Spring 2015, TR: 12:30-1:45; Room ECE310
Instructor: Prof. Majeed M. Hayat [hayat@unm.edu]

Objective: To learn advanced concepts and techniques in modern probability theory and stochastic process that are relevant to problems in communication, image processing, signal estimation, stochastic control, and photonic devices and systems.

Topics:
Concepts from probability theory and stochastic processes:
• Review of probability and measure, random variables, integration, Kolmogorov zero-one law, and the basic limit theorems for the convergence of random sequences.
• Martingales and sub/super-martingales, Doob’s up-crossing inequality, convergence.
• Continuous-time, discrete-space Markov processes, Kolmogorov equations, queuing.
• Absolute continuity of measures, the Radon-Nykodym theorem and the Hahn decomposition theorem: Application to continuous-time detection (general form of the likelihood test).
• Renewal processes and renewal theory.
• Branching processes (the Galton-Watson, and the age-dependent branching processes).
  Application to photomultiplier tubes and avalanche photodiodes.
• Point processes and filtered point processes, application to shot noise and optical-receiver output, doubly stochastic shot-noise processes, optimal receivers in an integrate-and-dump on-off keying optical communication, design of equalizers for minimum intersymbol interference.

Large deviations and quick sampling and their applications
• Kramar’s and Ellis’s Theorems, Sanov’s Theorem
• Principles of importance sampling, large deviations for Markov chains, twisted distributions and importance sampling. Applications to detection theory.

Stochastic calculus:
• Stochastic integration: The Ito integral, existence and uniqueness of solutions
• Examples of stochastic differential equations and Ito’s formula.

Markov random fields and their simulations
• Markov random fields, Gibbs distributions, Clifford-Hammersley equivalence theorem.
• Gibbs sampler, MCMC simulation, application to image modeling, analysis and restoration.

Basics of random matrix theory
• Wigner’s theorem, distribution of eigenvalues, Gaussian ensembles, properties of empirical distributions, central limit theorem for linear statistics of eigenvalues of Wigner matrices,
• Applications to communication theory and Anderson localization.

Prerequisite: ECE 541; Relevant/recommended courses: Math 510, ECE642, Math 541

Text and Course requirements: Class notes; bi-weekly homework problems.