ASEN 6519 Cooperative Information Gathering

Spring 2025 Syllabus

Lecture: AERO N250 Monday and Wednesday, 1:00 PM – 2:15 PM

Instructor

Prof. Eric Frew
Office: AERO Email: eric.frew@colorado.edu
Hours: TBD

Text

Required: Silvia Ferrari and Thomas A. Wettergren. *Information-Driven Planning and Control.* MIT Press. 2021.

Prerequisites

This class is open to graduates with a background in dynamics and control (ASEN 5114 or ASEN 5014) and/or estimation and sensor fusion (ASEN 5070).

Overview

The purpose of this course is to introduce students to algorithms and approaches for coordinating multiple robotic sensors to collect information. Here, information means data that is relevant to a particular process or problem. Not all measurements of a phenomenon are useful. This notion can be formalized into various measures of information which will be described.

Given a formal definition of information, the course will then focus on formulating and solving distributed cooperative control problems to collect and deliver information to the best locations at the best times. The course will cover basic notions of consensus, distributed optimization, and cooperative control. Next, we will formulate geospatial estimation problems and model based sensor fusion problems that are well-suited to information-theoretic control.

The final portion of the course will study advanced topics. The exploration vs. exploitation tradeoff will be considered. This refers to the need to learn about an environment (exploration) before informed decisions can be made (exploitation). Complex examples using ensemble Kalman filters for numerical weather prediction will be explored, with emphasis on simplified formulations that will allow unmanned aircraft systems to perform autonomous sampling.

The course will combine traditional lectures in the early part of the semester with more informal seminar-style interactions. Students will be assigned papers from the current literature with discussion in class led by the instructor. The final project of the course will consist of a research paper on a related topic that should be suitable for submission to an aerospace conference.

Topics covered in this course include:

1. Review of basic probability – probability density function (pdf), expectation, covariance, Gaussian distribution, uniform distribution, conditional probability, Baye's rule
2. Formal definitions of information = entropy, mutual information, Fisher information, Shannon capacity, Kullback-Leibler divergence
3. Kalman filtering and the information form of the Kalman filter, the extended Kalman filter (EKF), particle filters
4. Target search and tracking
5. Consensus and distributed data fusion
6. Submodularity and other properties of set functions
7. Cooperative control and distributed optimization
8. Communication-aware information gathering
9. Value of information
10. Geospatial estimation and Gaussian processes (GPs)
11. Exploration vs. exploitation
12. Numerical weather prediction and the ensemble Kalman filter (EnKF)
13. Advanced topics in the literature

Course Grading

20% Homework
20% Project Abstract
20% Project First Draft
40% Project Final Draft

Course Readings

The schedule for course reading material is provided in a separate document. Students are expected to complete the reading assignments **before** the class on the date on which they are listed. The majority of work expected of students outside of class time for this course is reading the material.

Homework Policy

Homework will be assigned sporadically throughout the semester. Students are allowed to collaborate on the homework; however, each student must submit her own work.

Research Paper

The main mechanism for disseminating research into the broader scientific community is through conference and journal publications. As researchers, technical writing is one of the most critical, yet overlooked, skills you can obtain. As part of this course, each student will submit a paper on a current course-related topic of their choice. Details of this assignment will be provided during the first month of the course.

University Policies

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part in adhering to the Honor Code.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or DSinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website. If you have a temporary illness, injury or required medical isolation for which you require adjustment, notify the instructor as soon as possible.

Accommodation for Religious Obligations

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please communicate the need for a religious accommodation in a timely manner. See the campus policy regarding religious observances for full details.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure 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 race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy.

For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email CUreport@colorado.edu. Information about university policies, reporting options, and OIEC support resources including confidential services can be found on the OIEC website. Please know that faculty and graduate instructors are required to inform OIEC when they are made aware of incidents related to these concerns regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about their options and support resources. To learn more about reporting and support for a variety of concerns, visit the Don't Ignore It page.

Mental Health and Wellness

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through Academic Live Care. The Academic Live Care site also provides information about additional wellness services on campus that are available to students.

Acceptable Use of AI in this Class

Generative artificial intelligence tools—software that reproduces text, images, computer code, audio, video, and other content—have become widely available. Well-known examples include ChatGPT for text and DALL•E for images. This statement governs all such tools, including those released during our semester together. Keep in mind that the goal of gen AI tools is to reproduce content that seems to have been produced by a human, not to produce accurate or reliable

content; therefore, relying on a gen AI tool may result in your submission of inaccurate content. It is your responsibility—not the tool's—to assure the quality, integrity, and accuracy of work you submit in any college course. If gen AI tool use is suspected in completing assignments for this course in ways not explicitly authorized, I will follow up with you. I may contact the Office of Student Conduct & Conflict Resolution to report suspected Honor Code violations. In addition, you must be wary of unintentional plagiarism or data fabrication. Please act with integrity, for the sake of both your personal character and your academic record.

You may conditionally use gen AI tools in this course on **any** assignment. Gen AI use is permitted for the purpose of i.) creating implementation of algorithms for simulations, ii.) creating imagery of concepts, block diagrams, example applications but not to generate figures with data or results, iii.) as background research to motivate or explain concepts. Gen AI **may not be used** to write full paragraphs of text or provide itemized lists for direct inclusion in submissions, **nor may it be used** with a direct prompt to solve a homework problem. In all cases there must be clear attribution and explanation of AI's role in the completion of the assignment. If you use gen AI tools on assignments in this class, document your usage with the Chicago Manual of Style or appropriate citation guidelines for this course.

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