ASEN 5519-003: Decision Making under Uncertainty

Zachary Sunberg

Spring 2021

Prerequisites

- Basic familiarity with probability
- Fluency in a high level programming language and willingness to learn Julia.

Rough Schedule and List of Topics

(See Canvas for detailed schedule.)

1. **Probabilistic Models [1/14 - 1/19]**:
   - Probability
   - Conditional probability
   - Markov processes
2. **Markov Decision Processes [1/21 - 2/9]**:
   - Markov decision processes (MDPs)
   - Value iteration (contraction proof of convergence)
   - Policy iteration
   - Approximate dynamic programming
   - Online tree search
3. **Reinforcement Learning [2/11 - 3/4]**:
   - Exploration and exploitation
   - Bandits
   - Model-free RL
   - Model-based RL
   - Deep Q learning
   - Policy gradient
   - Actor-critic
4. **POMDPs [3/9 - 3/30]**:
   - Hidden Markov models
   - Bayesian filters
   - Particle filters
   - Partially observable Markov decision processes (POMDPs)
   - Exact POMDP methods
   - Offline POMDP methods
   - Online POMDP methods
   - QMDP
5. **Other Topics [4/1-4/29]**: Bayesian Networks, games, alternative optimization objectives (risk averse, robust, constrained), ρ-POMDPs, meta-learning, AlphaStar, review of academic publications

Learning Technology

Canvas will be the main hub for the course. A detailed schedule and assignments will be posted here. **Piazza** will host course discussions. Students are encouraged to ask questions here.

Textbook

Mykel J. Kochenderfer, Tim A. Wheeler, and Kyle H. Wray, *Algorithms for Decision Making*. 2020. Available Online: `http://algorithmsbook.com`. Can be ordered from Lulu for approximately $40.00, link will be posted on canvas.

Additional References

- Mykel J. Kochenderfer, *Decision Making Under Uncertainty: Theory and Application*, MIT Press, 2015. $70.00, Available online: `https://ieeexplore.ieee.org/book/7288640`
- Laura Graesser, Wah Loon Keng, *Foundations of Deep Reinforcement Learning: Theory and Practice in Python*. Pearson Education, 2020. $50.00.
- Richard S. Sutton and Andrew G. Barto, *Reinforcement Learning: An Introduction*, 2nd Ed. MIT Press, 2018. $80.00, Available online: `http://incompleteideas.net/book/the-book-2nd.html`
- Dimitri P. Bertsekas, *Dynamic Programming and Optimal Control*, Athena Scientific, 2012 (4th Ed.). $134.50

Assignments and Grading

40% Homework Assignments. There will be 6 large homework assignments, due approximately every two weeks. A typical assignment will consist of

- Several conceptual questions or exercises.
- One open-ended 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.

30% Quizzes. There will be three Quizzes consisting of several conceptual questions or exercises. The exact format has not been set, but it will most likely be a timed quiz that can be taken any time during a 24 or 48 hour period.
25% 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.
5% Peer Review. You will be assigned 2 project reports from other teams in the class to write peer reviews for.

Late Policy

For **homework**, there will be a **10% penalty** for submitting the assignment late on the day it is due and a **20% penalty** for every late day after that. For the **final project** and **peer review**, there will be a **5% penalty for every late *hour*** (due to the need for quick turnaround). Please use your knowledge of decision making under uncertainty to include appropriate contingency in your plans to avoid these penalties.

Instructor Contact

Professor Zachary Sunberg
AERO 263 zachary.sunberg@colorado.edu
Office Hours (`https://zoom.com/my/zsunberg`):
T/TH 11:20 am - 12:20 pm
4-5pm the day before any homework is due

Meetings

T/TH 10-11:15
AERO N240 / Zoom Link on Canvas

University Policies

Please find an accessible online copy of the policies here: `https://www.colorado.edu/academicaffairs/student-syllabus-statements`**. The linked document contains urls to other department websites that are note included in the text below.**

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. 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 race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteranstatus, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Code of Conduct.

Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- maintain 6-foot distancing when possible, wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders,
- clean local work area,
- practice hand hygiene,
- follow public health orders, and
- if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the Accommodation for Disabilities statement on this syllabus.

All students who are new to campus must complete the COVID-19 Student Health and Expectations Course. Before coming to campus each day, all students are required to complete the Buff Pass.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, causing you to miss assignments, **please notify me by email as soon as possible**.

Accommodation for Disabilities

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.

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.

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 policy may include: plagiarism, 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. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or

harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Religious Holidays

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, please email me beforehand if any assignments may conflict with your religious practice. See the campus policy regarding religious observances for full details.