113-1 (Fall 2024) Semester

Reinforcement Learning

Assignment #1

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Outline

- Tasks
 - Iterative policy evaluation
 - Policy iteration
 - Value iteration
 - Async dynamic programming
- Environment
- Code structure
- Report
- Grading
- Submission
- Policy
- Contact

Tasks

Task 1 - Iterative Policy Evaluation

- Problem
 - Evaluate a given non-deterministic policy (probability distribution)
- Solution
 - Iterative application of Bellman expectation backup

```
Iterative Policy Evaluation, for estimating V \approx v_{\pi}

Input \pi, the policy to be evaluated Algorithm parameter: a small threshold \theta > 0 determining accuracy of estimation Initialize V(s), for all s \in \mathbb{S}^+

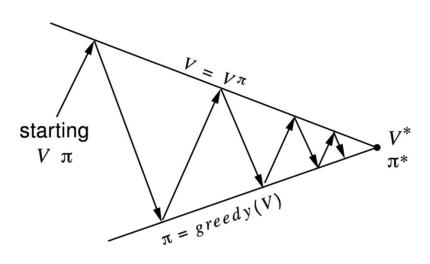
Loop:
\Delta \leftarrow 0
Loop for each s \in \mathbb{S}:
v \leftarrow V(s)
V(s) \leftarrow \sum_a \pi(a|s) \sum_{s',r} p(s',r|s,a) \big[ r + \gamma V(s') \big]
Synchronous update \Delta \leftarrow \max(\Delta,|v-V(s)|)
until \Delta < \theta
```

[source]

Task 2 - Policy Iteration

Problem

- Find the optimal deterministic policy
- Solution
 - Policy evaluation: iterative policy evaluation
 - Policy improvement: greedy policy improvement
 - Eventually converges to optimal policy



```
V(s) \in \mathbb{R} and \pi(s) \in \mathcal{A}(s) arbitrarily for all s \in \mathbb{S}
```

Policy Iteration (using iterative policy evaluation) for estimating $\pi \approx \pi_*$

Loop:

1. Initialization

2. Policy Evaluation

$$\Delta \leftarrow 0$$

Loop for each $s \in S$:

 $v \leftarrow V(s)$

$$V(s) \leftarrow \sum_{s',r} p(s)$$

$$V(s) \leftarrow \sum_{s',r} p(s',r|s,\pi(s))[r+\gamma V(s')]$$
 Synchronous update $\Delta \leftarrow \max(\Delta,|v-V(s)|)$

until $\Delta < \theta$ (a small positive number determining the accuracy of estimation)

3. Policy Improvement

```
policy-stable \leftarrow true
For each s \in S:
```

$$old\text{-}action \leftarrow \pi(s)$$

$$\pi(s) \leftarrow \arg\max_{a} \sum_{s',r} p(s',r|s,a) [r + \gamma V(s')]$$

If old-action $\neq \pi(s)$, then policy-stable \leftarrow false

If policy-stable, then stop and return $V \approx v_*$ and $\pi \approx \pi_*$; else go to 2

Task 3 - Value Iteration

- Problem
 - Find the optimal deterministic policy
- Solution
 - Iterative application of Bellman optimality backup

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Task 4 - Async Dynamic Programming

Problem

- Find the optimal deterministic policy with better efficiency
- Less environment interaction

Solutions

- In-place dynamic programming
- Prioritized sweeping
- Real-time dynamic programming

Environment

Grid World

State space

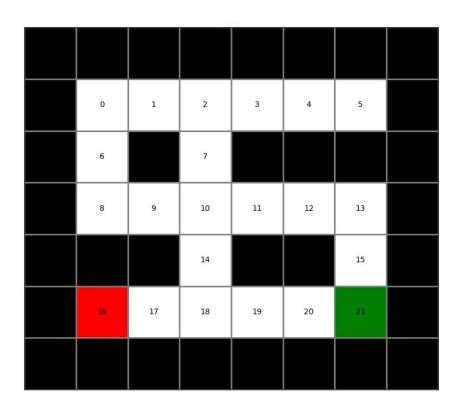
- Nonterminal states: Empty, Wall
- Terminal states: Goal, Trap
- 0-indexed

Action space

- Up, down, left, right
- Hitting the wall will remain at the same state

Reward

- Step reward given at every transition
- Goal reward given after reaching goal state
- Trap reward given after reaching trap state



Done Flag

- Separator for episodes
- Return true from step when doing any action at terminal states
- Need to modify the Bellman equation

$$v_{\pi}(s) = \sum_{a \in \mathcal{A}(s)} \pi(a|s) \sum_{s' \in \mathcal{S}, r \in \mathcal{R}} p(s', r|s, a)(r + \gamma v_{\pi}(s'))$$

$$v_{\pi}(s) = \sum_{a \in \mathcal{A}(s)} \pi(a|s) \sum_{s' \in \mathcal{S}, r \in \mathcal{R}} p(s', r|s, a)(r + \gamma v_{\pi}(s')(1 - Done))$$

Code Structure

requirement.txt

• Conda

```
conda create -n rl_assignment_1 python=3.11
conda activate rl_assignment_1
pip install -r requirement.txt
```

venv

```
python -m venv venv
source venv/bin/activate
pip install -r requirement.txt
```



DP_solver.py

class **DynamicProgramming**

- Parent class for DP algorithms
- TODO: get_q_value()

class IterativePolicyEvaluation

TODO: get_state_value(), evaluate(), run()

class **PolicyIteration**

TODO: get_state_value(), policy_evaluation(), policy_improvement(), run()

class ValueIteration

TODO: get_state_value(), policy_evaluation(), policy_improvement(), run()

class AsyncDynamicProgramming

• TODO: run()

Feel free to add any function if needed

You must have run() for us to grade your code.

gridworld.py

- Methods:
 - get_action_space(): Get the dimension of action space
 - get_state_space(): Get the dimension of the state space
 - step(): Interact with the environment
 - reset(): Reset the environment
 - visualize(): Draw the maze with policy and values
 - run_policy(): Run the policy from given start state. Output the state history
- Step count:
 - Increment every time when step() method is called
 - Private member. Use get_step_count() to access.
- Step reward may not be constant at every state transition at private test cases
 - Must use step() to get the reward function
- Don't try to modify or override any private member (double underscore prefix)
- You cannot call reset() by yourself. We may rename the function when grading.

test cases

main.py

- run_policy_evaluation()
- run_policy_iteration()
- run_value_iteration()
- run_async_dynamic_programming()

These methods will call your written functions in DP_solver.py.

The output will be an image and the step count for the algorithm.

sample_solutions\

- iterative_policy_evaluation.png
- policy_iteration.png
- value_iteration.png
- step_counts.txt

The optimal policy might not unique.

Policy in sample solutions are obtained in the traverse order of action index.

Report

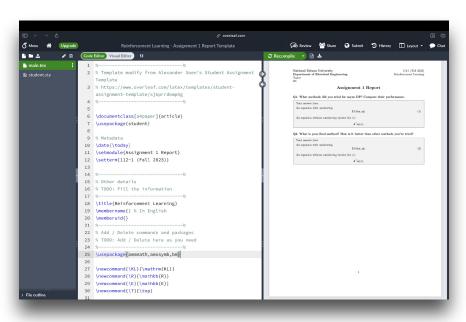
Report

- Q1. What methods have you tried for async DP? Compare their performance. (6%)
 - 2% per method tried with reasonable result and comparison
- Q2. What is your final method? How is it better than other methods you've tried? (4%)
 - 2% for reasonable explanation
 - 2% for novel method (Out of the three methods mentioned in class)

- LaTeX PDF format. Handwriting is forbidden.
 - Overleaf template
 - Write clear and concise in few sentences

Overleaf

- Online LaTeX editor
- LaTeX
 - Good for math equations, tables and indexes
 - Widely used in paper writing and math writing
- Traditional Chinese will cause some compile problems
- Official guide





Grading

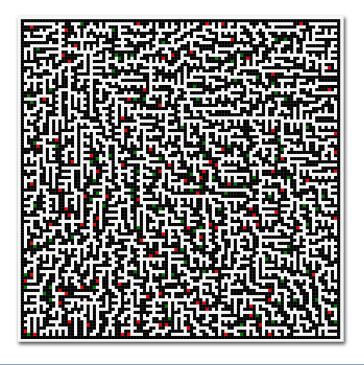
Grading

- Iterative policy evaluation (25%)
 - Test cases (5% x 5 cases)
- Policy iteration (20%)
 - Test cases (4% x 5 cases)
- Value iteration (25%)
 - Test cases (5% x 5 cases)
- Async dynamic programming (20%)
 - Better than your sync DP (5% x 2 cases) (Both policy iteration and value iteration)
 - Report (10%)

The total score is 90%.

Criteria

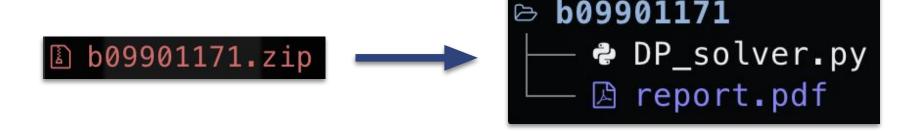
- Test cases:
 - Call run() and check the final output
 - Task 1: Check the values after evaluation
 - Task 2, 3, 4: Only check if the output policy is optimal
 - Run time limit **3 minute** for each case to avoid infinite loops
 - Up to 1500 states in private test cases
 - •Only task 4 considers step count



Submission

Submission

- Submit on NTU COOL with following zip file structure
 - Get rid of pycache, DS_Store, __MACOSX, etc.
 - Student ID with lower case
 - 10% deduction for wrong format



- Deadline: 2024/09/26 Thu 09:30am
- No late submission is allowed

Policy

Policy

Package

- You can use any Python standard library (e.g., heap, queue...)
- System level packages are prohibited (e.g., sys, os, multiprocess, subprocess...) for security concern

Collaboration

- Discussions are encouraged
- Write your own codes

Plagiarism & cheating

- All assignment submissions will be subject to duplication checking (e.g., MOSS)
- Cheater will receive an F grade for this course

Grade appeal

• Assignment grades are considered finalized two weeks after release

Contact

Questions?

- General questions
 - Use channel **#assignment 1** in slack as first option
 - Reply in thread to avoid spamming other people
- Personal questions
 - DM me on Slack: **TA 尤展鴻 Chan-Hung Yu**

