ASEN 6519-007: Decision Making under Uncertainty

Zachary Sunberg

Spring 2020

Prerequisites

1. Fluency in a high level programming language and willingness to learn a new one (any language will be allowed on assignments, but some Julia, up to the level of writing functions, will be required)
2. Basic knowledge of applied probability

Rough Schedule and List of Topics

(See Canvas for detailed schedule.)

1. **Probabilistic Models [1/16 - 1/23]**:
   - Probability
   - Conditional probability
   - Bayesian networks
   - Markov processes

2. **Problems with Outcome Uncertainty [1/28 - 2/13]**:
   - Markov decision processes (MDPs)
   - Value iteration (contraction proof of convergence)
   - Policy iteration
   - Approximate dynamic programming
   - Online tree search

3. **Problems with Model Uncertainty [2/18 - 3/5]**:
   - Reinforcement learning (RL)
   - Exploration and exploitation
   - Bandits
   - Model-free RL
   - Model-based RL
   - Deep Q learning
   - Policy gradient
   - Actor-critic

4. **Problems with State Uncertainty [3/10 - 4/2]**:
   - Hidden Markov models
   - Bayesian filters
   - Particle filters
   - Partially observable Markov decision processes (POMDPs)
   - Exact POMDP methods
   - Convexity of POMDP value functions
   - Offline POMDP methods
   - Online POMDP methods
   - QMDP

5. **Other Topics [4/7-4/30]**: Alpha Go, Alpha Star, D-separation of Bayesian networks, Bayesian network parameter and structure learning, games, alternative optimization objectives (risk averse, robust, constrained), ρ-POMDPs, meta-learning, how to review 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.
RedPen.jl will be used to submit solutions to the open-ended homework assignments.

Assignments and Grading

60% Homework Assignments. There will be 6 large homework assignments, due approximately every two weeks. Each assignment will consist of
- Several conceptual questions
- Two or three exercises that will require some programming or math
- 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. **Note that attempts to de-obfuscate obfuscated code will be considered a violation of the honor code.**

35% Final Project. A final project chosen by the student that ideally connects to their research. Deliverable will be a 6 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 **20% penalty for every late day**. For the **final project** and **peer review**, there will be a **20% 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.

Textbook

Mykel J. Kochenderfer, Decision Making Under Uncertainty: Theory and Application, MIT Press, 2015. $70.00, Available online: `https://ieeexplore.ieee.org/book/7288640`

Additional References

- 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

Instructor Contact

Professor Zachary Sunberg
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AERO 263
Office Hours: T/TH 11:20 am - 12:20 pm, W 4-5 pm

Meetings

T/TH 10-11:15 am AERO 114

Teaching Assistant

Tucker Farrell

University Policies

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 or injury, see Temporary Medical Conditions under the Students tab on the Disability Services website.

Classroom Behavior

Students and faculty each have responsibility for maintaining an appropriate learning environment. 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.

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 tothe 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 theHonor Code Office website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, intimate partner abuse (including 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 instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, 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 contact me at least two weeks in advance if you require religious accommodation. See the campus policy regarding religious observances for full details.

[accessible online copy of policies: `https://www.colorado.edu/academicaffairs/student-syllabus-statements`]