ES 255: DETECTION AND ESTIMATION THEORY & APPLICATIONS (Fall 2005)

Teaching Staff

Prof. Patrick J. Wolfe (Instructor) (Teaching Fellow TBA)
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Logistics

Location: Maxwell Dworkin 221
Meeting Time: Tu., Th., 10-11:30am
Catalog Number: 9816
Website: http://www.courses.fas.harvard.edu/∼es255

Course Content

Statistical decision theory; hypothesis testing; linear and non-linear estimation; maximum likelihood and Bayes approaches; stochastic processes and systems; signal detection and estimation in noise; Wiener and Kalman filtering; applications to physical, chemical, and biological systems.

Prerequisites

Knowledge of probability theory and calculus. In general what we really require is a level of mathematical maturity. In general, you will have it easier if your background in mathematics and statistics is strong. This is a really a course in applied statistics!

Text

H. L. Van Trees, *Detection, Estimation, and Modulation Theory, Part I* (Wiley, ISBN 0-471-09517-6).

Lecturing Style

I do not teach from slides; instead, I use the blackboard. I like to prove every result that I teach in detail. So, you are guaranteed to have reasons provided for every claim that I will make. It is mathematics after all!

This is the first time that I am teaching this course. I will learn from this experience and will figure out what is the best way of presenting the material. I am very much open to suggestions and criticism and encourage you to give me your valuable comments and opinions so that I can improve future offerings.

Evaluation

- Four problem sets - 25%
- Midterm examination - 25%
- Final examination ("all-inclusive") - 50%

NB: While the grading breakdown above is indicative of relative weights, I do reserve the right to rescale grades based on the performance of the class. Naturally, this will be done only in the event that it raises grades, and will not lower your "raw" scores.

Class Schedule and Syllabus

Below you can find the material that I intend to cover on each class date. There are no guarantees that I will not fall behind or ahead of this schedule. Moreover, based on the input provided by students, I may choose to cover additional material. It is also possible that I may assign additional readings.

Tuesday Sept 20: Brief discussion of physical situation that give rise to detection, estimation and modulation problems, detection theory, estimation theory, modulation theory. Formulation of the hypothesis testing problem, Bayes Decision Criteria.

Thursday Sept 22: Minimax Test, Neyman-Pearson Test, LRT, sufficient statistics. M-hypotheses testing.

Tuesday Sept 27: Estimation Theory, Bayes Estimation

Thursday Sept 29: Bayes Estimation (continued), Non-random Parameter Estimation, Minimax Likelihood Estimation, Cramer-Rao inequality, Efficiency.

Tuesday Oct 4: Non-random parameter estimation (continued), Non-linear example, asymptotic results, intuitive explanation of when C-R bound is accurate, bounds for random variables. Definition of Gaussian random vector, General Gaussian Problem, Definition of LRT and define quadratic forms.

Thursday Oct 6: General Gaussian Problem (continued), Equal Co-variance Matrices, Unequal Co-variance matrices, the chi-square density.

Tuesday Oct 11: Extension of results to waveform observations, Deterministic waveforms, Time domain and frequency domain characterization, Orthogonal function representation, complete orthonormal sets and their geometric interpretation, Second moment characterization, Gaussian Random Processes.

Thursday Oct 13: Orthogonal Representation for random processes, Karhunen-Loeve expansion, Integral equations, Mercer theorem, Convergence in mean square sense.

Tuesday Oct 18: Solution of Integral Equations, White noise and its properties, Optimum Linear Filter.

Thursday Oct 20: Physical motivation for detection problems including Communications and Radar/Sonar. Detection of Known Signals in additive white Gaussian noise, simple binary detection, General binary detection.

Tuesday Oct 25: M-ary detection in white Gaussian noise, Sensitivity.

Thursday Oct 27: Estimation of Signal Parameters, Linear estimation, Non-Linear Estimation.

Tuesday Nov 1: Non-Linear Estimation (continued), Introduction to colored noise problem.

Thursday Nov 3: Colored Noise Problem, Whitening Derivation, Duality with Known Channel Problem.

Tuesday Nov 8: Signals With unwanted Parameters, Random phase, Random amplitude‘and phase.

Thursday Nov 10: Multiple parameter estimation, Continuous waveform estimation.

Tuesday Nov 15: Linear Modulation, Model for linear problem, Equation for MAP interval estimation

Thursday Nov 17: Realizable linear filters, Weiner-Hopf Equation, Example of one pole spectrum plus white noise, Unrealizable filters, Closed form error expressions in the presence of white noise.

Tuesday Nov 22: State-Variable Approach to optimum filters (Kalman-Bucy problem)

Thursday Nov 24: Thanksgiving

Tuesday Nov 29: Derivation of Kalman-Bucy estimation equations. Properties of variance equation.

Thursday Dec 1: Application to typical estimation problems, Generalizations, Amplitude modulation.

Tuesday Dec 6: Non-linear modulation, MAP Estimation Equation,

Thursday Dec 8: Frequency Modulation, Optimum angle modulation.

Tuesday Dec 13: Comparison of various systems for transmitting analog messages, Sampled and quantized systems, Bounds on Analog transmission

Thursday Dec 15: Gaussian signals in Gaussian noise, Simple binary problem, Various receiver realization.

Tuesday Dec 20: General binary problem, Symmetric binary problems.