ASEN 6519: Advanced State Estimation
Spring 2020 Course Syllabus

General Information

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

Time and Location: Tues & Thurs 8:30 am - 9:45 am, AERO 114.

Course Website: `canvas.colorado.edu` (posted course materials, announcements, recorded lectures)

Office Hours: TBD (other times by appointment only)

Course Textbook:

B. Ristic, S. Arulumpalam, N. Gordon, *Beyond the Kalman Filter: Particle Filters for Tracking Applications*, Artech House Radar Library, 2004, ISBN-13: 978-1580536318.

Description This new course will introduce students to principles and techniques for designing, implementing, and analyzing probabilistic state estimators for dynamical systems that require going beyond traditional least-squares and Kalman filtering approaches. Special emphasis will be placed on the development of practical discrete-time Bayesian state space filtering algorithms for systems that are characterized by partial observability and non-Gaussian uncertainties, which arise in many applications governed by complex non-linear stochastic dynamics and measurement processes. Topic coverage will include:

- Nonlinear least-squares and maximum likelihood estimation, Cramer-Rao bounds;
- Principles of Bayesian estimation theory and recursive Bayesian filtering;
- Statistical linearization and Unscented / Sigma Point filtering;
- Nonparametric and Sequential Monte Carlo Particle filtering;
- Particle filter variance reduction methods (Rao-Blackwellization, MCMC augmentation);
- Gaussian mixture filtering and mixture condensation techniques;
- Multiple model filtering techniques for jump-Markov hybrid dynamics;
- Data association algorithms for tracking in clutter (NN, PDA, MHT, RBPF);
- Bayesian decentralized state estimation and data fusion with multiple networked filters;

- Highlights of other topics of as time/interest permits (e.g. set-valued & event-triggered estimation; negative & soft data fusion, active sensing and decision-making; intro to PHD/FISST; GraphSLAM for localization; extended object tracking).

Students will complete programming projects related to target tracking, vehicle navigation, localization, control, and other applications connected to their research or professional interests.

Prerequisites: (FIRM REQUIREMENTS) (1) ASEN 5044: Statistical Estimation for Dynamical Systems (or equivalent graduate level coursework in probability and linear estimation/Kalman filtering with permission of instructor); and (2) demonstrable competency completing projects and assignments on ones own in a technical programming language (e.g. Matlab/Octave, Python, C/C++, C#, Java, Julia, etc.).

Course Details

Grading and Project Assignments Course work will largely be assignment and project-oriented. There will be no exams. Several required topical exercises related to the lectures will be posted as assignments to ensure that students demonstrate understanding of the course material, as well as to provide periodic feedback and guidance as students try to integrate/explore concepts into their final projects. These exercises will consist of short theoretical and programming problems for toy applications, as well as questions to guide the development of final project applications.

Four exercise-based assignments will be posted, to coincide with major lecture topics being covered. The final project will be developed over the course of the semester, and will serve in place of a final exam. Students are highly encouraged to collaborate with one another on assignments, although individual assignments must be submitted. Students have the option of working together in groups of two (max) on the final project if they so choose, though some level of individual contributions/work will be expected on group projects.

Grading breakdown: assignment exercises: 40% (10% each); final project: 40%; class participation: 20% (students are highly encouraged to ask and answer questions during class, office hours, via e-mail, etc.). Note that group final project report submissions will result in the same grade for both group members.

Benefits and Learning Objectives This course will enable students to:

1. define, explain and demonstrate fundamental problems in non-linear non-Gaussian state estimation along with algorithmic tools for recursive Bayesian filtering, including: non-linear least squares and maximum likelihood techniques; Monte Carlo techniques including the particle filter and Rao-Blackwellized particle filters; Gaussian mixutre filters; multiple model filters; data association filters; decentralized data fusion techniques.

2. develop and implement software to simulate and evaluate the performance of advanced state estimation algorithms for real-world/research applications.

Tentative Course Schedule (may vary somewhat)

Week(s)	Topic
1	Course intro & overview
1-2	Nonlinear least squares and maximum likelihood point estimation
3-4	Bayesian estimation principles and DT recursive Bayes filters
5-7	Particle filters and variants (Rao-Blackwellization, MCMC augmentation, etc.)
7-8	Gaussian mixture filtering
9-10	Jump Markov dynamical systems and multiple model filters
–	SPRING BREAK
11-12	Data association filters
13-14	Decentralized data fusion and state estimation
15	Other select advanced topics (time + interest permitting)

General Policies

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 Medical Conditions: Injuries, Surgeries, and Illnesses guidelines under Quick Links at Disability Services website and discuss your needs with your professor.

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- http://www.colorado.edu/policies/classbehavior.html
- http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

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