LAB 2

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Deadline: 2023/04/11(Tue) 12:00

Demo: 2023/04/11(Tue)

In this lab,

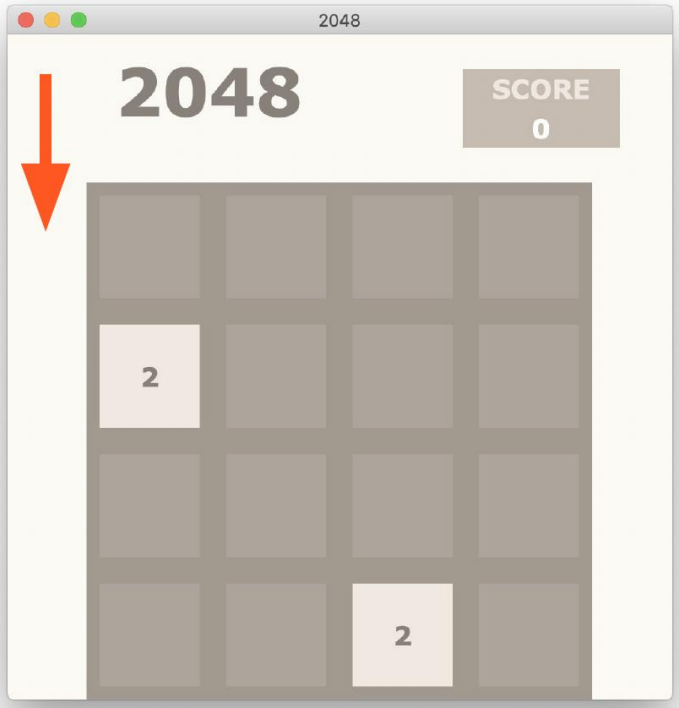
Must use sample code, otherwise no credit.

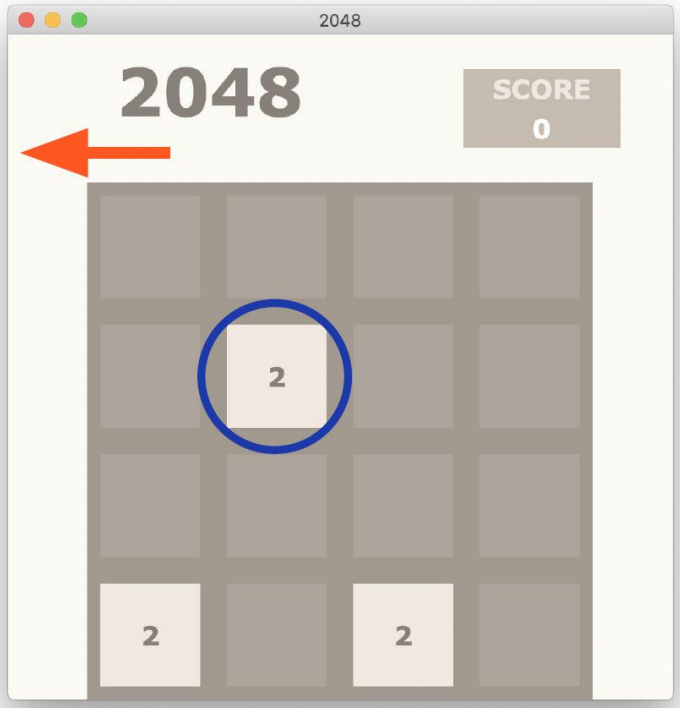
Outline

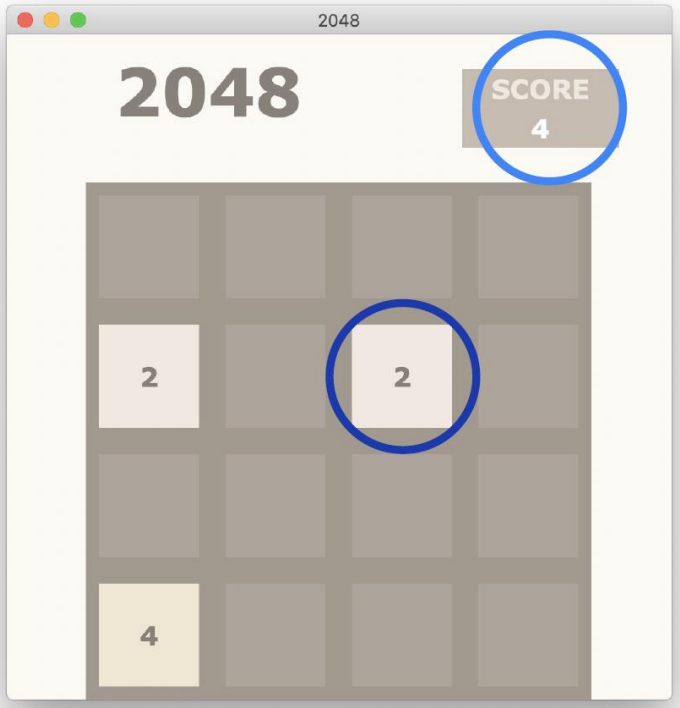
- 2048 Game Rule
- Game State
- Temporal Difference Learning
- n-tuple Network
- Modify and Run Sample Code
- Scoring Criteria
- Reminders

2048 Game Rules (1/2)

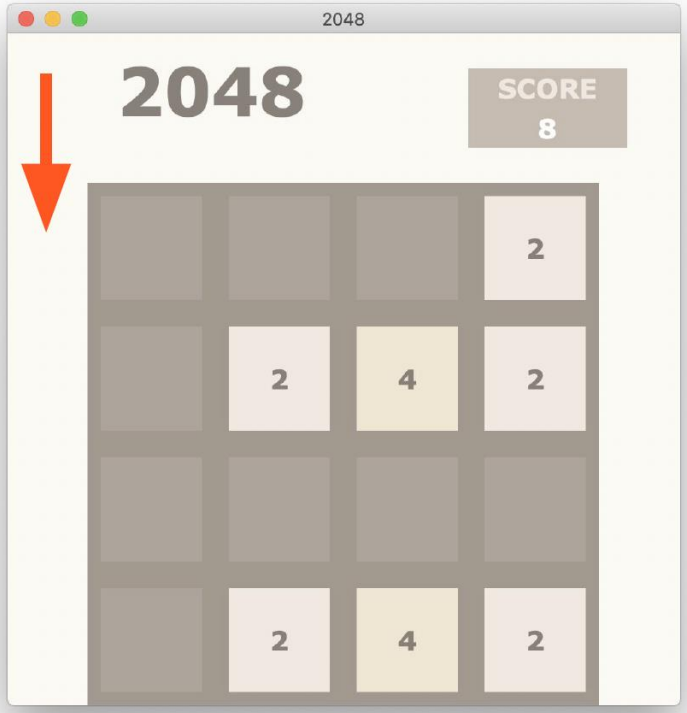
popup: **2** (90%), **4** (10%)

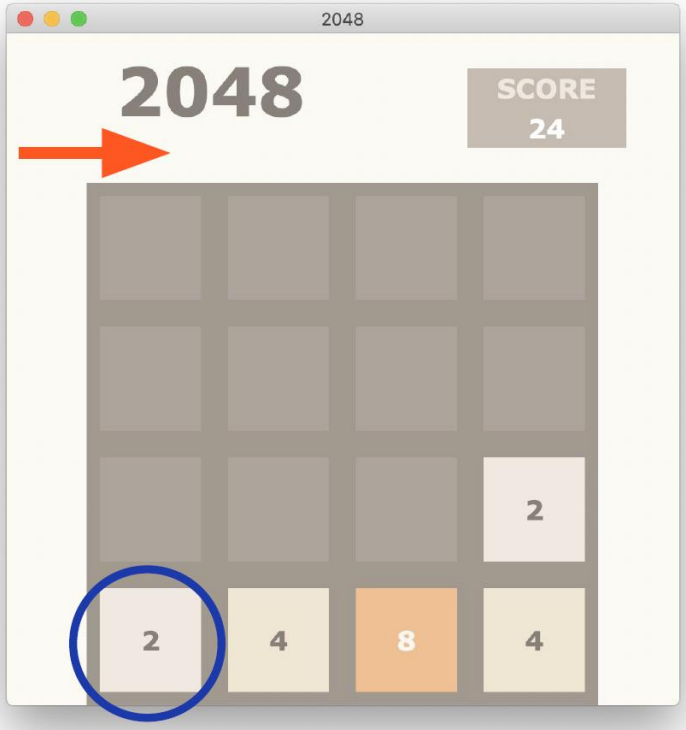




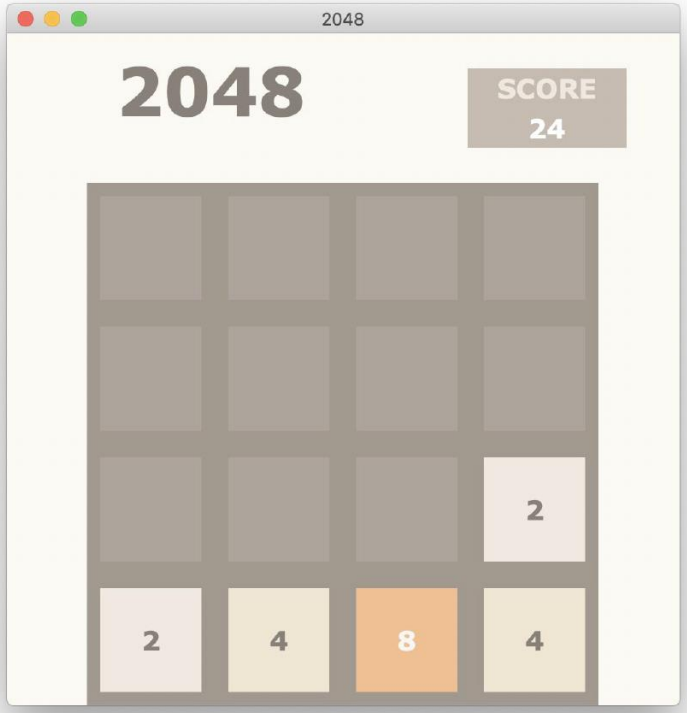


2048 Game Rules (2/2)

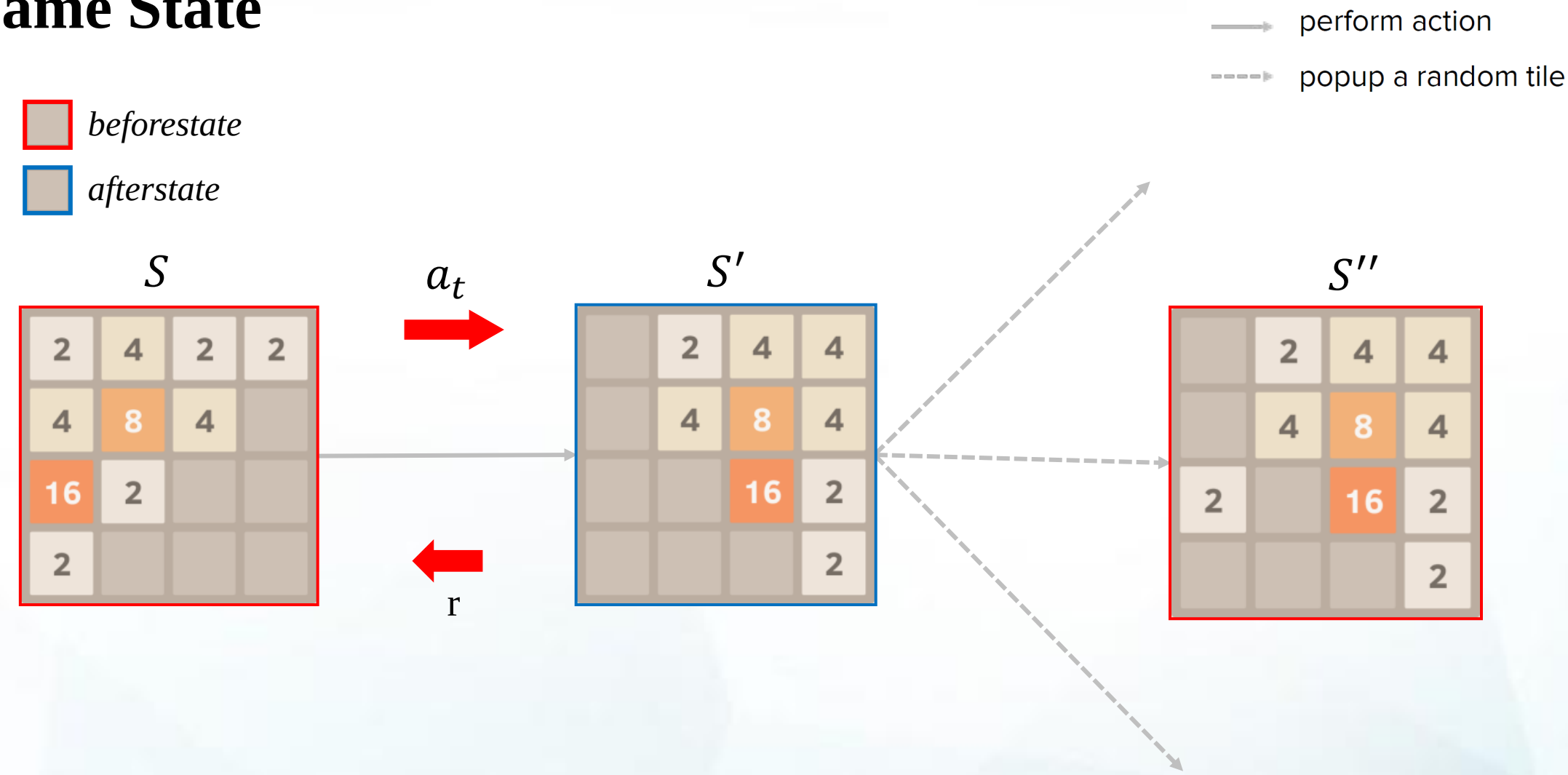




does not popup



Game State


perform action
popup a random tile
beforestate
afterstate
S
a_t
S'
S''
r

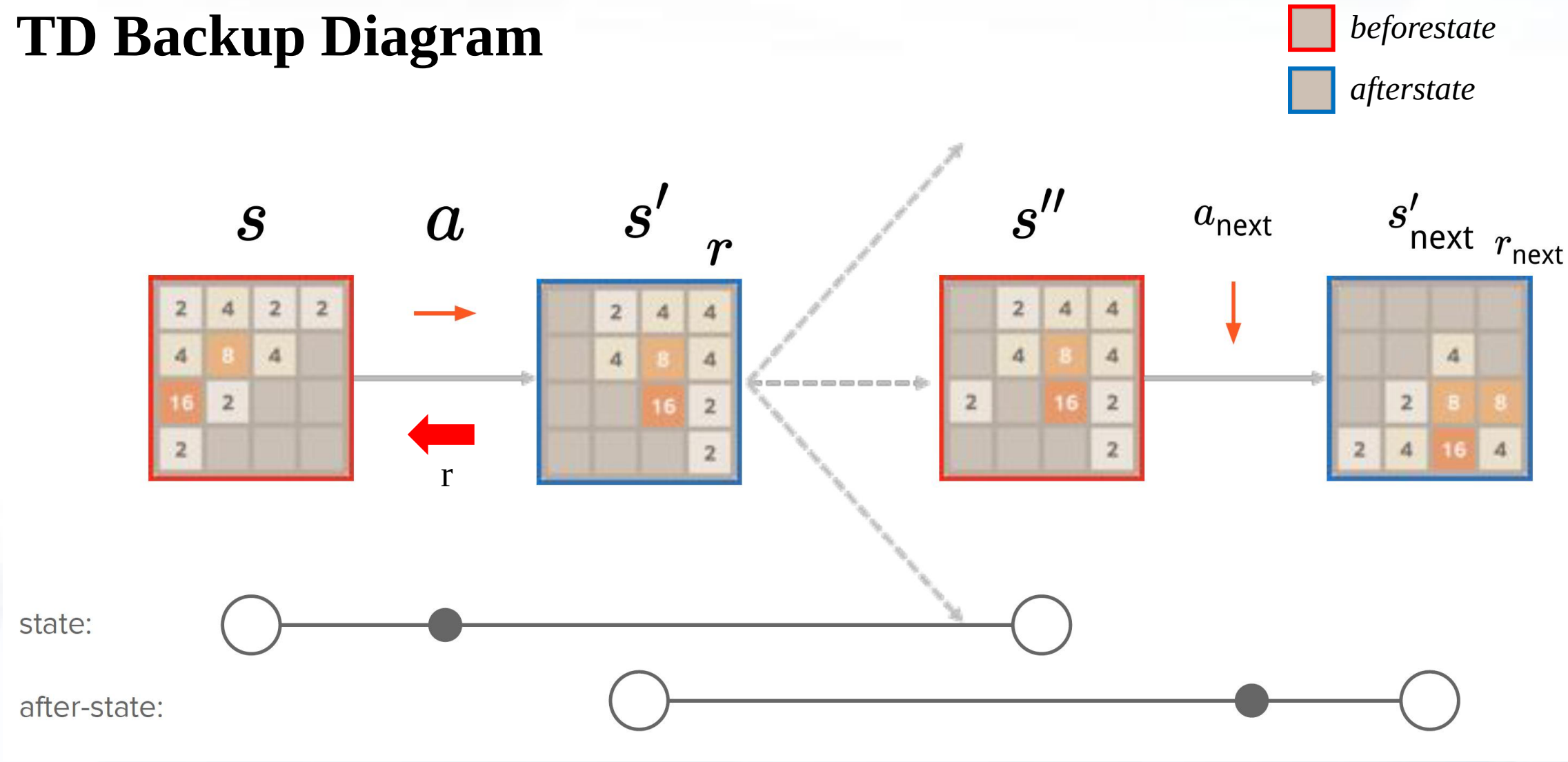
Temporal Difference Learning (TD)

For each episode,

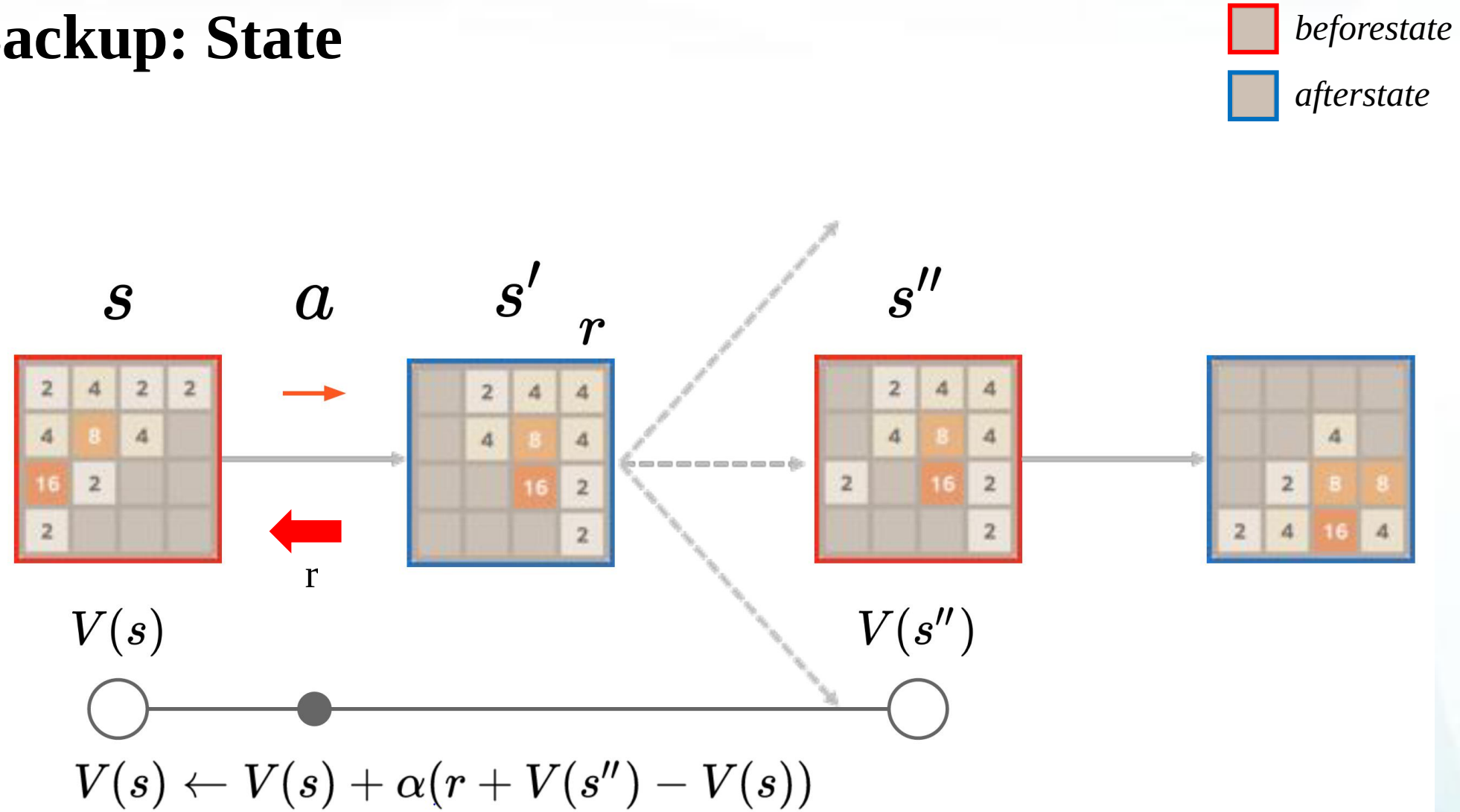
```
Initialize (before-)state s
While s is not terminal do
  a ← argmax_a' EVALUATE(s, a')
  r, s', s'' ← MAKE_MOVE(s, a)
  STORE(s, a, r, s', s'')
  s ← s''
End While
For (s, a, r, s', s'') from terminal down to initial do
  LEARN_EVALUATION(s, a, r, s', s'')
End For
```

perform TD backup

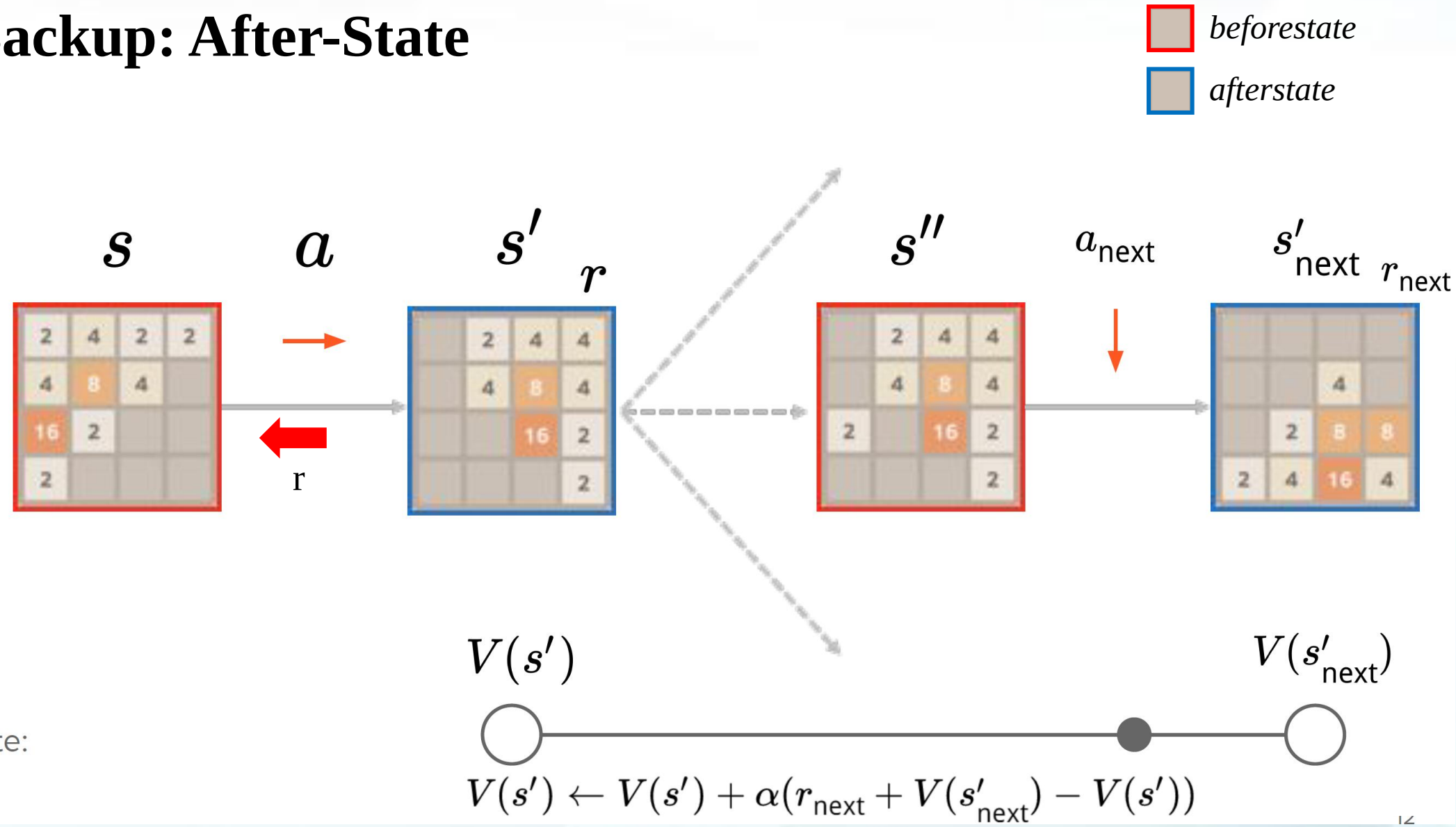
TD Backup Diagram



TD Backup: State



TD Backup: After-State



Why use n-tuple network?

- The expected score/return G_t from a board S

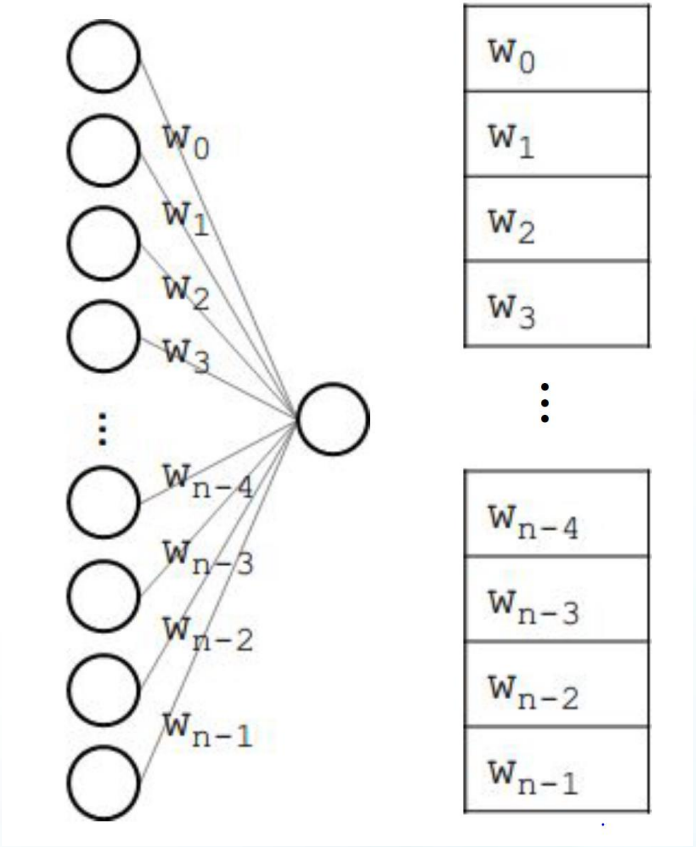
- But, #states is huge
  - About 17^{16} ($=10^{20}$).
    - Empty (→ 0), 2 ($=2^1$ → 1), 4 ($=2^2$ → 2), 8 ($=2^3$ → 3), …, 65536 ($=2^{16}$ → 16).

- Need to use value function approximator.

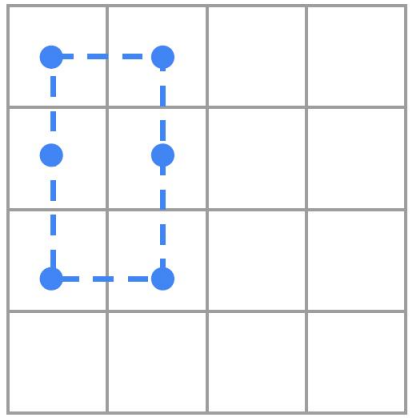
n-tuple network

n-tuple network (a.k.a. RAM-based neural network) is a type of artificial neural network.

- A large number of input nodes.
  - Input values are either 1 or 0.
  - Input is a sparse vector.
- No hidden layers.
- Only 1 output node.



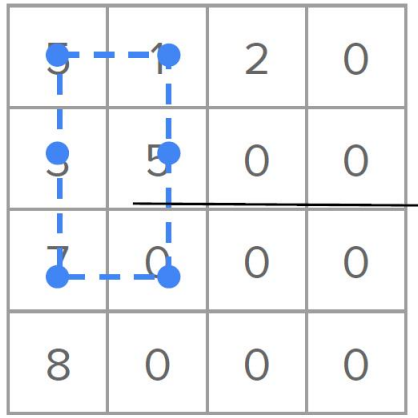
Example: 2048 with n-tuple network



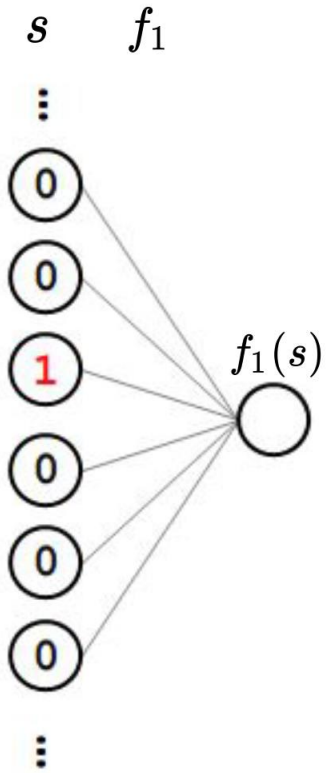
a 6-tuple pattern f_1

5	1	2	0
3	5	0	0
7	0	0	0
8	0	0	0

board s



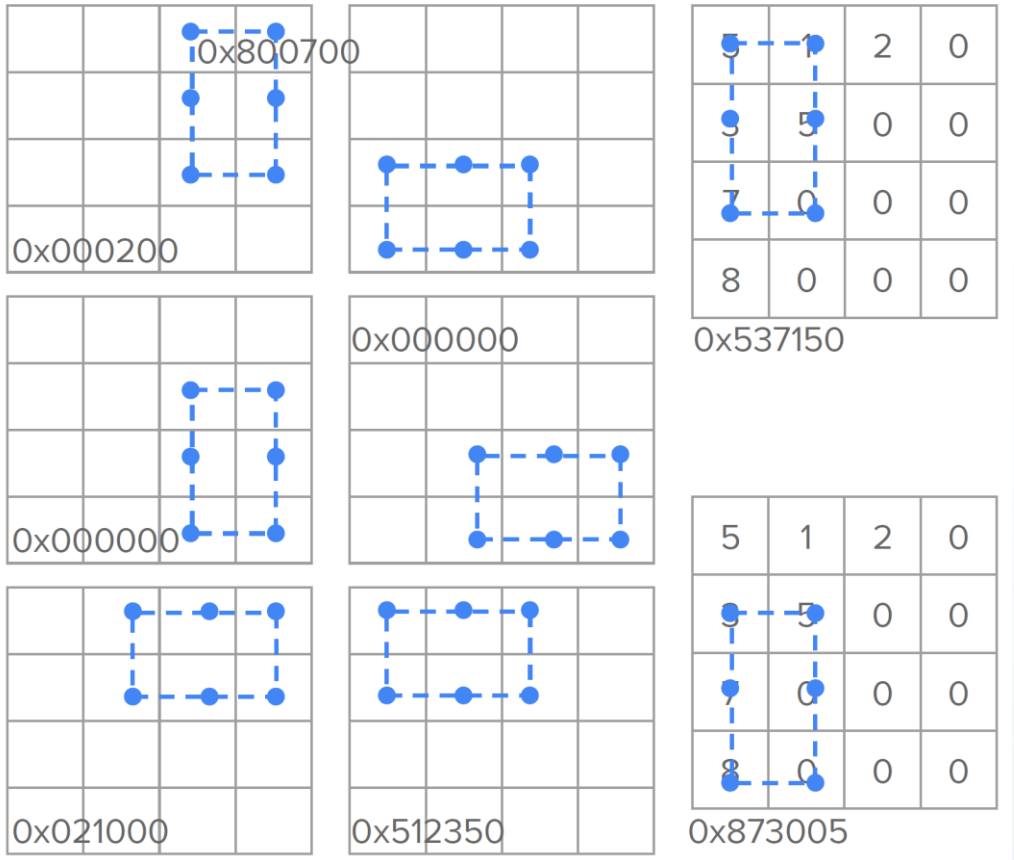
0x537150

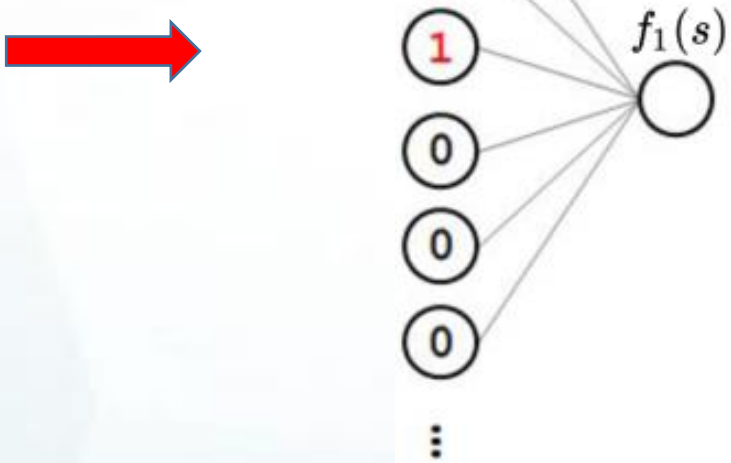


0.34
0
6.48
-3.14
0.25
0

All Isomorphism

- Rotations and Reflections
- The sum of the eight values can represents the board.

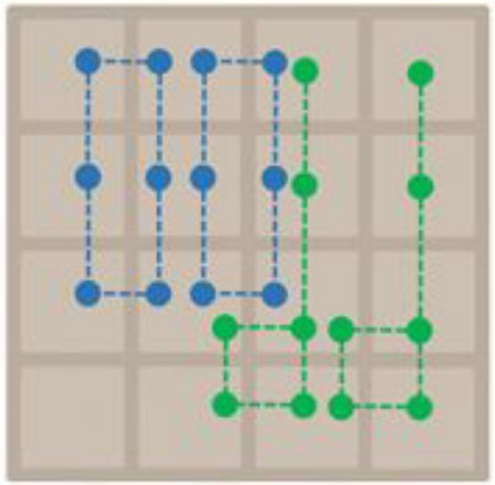


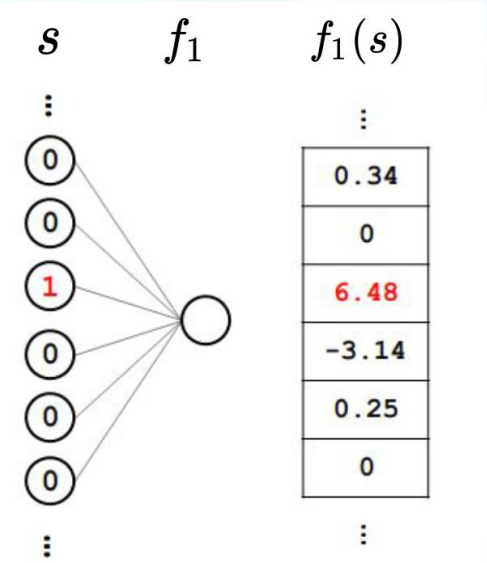


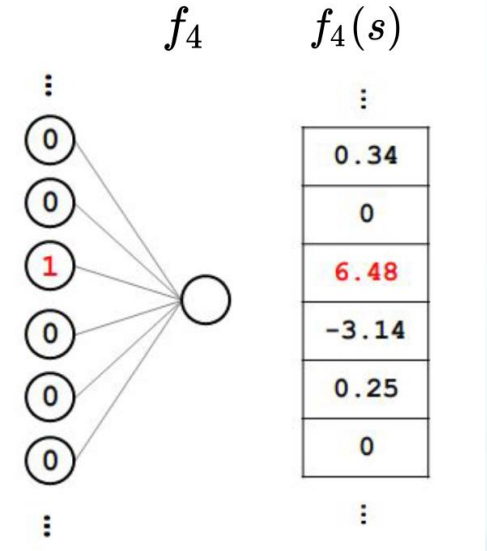
Multiple n-tuple

- Example: 4 kinds of 6-tuple.
- Calculate (use int):
  - Size: 4* 15^6 * 4 byte

$$V(s) = f_1(s) + f_2(s) + f_3(s) + f_4(s)$$







Sample Code

- Implement V(state)
  - Compile with C++11 support
  - g++ -std=c++11 -O3 -o 2048 2048.cpp

Training:

```
// restore the model from file
tdl.load("");

// train the model
std::vector<state> path;
path.reserve(20000);
for (size_t n = 1; n <= total; n++) {
  board b;
  int score = 0;

  // play an episode
  debug << "begin episode" << std::endl;
  b.init();
  while (true) {
    debug << "state" << std::endl << b;
    state best = tdl.select_best_move(b);
    path.push_back(best);

    if (best.is_valid()) {
      debug << "best " << best;
      score += best.reward();
      b = best.after_state();
      b.popup();
    } else {
      break;
    }
  }
  debug << "end episode" << std::endl;

  // update by TD(0)
  tdl.update_episode(path, alpha);
  tdl.make_statistic(n, b, score);
  path.clear();
}

// store the model into file
tdl.save("weights.bin");

return 0;
```

Save your model weight

Evaluating (demo):

Set total count to 1000 games

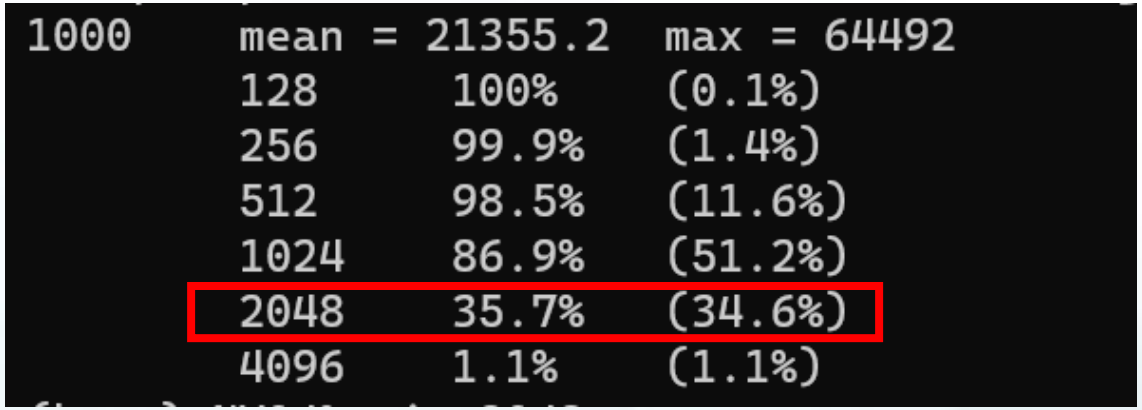
Load your model weight

```
int main(int argc, const char* argv[]) {
  info << "TDL2048-Demo" << std::endl;
  learning tdl;

  // set the learning parameters
  float alpha = 0.1;
  size_t total = 1000;
  unsigned seed;
  __asm__ __volatile__ ("rdtsc" : "=a" (seed));
  info << "alpha = " << alpha << std::endl;
  info << "total = " << total << std::endl;
  info << "seed = " << seed << std::endl;
  std::srand(seed);

  // initialize the features
  tdl.add_feature(new pattern({ 0, 1, 2, 3, 4, 5 }));
  tdl.add_feature(new pattern({ 4, 5, 6, 7, 8, 9 }));
  tdl.add_feature(new pattern({ 0, 1, 2, 4, 5, 6 }));
  tdl.add_feature(new pattern({ 4, 5, 6, 8, 9, 10 }));

  // restore the model from file
  tdl.load("weights.bin");

  // train the model
  std::vector<state> path;
  path.reserve(20000);
  for (size_t n = 1; n <= total; n++) {
    board b;
    int score = 0;
```

Scoring Criteria

Show your work, otherwise no credit will be granted.

- Report (50%)
  - (DO explain; do not only copy and paste your codes.)
- Performance (50%)
  - The 2048-tile win rate in 1000 games,$\lceil \text{winrate}_{2048} \rceil$.(30%)
  - Questions. (20%)



Reminders

- You can design your n-tuple.
- You should avoid using CNN in this lab.
- 2048-tile should appear within 10,000 episodes.
- You have to load your weight while demo.

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.
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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