

ECE5550

APPLIED KALMAN FILTERING

Fall 2016

Theory and application of Kalman filters for state estimation, information fusion, multitarget tracking, and data association. Special focus on the discrete linear Kalman filter, the extended Kalman filter, and the unscented Kalman filter. Practical issues related to robust performance are studied. Prer., Math 381 or ECE3610, and Math 313 (or equivalent).

Instructor: Dr. Gregory Plett **Office:** EN-290 **Phone:** 255-3468 **email:** gplett@uccs.edu
Course web-page: <http://mocha-java.uccs.edu/>

Office hours: TBD

Required text: Simon, D., *Optimal State Estimation: Kalman, H_∞ and Nonlinear Approaches*, Wiley Interscience, 2006.

Optional text: Bar-Shalom, Y., Rong Li, X., and Kirubarajan, T., *Estimation with Applications to Tracking and Navigation: Theory, Algorithms, and Software*, Wiley Interscience, New York, 2001.

Optional software: The Matlab[®] Student Version, which is available on EAS CLaaS
 (see <http://www.uccs.edu/eas/claas.html>).

Evaluation: Homework assignments, mini projects: 75%
 Final project: 25%

Grading: 90–100= A^- to A ; 80–89= B^- to B^+ ; 70–79= C^- to C^+ ; 60–69= D^- to D^+ ; 0–59= F

Course topics	Simon	Bar-Shalom	Est. weeks
1. Introduction to Kalman filters.	Introduction	Ch. 1	0.5
2. State-space dynamic systems.	Ch. 1	Ch. 1	1.5
3. Dynamic systems with noisy inputs.	Chs. 2–4	Chs. 1, 4	2.0
4. The linear Kalman filter.	Ch. 5	Chs. 5, 6	3.0
5. Kalman filter generalizations.	Chs. 6, 7, 9	Chs. 7, 8	2.0
6. Nonlinear Kalman filters.	Chs. 13–14	Ch. 10	1.5
7. Particle filters.	Ch. 15	—	1.5
8. IMM/multitarget tracking.	Ch. 10	Ch. 11	1.5
9. Simultaneous state and parameter estimation.	—	Ch. 11	1.5
10. Kalman filter applications.	—	—	0.5
A. Linear algebra (matrix) review.	Ch. 1	Ch. 1	—

Work Load: This is an aggressive course requiring weekly homework assignments. Expect to spend six to nine hours per week outside of class reading the textbook and completing homework assignments. This is in accord with UCCS policy relating credit hours for a lecture course to student workload. Some students will find that more time is required, while others will find that less time is required.

Homework Policy #1: Homework will be collected at the beginning of class on the assigned date. Homework turned in after the class period will be penalized 10%. Homework turned in after the due date will be penalized an additional 25% per day unless previous arrangements have been made with the instructor. Examinations will be based on the homework problems and the material covered in class. It is to your advantage to understand the fundamental concepts that are demonstrated in the homework problems. It will be difficult to earn higher than a "C" without performing well on the homework assignments.

Homework Policy #2: Your coursework (homework/project/exams) is expected to be a bona-fide individual effort. Copying homework, project or exam solutions from another student or other source is CHEATING and will not be tolerated. You may (and are encouraged to) discuss homework/project problems with other students, but only to the extent that you would discuss them with the instructor. Don't ask another student a question that you would not expect the instructor to answer. Most of us know when we are compromising our integrity. If you are in doubt, ask first.

Homework Policy #3: Part of your engineering education involves learning how to communicate technical information to others. Basic standards of neatness and clarity are essential to this process of communication. Your process of solving a problem must be presented in a logical sequence. Consider your assignments to represent your performance as an engineer. Do not submit scrap paper, and do not submit paper containing scratched out notes. Graphs are to be titled and axes are to be labeled (with correct units). The above standards of clarity and neatness also apply to your work on exams.

Attendance: Attendance is your responsibility. Class lectures will cover a significant amount of material. Some will not be in the text or may be explained differently. It is to your advantage to take notes, ask questions, and to fully participate in the classroom experience.

Missed Exams: Missed exams will count as ZERO without a physician's documentation of an illness, or other appropriate documentation of an emergency beyond your control and requiring your absence.

Drop Date: This course complies with the UCCS campus rules for drop date.

Disability Accomodation: If you have a disability for which you are requesting an accommodation, you are encouraged to contact Disability Services within the first week of classes.

Military Students: If you are a military student with the potential of being called to military service and /or training during the course of the semester, you are encouraged to contact me no later than the first week of class to discuss the class attendance policy.

Homework Format Rules: Points will be deducted for failure to comply with the following rules:

1. Use 8 1/2 by 11 paper (engineering paper is good).
2. Write on one side of the paper only.
3. Enclose your final answer to each problem in a box so that it may be clearly identified.
4. Write name and date and homework set number in the right corner.
5. Staple in the upper left corner. Use only one staple!
6. Be sure to write in pencil. Do not use ink to complete your homework assignments.

The Course Reader: These notes have been entered using L^AT_EX, and typeset with L^AT_EX_{2_ε} on a Macintosh Core i7 computer running the OS X operating system.

Course Outcomes

The following are expected outcomes for each unit of the course. By the end of the noted unit, the student should be able to:

Unit 2: State-space dynamic systems.

- Convert a linear time-invariant ordinary-differential and ordinary-difference equations into state-space models
- Simulate continuous-time and discrete-time state-space models in Simulink
- Implement NCP, coordinated-turn, and NCV models in both continuous and discrete time
- Compute the dynamic response of a state-space model to a given input
- Convert a continuous-time state-space model to a discrete-time state-space model
- Evaluate controllability and observability of state-space models

Unit 3: Dynamic systems with noisy inputs.

- Evaluate the mean of a random variable given its pdf
- Evaluate the correlation and covariance between multiple random variables given their joint pdf
- Determine whether joint random variables are independent and/or uncorrelated
- Compute the pdf of a random variable that is the result of evaluating a function of a different random variable having known pdf
- Create samples of a random variable having a given pdf in MATLAB
- Determine the mean and covariance of the state and output of a linear (continuous-time or discrete-time) dynamic system that is driven by white noise
- Convert continuous-time process-noise covariance matrix to discrete-time process-noise covariance matrix

Unit 4: The linear Kalman filter.

- Implement a linear Kalman filter in MATLAB
- Find the steady-state Kalman gain
- Optimally initialize a linear Kalman filter using the first few data samples

Unit 5: Kalman filter generalizations.

- Implement a robust form of the Kalman filter that maintains symmetric positive-semi-definite covariance matrices
- Implement a sequential Kalman filter
- Implement a square-root Kalman filter
- Implement a Kalman filter that correctly handles correlated process and/or measurement noise
- Implement a Kalman predictor or smoother
- Implement measurement validation gating to discard noisy measurements

Unit 6: Nonlinear Kalman filters.

- Implement an extended Kalman filter for a given problem
- Implement a (square-root or standard) sigma-point Kalman filter for a given problem

Unit 7: Particle filters.

- Implement a particle filter for a given problem

Unit 8: IMM/multitarget tracking.

- Implement a target tracker with polar measurements and a Cartesian state
- Implement an interacting multi-mode Kalman filter

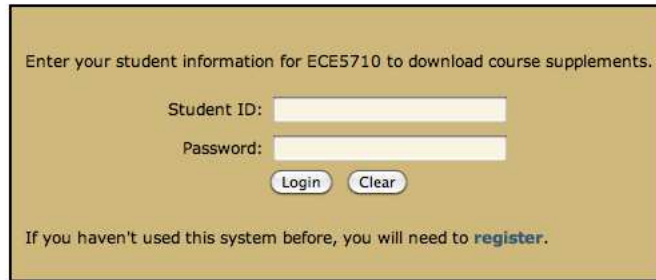
Unit 9: Simultaneous state and parameter estimation.

- Implement dual and joint EKF and SPKF

The EduFile Course Supplement Management System (*EduFile*):

The class homepage is accessed via <http://mocha-java.uccs.edu/>. Click on the [+] sign next to the course name, and then click on the link to access course supplements.

Follow this link, and you will be directed to the log-on screen:



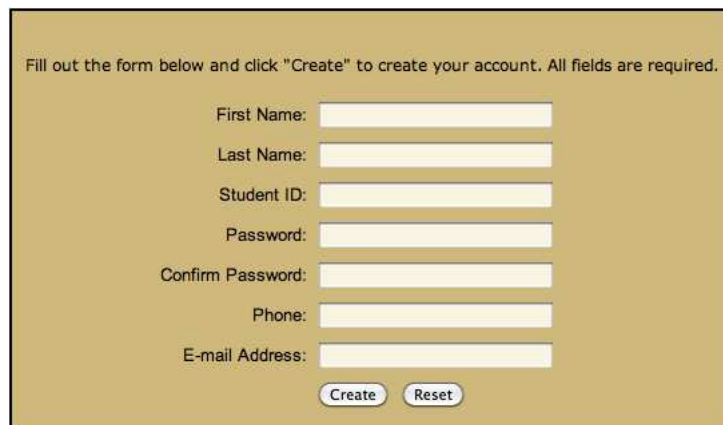
Enter your student information for ECE5710 to download course supplements.

Student ID:

Password:

If you haven't used this system before, you will need to [register](#).

The first time you use the system, click on the word "register". You will be directed to the screen:



Fill out the form below and click "Create" to create your account. All fields are required.

First Name:

Last Name:

Student ID:

Password:

Confirm Password:

Phone:

E-mail Address:

Enter the requested information and press "Create". You should see the screen:

User Added To Course

The user 111223333 has been added to course ECE5710. You are currently registered in another course with this system. Your student ID has been added to the course you have requested. However, you will not be able to use the system until your account has been enabled by your instructor.

Note that passwords are case-sensitive!

You will not immediately gain access to course supplements. You will receive email notification when your account is enabled for this course. Only then may you log on using your student ID and password. You will see a screen like this (tailored to ECE5550, of course):

Welcome to EduFile

Course Info	
Instructor Name:	Dr. Gregory Plett (glp@eas.uccs.edu)
Course Name:	Modeling, Simulation, and Identification of Battery Dynamics
Course Description:	Derives mathematical models of the electrochemical dynamics of battery cells, including thermodynamic and kinematic properties, at multiple scales. Modern, lithium-ion chemistries are emphasized. Students will use simulation software and will use lab-test data to create and validate parameterized models. Prer., ECE2205, MATH2350, MATH3400 or equiv.

Click on the Filename to download the file you need.

Update Since Last Download?	Downloaded	Filename	File Description
LECTURE NOTES			
No	Yes	CH01-BootCamp.pdf	Lecture notes chapter 1

[Edit Personal Info](#)

At the top of the page, the course name, course description and instructor are listed. By clicking on the instructor email address, you may send an email message directly from your web browser to the instructor. Below the course description is a listing of supplements that you may download. These are divided into categories (*e.g.*, ANNOUNCEMENTS, CHAPTER 1...) as assigned by the instructor.

In the figure, we see that this student has downloaded the syllabus and the first chapter of the lecture notes. Furthermore, she is assured that she has the most recent copy of the lecture notes since the flag "Update Since Last Download" says "No". However, the syllabus has been updated since the last time she downloaded it, so she should retrieve the newer version. This student has not downloaded the tutoring schedule or the example Matlab simulation files, which she might want for extra help and understanding of the material. Not shown, because it falls at the bottom of the page, is a button allowing the student to modify her personal information (name, password, and so forth).