

Course Name: Mathematical Methods for Signal Processing

Course Number: EE 510

Credit: 4-0-0-4

Prerequisites: IC111 Linear Algebra, IC 210 Probability, Statistics and Random Processes

Students intended for: 3rd and 4th year UG/PG or teachers consent

Elective or Compulsory: Elective

Semester: Odd/Even

Course Preamble: In the field of signal processing we encounter problems which requires mathematical rigor – mostly in the area of linear algebra, functional analysis, optimization and estimation theory. This course develops the mathematical framework required for signal processing which consists of certain mathematical tools as well as algorithms. How these mathematical concepts are reflected in signal processing is brought out. After finishing this course the students will be in a better position to read and appreciate the current literature and problems in this area.

Course Outline:

- Linear algebra and representation in vector spaces.
- Linear operator theory and matrix factorization.
- Estimation theory.
- Non-linear programming/optimization.

Modules:

Vector Spaces and Linear Algebra: [10 Lectures]

Metric spaces, vector spaces, norm, inner product, Hilbert and Banach spaces, linear transformations, projections.

Representation and approximation in vector spaces: [11 Lectures]

Approximation in Hilbert space, orthogonality, error minimization, least squares, polynomial approximation, linear regression, MMSE, optimal filtering, IRLS, generalized Fourier representation.

Linear operators: [9 Lectures]

Linear operators, operator norms, adjoint, matrix inverse, pseudo inverse, condition number, eigenvalues and eigenvectors.

Matrix factorizations: [5 Lectures]

LU, Cholesky and QR factorization. Singular value decomposition.

Selected topics in detection, estimation and optimization: [21 Lectures]

Neyman-Pearson theory, Bayes decision theory, ML detection, ML estimate, Cramer-Rao bound, MAP estimate, Kalman filter, iterative methods -conjugate gradient, k-means and EM algorithm, constrained non-linear programming – Lagrange multipliers, duality, KKT conditions.

Text Books:

1. Mathematical Methods and Algorithms for Signal Processing, Todd K. Moon and Wynn C. Stirling, Prentice Hall, 2000.

Reference Books:

1. A Mathematical Introduction to Signals and Systems, Vol. 1 and Vol. 2, A.D. Lewis, 2013. (Available at Queen's University Website).
2. Structure and interpretation of Signals and Systems, Edward A. Lee, Pravin Varaiya, Addison Wesley, 2002.
3. Linear Algebra and Functional Analysis for Signals and Systems, Alexandre Megretski and John Wyatt, MIT 2009.
4. Optimization by Vector Space Methods, David G. Luenberger, John Wiley, 1969.