ECE 275A - Parameter Estimation I

Fall 2023 - 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 CSB 001.

Instructor:

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Teaching Assistant:

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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. The minimal suggested prerequisites for the course are linear algebra, basic probability (e.g., ECE 109, ECE 174), and Matlab 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 30%, Mid-Term Exam 30%, Final Exam 40%.

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. Homework is graded using an "A for effort" scheme. Individual homework problems are not corrected. 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 11th of December, 2023. 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 are every Friday at 1:30 PM via Zoom. In-person office hours can be scheduled by contacting the instructor or teaching assistant.

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, the developed solutions you hand in 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.