System Identification

Dates and time

16-10-2023
23-10-2023
30-10-2023
06-11-2023
from 13.45-16.00

13-11-2023
20-11-2023
27-11-2023
04-12-2023
from 10.15-12.30

Course location

Cursus- en vergadercentrum Domstad, Utrecht (in person)

ECTS

6 ECTS if the homework is completed successfully.
1 ECTS for auditing the entire course.

Lecturers

dr. ir. M. Schoukens, Eindhoven University of Technology
dr. ir. K. Batselier, Delft University of Technology
dr. ir. R. Tóth, Eindhoven University of Technology

Objective

System Identification is involved with data-driven modeling of dynamical systems. The objective of this course is to present an overview of the most important system identification techniques and the connected results on statistical constituency and efficiency. Time- and frequency-domain methods will be covered, as well as parametric and non-parametric approaches. We will discuss identification both under open-loop and closed-loop data. The main focus of the course is on identification of linear time-invariant systems, some extensions of the discussed methods will be made to nonlinear systems as well.

Contents

- Introduction and basic concepts (2hrs)
  discrete-time signal and system analysis; estimation theory; identification cycle
- Estimating frequency response functions (2hrs)
  leakage/transients and noise in the frequency domain; multisine signal design; FRF estimation with arbitrary and periodic signals; nonparametric noise models;

- Parametric identification in the frequency domain (2hrs)
  frequency-domain continuous- and discrete-time transfer function estimation; Levy and Sanathanan-Koerner method; estimation using nonparametric noise models;
- Parametric (prediction error) identification methods and closed-loop identification (4hrs)
  model structures and model sets, PEM methods for ARX, ..., BJ, convergence and consistency, closed-loop methods, residual analysis and model (in)validation;
- Subspace algorithms (4hrs)
  data equations, MOESP, instrumental variables, N4SID; Ho-Kalman;
- Nonlinear models: from the Best Linear Approximation to nonlinear models (2hrs)
  detecting nonlinearities in the frequency domain; estimating linear approximation of a nonlinear system; intro to block-oriented identification; intro to nonlinear state-space identification.

Prerequisites

Calculus and linear algebra. Basic knowledge of statistics and linear systems theory and/or time series analysis is also recommended.

Course materials

The lecture slides and recommended reading material will be distributed during the course.

The lecture material will be based on the following books and papers:

- P.M.J. Van den Hof, System Identification - Data-Driven Modelling of Dynamic Systems, Lecture Notes, Feb 2020. (http://www.publications.pvandenhof.nl/discsysid/ManuscrSysid_Febr2020.pdf)
- Verhaegen, M. and Verdult, V., 2007. *Filtering and system identification: a least squares approach*. Cambridge University Press.
- R. Pintelon and J. Schoukens, System Identification: A Frequency Domain Approach, 2nd Edition, Wiley – IEEE Press, 2012.
- M. Schoukens and K. Tiels, Identification of block-oriented nonlinear systems starting from linear approximations: A survey, Automatica, vol. 85, pp. 272-292, 2017.
- J. Schoukens and L. Ljung, Nonlinear system identification: A user-oriented road map, IEEE Control Systems Magazine, vol. 39 (6), pp. 28-99, 2019.

Homework assignments

4 homework sets will be distributed via the course website (1 for each course topic). Homework is graded on a scale from 1 to 10. Missing sets receive the grade 1. The final grade for the course is a weighted average of the grades for the homework sets.