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.
4. Statistical Signal and Data Processing Tools for the Analysis of Neurobiological Recordings: Poisson process for neurobiological spikes; Characterization of multiple 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).

Recommended courses

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, Python, 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;

More advanced texts
- P. Bremaud, Markov Chains, Springer-Verlag, 1999;
- P. Bremaud, Mathematical Principles of Signal Processing, Springer-Verlag, 2002;
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.