling approach (P/GS), Lyapunov-based adaptive control schemes (LbAC), Active/Adaptive Disturbance Rejection Control (ADRC),

- implementation examples of selected adaptive control systems and their analysis; selected issues on practical implementation of adaptive control systems (identifiability in a closed-loop system, persistent excitation, supervision/safety nets, saturation of control signals, sampling time selections),

- examples of commercially available adaptive control systems.

Lectures are performed using multimedia presentations illustrated with simulation examples and occasional mathematical derivations on the blackboard.

Laboratory program covers the following topics:

- simple deterministic time-response methods of SISO system identification,

- parametric identification by the batch-type Least Squares method,

- recursive parametric identification by the Recursive Least Squares method for the time-invariant and time-varying parameters,

- adaptive control in the MIAC-STR scheme with a pole-placement controller synthesis,

- adaptive control in the MRAC scheme,

- adaptive control in the ADRC scheme.

Teaching methods

A) Lectures: multimedia presentations (slides) illustrated with selected numerical/simulation examples, together with additional mathematical derivations provided on a blackboard.

B) Laboratory classes: practical computer excercises performed in the 2-person groups in the Matlab-Simulink environment.

Bibliography

Basic

1. Robust and Adaptive Control with Aerospace Applications, E. Lavretsky, K. A. Wise, Springer-Verlag, London, 2013

2. Adaptive Control. Second Edition, K. J. Aström,, B. Wittenmark, Addison Wesley, 1995

3. System Identification, T. Söderström, P. Stoica, Prentice Hall International, Cambridge, 1989

Additional

1. Adaptive Control. Algorithms, Analysis and Applications, I. D. Landau, R. Lozano, M. M'Saad, A. Karimi, Springer, London, 2011

2. Stable Adaptive Systems, K. S. Narendra, A. M. Annaswamy, Dover Publications, New York, 2005

3. Robust adaptive control, P. Ioannou, J. Sun, Dover Publications, New York, 2012

4. Adaptive Control Tutorial, P. Ioannou, B. Fidan, Advances in Design and Control, SIAM, Philadelphia 2006

Breakdown of average student's workload

	Hours	ECTS
Total workload	116	4,0
Classes requiring direct contact with the teacher	63	2,0
Student's own work (literature studies, preparation for laboratory classes, testing the programs after classes, preparation for the exam)[1]	53	2,0

[1] delete or add other activities as appropriate