INDIAN INSTITUTE OF TECHNOLOGY KANPUR

Department of Electrical Engineering

First Course Handout | Semester I, AY 2026-27

EE602: Statistical Signal Processing

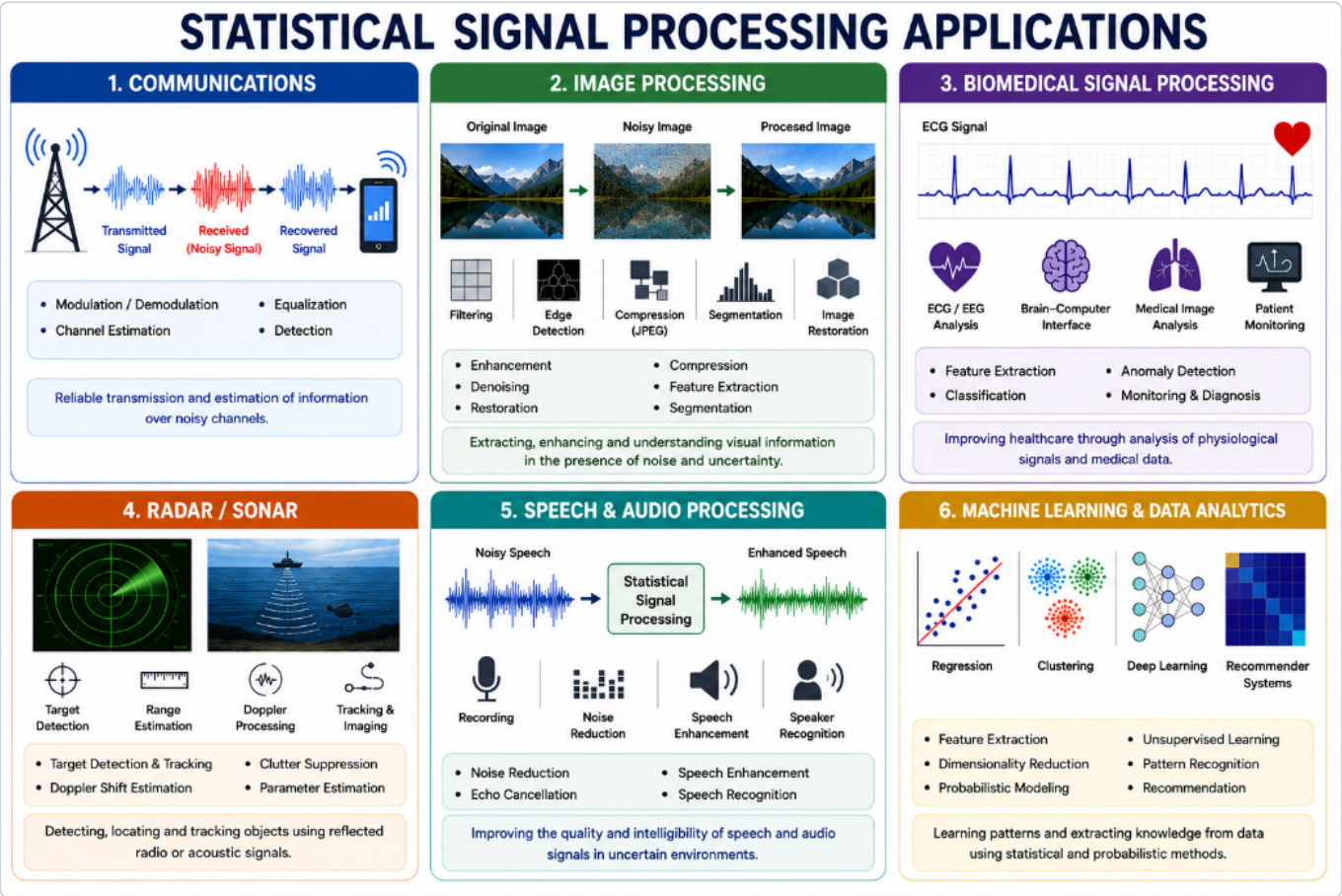
OBJECTIVES

This course provides a comprehensive introduction to the theoretical foundations and practical applications of statistical signal processing. It develops the fundamental principles of probabilistic and statistical methods for signal analysis and demonstrates their application across a broad range of disciplines, including Signal Processing, Wireless Communications, Image Processing, and Machine Learning.

The course begins by introducing the mathematical framework for statistical signal analysis, followed by the development of analytical models for a variety of estimation, detection, and learning problems. Emphasis is placed on rigorous performance analysis, enabling students to understand the theoretical limits and practical trade-offs associated with different statistical signal processing techniques.

Key topics covered in the course include Minimum Mean Squared Error (MMSE) estimation, Kalman filtering, Adaptive filtering, Machine Learning, Sparse signal representation, Probabilistic graphical models, among others. The course also explores several important applications, including linear regression, MIMO wireless communications, recommender systems, unsupervised learning, probabilistic clustering, and other modern data-driven signal processing techniques.

The course combines theoretical lectures with practical examples and computational implementations to provide students with both conceptual understanding and hands-on experience. As a major component of the course, students will work in teams of two to prepare a term paper that investigates a contemporary research problem involving statistical signal processing. The project will involve an in-depth study, critical analysis, and presentation of a state-of-the-art applications in areas such as signal processing, wireless communications, image processing, machine learning, or related interdisciplinary fields.



PREREQUISITES

B.Tech (EE)	EE320 / EE200 for B.Tech students in EE department.
M.Tech / Ph.D (EE)	No prerequisite for M.Tech/ Ph.D. students enrolled in EE Department.
Other Students	Instructor consent for all other students.
Expected Background	Students are expected to be familiar with basic concepts of: • Probability, Random Variables and Random Processes • Linear Algebra, Properties of Matrices etc. • Calculus, differentiation, integration

SPECIAL EMPHASIS

Minimum Mean Square Error (MMSE) | **Kalman Filter** | **EM Algorithm** | **Adaptive Filtering** | **MUSIC Algorithm** | **Probabilistic Graphical Models** | **Applications: Signal Processing, Machine Learning, Wireless Comm.**

COURSE CONTENTS

Topics	No. of Lectures
ML Estimation	
Maximum likelihood estimation (MLE), Justification for MLE	2
MLE for the multivariate Gaussian, MLE for linear regression	2
Properties of ML estimate – Mean and Covariance	2
Bayesian Estimation	
Conditional Gaussian PDF and MMSE Estimation for Gaussian vectors	1
Principle of LMMSE estimation and Derivation of the LMMSE estimator	1
Online estimation for Random Parameter Vector: Kalman Filter and application in tracking	1
Iterative Estimation	
Online estimation for Random Parameter Vector: Kalman Filter and application in tracking; Application of Kaman Filter for Robotics	2
Expectation-Maximization (EM) algorithm and derivation for Gaussian Mixture Models	2
Application of EM: Unsupervised learning – Probabilistic clustering	1
Adaptive Signal Processing	
Introduction to adaptive signal processing, applications in wireless	1
Steepest Descent Algorithm and convergence analysis, asymptotic MSE	2
Least Mean Squares (LMS) algorithm and stochastic gradient descent	2
Convergence of (LMS)	2
Recursive Least Squares (RLS) algorithm and convergence	2
Compressive Sensing	
Sparse estimation and sparse signal recovery: Application in Image/ Video Processing	1

Topics	No. of Lectures
Orthogonal Matching Pursuit (OMP) and application in Wireless Communication	2
Simultaneous Orthogonal Matching Pursuit (SOMP) for Sparse Regression	1
Sparse Learning guarantees for signal recovery	1
Applications of OMP – OFDM Channel Learning	1
Sparse Bayesian Learning	2
Sparse Adaptive Filtering	1
MUSIC Algorithm	
Introduction to array processing	1
Signal covariance matrix, Multiple Signal Classification	1
Probabilistic Graphical Models	
Introduction to Probabilistic Graphical Models	1
Bayesian networks	2
Factorization of PDF	1
Bayesian inference and estimation over graphs	2

LECTURE, TUTORIAL & LAB SCHEDULE & VENUE

Venue: L16
Timings: Monday 12:00 – 13:15, Thursday 12:00 – 13:15
Office Hours or, recommended mode of contact beyond formal contact hours: Saturday 12 noon. Students can also contact both instructor as well as TAs via e-mail.

EVALUATION COMPONENTS & POLICIES

Component	Weightage
Assignments (Theory + MATLAB)	**15%**
Mid-Sem	**20%**
Quiz-I	**10%**
Quiz-II	**10%**
Term Paper	**10%**
End-Sem	**25%**
Attendance	**10%**

COURSE POLICIES

Exam/ Assignment/ Term Paper Policy:

If a student misses any one or more of Quiz-I/ Quiz-II/ Mid-sem, marks will be pro-rated based on remaining ones, if valid reason is provided along with supporting documents. If a student misses the end-sem exam, he/ she can apply to DOAA for makeup examination. Assignment solution or term paper submission is due by 12 Noon of respective due date. 15%

Marks will be deducted for late submission. No makeup or prorating will be done for missed assignment submissions or term paper.

Attendance Policy:

Minimum 80% attendance is required to score the 10% marks specified for attendance as per Evaluation Policies in Section 7. Attendance will be recorded in every session.

Honesty Practices:

Students are expected to observe a personal code of honesty in submission of assignment solutions and term paper. This will be based on honor code. Term papers will be checked by software to detect any plagiarism. 25% marks will be deducted for plagiarism.

BOOKS & REFERENCES

Properly Formatted along with listing of possible internet sources.

Title	Author(s)	Remarks
Fundamentals of Statistical Signal Processing: Estimation Theory	Steven M. Kay	Primary reference for estimation theory, Maximum Likelihood (ML), Bayesian estimation, MMSE estimation, and Cramér–Rao Lower Bound (CRLB).
Adaptive Filter Theory	Simon Haykin	Comprehensive reference on adaptive signal processing, LMS, RLS, convergence analysis, and practical applications.
Mathematical Methods and Algorithms for Signal Processing	T. K. Moon and W. C. Stirling	Covers mathematical foundations, optimization methods, statistical inference, and signal processing algorithms.
Fundamentals of Adaptive Filtering	Ali H. Sayed	Advanced treatment of adaptive filtering, stochastic gradient methods, and distributed learning algorithms.
Introduction to Compressed Sensing	M. A. Davenport, M. F. Duarte, Y. C. Eldar, and G. Kutyniok	Reference for sparse signal recovery, compressive sensing, sparse optimization, and modern sensing techniques.
Probabilistic Graphical Models: Principles and Techniques	Daphne Koller and Nir Friedman	Standard reference for Bayesian networks, graphical models, probabilistic inference, and machine learning.
Introduction to Graph Signal Processing	Antonio Ortega	Covers graph signal processing, graph Fourier transform, graph filtering, and signal processing over networks.

INSTRUCTOR AND TA INFORMATION

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