COM-500

Statistical signal and data processing through applications

Ridolfi Andrea

Cursus	Sem.	Type
Communication systems minor	E	Opt.
Computer science	MA2	Opt.
Cybersecurity	MA2	Opt.
SC master EPFL	MA2, MA4	Obl.

Language of teaching	English
Credits	6
Session	Summer
Semester	Spring
Exam	Written
Workload	180h
Weeks	14
Hours	**5 weekly**
Courses	3 weekly
Exercises	2 weekly
Number of positions	

Summary

Building up on the basic concepts of sampling, filtering and Fourier transforms, we address stochastic modeling, spectral analysis, estimation and prediction, classification, and adaptive filtering, with an application oriented approach and hands-on numerical exercises.

Content

1. Fundamentals of Statistical Signal Processing: Signals and systems from the deterministic and the stochastic point of view. Processing and analysing signals and systems with a mathematical computing language.
2. Models, Methods, and algorithms : Parametric and non-parametric signal models (wide sense stationary, Gaussian, Markovian, auto regressive and white noise signals); Linear prediction and estimation (orthogonality principle and Wiener filter); Maximum likehood estimation and Bayesian a priori.
3. Statistical Signal Processing Tools for Spread Spectrum wireless transmission: Coding and decoding of information using position of pulses (annihilating filter approach); Avoiding interference with GPS (spectral mask and periodogram estimation); Spectrum estimation for classical radio transmissions (estimating frequencies of a harmonic signal).
4. Statistical Signal Processing Tools for the Analysis of Neurobiological Signals: Identification of spikes (correlation-bases methods); Characterization of multiple state neurons (Markovian models and maximum likelihood estimation); Classifying firing rates of neuron (Mixture models and the EM algorithm); Principal Component Analysis.
5. Statistical Signal Processing Tools for Echo cancellation: Adaptive filtering (least mean squares and recursive least squares).

Keywords

Statistical tools, spectral analysis, prediction, estimation, annihilating filter, mixture models, principal component analysis, stochastic processes, adaptive filtering, mathematical computing language (Matlab or similar).

Learning Prerequisites

Required courses

Stochastic Models in Communications (COM-300), Signal Processing for Communications (COM-303).

Recommended courses

Mathematical Foundations of Signal Processing (COM-514).

Important concepts to start the course

Calculus, Algebra, Fourier Transform, Z Transform, Probability, Linear Systems, Filters.

Learning Outcomes

By the end of the course, the student must be able to:

- Choose appropriate statistical tools to solve signal processing problems;
- Analyze real data using a mathematical computing language;
- Interpret spectral content of signals;
- Develop appropriate models for observed signals;
- Assess / Evaluate advantages and limitations of different statistical tools for a given signal processing problem;
- Implement numerical methods for processing signals.

Teaching methods

Ex cathedra with exercises and numerical examples.

Expected student activities

Attendance at lectures, completing exercises, testing presented methods with a mathematical computing language (Matlab or similar).

Assessment methods

- 20% midterm
- 10% mini project
- 70% Final exam

Supervision

Office hours	Yes
Assistants	Yes
Forum	Yes

Resources

Bibliography

Background texts

- P. Prandoni, *Signal Processing for Communications*, EPFL Press;
- P. Bremaud, *An Introduction to Probabilistic Modeling*, Springer-Verlag, 1988;
- A.V. Oppenheim, R.W. Schafer, *Discrete Time Signal Processing*, Prentice Hall, 1989;
- B. Porat, *A Course in Digital Signal Processing*, John Wiley & Sons,1997;
- C.T. Chen, *Digital Signal Processing*, Oxford University Press;
- D. P. Bertsekas, J. N. Tsitsiklis, *Introduction to Probability,* Athena Scientific, 2002 (excellent book on probability).

More advanced texts

- L. Debnath and P. Mikusinski, *Introduction to Hilbert Spaces with Applications*, Springer-Verlag, 1988;
- A.N. Shiryaev, *Probability*, Springer-Verlag, New York, 2nd edition, 1996;
- S.M. Ross, *Introduction to Probability Models*, Third edition, 1985;
- P. Bremaud, Markov Chains, Springer-Verlag, 1999;
- P. Bremaud, Mathematical Principles of Signal Processing, Springer-Verlag, 2002;
- S.M. Ross, *Stochastic Processes*, John Wiley, 1983;
- B. Porat, *Digital Processing of Random Signals*, Prentice Hall,1994;
- P.M. Clarkson, *Optimal and Adaptive Signal Processing*, CRC Press, 1993;
- P. Stoïca and R. Moses, *Introduction to Spectral Analysis*, Prentice-Hall, 1997.

Ressources en bibliothèque

- Probability / Shiryaev
- Stochastics Processes / Ross
- Discrete Time Signal Processing / Oppenheim
- Introduction to Spectral Analysis / Stoïca
- Digital Processing of Random Signals / Porat
- Introduction to Probability / Bertsekas
- Introduction to Hilbert Spaces with Applications / Debnath
- Signal Processins for Communications / Prandoni
- An Introduction to Probabilistic Modeling / Bremaud
- A Course in Digital Signal Processing / Porat
- Optimal and Adaptive Signal Processing / Clarkson
- Digital Signal Processing / Chen
- Introduction to Probability Models / Ross

Notes/Handbook

- Slides handouts;
- Collection of exercises.