Course Announcement: Optimal Estimation (EML 6934, Section 6385) Fall 2009

University of Florida, Mechanical and Aerospace Engineering

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Course website: `http://humdoi.mae.ufl.edu/~prabirbarooah/EML6934F09.html`
Currently the website contains the following two items that might of interst to potential students:

- Lecture notes taken by one of the students the last time the course was offered (Spring 2008)[1]
- Scanned copies of the feedback provided by the students in their course evaluations (from Spring 2008).

Course Summary: Measurements are invariably corrupted with noise. Quantities of interest are to be estimated from such noisy data, where these quantities can be unknown but fixed parameters, random variables, or states of a dynamical system that change with time. We will deal with the question of determining accurate estimates of the quantities of interest from noisy data. The accuracy of an estimate is typically measured by the variance of the estimation error. Optimal estimates refers to estimates whose error variance is minimal. The emphasis will therefore be on computing optimal, or "most accurate" in appropriate sense, estimates.

The purpose of this course is to provide a firm background in the mathematical basis of estimation algorithms that have been developed over time and now are widely used by engineers. Applications from diverse areas of mechanical and aerospace engineering will be provided as examples to illustrate typical situations in which estimation plays a crucial role. We will start with the simple situation when a parameter x is to be estimated from n noisy measurements $y_i = x + \epsilon_i, i = 1, \dots, n$, where ϵ_i is measurement noise. We will then reexamine this problem in the more general setting of estimating one random variable given the measurement of another. Finally, we will examine the state estimation problem in which the state x_k of the linear system $x_{k+1} = A_k x_k + B_k u_k + w_k$, $y_k = C_k x_k + \theta_k$ is to be estimated, where w_k and θ_k are noise sequences (called stochastic processes) affecting the dynamic evolution and measurements.

[1] Please be aware that these notes do not come with any "warranty" of any sort whatsoever. The *only* reason I am making them available to you is to help you get an idea of what kind of material is covered in this class.

Credits: 3. Letter grade.

Syllabus: Review of Probability and Random Variables: axiomatic definition of probability, combinatorial problems, random variables, probability spaces, marginal and joint density functions, random vectors, expectation, moments.

Parameter estimation: Unbiased Minimum Variance and Best Linear Unbiased Estimation. Recursive Least Squares Algorithm. Maximum Likelihood and Maximum A-posteriori Estimators. Asymptotic properties of estimators - unbiasedness and consistency. Cramer-Rao Lower bound. Reexamination of the unbiased minimum variance estimator - conditional mean. Review of Linear Least Squares Estimation - Optimization in Hilbert Spaces and the Projection Theorem.

State estimation: Discrete time Kalman Filter, Extended Kalman Filter. Discrete time prediction and smoothing.

Prerequisites: *Very strong mathematical background is required for this course.* Since the major issue is noise, probability and statistics, especially random variables and stochastic processes will be of central importance. Equality important will be linear algebra. Relevant topics from probability and linear algebra will be reviewed during the course, though some familiarity will be beneficial. If you have never heard of the Normal distribution, range and null space of a matrix, or state-space models of dynamic systems, you may face some difficulty in this course. On the other hand, if you have used the Kalman Filter but didn't have the opportunity to understand it well, this course will be very useful for you.

Text: There is no required textbook for this course. The following are recommended as references:

1. *A first course in probability*, Sheldon Ross, Prentice Hall, ISBN 0130338516 (good for a review of probability and random variables for the beginner, Chapters 1- 7)

2. *Optimal Estimation of Dynamic Systems*, John L. Crassidis and John L. Junkins, Chapman & Hall/CRC, ISBN 158488391X (good book written with an MAE audience in mind than an ECE one, but does not deal with the statistical component in detail)

3. *Lessons in Estimation Theory for Signal Processing, Communications, and Control*, 3rd Ed., Jerry M. Mendel, ISBN 0131209817 (contains all the material to be covered in the course, but poorly organized and confusing.)

4. *A tutorial introduction on Estimation and Filtering*, Ian Rhodes, *IEEE Transactions on automatic control*, vol. AC-16, no. 6, Dece. 1971, pp. 688-706. (best resource among all of the above, but extremely dense, and not for beginners.)

Meeting time and room: MWF, period 4[2] (10:40 - 11:30 am), MAE-A 327

Grading: grading will based on three exams (20%,20%,30%) and homework/quizzes(30%). Some of the quizzes will be unannounced.

[2]The class may be listed as a period 5 class right now, but that'll be changed to period 4 soon.