System Identification

Code: 03.S.07.O.203

Course Manager: Dan Stefanoiu

Duration: 42 h course, 28 h laboratory applications

ECTS value: 6 credits / 60

Objective. This course aims to introduce the students the general concepts of System Identification theory and applications.

Requested background. Mathematics and Physics (as taught in the first 2 years of any technical university); Numerical Methods; Systems Theory.

Course structure. The course is structured into 4 chapters: Introduction, Mathematical models, Input stimulating signals, Basic identification methods and techniques.

Lab structure. The laboratory works are developed following 8 themes, as listed in the end (see **Laboratory Themes**). There are 4 thought exercises and 3 simulation problems to be solved for each theme.

Course WEB site: www.geocities.com/aplimathes/SISP

Main references

[LjL99] Ljung L. – ***System Identification - Theory for the User***, **Prentice Hall, Upper Saddle River, N.J., 2nd edition,1999 (in English).**

[PrMa96] Proakis J.G., Manolakis D.G. – ***Digital Signal Processing. Principles, Algorithms and Applications.***, **third edition, Prentice Hall, Upper Saddle River, New Jersey, USA, 1996 (in English).**

[SoSt89] Söderström T., Stoica P. – ***System Identification***, **Prentice Hall, London, UK, 1989 (in English).**

[SMS04] Stefanoiu D., Matei I., Stoica P. – ***Practical Approaches to System Modeling and Identification***, **Printech Press, Bucharest, Romania, 2004 (in Romanian).**

[SCS05] Stefanoiu D., Culita J., Stoica P. – ***A Foundation of System Modeling and Identification***, **Printech Press, Bucharest, Romania, 2005 (in Romanian).**

[TeSt80] Tertisco M., Stoica P. – ***Identification and Estimation of Systems Parameters***, **Editura Didactica & Pedagogica, Bucharest, Romania, 1980 (in Romanian).**

[TeSt85] Tertisco M., Stoica P. – ***Time Series Modeling and Prediction***, **Romanian Academy Press, Bucharest, Romania, 1985 (in Romanian).**

[TSP87] Tertisco M., Stoica P., Popescu Th. – ***Computer Aided Identification of Industrial Processes***, **Editura Tehnica, Bucharest, Romania, 1987 (in Romanian).**

Course Contents

1. Introduction (6h / 6h)

- 1.1. Systems and processes
- 1.2. General problem of System Identification
- 1.3. Diagram of an identification experiment
- 1.4. Example: identification of a mobile electrical heater

2. Mathematical models (9h / 15h)

- 2.1. Groups of models
- 2.2. General statistical models (the expecting operator, ergodic hypothesis, mean, correlation, power spectral density, white noise, colored noise)
- 2.3. Identification of non parametric models (transient analysis, correlation analysis, frequency analysis, spectral analysis)
- 2.4. Classes of parametric models (general, ARMAX, RSISO, state based, non linear)
- 2.5. The parametric identification problem (from Optimization Theory view and from Estimation Theory view)
- 2.6. Statistical properties of estimated parameters

3. Input stimulating signals (6h / 21h)

- 3.1. Stimulating processes with appropriate signals
- 3.2. The concept of persistency (in time and frequency)
- 3.3. Ideal stimulating signals (white noises)
- 3.4. Generating practical stimulating signals (pseudo-random sequences)

4. Identification methods and techniques (21h / 42h)

- 4.1. Basic Least Squares Method (LSM)
  - A. General presentation (Gauss LS problem)
  - B. Geometrical interpretation of LS solution
  - C. Fundamental theorem of LSM
  - D. Recovering statistical properties in case of inadequate data (data affected by systematic errors and data affected by colored noises)
  - E. Identification of ARX models by using LSM
- 4.2. Variable Instrumental Method (VIM)
  - A. General presentation
  - B. Fundamental theorem
  - C. Identification of ARX models by using VIM
- 4.3. Optimization methods
  - A. Newton-Raphson Method (general)
  - B. Gradient based methods
  - C. Gauss-Newton Method (case of quadratic cost function)
- 4.4. Statistical estimation methods
  - A. Bayes Method (general)
  - B. Maximum Likelihood/Verisimilitude Method (case of constant conditional probability)
- 4.5. Extended LSM (ELSM).
- 4.6. Prediction Error Minimization Method (PEMM)

- **4.7. Identification and prediction of auto-regressive processes (AR and ARMA)**
  - A. LSM
  - B. Yule-Walker-Wiener Method
  - C. Levinson-Durbin Algorithm
  - D. Aplications (optimal prediction, spectral estimation)
- **4.8. Basic recursive (on-line) LSM**
- **4.9. Basic recursive (on-line) VIM**
- **4.10. Windowed recursive LSM and VIM**
  - A. Using Rectangular Windows
  - B. Using Exponential Windows
- **4.11. Recursive LSM based on QR decomposition**
- **4.12. Model structure selection criteria**
- **4.13. Model validation methods**
  - A. Whitening test in case of models identified by LSM
  - B. Whitening test in case of models identified by VIM
- **4.14. An opening to advanced identification methods**
  - A. Multidimensional LSM (LSM-M)
  - B. Kalman-Bucy Method/Filter

Laboratory Themes

1. Time and frequency characteristics of stochastic processes (2h / 2h)
2. Identification of non parametric models (ARX and OE) (2h / 4h)
3. Identification of parametric models (ARX and OE)
   by using the Least Squares Method (4h / 8h)
4. Identification of parametric models (ARX and OE)
   by using the Instrumental Variables Method (4h / 12h)
5. Identification of parametric models (ARMA and OE)
   by using the Minimum Prediction Error Method (4h / 16h)
6. Recursive identification methods (4h / 20h)
7. Identification of complex models.
   Identification of process physical parameters. (4h / 24 h)
8. Modeling and prediction of time series (4h / 28h)