AY 2006–2007 COURSE DESCRIPTION

PARAMETER ESTIMATION

ECE 275A (Fall) and ECE 275B (Winter)

INSTRUCTOR: Prof. Ken Kreutz-Delgado

Phone and Email: (858) 534-7895, kreutz@ece.ucsd.edu
Office Location: Engineering Building EBU-1, Room 5605
Office Hour: 1-2pm Monday

Administrative Assistant: Ms. Nicoele Watson
Location: EBU-1, Room 5600
Contact Information: (858) 822-4697, nwatson@ece.ucsd.edu

CLASS WEBSITE: Accessible from http://dsp.ucsd.edu/~kreutz

WINTER LECTURE VENUE: York Hall 3050B, TTH 12:30-1:50pm.

FINAL EXAM DATE AND TIME: Tuesday, March 20, 2007, 11:30am-2:30pm.

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

OVERVIEW. This is a two quarter graduate course sequence in parameter estimation with applications to parameter state and system identification offered during the Fall and Winter Quarters. The problems of parameter estimation, state estimation, and system identification are discussed in a general unified framework. The course is concerned with the issues 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 Signal Processing; Communications Theory; Learning and Adaptive Systems; Stochastic/Adaptive Control Theory; and related areas.

The first quarter (ECE 275A) assumes that the parameters are unknown, but deterministic (nonrandom). The emphasis will be primarily on i) the use of deterministic least squares techniques, primarily assuming a linear model, and ii) classical statistical techniques, including the maximum likelihood method for estimating unknown deterministic parameters, assuming a parameterized statistical model of independent and identically distributed measurement data.

1Detailed and advanced aspects of dynamical system identification are deemphasized. Students interested in this issue are recommended to take the MAE Department system identification course, MAE 283A as a followup to ECE 275AB.
The second quarter (ECE 275B) completes the classical statistical perspective and describes the (classical) Bayesian perspective which assumes the existence of a prior probability distribution function for the unknown (but now assumed to be random) parameters. The course stops short of the modern empirical (also known as the hierarchical) Bayes approach where hyperparameters over families of prior distributions are learned. It is expected that students will pick up from this point in a follow-up graduate course on Bayesian statistical learning theory as taught in the ECE department (e.g., by Prof. Nuno Vasconcelos) and/or CSE Department (e.g., by Prof. Sanjoy Dasgupta).

The material in this course is presented and discussed in a mathematically mature framework. 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 ECE 275AB are strongly encouraged to subsequently take Math 280ABC (Probability Theory) and/or Math 281ABC (Mathematical Statistics). ECE students who have done so tell me that they are very well prepared for the rigors of these graduate mathematics courses after having taken ECE 275AB.

**CATALOG COPY**

**ECE 275A (Fall).** Parameterizations of static and dynamic linear models (including ARMA, State-Space, and Hidden Markov); Probability models (Exponential Class and mixture distributions); Least Squares solutions (Batch, Recursive, Total, Sparse, Pseudoinverse, QR, SVD); Statistical figures of merit (bias, consistency, Cramér-Rao lower bound, efficiency); Maximum Likelihood estimation (MLE); Sufficient Statistics; Algorithms for computing the MLE including the Expectation Maximization (EM) algorithm. Time Permitting: The problem of missing information; The problem of outliers; Confidence intervals; The problem of model order selection.

**ECE 275B (Winter).** The Bayesian framework and the use of statistical priors; sufficient statistics and reproducing probability distributions; Minimum Mean Square Estimation (MSE); Linear Minimum Mean Square Estimation; Maximum A Posteriori (MAP) Estimation; Minimax estimation; Kalman Filter and Extended Kalman Filter (EKF); Baum-Welsh algorithm; Viterbi Algorithm. Applications to identifying the parameters and states of Hidden Markov Models (HMMs) including ARMA, state-space, and finite-state dynamical systems. Applications to parametric and non-parametric density estimation.

**REQUIREMENTS.** Students are expected to know well 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 may be fuzzy on some of these concepts, but are able to use the many references provided below to fill in the blanks via self-study, can do (and have done) well in the course. A good source for review of the background material is provided by the Appendices of the text by H. Sorenson cited as reference P1 below.
Students who do not feel adequately prepared are encouraged to take, or audit, ECE 109 (Probability Theory), ECE 153 (Stochastic Processes), and/or ECE 174 (Linear Least-Squares and Optimization Theory) prior to taking ECE 275AB.

It is highly recommended that ECE graduate students read Chapter 1 of reference P14 (the text by Wong and Hajek) cited below. They are strongly encouraged to set themselves the goal of clearly understanding this chapter as soon as possible, and certainly by the time they complete their graduate studies. Although the material in this chapter may seem abstruse to some at first, over time the clarity and utility of this formulism should become manifest. We will discuss some aspects of this chapter in ECE 275AB. Those students who decide to take Math 280ABC (Probability Theory) subsequent to ECE 275AB will get a thorough and rigorous explanation of the material in Chapter 1 of Wong and Hajek, but it is hoped that all ECE graduate students, over time, will come to grips with this material. An excellent accessible introduction to advanced concepts in probability theory is given in reference P15, which is available in an inexpensive paperback edition.

GRADING. The overall course grade is broken down as follows: Homework and Projects 30%, Midterm 30%, Final 40%. As discussed in the first lecture, this breakdown is nonnegotiable. Also as discussed in the first lecture, Homework (and Homework only) is graded using an “A for Effort” scheme. The Midterm and Final are graded in the traditional manner. All tests are closed book and notes. Please bring paper, pencils, and a calculator to all exams.

LECTURE SOURCE MATERIALS

The lecture is mainly drawn from the required textbooks and the primary secondary source texts listed below. In addition, lecture supplements and source research articles will be placed on electronic reserves at the class web site accessible from http://dsp.ucsd.edu/~kreutz. Whenever possible, a reference to a source (text and pages) for the lecture will be given in class.

REQUIRED TEXTBOOKS


RECOMMENDED TEXTBOOKS


OTHER PRIMARY TEXT SOURCES


[P15] *Concepts of Probability Theory*, 2nd Revised Edition, Paul E. Pfeiffer, Dover 1978. This inexpensive Dover Publications paperback reprint is highly recommended for students who have not had a rigorous advanced course in probability theory and want/need to educate themselves on the theoretical aspects of the subject. For example, Chapter 4 gives a nice 20 page crash-course on the Lebesgue integral and its relationship to the elementary Riemann integral. This would be a good supplementary text for MATH280.

[P16] *Digital Processing of Random Signals: Theory and Methods*, Boaz Porat, Prentice-Hall, 1994. This is an excellent advanced textbook which rigorously covers a large set of topics. After you have taken ECE275AB, ECE250, ECE251ABCD, and ECE256AB, you should have a good grasp of the material presented in this book.


SECONDARY TEXTBOOK REFERENCES


OTHER IMPORTANT INFORMATION SOURCES

Most of you know that the Google search engine can yield a large amount of useful information and source material for virtually any subject of interest. The Google Scholar search...
engine is particularly useful for searching for published research papers. Furthermore, 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\textsuperscript{2}) can be found at the JSTOR database, http://www.jstor.org. Contemporary, up-to-the-minute engineering-related research articles can also be found at the IEEE Xplore website, http://ieeexplore.ieee.org.

\textsuperscript{2}For example do a JSTOR search for the author ‘Bayes’ in the category ‘General Science’ to find the original exposition of what is now known as ‘Bayes’ rule.'