ECE 275A - Parameter Estimation I

Spring 2025 - Syllabus

Parameter estimation is a key task in artificial intelligence, data mining, signal processing, communications theory, machine learning, adaptive systems, stochastic control theory, and related areas. This course is focused on learning the unknown parameters defining a probability model whose purpose is to explain and capture the behavior of observed data. We cover classical estimation, where the parameters are unknown but deterministic (non-random), and Bayesian estimation, where the parameters are random and modeled statistically by a prior distribution. In the classical setting, we will develop the Cramer-Rao lower bound, the search for a minimum variance unbiased estimator, the maximum likelihood method, and the expectation-maximization algorithm. In the Bayesian setting, we will establish minimum mean squared error (MMSE) estimation, maximum a posteriori (MAP) estimation, sequential state-space models, and the Kalman filter.

Summary of topics discussed:

1. Parameterized probability models (exponential class and mixture distributions) and their relationship to static and dynamic system models
2. Statistical figures of merit (bias, consistency, the Cramer-Rao lower bound, and efficiency)
3. The minimum variance unbiased estimator
4. The maximum likelihood estimator (MLE) and the expectation-maximization (EM) algorithm
5. Minimum mean squared error (MMSE) estimation and maximum a posteriori (MAP) estimation
6. Sequential Bayesian estimation and the Kalman filter

Time and place: Lectures are Tuesdays and Thursdays 3:30PM – 4:50PM in WLH 2111.

Instructor:

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Teaching Assistant (TA):

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Course Website: Handouts and homework assignments will be posted on the Canvas website.

Prerequisites: 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 non-negative, that an orthogonal transformation can diagonalize it, and that this diagonalization corresponds to a decorrelation of the components of the random vector. A student should also know how to find the minimum norm solution for linear inverse problems $\min_{\mathbf{x}} \|\mathbf{y} - \mathbf{A}\mathbf{x}\|^2_{\mathbf{W}}$ where $\mathbf{y}$ is a measurement, $\mathbf{A}$ is an arbitrary matrix, and $\mathbf{W}$ is an arbitrary positive definite weight matrix. The minimal suggested prerequisites for the course are ECE 109 and ECE 174 or equivalent and Matlab/Python programming experience. A recommended prerequisite is the linear algebra class ECE 269.

Bibliography: The main required textbook is

- *Fundamentals of Statistical Signal Processing. Volume 1: Estimation Theory*, Steven M. Kay, Prentice-Hall, 1993.

An additional optional reference is

- *Optimal Filtering*, Brian D. O. Anderson and John B. Moore, Prentice-Hall, 1979.

Further lecture notes and research papers will be used, which will be posted on this course website. A reference to a source (text and pages) for the lecture will be given in class whenever possible.

Grades: Homework 20%, Quizzes 10%, Mid-Term Exam 30%, Final Exam 40%, and Bonus Points 5%

Homework: Homework problems will be posted approximately every 1-2 weeks on the course website and due one week later. Some homework problems are to be solved in Matlab or Python. It is expected that all completed problems are turned in on time. Only some homework problems are corrected. For other problems points are assigned proportionally to the percentage of work done. Because homework is not graded for correctness, students must read the solutions to determine if they performed the homework correctly or not.

Exams: The date of the final exam is the 9th of June, 2025. Exams are graded traditionally. Both exams are closed books and notes. Only nonprogrammable calculators can be used. All other electronic storage and communication devices are banned. Cheating will result in penalties.

Office Hours: Office hours on lecture material are every Friday at 1:30 PM via Zoom. In-person office hours can be scheduled by contacting the instructor. TA office hours are Friday 1:30pm–2:30 pm in EBU1 4506.

Collaboration Policy: The goal of homework is to give you practice in mastering the course material. Consequently, you are encouraged to form study groups to discuss the course material and problem sets. However, your solutions should reflect your understanding of the course material. It is not acceptable to copy a solution that somebody else has written. You must develop each problem solution by yourself without assistance.