ASEN/CSCI 5264: Decision Making under Uncertainty

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Prerequisites

- Basic familiarity with probability
- Basic familiarity with linear algebra and multivariable calculus (e.g. matrix inversion, gradients)
- Fluency in a high level programming language and willingness to use Julia for homework assignments

Rough Schedule and List of Topics

(See Canvas for detailed and updated schedule.)

1. **Probabilistic Models**:
   - Probability
   - Conditional probability
   - Markov processes
   - Introduction to Bayesian networks
2. **Markov Decision Processes**:
   - Markov decision processes (MDPs)
   - Value iteration (contraction proof of convergence)
   - Policy iteration
   - Approximate dynamic programming
   - Online tree search
3. **Reinforcement Learning**:
   - Exploration and exploitation
   - Bandits
   - Model-free RL
   - Model-based RL
   - Deep Q learning
   - Policy gradient
   - Actor-critic
   - Entropy Regularization
4. **POMDPs**:
   - Hidden Markov models
   - Bayesian filters
   - Particle filters
   - Partially observable Markov decision processes (POMDPs)
   - Exact POMDP methods
   - Offline POMDP methods
   - Online POMDP methods
   - QMDP and other formulation approximation
5. **Game Theory**:
   - Normal form Games
   - Nash Equilibria
   - Markov Games

Websites

- **Canvas** will be the course hub.
- **Gradescope** will be used for all assignments and exams.
- **Github** will be used to host all public course materials at `https://github.com/CU-ADCL/CU-DMU-Materials`.
- **Ed** (`edstem.org`) will be used for discussions.

Attendance and Participation

Learning is a collaborative effort between the instructor and students. If students are registered for the in-person section, they are expected to attend class and participate in discussions and exercises. Remote students are expected to watch the recorded lectures, ask questions on the discussion board if there is confusion, and monitor course announcements delivered via Canvas.

Textbook

Mykel J. Kochenderfer, Tim A. Wheeler, and Kyle H. Wray, *Algorithms for Decision Making*. 2022. Available Online: `http://algorithmsbook.com`.

Additional References

- Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Ed. MIT Press, 2018. Available online: `http://incompleteideas.net/book/the-book-2nd.html`
- Mykel J. Kochenderfer, *Decision Making Under Uncertainty: Theory and Application*, MIT Press, 2015. Available online: `https://ieeexplore.ieee.org/book/7288640`
- Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 4th Ed. Pearson, 2022.
- Stefano Albrecht, Filippos Christianos, and Lukas Schafer, *Multi-Agent Reinforcement Learning: Foundations and Modern Approaches*. Available online: `https://www.marl-book.com/`
- Dimitri P. Bertsekas, *Dynamic Programming and Optimal Control*, Athena Scientific, 2012 (4th Ed.).

Assignments and Grading

- **35% Homework Assignments.** There will be 6 homework assignments, due approximately every two weeks. A typical assignment will consist of
  - Several conceptual questions or exercises.
  - One open-ended programming problem. You solution will be evaluated locally with obfuscated code and the score submitted to a leaderboard. The best performers will share their solution in class.
- **35% Exams.** There will be two in-class exams. The one with the higher score will be weighted 20% and the one with the lower score will be weighted 15%. Remote students can either attend class in-person on exam days or get a proctor, such as a supervisor at work, and take it remotely. Detailed instructions will be provided on Canvas.
- **30% Final Project.** A final project chosen by the student that ideally connects to their research. Deliverable will be a 4-8 page report. Project may be completed in teams of up to 3.

As of the beginning of the course, participation is not expected to be a factor in assigning grades, however it may become a factor at the instructor's discretion. The class will be notified if participation from that point forward will be considered.

Late Policy

To ensure proper progression through the course, students are expected to begin assignments early and submit homework assignments on time. However, in order to provide for minor unforeseen events or responsibilities, students may turn in late homework assignments within 72 hours of the due date with a 10% penalty without any questions asked.

If a student has a special circumstance such as a major medical procedure, major family responsibility, or a religious observance that will prevent them from completing course work on time, this should be coordinated with the instructor well before the due date.

AI Policy

I approach the class with the assumption that all students have a strong desire to learn rather than just to complete the assignments. In this course, you are highly-encouraged to use AI (specifically large language models such as Claude) as a *learning tool*. You can ask it questions or have it assist in writing some code, but any prose or mathematical work that you turn in must be written by you, and any code must be written by or closely directed by you. You must understand everything that you turn in. This policy is difficult to enforce in homework, however, you will have to complete the exams without AI, so we trust that you will not violate it on the homework.

Course Staff

Instructor: Professor Zachary Sunberg
AERO 263 zachary.sunberg@colorado.edu
Office Hours: Posted on Canvas

Teaching Assistant: Tyler Becker
Tyler.Becker-1@colorado.edu
Office Hours: Posted on Canvas

Teaching Assistant: Xavier O'Keefe
Xavier.Okeefe@colorado.edu
Office Hours: Posted on Canvas

Meetings

T/TH 4-5:15 pm, AERO 111 – Lecture video will automatically be posted online after class - see Canvas for link.

Additional 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 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.

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, please contact the instructor via email.

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. Please contact the instructor via email for

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.

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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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.

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.