Lab1: Temporal Difference Learning

Lab Objective:

In this lab, you will learn temporal difference learning (TD) algorithm by solving the 2048 game using an n-tuple network.

Important Date:

1. Submission Deadline: 9/21 (Sun) 23:59
2. Demo date: 9/22 (Mon)

Turn in:

1. Experiment report (.pdf)
2. Source code (.cpp) [NOT including model weights]

Notice: zip all files with name “RL_LAB1_StudentId_Name.zip”,
e.g.:「RL_LAB1_313551126_李謙蓉.zip」

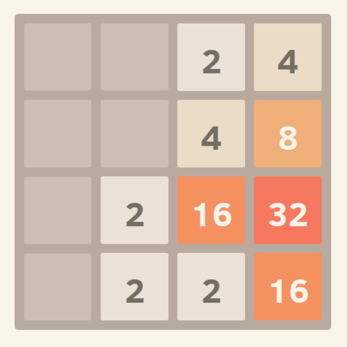
Lab Description:

- Understand the concept of (before-)state and after-state.
- Learn to construct and design an n-tuple network.
- Understand TD algorithm.
- Understand Q-learning network training.

Requirements:

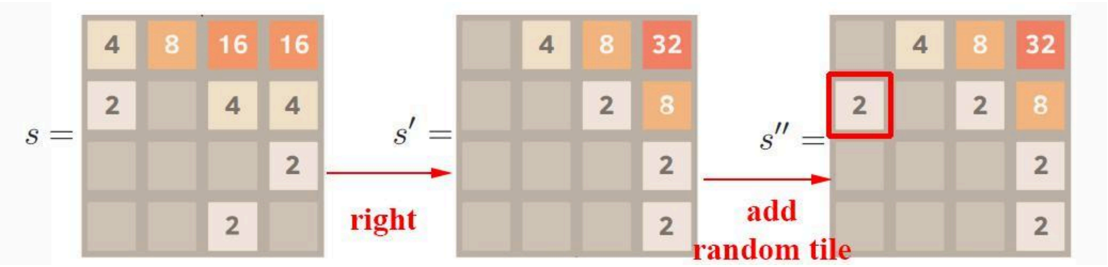
- Implement TD(0) algorithm
  - Construct an n-tuple network.
  - Action selection according to the n-tuple network.
  - Calculate TD-target and TD-error.
  - Update V(state), not V(after-state).
    - That is, you need to use the information of P(popup tile 2) = 0.9 and P(popup tile 4) = 0.1 in your code.
  - Understand temporal difference learning mechanisms.

Game Environment – 2048:



- Introduction: 2048 is a single-player sliding block puzzle game. The game's objective is to slide numbered tiles on a grid to combine them to create a tile with the number 2048.
- Actions: **Up**, **Down**, **Left**, **Right**
- Reward: The score is the value of new tile when two tiles are combined.

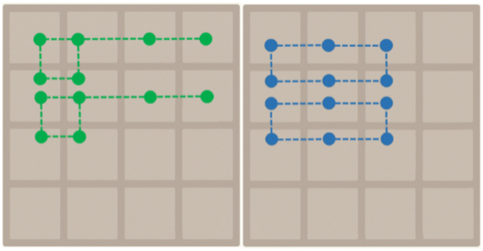
- A sample of two-step state transition



Implementation Details:

Network Architecture

- n-tuple patterns: 4×6-tuples with all possible isomorphisms



Training Arguments

- Learning rate: 0.1
  - Learning rate for features of n-tuple network with m features: $0.1 \div m$
- Train the network at least 100k episodes

Algorithm:

A pseudocode of the game engine and training. (modified backward training method)

```
function PLAY GAME
$score \leftarrow 0$
  $s \leftarrow$ INITIALIZE GAME STATE
  while IS NOT TERMINAL STATE($s$) do
    $a \leftarrow$  EVALUATE($s, a'$)
    $r, s', s'' \leftarrow$ MAKE MOVE($s,\ a$)
    SAVE RECORD($s,\ a,\ r,\ s',\ s''$)
$score \leftarrow score + r$
$s \leftarrow s''$
  for ($s,\ a,\ r,\ s',\ s''$) FROM TERMINAL DOWNTO INITIAL do
    LEARN EVALUATION($s,\ a,\ r,\ s',\ s''$)
  return $score$

function MAKE MOVE($s,\ a$)
  $s', r \leftarrow$ COMPUTE AFTERSTATE($s,\ a$)
  $s'' \leftarrow$ ADD RANDOM TILE($s'$)
  return $(r, s', s'')$
```

TD-state

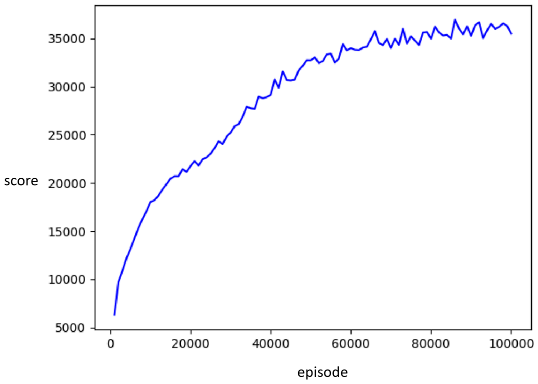
```
function EVALUATE($s,\ a$)
  $s',\ r \leftarrow$ COMPUTE AFTERSTATE($s, a$)
$S'' \leftarrow ALL\ POSSIBLE\ NEXT\ STATES\left(s'\right)$
  return $r + \Sigma_{s'' \in S''} P\left(s, a, s''\right) V\left(s''\right)$

function LEARN EVALUATION$\left(s, a, r, s', s''\right)$
$V(s) \leftarrow V(s) + \alpha(r + V(s'') - V(s))$
```

Scoring Criteria:

Show your work, otherwise no credit will be granted.

- Report (20% + Bonus 20%)
    - A plot shows scores (mean) of at least 100k training episodes (20%)

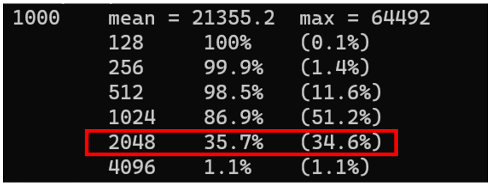
      E.g.



    - Bonus: (20%)
        - Describe the implementation and the usage of n-tuple network. (5%)
        - Explain the mechanism of TD(0). (5%)
        - Describe your implementation in detail including action selection and TD-backup diagram. (10%)

- Demo Performance (80%)
    - The 2048-tile win rate in 1000 games, $[winrate_{2048}]$.(60%)

      E.g.



```
1000    mean = 21355.2   max = 64492
        128      100%     (0.1%)
        256      99.9%    (1.4%)
        512      98.5%    (11.6%)
        1024     86.9%    (51.2%)
        2048     35.7%    (34.6%)
        4096     1.1%     (1.1%)
```

    - Questions. (20%)

References:

[1] Szubert, Marcin, and Wojciech Jaśkowski. "Temporal difference learning of N-tuple networks for the game 2048." 2014 IEEE Conference on Computational Intelligence and Games. IEEE, 2014.

[2] Kun-Hao Yeh, I-Chen Wu, Chu-Hsuan Hsueh, Chia-Chuan Chang, Chao-Chin Liang, and Han Chiang, Multi-Stage Temporal Difference Learning for 2048-like Games, accepted by IEEE Transactions on Computational Intelligence and AI in Games (SCI), doi: 10.1109/TCIAIG.2016.2593710, 2016.

[3] Oka, Kazuto, and Kiminori Matsuzaki. "Systematic selection of n-tuple networks for 2048." International Conference on Computers and Games. Springer International Publishing, 2016.

[4] moporgic. “Basic implementation of 2048 in Python.” Retrieved from Github: https://github.com/moporgic/2048-Demo-Python.

[5] moporgic. “Temporal Difference Learning for Game 2048 (Demo).” Retrieved from Github: https://github.com/moporgic/TDL2048-Demo.

[6] lukewayne123. “2048-Framework” Retrieved from Github: https://github.com/lukewayne123/2048-Framework.