

COM-500

**Statistical signal and data processing through applications**

Ridolfi Andrea

Cursus	Sem.	Type
Communication systems minor	E	Opt.
Computer science	MA2, MA4	Opt.
Cybersecurity	MA2, MA4	Opt.
Robotics, Control and Intelligent Systems		Opt.
SC master EPFL	MA2, MA4	Obl.

Language of teaching	English
Credits	8
Session	Summer
Semester	Spring
Exam	Written
Workload	240h
Weeks	14
<b>Hours</b>	<b>5 weekly</b>
Courses	3 weekly
Exercises	2 weekly
<b>Number of positions</b>	

**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 and Data 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 likelihood estimation and Bayesian a priori; Maximum a posteriori estimation.
- 3. Statistical Signal and Data Processing Tools for Spread Spectrum Wireless Transmission:** Coding and decoding of information using position of pulses (annihilating filter approach); Spectrum estimation (periodogram, line spectrum methods, smooth spectrum methods, harmonic signals).
- 4. Statistical Signal and Data Processing Tools for the Analysis of Neurobiological Recordings:** Poisson process for neurobiological spikes; Characterization of multi-state neurons (Markovian models and maximum likelihood estimation); Classifying firing rates of neuron (Mixture models and the EM algorithm); Hidden Markov models; Spike sorting and Principal Component Analysis.
- 5. Statistical Signal and Data Processing Tools for Echo Cancellation:** Adaptive filtering (least mean squares and recursive least squares); Adaptive echo cancellation and denoising.

**Keywords**

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

**Learning Prerequisites****Required courses**

Stochastic Models in Communications (COM-300), Signal Processing for Communications (COM-303) / Signal Processing (COM-202).

**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.

### Transversal skills

- Use a work methodology appropriate to the task.
- Demonstrate the capacity for critical thinking
- Access and evaluate appropriate sources of information.
- Make an oral presentation.
- Write a scientific or technical report.

### 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, Python, or similar).

### Assessment methods

- 20% midterm
- 20% mini project
- 60% 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. Schaffer, *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 Processings 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.

### Moodle Link

- <https://go.epfl.ch/COM-500>