System modelling and identification - course description

General information

Course name	System modelling and identification
Course ID	11.9-WE-AutD-SysModelIdentyf.-Er
Faculty	Faculty of Computer Science, Electrical Engineering and Automatics
Field of study	Automatic Control and Robotics / Computer Control Systems
Education profile	academic
Level of studies	Erasmus programme
Beginning semester	winter term 2017/2018

Course information

Semester	1
ECTS credits to win	7
Course type	obligatory
Teaching language	english
Author of syllabus	• dr hab. inż. Andrzej Janczak, prof. UZ

Classes forms

The class form	Hours per semester (full-time)	Hours per week (full-time)	Hours per semester (part-time)	Hours per week (part-time)	Form of assignment
Lecture	30	2	-	-	Exam
Laboratory	30	2	-	-	Credit with grade

Aim of the course

To provide fundamental knowledge in system identification, including: input signal selection, model order selection, non-recursive and recursive identification methods.

To develop skills in building system models based on structure knowledge and input-output measurements, including nonparametric identification methods, parametric identification methods, neural networks and fuzzy models.

Prerequisites

Signals and dynamic systems, Control engineering, Artificial intelligence methods

Scope

Introduction. Plants and their models. Model using. System identification and mathematical modelling. Equivalence of models and model equivalence criteria. Parameter estimation. Identifications error definitions. Building system models based on structure knowledge and measurements. Identification algorithm scheme.

Nonparametric identification methods. Transient states analysis. Frequency identification methods. Correlation methods. Power spectrum analysis.

Least squares method. Linear static models. Least squares problem. Normal equations**.** Analysis of least squares estimator. Best linear unbiased estimator. Confidence intervals of parameter estimates. Model complexity. Finding the least squares solution with orthogonal-triangular decomposition. Recursive least squares algorithm.

Models of dynamic systems. Model classification. General structure of linear model. AR, AR, MA, ARMA, FIR, ARX, ARMAX, OE, and Box-Jenkins models. Multi-input multi-output models. Nonlinear models. Wiener and Hammerstein models. Volterra and Kolmogorov-Gabor models. State-space models. Model structure selection.

Input signals. Deterministic signals. Stochastic signals. Input signals used in system identification. Persistent excitation condition.

Prediction error method. Simulation and prediction. Optimal predictors. Least-squares estimation of ARX model parameters. Parameter consistency problem. Instrumental variables method. Choice of instrumental variables. Prediction error method.

Recursive identification. Properties of recursive identification algorithms. Recursive least squares method. Exponential forgetting. Recursive instrumental variables method. Recursive prediction error method. Parameter adaptation of self-tuning controller.

Closed-loop identification. Identifiability of closed-loop systems. Direct identification methods. Indirect identification methods. Influence of feedback loop on estimation accuracy.

Modeling of static and dynamic nonlinear systems using neural networks and fuzzy models. Neural network models of static and dynamic nonlinear systems. Learning algorithms. Generalization.

Neural network model testing and validation. Optima architecture selection. Fuzzy logic. Fuzzy models. Mamdani, Takagi-Sugeno-Kang and Tsukamoto inference methods. Neuro-fuzzy models. Parameter optimization. Rule base optimization. Operator optimization. Examples of neural network and fuzzy modelling.

Teaching methods

Lecture, laboratory exercises.

Learning outcomes and methods of theirs verification

Outcome description	Outcome symbols	Methods of verification	The class form

Outcome description	Outcome symbols	Methods of verification	The class form
Can construct models of linear dynamical systems using the prediction error method		• a test	• Lecture • Laboratory
Can construct models of dynamical linear systems using the instrumental variables method		• a test	• Lecture • Laboratory
Can construct models of linear systems using the least squares method		• a test	• Lecture • Laboratory
Can construct models of linear dynamical systems using the transient response analysis		• a test	• Lecture • Laboratory
Knows definitions of systems identification, mathematical modeling and general system identification algorithm		• a test	• Lecture • Laboratory
Knows linear dynamical systems classification, general model structure, AR, MA, ARMA, FIR, ARX, ARMAX, OE and Box- Jenkins models		• a test	• Lecture • Laboratory
Knows principles of linear dynamical system identification with recurrent methods		• a test	• Lecture • Laboratory
Knows principles of linear dynamical system identification with predication error method		• a test	• Lecture • Laboratory
Knows principles of linear dynamical system identification with least squares method		• a test	• Lecture • Laboratory
Knows principles of linear dynamical system identification with instrumental variables method		• a test	• Lecture • Laboratory
Knows principles of linear dynamical system identification with neural networks and fuzzy systems		• a test	• Lecture • Laboratory

Assignment conditions

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%

Recommended reading

1. Ljung L.: *System identification. Theory for the User*. Prentice Hall, Upper Saddle River, 1999

2. Nelles O.: *Nonlinear System Identification. From Classical Approaches to Neural Networks and Fuzzy models*. Springer, New York, Berlin, Heidelberg, 2001

3. Soderstrom T., Stoica P.: *System Identification*. Prentice Hall, Upper Saddle River, 1994

Further reading

1. Norgaard M., Ravn O., Poulsen N.K., Hansen L.K.: *Neural Networks for Modelling and Control of Dynamic Systems*. Springer, London, 2000

Notes

Modified by dr hab. inż. Andrzej Janczak, prof. UZ (last modification: 02-05-2017 11:58)