

112-1 (Fall 2023) Semester

# Reinforcement Learning

## Assignment #1

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# Outline

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- 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  $s \in \mathcal{S}^+$

Loop:

$$\Delta \leftarrow 0$$

Loop for each  $s \in \mathcal{S}$ :

$$v \leftarrow V(s)$$

$$V(s) \leftarrow \sum_a \pi(a|s) \sum_{s',r} p(s',r|s,a) [r + \gamma V(s')] \quad \text{Synchronous update}$$

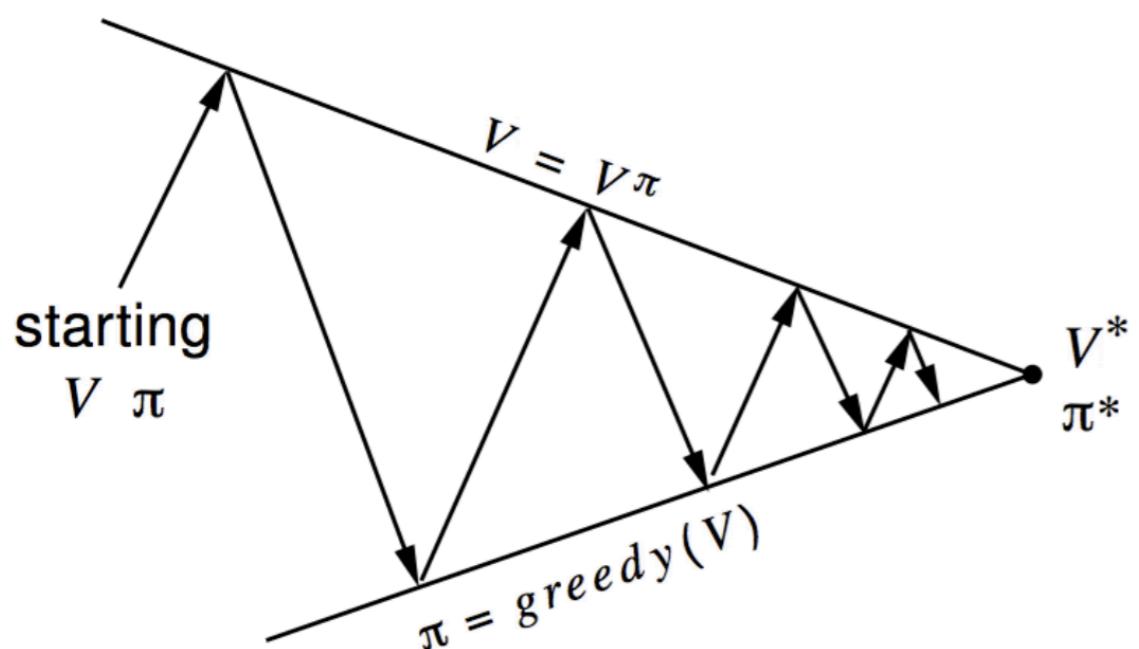
$$\Delta \leftarrow \max(\Delta, |v - V(s)|)$$

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



[source]

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

1. Initialization  
 $V(s) \in \mathbb{R}$  and  $\pi(s) \in \mathcal{A}(s)$  arbitrarily for all  $s \in \mathcal{S}$
2. Policy Evaluation  
Loop:  
 $\Delta \leftarrow 0$   
Loop for each  $s \in \mathcal{S}$ :  
 $v \leftarrow V(s)$   
 $V(s) \leftarrow \sum_{s',r} p(s',r|s,\pi(s)) [r + \gamma V(s')] \quad \text{Synchronous update}$   
 $\Delta \leftarrow \max(\Delta, |v - V(s)|)$   
until  $\Delta < \theta$  (a small positive number determining the accuracy of estimation)
3. Policy Improvement  
 $policy-stable \leftarrow true$   
For each  $s \in \mathcal{S}$ :  
 $old-action \leftarrow \pi(s)$   
 $\pi(s) \leftarrow \arg \max_a \sum_{s',r} p(s',r|s,a) [r + \gamma V(s')]$   
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

## Value Iteration, for estimating $\pi \approx \pi_*$

Algorithm parameter: a small threshold  $\theta > 0$  determining accuracy of estimation  
Initialize  $V(s)$ , for all  $s \in \mathcal{S}^+$ , arbitrarily except that  $V(\text{terminal}) = 0$

Loop:

```
| Δ ← 0
| Loop for each  $s \in \mathcal{S}$ :
|    $v \leftarrow V(s)$ 
|    $V(s) \leftarrow \max_a \sum_{s',r} p(s',r|s,a)[r + \gamma V(s')]$  Synchronous update
|   Δ ← max(Δ, | $v - V(s)$ |)
until Δ < θ
```

Output a deterministic policy,  $\pi \approx \pi_*$ , such that

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

[\[source\]](#)

# Task 4 - Async Dynamic Programming

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- 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

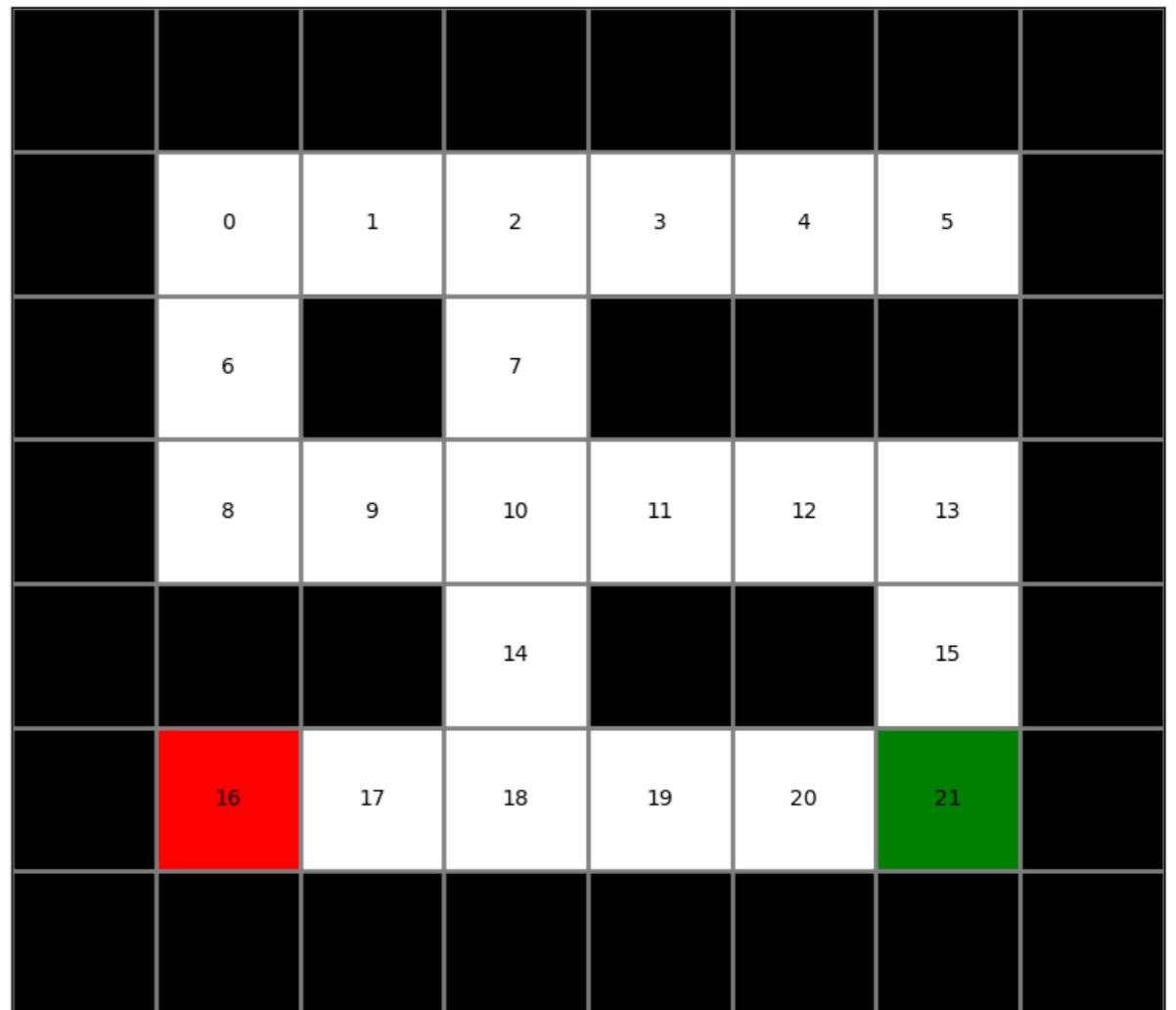
- Nonterminal states: Empty, Wall
- Terminal states: Goal, Trap
- 0-indexed

## 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

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- 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

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- [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
```



# gridworld.py

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- 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)**

# DP\_solver.py

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## 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()

# Report

# Report

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- 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](#)

The screenshot shows the Overleaf LaTeX editor interface. On the left, there's a file tree with 'main.tex' and 'student.sty' selected. The main area displays the LaTeX code for a report template. On the right, there's a preview of the assignment report titled 'Assignment 1 Report' from 'National Taiwan University, Department of Electrical Engineering'. It contains two questions:

Q1. What methods did you try for async DP? Compare their performance.  
Your answer here.  
An equation with numbering:  $\text{Exp}(u, \eta)$ . (1)  
An equation without numbering (notice the  $\lambda$ ):  $\lambda^* u(x)$ .

Q2. What is your final method? How is it better than other methods you've tried?  
Your answer here.  
An equation with numbering:  $\text{Exp}(u, \eta)$ . (2)  
An equation without numbering (notice the  $\lambda$ ):  $\lambda^* u(x)$ .

Overleaf

# Grading

# Grading

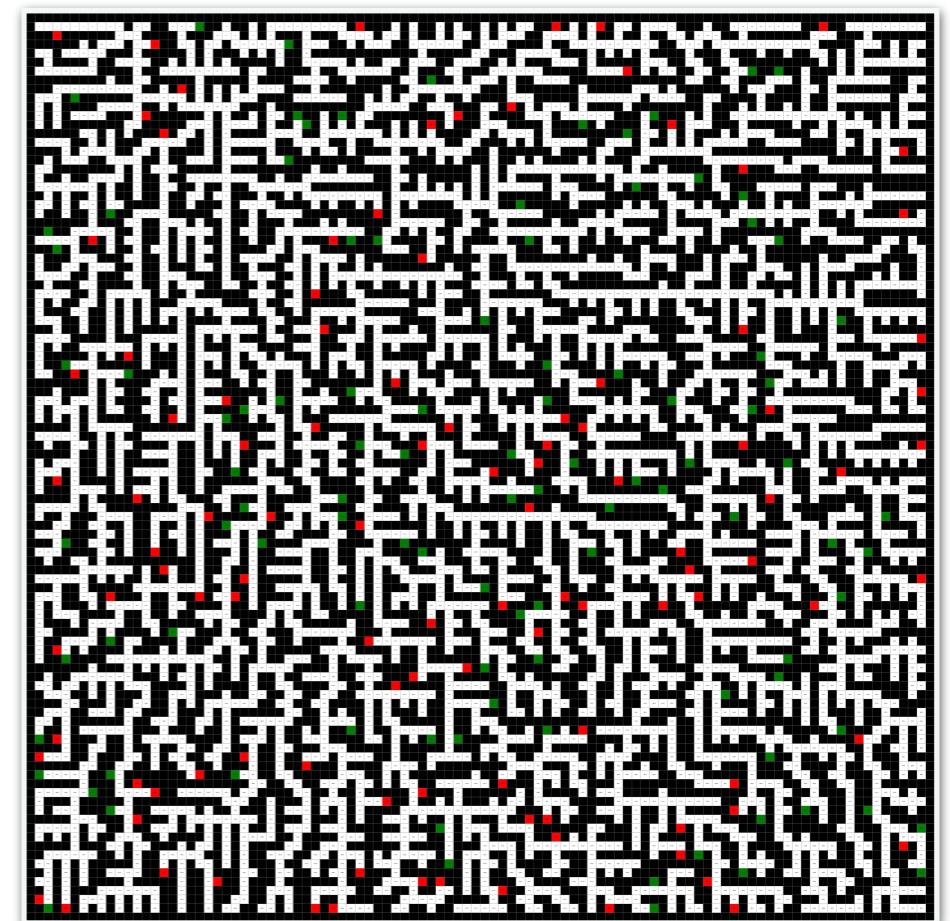
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- Iterative policy evaluation (25%)
  - Test cases (5% x 5 cases)
- Policy iteration (20%)
  - Test cases (4% x 5 cases)
- Value iteration (25%)
  - Test cases (5% x 5 cases)
- Async dynamic programming (30%)
  - Better than your sync DP (5% x 2 cases)
  - Performance (10%) (According to the ranking and distribution over the class)
  - Report (10%)

# Criteria

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- Test cases:
  - Call run() and check the final output
  - Task 1: Check the value after evaluation
  - Task 2, 3, 4: Only check the output policy
  - 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
- Sample solutions are provided for reference

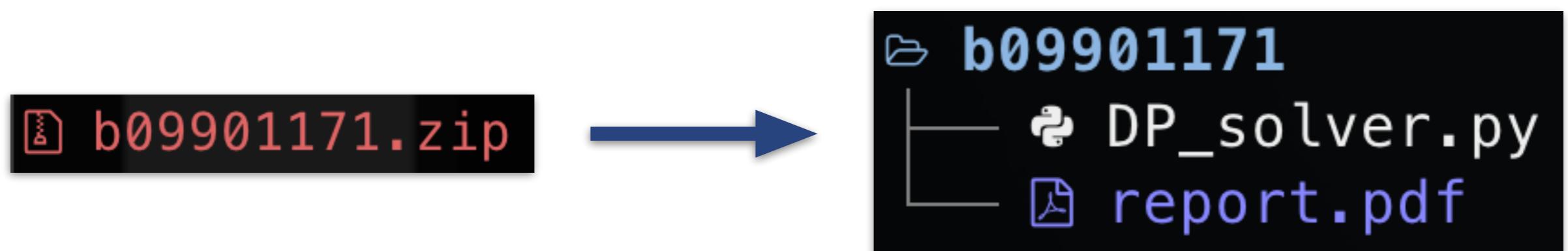


# Submission

# Submission

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



- **Deadline: 2023/09/28 Thu 09:30am**
- **No late submission is allowed**

# Policy

# Policy

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## Package

- You can use any Python standard library (e.g., heap, queue...)
- System level packages are prohibited (e.g., sys, os, multiprocessing, 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 黃柏睿 Bo-Ruei Huang**

