ASEN 6519 (SECTIONS 5 & 6)
SAFE AUTONOMY AMID UNCERTAINTY
SPRING 2026

LECTURE INFORMATION

Mondays and Wednesdays: 4:00 - 5:15 PM
Room: AERO N250
Video recording will be made available after each lecture on the course canvas page

INSTRUCTOR

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Office hour: By appointment

COURSE DESCRIPTION

Autonomous systems are rapidly advancing and increasingly deployed across high-impact, safety-critical applications. Ensuring that these systems behave safely under uncertainty is a central challenge in modern robotics, aerospace systems, cyber-physical systems, and even finance. Meeting this challenge requires rigorous mathematical modeling of real-world processes (many of which are inherently stochastic) and principled methods for analyzing and controlling uncertain dynamical systems.

This course provides a **deep introduction to the theory and practice of *safety-critical autonomy under uncertainty*, combining foundations in stochastic systems with emerging machine-learning-based approaches for data-driven modeling and verification**.

The course is organized into two complementary parts:

Part I: Foundations (lecture-based).

We develop the core theoretical tools needed to model, analyze, and certify stochastic dynamical systems. Topics include:

- Mathematical models of stochastic systems (e.g., Markov processes, stochastic differential and difference equations)
- Formal languages and temporal logic for specifying safety and performance
- Abstraction-based verification/control and model reduction

- Stochastic dynamic programming and optimal control
- Stochastic barrier functions and certificate-based analysis

Part II: Research Frontiers (seminar-style).

This portion adopts a research-oriented format involving paper presentations and invited talks from domain experts. We explore recent advances at the intersection of machine learning and control, focusing on questions such as:

- How can data be used to learn system dynamics?
- How can data-driven methods yield finite abstractions or safety certificates with uncertainty bounds?
- How can deep learning incorporate uncertainty quantification for verification and control?
- How do modern generative and physics-informed models propagate uncertainty effectively?
- How can ML-based models be designed to support formal guarantees?

This course is designed to be aligned with the objectives of the CEAS's Autonomous Systems Interdisciplinary Research Theme and is open to AES, CS, ME, ECEE, and Robotics students.

PREREQUISITES

Students are expected to be familiar with linear algebra, differential/difference equations, controls, basic of graph theory, probability theory, and estimation. The prerequisite for this course is *ASEN 5044 Statistical Estimation* or an equivalent course.

GRADING AND EVALUATION

Classwork consists of:

- homework 10%
- paper presentation 40%
- final project 50%

TEXTBOOKS

- *Principles of Model Checking*
  Christel Baier and Joost-Pieter Katoen
  MIT Press
  2008
  e-book through CU library: https://tinyurl.com/yxoxgjav

- *Gaussian Processes for Machine Learning by Rasmussen and Williams*
  Rasmussen and Williams
  MIT Press
  2006

- *Pattern Recognition and Machine Learning*
  Christopher Bishop
  Springer
  2007

- *Convex Optimization*
  Boyd and Vandenberghe
  Cambridge University Press 2004

COURSE OUTLINE

- Markov decision processes (MDPs)
- Probabilistic temporal logics: PCTL, LTL, etc.
- PCTL/LTL model checking and Strategy synthesis
- Discrete-time, continuous-space stochastic difference equations
- Uncertain MDP abstractions
- Multi-objective analysis
- Stochastic barrier functions & reach-avoid certificates
- Kernel learning
- Deep kernel learning
- Robust uncertainty learning and ambiguity sets
- Probably Approximately Correct (PAC) Learning
- Physics-informed learning for stochastic differential equations
- Bayesian neural networks and their analysis

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.

Additional classroom behavior information

- Student Classroom and Course-Related Behavior Policy.
- Student Code of Conduct.
- Office of Institutional Equity and Compliance.
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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 your faculty member in a timely manner so that your needs can be addressed.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information does not always align with how they identify. If you wish to have your preferred name (rather than your legal name) and/or your preferred pronouns appear on your instructors' class rosters and in Canvas, visit the Registrar's website for instructions on how to change your personal information in university systems.

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 of 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 Student Conduct & Conflict Resolution and will be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

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 OIEC@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 the person impacted receives outreach from OIEC about resolution options and support resources. To learn more about reporting and support a variety of concerns, visit the Don't Ignore It page.

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. In this class, inform the instructors of such conflicts at least three weeks in advance.

See the campus policy regarding religious observances for full details.

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.

CU Community of Care

CU Boulder is committed to a community of care in which students are supported by faculty and staff throughout their college journey. You don't have to face academic challenges alone – CU and the college are here to help you learn and succeed in your coursework and campus life. Part of this community of care is your connection to faculty and staff across campus. Our college promotes and hopes you will connect with faculty or staff who may reach out during your educational journey at CU.

Acceptable Use of AI in This Class

Generative artificial intelligence tools, i.e., 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 specifically to **assist with coding assignments, provided you clearly attribute and explain the role of AI** in completing the work. 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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