Rowan University

Department of Electrical and Computer Engineering

ECE 09402 & ECE09502

Special Topics in ECE: Estimation and Detection Theory

Fall 2013

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Class Meeting: Thursdays 4:30 pm – 7:15 pm at Rowan 204
Required Text:

- Steven M. Kay, *Fundamentals of Statistical Signal Processing Vol I: Estimation Theory*, Prentice Hall.
- Steven M. Kay, *Fundamentals of Statistical Signal Processing Vol II: Detection Theory*, Prentice Hall.

Class Homepage: http://syen.ualr.edu/nxbouaynaya/Teaching.htm

About the class & Objectives

Modern estimation and detection theory can be found at the heart of many electronic signal processing systems for information extraction and decision making. These systems include

1. Radar
2. Sonar
3. Speech
4. Image analysis
5. Biomedicine
6. Communications
7. Control
8. Seismology,

and all share the common problems of 1) needing to estimate the values of a group of parameters and 2) being able to decide when an event of interest occurs and then to determine more information about that event. The latter task, information extraction, is the subject of *estimation theory*. The former problem, that of decision making, is the subject of *detection theory*. In radar, we are interested in determining the presence of an approaching aircraft and its position, as for example, in airport surveillance radar. Another common application is in sonar, in which we are also interested in the position of a target, such as a submarine. In digital communication systems, the function of the detector is to decide which signal was sent by the transmitter, as in the radar problem, although now we always have a signal present – the question is *which* signal. An important problem in speech processing is speech recognition, which is the recognition of speech by a machine (digital computer). The parameters of the speech model are estimated and a decision is made about which word was spoken.

Estimation and detection theory is a subject that is standard fare in engineering and statistics. The treatment of the topic ranges from the highly theoretical derivations written by statisticians to the more practical treatments contributed by the many user of applied statistics including engineers. This course will try to strike a balance between these two extremes. This class has five main goals:

1. To obtain optimal scalar and vector estimators using different optimality criteria (what does optimal mean? And how can we derive these optimal estimates?).
2. To study the performance of the derived estimators (how good are these estimates? Can we do better?)
3. To obtain optimal detectors of signals in noise.
4. To analyze the performance of the derived detectors.
5. To be able to apply the theory to actual estimation and detection problems in different areas in signal processing, communications, and control.

Course Prerequisites

- Basic knowledge of probability, statistics and random variables, linear algebra
- Calculus III or Math for Engineering Analysis,
- Expertise of MATLAB or C/C++
- Enthusiasm and perseverance

Class workload and study guidelines

Homeworks are due at the beginning of the lecture. Since the solution will be posted on the course web page immediately after the lecture, no late homework will be accepted. Students with documented medical reasons may be excused.

In order to get the most out of the course, try to stay ahead. By the weekend, make sure you have reviewed the material covered in the lectures of the preceding week. Read the assigned material, but at a minimum, make sure to review your lecture notes. This way, the next lectures will be much more informative and meaningful. Feel free to go to the instructor's office hours if you have questions regarding the material covered in the lecture or solutions of homeworks that were posted on the web page, if you want to discuss your work, etc. Also, it is a good idea to retain a copy of your homework before you turn it in. This lets you compare them with our solutions right away, rather than waiting a week until they come back to you graded. In the exams and the homeworks, we expect you to concisely explain your reasoning. Giving a numerical answer, even correct, does not guarantee full credit if you don't justify it. Partial credit may be given if you show a correct understanding of the problem and the concepts involved.

Course Project

The project will consist of an in-depth study of an implementation of detection and estimation principles. The goal is to explore contemporary research topics in the area of estimation, detection and generally statistical signal processing that are not covered in class. Pick or suggest a topic of interest and provide a comprehensive treatment of it: introduce the problem/topic, survey what has been done on the topic, implement (Matlab or C) the estimation/detection problem technique for various scenarios and make a demo, to be performed and explained live in class during your presentation. Do not forget to study the performance of your technique or algorithm and show its strength and weaknesses. You may compare various methods (e.g., various tracking algorithms).

One useful resource is IEEE Xplore where you can search many of the relevant IEEE journals such as IEEE Transactions on Signal Processing, IEEE Transactions on Image Processing, IEEE Transactions on Communications and IEEE Transactions on Speech and Audio Processing among many others. The project will consist in three parts: 1) a single spaced 5-8 report, 2) a live demo, of your implementation, or comparison between different implementations/techniques, and 3) a ppt presentation in front of the class in which you will introduce your selected topic and live demo (10 mn long).

Possible project topics: the EM algorithm and its applications, the Kalman filter and its applications, white-spaces detection, distributed detection and estimation, sensor fusion, sequential detection and estimation, applications in your domain of interest (biology, image processing, speech processing, etc.), particle filters, radar signal processing (detection, tracking, SAR imaging).

Project timeline: Choose topic (Oct 10), make a list of relevant papers, skeleton of the paper, outline of the demo (Nov 28), in class presentations and demos (Dec 5-12).

Course Topics

Estimation Theory:

Minimum Variance Unbiased Estimation
Cramer-Rao Lower Bound
Linear Models + Unbiased estimators
Maximum Likelihood Estimation
Least Squares Estimation
Bayesian estimation
Kalman Filtering

Detection Theory:

Statistical Detection Theory
Deterministic Signals
Random Signals

Academic Integrity

Rowan University Academic Integrity Policy:

http://www.rowan.edu/provost/policies/AcademicIntegrity.htm