EE-607

Advanced Methods for Model Identification

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Cursus	Sem.	Type
Electrical Engineering		Opt.
Energy		Opt.

Language of teaching	English
Credits	4
Session	
Exam	Project report
Workload	120h
Hours	**42**
Lecture	34
Practical work	8
Number of positions	**20**

Frequency

Every year

Remark

Next time: TBA

Summary

This course introduces the principles of model identification for non-linear dynamic systems, and provides a set of possible solution methods that are thoroughly characterized in terms of modelling assumptions and uncertainty levels.

Content

Model identification methods are widely employed in various branches of Engineering and Information theory. In fact, many operating processes can be approximated by mathematical models, allowing to predict their future trends or infer their current state. In this context, non-linear dynamic models represent the most likely approximation of time-variant real-world applications and stochastic processes, but their inherent non-linearity prevents from the adoption of traditional straightforward identification approaches. Although non-linear systems are typically associated to unique ad hoc solutions, adaptive mathematical tools have been developed to define more general and signal-independent identification methods.
This course is intended to present several approaches towards model identification problems, in order to help the students to solve experimental modelling problems in their peculiar research areas. The covered topics refer to system modelling, parameter identification and state estimation techniqes. In this regard, the course considers how non-linear process models and non-normal noise covariances could affect the identification accuracy and reliability. A part of the course is expected to take place in computer labs in order to allow a practical implementation of the covered topics.
This course introduces the principles of model identification for non-linear dynamic systems, and provides a set of possible solution methods that are thoroughly characterized in terms of modelling assumptions and uncertainty levels.
The course is intended to provide the mathematical tools to model, identify and predict the state and behaviour of complex systems, based on a set of experimental measurements and observations.
34 hours in total are foreseen.

1. Model identification: principles and applications (02 hours)

a. Identification problems in linear and non-linear systems.
b. Overview of parametric and non-parametric methods.
c. Mathematical models for dynamic or stochastic systems.
d. Plausible application fields and practical examples.

2. Recall on the identification methods based on spectral analysis (04 hours)

a. Static spectral analysis in Fourier transform domain.
b. Resolution enhancement approaches (STFT, IpDFT).
c. Non-periodicity and truncation effects in discrete time.
d. Dynamic extension through Taylor series expansion.
e. Measurement uncertainty and Cramer-Rao bounds.

3. Recall on the identification methods based on correlation analysis (04 hours)
a. Properties of Auto- and Cross-correlation functions.
b. Influence of stochastic disturbances on correlation.
c. Definition of system impulse response by deconvolution.
d. Auto-regressive integrated moving average (ARIMA) predictors.
e. Proper setting to avoid excessive smoothing and stationarization.
f. Influence of noise model on prediction accuracy.

4. Identification methods based on parametric models (06 hours)
a. Fundamentals of Weighted Least Squares (WLS) estimator.
b. Estimates covariance and model uncertainty.
c. Parameter identifiability: criteria and conditions.
d. Tikhonov regularization to avoid ill-posed problems.
e. Two-stages LS approximation in non-parametric conditions.
f. WLS-based approximation of system frequency response.

5. Identification methods based on probabilistic approaches (06 hours)
a. Bayes and Maximum-Likelihood estimation (MLE).
b. Cramer-Rao bounds and estimation reliability.
c. Gauss-Markov model: linearity and uncorrelation.
d. Particle filters: non-linear process models.
e. Particle filters: non-normal covariance noises.

6. Identification methods for dynamic non-linear systems (06 hours)
a. Polynomial approximation.
b. Differentiability constraint.
c. Kernel-based identification.
d. Hammerstain-Wiener models.

7. Real application: state estimation in electrical power grids (06 hours)
a. Power system modelling as stochastic process.
b. State estimation measurement and process.
c. WLS-based static state estimation.
d. KF-based recursive state estimation.
e. Particle filter-based state estimation.

Practice (Matlab-Simulink):
This practice aims to give the student an intuitive know-how on the use of the tools that have been studied.
8 hours in total are foreseen.

1. Approximation of unknown power spectral density (02 hours)
a. Modeling of dynamic stochastic process
b. Computation examples
c. Estimation uncertainty

2. Linear WLS approach for grid state estimation (02 hours)
a. State estimation problem formulation
b. Suitable tuning of weights matrix
c. Measurement uncertainty effect

3. Kalman filter model to track a dynamic process (02 hours)
a. First-order state model
b. Second-order state model
c. Suitable probability thresholds

4. Particle filter estimation of the system internal state (02 hours)
a. Two-steps recursive procedure
b. Suitable selection of process model (grid)
c. Suitable selection of noise model (measurements)

Keywords

Model identification, non-linear system.

Learning Prerequisites

Required courses

Basics in linear algebra, probability, automatics.

Assessment methods

Project report.

Resources

Moodle Link

- https://go.epfl.ch/EE-607