University of Colorado Boulder
ASEN 5044
Statistical Estimation for Dynamical Systems
Fall 2017 Course Syllabus

General Information

Instructor: Prof. Nisar Ahmed (`Nisar.Ahmed@colorado.edu`)

Course Assistant: Jacob Denton (`Jacob.Denton@colorado.edu`)

Lecture Time and Location: Tues & Thur 11-12:15, ECCR 150. All lectures will be recorded and posted online via course D2L website. BBA/distance learning students may participate live through the Zoom meeting interface (see course website for instructions). For distance students who wish to attend live lectures, this course requires the use of the Zoom conferencing tool, which is currently not accessible to users using assistive technology. If you use assistive technology to access the course material, please contact your faculty member immediately to discuss.

Course D2L Website: `learn.colorado.edu` (will be used for posting all recorded lectures, assignments, exams, and announcements/corrections)

Prof. Ahmed's Office Hours: ECAE 175, Tues 4-5:30 pm

CA's Office Hours: Wed 2-3pm, AES Undergraduate Lounge (ECAE 124)

Required Textbook (for readings and assignments):
Dan Simon, 'Optimal State Estimation: Kalman, H_∞, and Nonlinear Approaches,' John Wiley and Sons, Inc., 2006, ISBN 9780471708582.
Note: errata for the text can be found online here: link

Recommended supplements (for your own edification, not required):
J. Crassidis and J. Junkins, 'Optimal Estimation of Dynamic Systems,' 2nd edition, Chapman and Hall, 2011 – available through CU library as downloadable pdf: link
R. Stengel, 'Optimal Control and Estimation,' Dover, 1994, 9780486682006.

Course Details

Description This course will introduce students to the theory and methods of statistical estimation for general linear and nonlinear dynamical systems, with a particular emphasis on aerospace and other engineering applications. Major topics include: review of applied probability and statistics; modeling and optimal state estimation for stochastic dynamical systems; theory and design of Kalman filters for linear systems; linearized and extended Kalman filters for non-linear systems.

Learning Objectives Students will gain both a fundamental and practical understanding of estimation algorithms from a general dynamical systems standpoint. This will prepare them to tackle challenging estimation problems that they will eventually encounter in later courses and in their own professional/research pursuits.

In particular, by the end of this course, students will:

1. be well-acquainted with basic theory and engineering usage of probability and statistics;

2. explore, explain, and apply core concepts of statistical estimation theory, especially to problems defined by discrete time stochastic linear and non-linear state space dynamic process models;

3. formulate and solve dynamic state estimation problems using Kalman filters, least-squares estimators, and other related statistical estimation algorithms;

4. design, simulate, evaluate, visualize and tune estimator performance for real applications in software (e.g. Matlab, Python).

Grading, Assignments and Exams Course grades will be determined on the basis of homework (20%), midterm 1 (25%), midterm 2 (25%), and a final project (30%). Students will be encouraged to work in pairs for the final project.

Weekly homework will be assigned, collected, and *partially graded*. Collaboration is encouraged, but students must turn in their own work.

All exams will be take home and open-book/open-note. Students will have exactly one week to complete exams and may not collaborate with each other in any way.

Online/BBA distance learning students will not require a proctor, but will submit all assignments and exams via dropboxes on the course D2L website.

Students are responsible for working out an alternative plan with the instructor for submitting assignments/exams if these cannot be completed in time.

Exams must be rescheduled at least 2 weeks prior; homework extensions require at least 48 hour notice. The rescheduling and extension policy will be strictly enforced.

All students must adhere to the CU Honor Code. See below under 'General Policies' for more information regarding expectations for academic integrity, and repercussions for violations thereof.

Anticipated Course Schedule (may vary)

Week(s)	Topic	Text Chaps.
1	Intro & overview	–
1-3	Basic linear dynamical systems theory	1.1-1.7
3-6	Probability and stochastic processes	2.1-2.7
6-7	Least squares estimation	3.1-3.7
7-8	Stochastic linear system analysis	4.1-4.2
8-9	The Kalman filter (KF)	5.1-5.5
9-11	KF tuning, testing, variations, and generalizations	6,7
11-14	Nonlinear filters: Bayes filter, Linearized KF, EKF	13.1,13.2
14-15	Continuous-time KF	8

General Policies (please read carefully) If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary Injuries guidelines under the Quick Links at the Disability Services website and discuss your needs with your professor.

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or

required attendance. In this class, students must contact the professor at least 2 weeks prior to anticipated absences for exams. See the campus policy regarding religious observances for full details.

The University of Colorado Boulder (CU Boulder) is committed to maintaining a positive learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the student code.

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy of the institution. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible for violating the academic in-

tegrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at honor-code.colorado.edu.