EENG519: Estimation Theory and Kalman Filtering - Syllabus

Tyrone Vincent

Spring 2017

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1 Motivation and Objectives

Estimation theory considers the extraction of useful information from raw sensor measurements. The basis for estimation theory has roots starting in the 18th century in attempts to calculate the orbits of planets from observations, but can be more directly traced to work during WWII when engineers were trying to convert data from radar into estimates of target range and velocity. Navigation and localization is still an important application of estimation theory, (including GPS), but applications occur any time measurements of a dynamic system are taken, such as in:

- Robotics
- Automotive
- Aerospace
- Manufacturing Systems
- Power Systems

Objectives Course Objective

Students will be able to:
Design and implement algorithms to estimate the states of dynamic systems from input/output data.

Objectives Course Outcomes

Specific outcomes are:

- Model dynamic systems with uncertain inputs
- Design and implement a Kalman Filter to estimate the internal states of a linear system with Gaussian uncertainties
- Design and implement filters to estimate the internal states of general systems with general uncertainties.

2 Syllabus

2.1 Administrative Details

My info:

- Prof. Tyrone Vincent
- Office: BB327D
- Office hours: M 3:00-4:30pm and T 1:00-2:30pm, other times by appointment
- Email: tvincent@mines.edu

Reading Material

- The textbook: Robert Grover Brown and Patrick Y. C. Hwang, *Random Signals and Applied Kalman Filtering*, Wiley, 2012.
- Lecture material will be posted on Canvas

Grading Scale

Available Points

Homework Assignments	100 pts
2 Exams	400 pts
Project	100 pts
Total	600 pts

Homework

- The purpose of the homework is for you to help you practice to learn the concepts presented in the course. You may work together on the homework, but what you turn in should be your own work, and you should have an understanding of what you turned in.
- Homework will be assigned as noted in the schedule
- Homework will be peer reviewed.

Exams

- The Exams will be given during one class period (75 minutes)
- Exams are closed book and closed notes, other than one sheet of 8.5 by 11 paper
- Exam solutions will be discussed the day the exams are returned. If you have a disagreement with the grading, you must hand the exam back to me at the end of the lecture.

Canvas

- This course will be using the Canvas system as a repository for important information.
  - `http://elearning.mines.edu/`.
  - You should automatically be enrolled in Spring2017-EENG519A.
- All current CSM students should have a Canvas account. Go to the Academic Computing and Networking site and search for "Canvas" to find instructions to log into particular courses.
- This system will be used to post homework assignments, homework solutions, references, etc.

MATLAB

- A tool for technical computing
- Programming like interface. (You should have already taken Fortran, C, or Java)
- Easy access to highly optimized numerical methods

Some of the assignments will require the use of MATLAB, a computational engine that is used extensively in control system design, as well as in signal processing, communications, and many other fields. You are responsible for becoming familiar with the MATLAB interface. If you have not used MATLAB before, you will want to try the introductory lab posted on Canvas.

Project

- The project will be on a subject of your choosing related to state estimation, and should have a significant computational/MATLAB component.
- I will be posting potential project problems, but you are also free to choose one of your own. You will submit your choice after Exam #1.
- You will complete small parts of the project throughout the semester, culminating in a short report and presentation.

2.2 Academic Integrity

Students are expected to be familiar with and follow the CSM Student Honor Code and Policy on Academic Integrity as detailed in the Graduate Bulletin.

2.3 Pre-requisite material

It is expected that students are familiar with linear algebra from EENG515 and basic probability theory.

3 Schedule

(Note: this schedule is subject to change)

Date	Topic	Lec.	Assignments
Thu, January 12	Introduction to the course, Probability Basics	1	
Tue, January 17	Bayes' Rule	2	
Thu, January 19	Random Variables	3	Homework #1 Due
Tue, January 24	Multiple Random Variables	4	
Thu, January 26	Estimators	5	
Tue, January 31	Least Squares	6	
Thu, February 2	State Space Systems	7	Homework #2 Due
Tue, February 7	State Space Systems Continued	8	
Thu, February 9	Jordan Form and Cayley Hamilton Theorem	9	
Tue, February 14	Deterministic State Estimation	10	Homework #3 Due
Thu, February 16	Recursive Least Squares	11	
Tue, February 21	Stochastic Processes	12	
Thu, February 23	Power Spectral Density	13	
Tue, February 28	System Identification	14	Homework #4 Due
Thu, March 2	Review for Exam		
Tue, March 7	**Exam #1**		
Thu, March 9	Review Exam		
Tue, March 14	Kalman Filter I	15	
Thu, March 16	Kalman Filter II	16	Homework #6 Due
Tue, March 21	Kalman Filter III	17	
Thu, March 23	Maximum A-Posteriori Filter	18	
March 28, 30	**No Class - Spring Break**		
April 4, April 6	Extended Kalman Filter and Moving Horizon Estimation	19	Homework #7 Due April 6
April 11, April 13	Simulation Methods	20	
April 18, April 20	Bayesian Filtering	21	Homework #8 Due April 20
Tue, April 25	Review for Exam		
Thu, April 27	**Exam #2**		
Tue, May 2	Review Exam		
Thu, May 4	Project Reports		