Statistical Parameter Estimation

ECE 275A Syllabus – Fall 2019

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Contact and Course Information - ECE275A

Courses: **Parameter Estimation I** – ECE 275A (Fall)

Instructor: **Prof. Ken Kreutz-Delgado**, **Email:** **kreutz@ece.ucsd.edu**
Office: Atkinson Hall, Room 4101, Tuesday and Thursday 5-6pm

Teaching Assistants

- **Jiunting Huang**, **Email:** **jih334@eng.ucsd.edu**

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Piazza Link is: **HERE**
Class Website: Accessible from **http://dsp.ucsd.edu/~kreutz**

275A Lecture Location & Times: Center Hall 105, TTh 6:30-7:50pm.

275A Final Exam Date & Time: Tuesday, December 10, 2019, 7-10pm.

NOTE: You CANNOT reschedule the Final Exam date and time!

Exams, Homework, Grading, & Cheating

- The overall course grade is broken down as follows:

  Homework 30%, Midterm 30%, Final 40%.

  NOTE: this breakdown is firm and nonnegotiable.

- Homework (*and Homework only*) is graded using an "A for effort" scheme. Individual homework problems are *not* corrected. Points are assigned proportional to the percentage of work done. Because homework is not graded for correctness, students must read the solutions, provided at the outset, to determine if they performed the homework correctly or not.

- The Midterm and Final are graded in the traditional manner.

- *All tests are closed book and notes*.

- Bring paper, pencils, and a *nonprogrammable* calculator to all exams. All other electronic storage and communication devices are banned.

- Cheating will be dealt with aggressively and will result in severe penalties.

Required Course Materials

The lecture is mainly drawn from the required textbooks and Lecture Supplements and source research articles located on the class website. Whenever possible, a reference to a source (text and pages) for the lecture will be given in class.

Required Textbooks (both quarters):

[T1] *Fundamentals of Statistical Signal Processing. Volume 1: Estimation Theory,* S.M. Kay, Prentice-Hall, 1993.

[T2] *Mathematical Methods and Algorithms for Signal Processing,* T.K. Moon and W.C. Stirling, Prentice-Hall, 2000

Students are expected to have proficiency and access to Python or Matlab or Python or the equivalent.

Other Important and useful Information Sources

- The *Google search engine* provides a vast amount of useful information and source material (such as reports and tutorials) for virtually any subject of interest. In particular, search "$\langle$*topic*$\rangle$ *wikipedia*" to find informative, sophisticated, and useful tutorial information about mathematical and technical topics available from Wikipedia

- The *Google Scholar* search engine is particularly useful for searching for published research papers. Because of your affiliation with UCSD, a tremendous number of journal and conference research papers can be found *and accessed* electronically *provided you use an on-campus computer with an IP address recognized as belonging to the UCSD network, or have set-up a UCSD proxy server if you work off-campus.*

- Many contemporary scientific and engineering journal databases (such as the very useful INSPEC and MathSciNet databases) are accessible from http://libraries.ucsd.edu/sage/databases.html. In particular, many mathematics, physics, and statistics journal papers (some even going back to the 1600's, including the very first paper to describe Bayes's Rule!) can be found on http://jstore.org.

ECE 275A Course Overview

- This is the first part of a two quarter graduate course sequence in classical and Bayesian statistical parameter estimation. Although mathematical, the course is taught with far less rigor than in the mathematics department and the emphasis is on geometric and other intuitive insights useful for creating new algorithms. As the physicists often note: "too much rigor can lead to *rigor mortis*."

- The problems of parameter estimation, state estimation, and system identification are described within a *probabilistic model-based framework.*

- We discuss techniques and insights useful for addressing issued involved with the identification of parameters defining static and dynamic system models; state variables; probability distributions; signals; and the solutions to systems of equations.

- The course is useful for students interested in careers or research in AI, Data Mining; Signal Processing; Communications Theory; Statistical/Machine Learning and Adaptive Systems; Stochastic/Adaptive Control Theory; and related areas.

ECE 275A – Classical Statistical Parameter Estimation

- ECE 275A and 275B are both concerned with learning the unknown parameters defining a probability model whose purpose is to explain and capture the behavior of observed data. In ECE 275A we will for the most part, but with some exceptions, make the classical (Fisherian) assumption that *the parameters are unknown, but deterministic (nonrandom).* Further, we will often make the neo-Fisherian assumption that the unknown parameters can be random (the Bayesian assumption), but have a so-called uninformative prior distribution.

- The emphasis in ECE 275A will be on i) the use of model discrepancy measures for parameter estimation; ii) the use of deterministic weighted least squares techniques in the special linear Gaussian model case, and iii) classical (aka Fisherian) statistical parameter estimation techniques, including the search for a minimum variance unbiased estimator and the maximum likelihood method for estimating unknown deterministic parameters, assuming a parameterized statistical model of independent and identically distributed (iid) measurement data.

- We will discuss: i) parameterized probability models (Exponential Class and mixture distributions) and their relationship to static and dynamic system models; ii) Least Squares solutions and their relationship to the Pseudoinverse and SVD); iii) Statistical figures of merit (bias, consistency, Cramér-Rao lower bound, efficiency); iv) Sufficient Statistics and their relationship to the minimum variance unbiased estimator; Maximum Likelihood estimation (MLE) and Algorithms for computing the MLE.

Background Requirements & Mathematical Maturity

- The material in this course is presented and discussed in a mathematically mature framework, and some mathematical maturity is required of the student. However, this is *not* a rigorous mathematics course and *most proofs of the deeper results are merely outlined at best.* Students interested in a mathematically rigorous theoretical development of much of the material discussed in ECE275AB are strongly encouraged to subsequently (or in parallel) take (or sit in on) Math280ABC (Probability Theory) and/or Math281ABC (Mathematical Statistics).

- Students are expected to know probability theory, vector (i.e., multivariate) random variables, complex variables, and linear algebra. For example, a student ideally would know what the covariance matrix of a random vector is; why its eigenvalues are real and nonnegative; that it can be diagonalized by an orthogonal transformation; and that this diagonalization corresponds to a decorrelation of the components of the random vector. In practice motivated students who are be fuzzy on some of these concepts may be able to use the many references provided in the full Syllabus to fill in the blanks via self–study.

- Students who do not feel adequately prepared are encouraged to take, or audit, ECE109 (Probability Theory), ECE153 (Stochastic Processes), and/or ECE174 (Linear Least-Squares and Optimization Theory) prior to taking ECE275AB. By the end of the first half of ECE275A, students should be fully comfortable with the concepts presented in the lecture supplement *Finite Dimensional Hilbert Spaces and Linear Inverse Problems* and the Lecture Supplement *Fundamental Concepts of Probability* (both located on the course website).