EPFL

COM-514   **Mathematical foundations of signal processing**

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Cursus	Sem.	Type
Communication systems minor	H	Opt.
Computational science and Engineering	MA1, MA3	Opt.
Computer and Communication Sciences		Opt.
Computer science	MA1, MA3	Opt.
Cybersecurity	MA1, MA3	Opt.
Data Science	MA1, MA3	Opt.
Robotics, Control and Intelligent Systems		Opt.
SC master EPFL	MA1, MA3	Opt.
Systems Engineering minor	H	Opt.

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

Summary

Signal processing tools are presented from an intuitive geometric point of view which is at the heart of all modern signal processing techniques. The student will develop the mathematical depth and rigor needed for the study of advanced topics in signal processing and approximation theory.

Content

Sequences, Discrete-Time Systems, Functions and Continuous-Time Systems (review of discrete-time Fourier transform; DFT; Fourier transform and Fourier series).
From Euclid to Hilbert: Linear Algebra Fundamentals for Representation Theory (vector spaces; Hilbert spaces; approximations, projections and decompositions; bases and frames; linear operators; adjoint; generalized inverses; matrix representations; computational aspects)
Sampling and Interpolation (sampling and interpolation with normal and non orthogonal vectors, sequences and functions; sampling and interpolation of bandlimited sequences and functions)
Polynomial and Spline Approximation (Legendre and Chebyshev polynomials; Lagrange interpolation; minimax approximation; Taylor expansions; B-splines)
Regularized Inverse Problems (regularized convex optimisation; Tikhonov regularisation; penalised basis pursuit; proximal algorithms; pseudo-differential operators and L-splines; representer theorems for continuous inverse problems with Tikhonov penalties)
Computerized Tomography (line integrals and projections, Radon transform, Fourier projection/slice theorem, filtered backprojection algorithm, algebraic reconstruction techniques).
Finite Rate of Innovation: Sampling Non Bandlimited Signals (overview and definitions, reconstruction methods and applications)
Adaptive Filtering (Wiener filtering, matrix inversion lemma, RLS, LMS, beamforming)

Learning Prerequisites

Required courses

Signal processing for communications (or Digital signal processing on Coursera)
Linear Algebra I and II (or equivalent).

Recommended courses

Signals and Systems

Important concepts to start the course

Good knowledge of linear algebra concepts. Basics of Fourier analysis and signal processing.

Learning Outcomes

By the end of the course, the student must be able to:
- Master the right tools to tackle advanced signal and data processing problems
- Develop an intuitive understanding of signal processing through a geometrical approach
- Get to know the applications that are of interest today
- Learn about topics that are at the forefront of signal processing research

Teaching methods

Ex cathedra with exercises and homeworks.

Expected student activities

Attending lectures, completing exercises

Assessment methods

mini project 30%, final exam (written) 70%

Resources

Virtual desktop infrastructure (VDI)
No

Bibliography

M. Vetterli, J. Kovacevic and V. Goyal, *"Signal Processing: Foundations"*, Cambridge U. Press, 2014.
Available in open access at http://www.fourierandwavelets.org

Ressources en bibliothèque
- Signal Processing: Foundations / Vetterli