

ASEN 5519-003 Decision Making under Uncertainty

Homework 3: Online MDP Methods

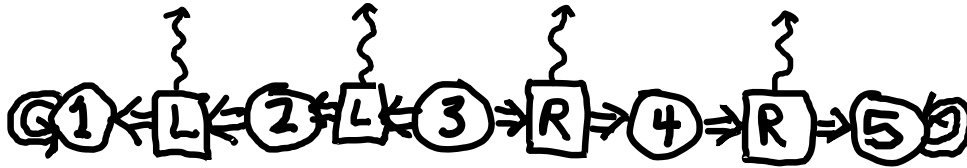
February 4, 2022

1 Conceptual Questions

Question 1. (20 pts) Do similar Q values imply similar rewards?

In the proof for Lemma 5 of the Sparse Sampling paper by Kearns, Mansour, and Ng,¹ the authors make the following claim: **if a policy π satisfies $|Q^*(s, \pi^*(s)) - Q^*(s, \pi(s))| \leq \beta$ for all $s \in \mathcal{S}$, then it immediately follows that $|\mathcal{R}(s, \pi^*(s)) - \mathcal{R}(s, \pi(s))| \leq \beta$.** In this exercise, you will demonstrate that this claim is mistaken.

Consider the MDP below:



The state space is $S = \{1, \dots, 5\}$ and the action space is $A = \{L, R\}$ (but not all actions are available from each state). Transitions are deterministic as shown. The discount factor is $\gamma = 0.9$.

Choose a reward function, \mathcal{R} , (i.e. values for the squiggly arrows), a policy, π , and a value β that constitute a counterexample to the claim above. Justify your answer.

2 Exercises

Question 2. (25 pts) Monte Carlo Tree Search

Write code that performs 7 iterations of Monte Carlo Tree Search on an MDP created with `HW3.DenseGridWorld(seed=2)`, starting at state (19, 19). You will need to produce three dictionaries:

- Q maps (s, a) tuples to Q value estimates.
- N maps (s, a) tuples to N , the number of times the node has been tried.
- t maps (s, a, s') tuples to the number of times that transition was generated during construction of the tree.

Then visualize the resulting tree with `HW3.visualize_tree(Q, N, t, SA[19, 19])`². **Submit an image of the tree, the code used to generate it, and a few sentences describing the tree after 7 iterations** (e.g. which actions have the highest Q values? Does this make sense?).

You will need to use the following functions from POMDPs.jl for the problem:

¹<https://www.cis.upenn.edu/~mkearns/papers/sparsesampling-journal.pdf>; Note: you do not need to read the paper to complete the problem.

²SA is from the `StaticArrays.jl` package.

- `actions(m)`
- `@gen(:sp, :r)(m, s, a)`
- `isterminal(m, s)`
- `discount(m)`
- `statetype(m)`
- `actiontype(m)`

(You may also wish to use `POMDPs.simulate` and `POMDPsimulators.RolloutSimulator` for the rollouts.)

`HW3.DenseGridWorld(seed=2)` generates a 60x60 grid world problem. There is a reward of +100 every 20 cells, i.e. at [20,20], [20,40], [40,20], etc. Once the agent reaches one of these reward cells, the problem terminates. All cells also have a cost generated by the seed.

Question 3. (20 pts) Planning with MCTS

In this exercise, you will compare MCTS with a heuristic policy and an optimal policy calculated using value iteration on the `DenseGridWorld(seed=3)` MDP.

- a) Write a simulation loop for the MDP equivalent to the following:

```
r_total = 0.0
disc = 1.0
while !isterminal(mdp, s)
    a = :left # replace this with the heuristic policy or mcts!
    s, r = @gen(:sp,:r)(mdp, s, a)
    r_total += d*r
    d *= discount(mdp)
end
```

Use this code to evaluate a heuristic policy of your choice with 100 Monte Carlo simulations starting from state (30,30). Report the mean accumulated reward and standard error of the mean.

- b) Use your Monte Carlo tree search from Question 2 to plan online in the simulation loop. Limit the planning time to 50ms. Evaluate the MCTS planner with 100 Monte Carlo simulations starting from state (30,30). Report the mean accumulated reward and standard error of the mean, along with a typical number of iterations that MCTS was able to complete each time it chose an action³.

3 Challenge Problem

Question 4. (10 pts code and description, 20 pts score) Fast Online Planning

Create a function `select_action(m,s)` that takes in a 100×100 `DenseGridWorld`, `m`, and a state `s`, and returns a near-optimal action within 50ms. You may wish to base this code on the MCTS code that you wrote for Question 2. Evaluate this function with `HW3.evaluate` and **submit the resulting json file along with the code and a one paragraph to one page description of your approach**, including tuning parameters that worked well, the rollout policy, etc. A score of 50 will receive full credit. There are no restrictions on this problem - you may wish to use a different algorithm, multithreading, etc. Starter code will be linked to on Canvas that will give suggestions for timing and other details.

³You can determine a typical number of iterations by just printing out the number; you don't need to keep careful statistics unless you want to