POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
Adaptive control [S2AiR2-SIiB>SA]

Course

Field of study
Automatic Control and Robotics

Year/Semester
1/1

Area of study (specialization)
Intelligent and Unmanned Systems

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
30

Other (e.g. online)
0

Tutorials
0

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

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

The objectives of the course are: discussion of selected techniques of recursive identification of dynamic systems and formation of skills of their implementation and practical use; introduction and explanation of selected techniques and algorithms of adaptive control used in automation and robotics systems; formation of skills of practical implementation of basic control systems adaptive control systems and shaping the ability to work in a small team.

Course-related learning outcomes

Knowledge:
1. The properties and uses of selected computational techniques necessary to solve specialised tasks in the identification of dynamical systems. [K2_W1]
2. Knowledge of selected types and structures of dynamical systems models for recursive identification in continuous and discrete time domain. K2_W5]
3. Theoretical and applied knowledge of selected adaptive control techniques and algorithms for linear and non-linear dynamic systems; knowledge of the applicability conditions of adaptive control methods. [K2_W9]
4. Basic knowledge of supervisory and protection circuits in adaptive systems; knowledge of examples of commercial systems using adaptive techniques. [K2_W9]

Skills:
1 Determine empirical dynamic models of single-input single-output (SISO/MISO) systems and be able to use them to design control systems. [K2_U10]
2. Select appropriate methods and tools to solve specific recursive identification and adaptive control tasks. [K2_U22]
3. Implement selected types of adaptive control algorithms and run them in a simulation environment and also in a rapid prototyping environment using real physical objects. [K2_U9][K2_U15].
4. Prepare and present the results of laboratory work. [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) In the scope of lectures the verification of the assumed effects of learning is realised through the assessment of the student's knowledge demonstrated during the completion of the lecture content in the form of a choice test; the test contains 30 questions - each with four answers A, B, C, D, of which two are correct and two are false; the choice of both correct answers by the student gives 1 point for a given question; the choice of one correct answer and leaving the other one blank gives 0.5 point for a given question; the choice of one correct answer and one false answer results in lack of point for a given question (other choices, or no choice at all, will also result in a failing score for that question). To pass the test at least 15.5 points is required to be earned.
B) As far as the laboratory classes are concerned, the verification of the assumed learning outcomes is realised through the assessment and 'defence' by the student team of the final report from the realisation of the rapid prototyping task; the quality of the obtained results, the content and quality of the final report, as well as the answers to factual questions related to the performed task and/or to the scope of the material covered in the laboratory classes are checked and assessed.

Programme content

The course covers the following topics:
- design and analysis of selected adaptive control algorithms,
- implementation issues concerning adaptive control systems,
- simulation and experimental verification of selected adaptive control laws,
- discussing selected applications of adaptive controllers.

Course topics

The lecture addresses the following detailed 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: multimedia presentation (slides) further illustrated by examples given and analysed on the blackboard.
B) Laboratory exercises: performance of programming, calculation, simulation and rapid prototyping tasks of control systems in topics given by the lecturer - practical exercises.

Bibliography

Basic:
[1] Robust and adaptive control with aerospace applications, E. Lavretsky, K. A. Wise, Springer, London, 2012
[2] Adaptive control. Algorithms, analysis and applications. Second Edition, I. D. Landau, R. Lozano, M. M'Saad, A. Karimi, Spronger, London, 2011
[3] Adaptive control. Second Edition, K. J. Astrom, B. Wittenmark, Addison Wesley, 1995

Additional:

[4] Wprowadzenie do identyfikacji systemów, M. M. Michałek, WPP, Poznań, 2023
[5] Adaptive control tutorial, P. Ioannou, B. Fidan, SIAM, Philadelphia 2006
[6] Direct adaptive control algorithms. Theory and applications. Second Edition, H. Kaufman, I. Barkana, K. Sobel, Springer, New York, 1998
[7] Advanced PID control, K. J. Astrom, T. Hagglund, ISA, 2006
[8] Cyfrowe przetwarzanie sygnałów. Od teorii do zastosowań, T. P. Zieliński, WKŁ, Warszawa, 2007

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	60	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	40	2,00