ECE 734 / ECE 836- Spring 2008
DETECTION AND ESTIMATION THEORY
Professor Yariv Ephraim
STII Room 221

Time: Wednesday 7:20-10:00 pm
Place: Fine Arts Building B212

Final Exam: Take home exam to be assigned on Wednesday 7 May and will be due on Mon 12 May by 10:00am in my office.

Office Hours: Monday: 6:15-7:15 pm
Wednesday: 6:15-7:15 pm
Other time by appointment

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Course Description:

The focus of this course is on linear estimation theory and its applications. An introduction to detection theory is also provided. In linear estimation, we first discuss estimation of vectors or random variables, and then proceed to estimation of discrete-time stationary and non-stationary scalar and vector signals. In particular, we cover Wiener and Kalman filtering theory. In detection theory we discuss some fundamentals such as the Neyman-Pearson theorem, simple and composite hypotheses, and performance bounds. This course is strongly recommended for students in the areas of Communications, Controls, and Signal Processing. This course is open to students who have already taken ECE 734 from other Professors. These students should register under ECE 836.

Complementary Material:

Students interested in the fundamentals of detection theory should take ECE 630-Statistical Communication Theory. Other aspects of detection theory, such as composite hypothesis testing and universal classification, are covered to some extent in ECE 751-Information Theory. Parameter estimation and the Cramer-Rao bound are covered in ECE 752-Spectral Estimation.

Prerequisites: ECE-528 or instructor permission.

Course Outline:

- Background (week 1-2)
    1. Linear and Nonlinear estimation
    2. The conditional mean and the projection theorem
    3. Course overview
- Deterministic least squares problems (Chap. 2, weeks 2-3)
    1. The deterministic least-squares criterion
    2. The classical solutions

3. Orthogonality condition and geometric interpretation
4. Regularized least-squares problems
5. An array algorithm: the QR method
6. Updating least-squares solutions
7. Downdating least-squares solutions

- Stochastic least squares problems (Chap. 3, weeks 4-5)
  1. Problem definition
  2. Linear least-squares estimators
  3. A geometric formulation
  4. Linear models
- The innovations process (Chap. 4, week 6)
  1. Estimation of stochastic processes
  2. The innovations process
  3. The exponentially correlated process
- State-space models (Chap. 5, week 7)
  1. The exponentially correlated process
  2. Going Beyond the stationary case
  3. Higher order processes and state space models
  4. Wide-sense Markov processes
- Innovations for stationary processes (Chap. 6, week 7)
  1. Innovations via spectral factorization
  2. Signals and Systems review
  3. Stationary random processes review
  4. Canonical spectral factorization
  5. Scalar rational z-spectrum
- Wiener theory for scalar processes (Chap. 7, week 8)
  1. The discrete-time Wiener smoother
  2. The Wiener-Hopf filtering equation and its solution
  3. Important special cases and examples (prediction, white noise)
  4. Innovations approach to the Wiener filter
- Approximate date for take home mid-term (Week 8)
- The Kalman filter (Chap. 9, week 9-10)
  1. The standard state-space model

    2. The Kalman filter recursions for the Innovations
    3. Recursions for predicted and filtered state estimators
    4. An important special case where Ri ¿ 0
    5. Approximate non-linear filtering (the extended Kalman filter)

- Smoothed estimators (Chap. 10, week 11)
    1. General smoothing formulas
    2. The Bryson-Frazier formulas
    3. Stochastic implementation of the adjoint variable

- Continuous-time state space estimation (Chap. 16, week 12)
    1. Continuous-time models
    2. Discrete-time approximation
    3. Kalman filter and smoother using the innovations process

- Hypothesis Testing (week 13-14)
    1. The Neyman-Pearson Theorem
    2. Simple hypotheses and the matched filter
    3. Elementary bounds on performance

Text Book:

1. T. Kailath, A. H. Sayed and B. Hassibi, *Linear Estimation.* Prentice Hall; 1st edition, New Jersey, 2000.

   A recent review of the above text book, written by H. V. Poor, can be found in *IEEE Trans. Inform. Theory*, vol.51, pp. 2236- 2240, June 2005.

2. R. E. Blahut, *Principles and Practice of Information Theory.* Addison-Wesley, Massachusetts, 1988.

   Only Chap. 4 of this book focusing on hypothesis testing will be covered.

Attendance and homework:

1. Students are encouraged to attend all classes.
2. Students are required to submit all homework assignments.
3. Students must not give or obtain any help in solving homework problems.
4. Homework assignments are due in class by 7:20 pm on the next Wednesday following their assignment.
5. Coping solutions for assigned problems will constitute a violation of the university honor code.

Communication:

We will communicate via email. Announcements, homework assignments and solutions will be emailed to you. I will use your email addresses which are on file at the GMU Registrar. If you wish to have your course material delivered to another email address, you may include a .forward command in your GMU directory. During the semester, please make sure that your mail box is not full. Also, for each email message that you will be sending me, please write ece734 on the subject line.

Grading:

Homework 15%; Mid-term 40%; Final 45%