Instructor: Zak M. Kassas

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Course Webpage: Available through Canvas
Office Hours: Wed. 5:00 pm – 6:30 pm

Lectures: Mon. & Wed., 3:30 pm – 4:50 pm, Information & Computer Science (ICS) 209
Text: Y. Bar-Shalom, X.R. Li, and T. Kirubarajan, *Estimation with Applications to Tracking and Navigation*, Wiley, 2001

Suggested References:

- A. Gelb, *Applied Optimal Estimation*, MIT Press, 1974
- G. Bierman, *Factorization Methods for Discrete Sequential Estimation*, Dover Publications, 1977
- S. Kay, *Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory*, Prentice Hall, 1993
- R. Stengel, *Optimal Control and Estimation*, Dover, 1994
- J. Mendel, *Lessons in Estimation Theory for Signal Processing, Communications, and Control*, Prentice Hall, Second Edition, 1995
- A. Jazwinski, *Stochastic Processes and Filtering Theory*, Dover, 2007
- H. V. Poor, *An Introduction to Signal Detection and Estimation*, Springer-Verlag, 2010
- R. Brown and P. Hwang, *Introduction to Random Signal Analysis and Kalman Filtering with Matlab Exercises*, Wiley, Fourth Edition, 2012
- H. Van Trees, K. Bell, and Z. Tian, *Detection Estimation and Modulation Theory (Part I)*, Wiley, Second Edition, 2013

Prerequisites: One of the following: MAE 278: Parameter & State Estimation; EECS 251A: Detection, Estimation, & Demodulation Theory; or consent of instructor

Course Objective: This course develops a fundamental and applied understanding of detection and estimation theory. Application examples from communication systems, signal processing, controls systems, robotics, target tracking, and navigation systems will be presented. Topics covered include: hypothesis testing, detector performance, estimator design [maximum-likelihood (ML), maximum *a posteriori* (MAP), least-squares (LS), minimum mean-square error (MMSE)], estimator properties, estimation of linear and nonlinear static systems (batch and recursive formulations), Kalman filters (derivation, implementation issues, performance), information filter, square-root information filter, smoothing, linear and nonlinear contintous-time and discrete-time stochastic dynamic systems, optimal estimation of nonlinear dynamic systems (Fokker-Planck-Kolmogorov Equation and Chapman-Kolmogorov Equation), extended Kalman filter (EKF) and iterated EKF, observability notions, adaptive filters, multiple model filter, sigma-point Kalman filter, and particle filter.

Attendance and Course Policy: Attendance is expected. You are responsible for material covered in class and in the reading assignments.

Project: There will be one final project. You are expected to propose your own project's topic whose scope should be within detection and estimation. The project may be theory and/or a novel application (simulation and/or implementation). You are expected to prepare a four-page report summarizing your results in the standard IEEE conference paper format. You are also expected to present a ten-minute class presentation.

Exams: There will be one midterm exam and a final. Missed exams may **not** be made up (unless it is the result of an officially excused absence).

Grading:

Project	20%
Midterm Exam	40%
Final Exam	40%

Tentative Topical Coverage:

Week	Topics
1	Introduction, Review of linear algebra, probability theory, and stochastic processes
2	Estimation theory basics, Maximum-likelihood (ML), Maximum *a posteriori* (MAP), Least-squares (LS), Minimum mean-square error (MMSE), Estimator properties, Fisher Information Matrix (FIM), Cramer-Rao Lower Bound (CRLB)
3	Detection theory basics, Hypothesis testing, Neyman-Pearson Lemma, Detector Performance, General Gaussian problem, Composite hypothesis testing
4	Linear estimation of static systems: Batch and recursive formulations, Nonlinear least-squares estimation, Continuous-time and discrete-time linear stochastic dynamic systems, Moment evolution theorm
5	Kalman filter: MMSE and MAP derivations, Steady-state Kalman filter, Monte Carlo and real-time statistical tests, Tuning, Initialization
6	Information filter, Square-root information filter (SRIF), Smoothing
7	Continuous-time and discrete-time nonlinear stochastic dynamic systems, Estimation of nonlinear dynamic stochastic systems: Fokker-Planck-Kolmogorov Equation and Chapman-Kolmogorov Equation
8	Extended Kalman filter (EKF), Iterated EKF, Observability notions
9	Adaptive filters, Multiple model filter
10	Sigma-point Kalman filter, Particle filter