

AY 2017-2018 COURSE DESCRIPTION

PARAMETER ESTIMATION I & II

ECE 275A (Fall) & ECE 275B (Winter 2018)

INSTRUCTOR: Prof. Ken Kreutz-Delgado

Phone and Email: (858) 534-7895, kreutz@ece.ucsd.edu

Office Location: Jacobs Hall 5605

Office Hour: Tuesday, Noon-1pm

Administrative Assistant (AA): Mr. Travis Spackman

Contact Information: (858) 822-4697, tspackman@ece.ucsd.edu, Jacobs Hall 2908

275B LECTURE LOCATION AND TIMES: Center Hall 218, TuTh 5-6:20pm.

275B FINAL EXAM DATE AND TIME: Thursday March 22 2018, 7-10pm.

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.¹ The course is useful for students interested in careers or research in Signal Processing; Communications Theory; Statistical Learning and Adaptive Systems; Stochastic/Adaptive Control Theory; and related areas.

The first quarter (ECE 275A) primarily (but not necessarily) 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 deterministic linear model; ii) classical (aka Fisherian) statistical techniques, including the maximum likelihood method for estimating unknown deterministic parameters, assuming a parameterized statistical model of independent and identically distributed (iid) measurement data; and iii) an introduction to Bayesian estimation.

¹Detailed and advanced aspects of the identification of dynamic systems are deemphasized. Students interested in these issues are recommended to take the MAE Department system identification course, MAE 283A as a followup to ECE275AB.

The second quarter (ECE275B) completes the maximum likelihood discussion (with a discussion of sufficient statistics, the Rao-Blackwell theorem, and the EM algorithm) and further elaborates on the (classical) Bayesian perspective which assumes the existence of a prior probability distribution function for the unknown (but now primarily 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 Professors Sanjoy Dasgupta, or Lawrence Saul).

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 ECE275AB are strongly encouraged to subsequently (or in parallel) take (or sit in on) Math280ABC (Probability Theory) and/or Math281ABC (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 ECE275AB.

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, 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).

It is highly recommended that by the end of the course ECE275AB, ECE graduate students will have read Chapter 1 of reference [P15] (the text by Wong and Hajek) cited below. They are strongly encouraged to set themselves the goal of clearly understanding Chapter 1 of [P15] as soon as possible in their graduate career, and certainly by the time they complete their graduate studies. Although the material in [P15] may seem abstruse at first, over time the clarity and utility of this formalism should become evident. We will discuss some aspects of this material in ECE275AB. Those students who decide to take Math280ABC (Probabil-

ity Theory) subsequent to ECE275AB 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 (as well as the Lebesgue integral and its importance in measure theoretic-based probability theory) is given in reference [P16].

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 your own paper and pens to all exams.

CHEATING. Cheating will be dealt with aggressively and severely.

LECTURE SOURCE MATERIALS

The lecture is mainly drawn from the required textbooks and, at times, from selected readings from some of the primary secondary source texts listed below (several of which are on reserve at the S&E library). In addition, lecture supplements and source research articles will be placed on electronic reserves at the class web site. 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.

In the second quarter of the course (i.e. during ECE275B) some lectures will also draw heavily from material given in Chapter 6 of [P13] and Chapter five of reference [P10], both listed below.

OTHER PRIMARY TEXT SOURCES

Students are **not** expected to read the following references, except for a few isolated cases of excerpted readings to be announced in class lecture. *Therefore, students should not be intimidated by the extensive list of references given below*. These references are provided as a *service* to students who either want to have a source for obtaining a deeper understanding of material presented in this course or who want to have a list of resources for when they are pursuing their PhD research. Other references pertaining to specific topics mentioned in the courses (e.g., vector calculus), will be provided in the course readings located on the class website.

- [P1] *Parameter Estimation: Principles and Problems*, H.W. Sorenson, Marcel Dekker, 1980. Extremely readable and insightful, but out of print.
- [P2] *Lessons in Estimation Theory for Signal Processing, Communications, and Control*, J.M. Mendel, Prentice-Hall, 1995. The text usually used at USC.
- [P3] *Statistical Signal Processing: Detection, Estimation, and Time Series Analysis*, L.L. Scharf, Addison-Wesley, 1991.
- [P4] *Mathematical Statistics: Basic Ideas and Selected Topics, Vol. 1*, 2nd Edition, P.J. Bickel and K.A. Doksum, Prentice-Hall, 2002. Highly Recommended.
- [P6] *Statistical Inference*, 2nd Edition, G. Cassella and R.L. Berger, Duxbury, 2002. Highly Recommended. Often available in the bookstore as a textbook for Math281, Mathematical Statistics.
- [P7] *Elements of Large-Sample Theory*, E.L. Lehmann, Springer, 1999.
- [P8] *Theory of Point Estimation*, 2nd Edition, E.L. Lehmann and G. Casella, Springer, 1998. Highly Recommended. Often available in the bookstore as a textbook for Math281, Mathematical Statistics.
- [P9] *The Theory of Statistical Inference*, S. Zacks, Wiley, 1971. Highly recommended for advanced results in point estimation but apparently out of print. Provides a detailed theoretical development of the theory of sufficient statistics.
- [P10] *Optimal Filtering*, B.D.O. Anderson and J.B. Moore, Prentice-Hall, 1979. Highly Recommended and now available as an inexpensive Dover Publications paperback reprint. The derivation of the Kalman Filter given in ECE275B is taken from chapter 5 of this book and it is highly recommended that it be purchased for the "B" part of this course.
- [P11] *Digital Processing of Random Signals*, B. Porat, Prentice-Hall, 1994. Reprinted as a paperback by Dover Press, 2008. Highly recommended for students who want to pursue careers in DSP and Communications Theory. This text provides a rigorous supplement to the material presented in this course and ECE251A. 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.
- [P12] *The EM Algorithm and Extensions*, G.J. McLachlan and T. Krishnan, Wiley, 1997.
- [P13] *Fundamentals of Speech Recognition*, L. Rabiner and B.-H. Juang, Prentice-Hall, 1993. (Chapter 6: Theory and Implementation of Hidden Markov Models.)
- [P14] *Statistics and Econometric Models*, Vol's 1 & 2, C. Gourieroux and A. Monfort, Cambridge University Press, 1995.

- [P15] *Stochastic Processes in Engineering Systems*, Eugene Wong & Bruce Hajek, Springer-Verlag, 1985. (Chapter 1: Elements of Probability Theory, pages 1–33.)
- [P16] *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.
- [P17] *Statistical Inference*, S.D. Silvey, Penguin Books, 1970. This is an excellent relatively gentle introduction to advanced concepts in statistical inference.

OTHER TEXTBOOK REFERENCES

- [R1] *Elements of Signal Detection and Estimation*, C. Helstrom, Prentice-Hall, 1995.
- [R2] *An Introduction to Signal Detection and Estimation*, 2nd Edition, H. Vincent Poor, Springer, 1994.
- [R3] *Statistical Methods for Speech Recognition*, F. Jelinek, MIT Press, 1997.
- [R4] *Statistical Analysis of Finite Mixture Distributions*, D.M. Titterton, A.F.M. Smith, and U.E. Makov, Wiley, 1985.
- [R5] *Likelihood*, (Expanded Edition), A.W.F. Edwards, Johns Hopkins University Press, 1992.
- [R6] *Hidden Markov Models*, R.J. Elliott, L. Aggoun, and J.B. Moore, Springer-Verlag, 1995.
- [R7] *Statistical Analysis with Missing Data*, R.J.A. Little and D.B. Rubin, Wiley, 1987.
- [R8] *Decision, Estimation, and Classification*, C.W. Therrien, Wiley, 1989.
- [R9] *Detection, Estimation, and Modulation Theory*, Vol. 1, H.L. Van Trees, Wiley, 1968.

OTHER IMPORTANT INFORMATION SOURCES

Of course the **Google search engine** can yield a large amount of useful information and source material (such as reports and tutorials) 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!²) can be found at the **JSTOR database**, located at <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>. Finally, **Wikipedia** has a vast amount of nontrivial, yet highly accessible, information on math, science, engineering, and computer science topics.

²For 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.'