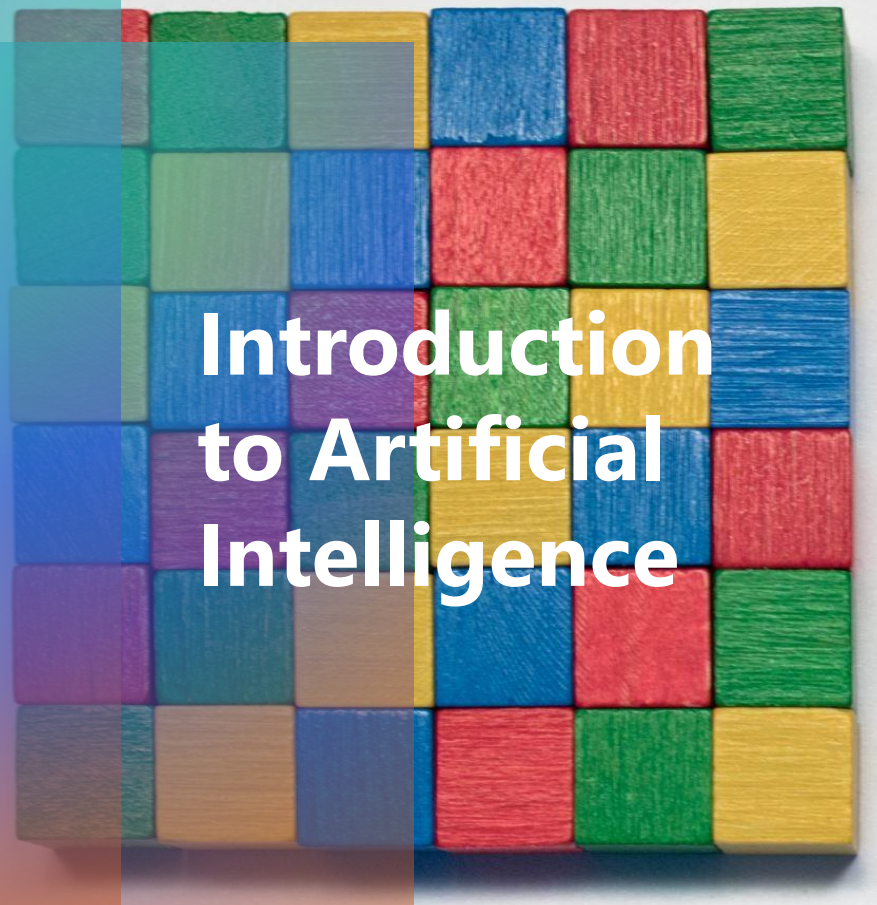
Feature-Based Reinforcement Learning for the Rubik Cube

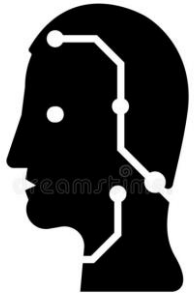


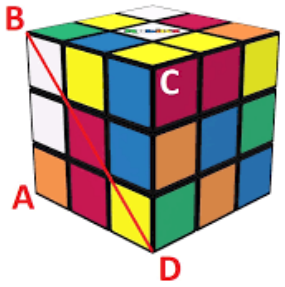
Introduction to Artificial Intelligence

Team Members:

1. Alisha Kareemulla
2. Thulasi Theja K S

Description of Project





Create and train a reinforcement learning agent that learns to solve a 2x2x2 and 3x3x3 size Rubik cube

This is done using feature-based state representations

Project Objectives

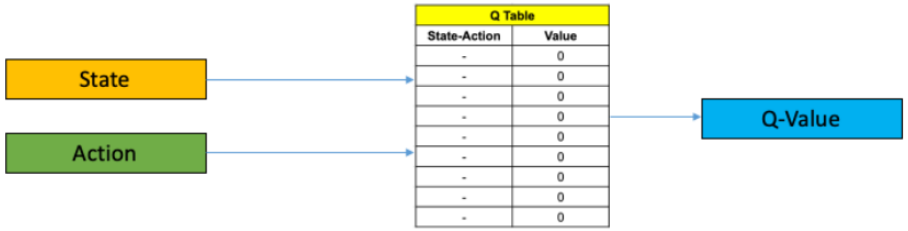
- Generating the initial cube and scrambling it randomly every time.
- Creating a RL agent that can solve 2x2x2 and 3x3x3 rubric cube.
- Training the agent based on the state of the cube using Reinforcement learning algorithms and comparing them.

Approach

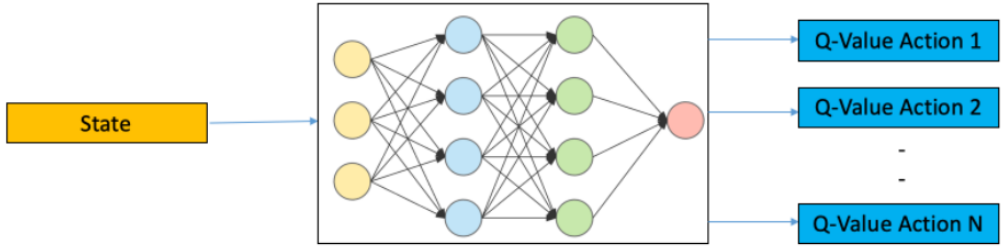
- Creating the rubric cube design for 2x2x2 and 3x3x3 using Python and its modules.
- Creating an agent that can solve the cube.
- Training the agent based on the state of the cube.
- Reinforcement learning algorithms i.e., Deep Q-Learning and SARSA is used.
- The reward system primarily focuses on the number of entirely-correct blocks / current state based on the algorithm.

Deep Q-Learning

- Involves Agent-> a
  set of states-> S
  set of Actions per state-> A
  reward, r
  epsilon
  Discount factor, gamma -> probability to succeed at every step -> between 0 and 1



Q Learning



Deep Q Learning

Procedure

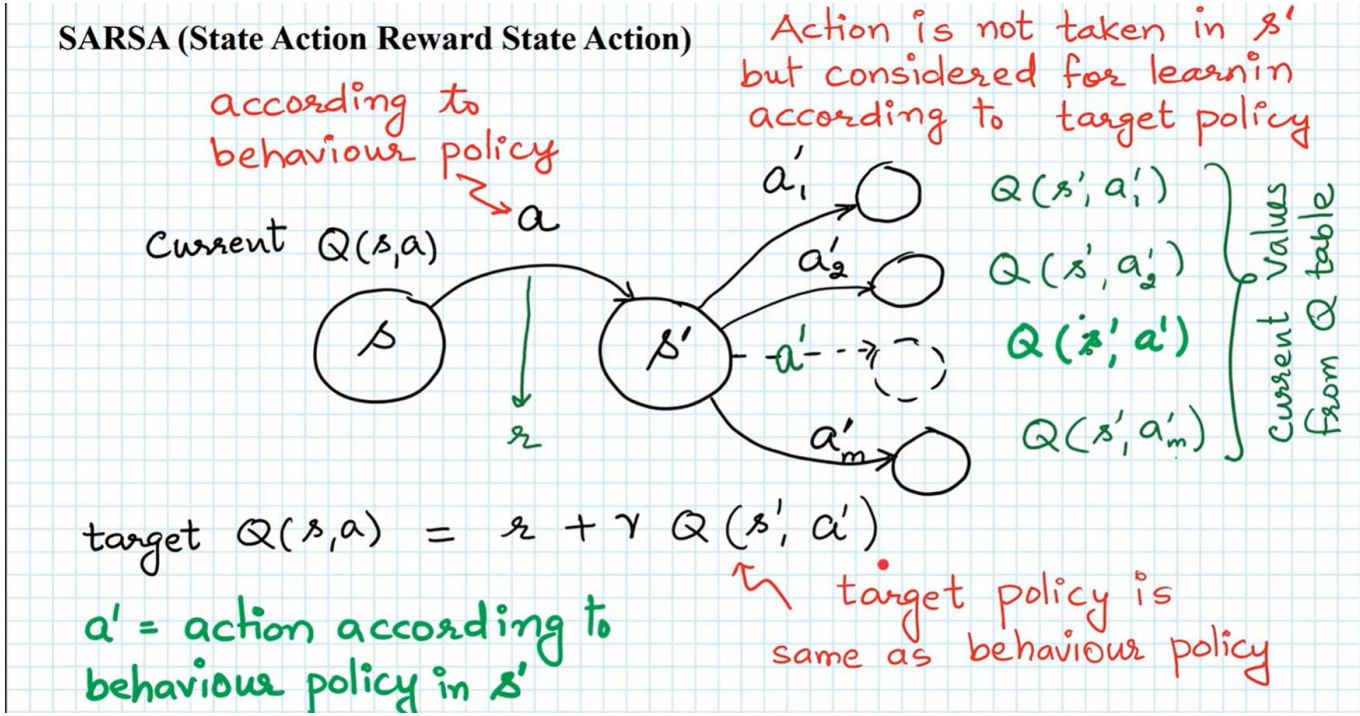
- All the past experience is stored by the user in memory.
- The next action is determined by the maximum output of the Q-network.
- The loss function here is mean squared error of the predicted Q-value and the target Q value – Q*.
- However, we do not know the target or actual value here as we are dealing with a reinforcement learning problem.
- The Q-value update equation derived from the Bellman equation

$$Q(S_t, A_t) \leftarrow Q(S_t, A_t) + \alpha\left[\boxed{R_{t+1} + \gamma \max_a Q(S_{t+1}, a)} - Q(S_t, A_t)\right]$$

SARSA

- State–action–reward–state–action (SARSA) is an algorithm for learning a Markov Decision process policy.

- Agent interacts with the environment and updates the policy based on actions taken, hence this is known as an on-policy learning algorithm



Final Hyperparameter Values:

- Discount (Gamma): 0.9
- Learning Rate: 0.05
- No. of Episodes: 100
- Epsilon: 0.2

Q – Learning vs SARSA (State Action Reward State Action) Algorithm

Q – Learning (Off policy)

Updated Q Value Current Q Value Target Q Value Current Q Value

$$Q(s,a) = Q(s,a) + \alpha\left[\, r + \max_{a'} \gamma Q(s',a') - Q(s,a) \,\right]$$

α = Learning Rate

Target policy is always Greedy Policy

SARSA (State Action Reward State Action) Algorithm (On policy)

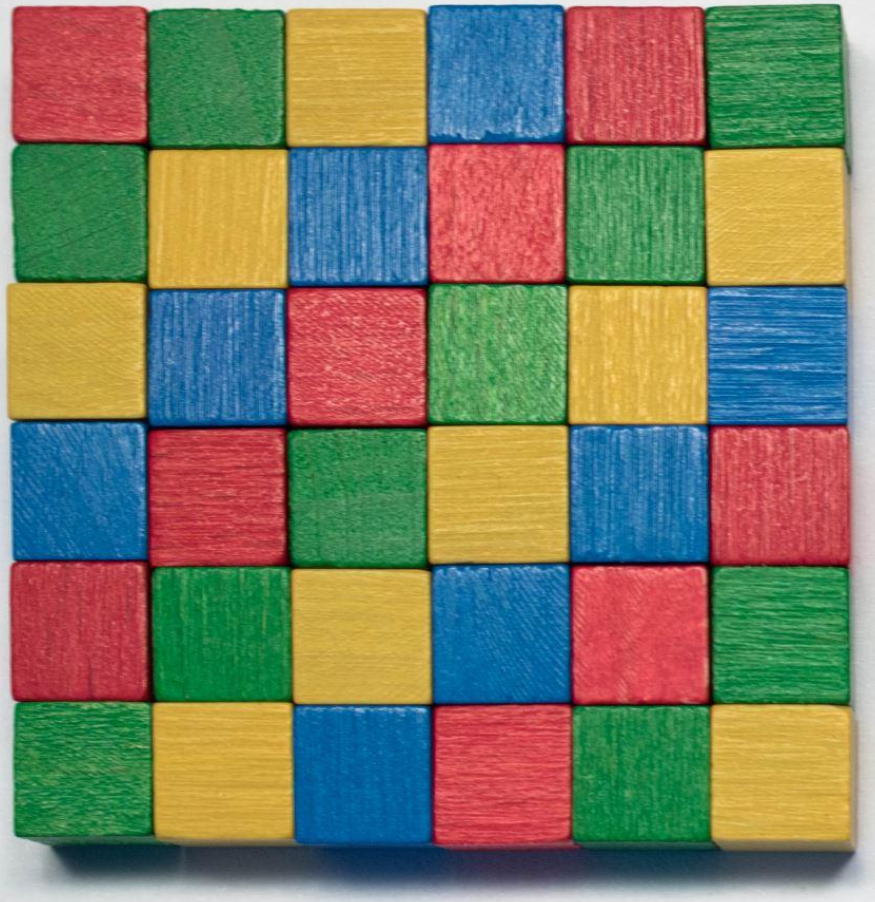
Updated Q Value Current Q Value Target Q Value Current Q Value

$$Q(s,a) = Q(s,a) + \alpha\left[\, r + \gamma Q(s',a') - Q(s,a) \right]$$

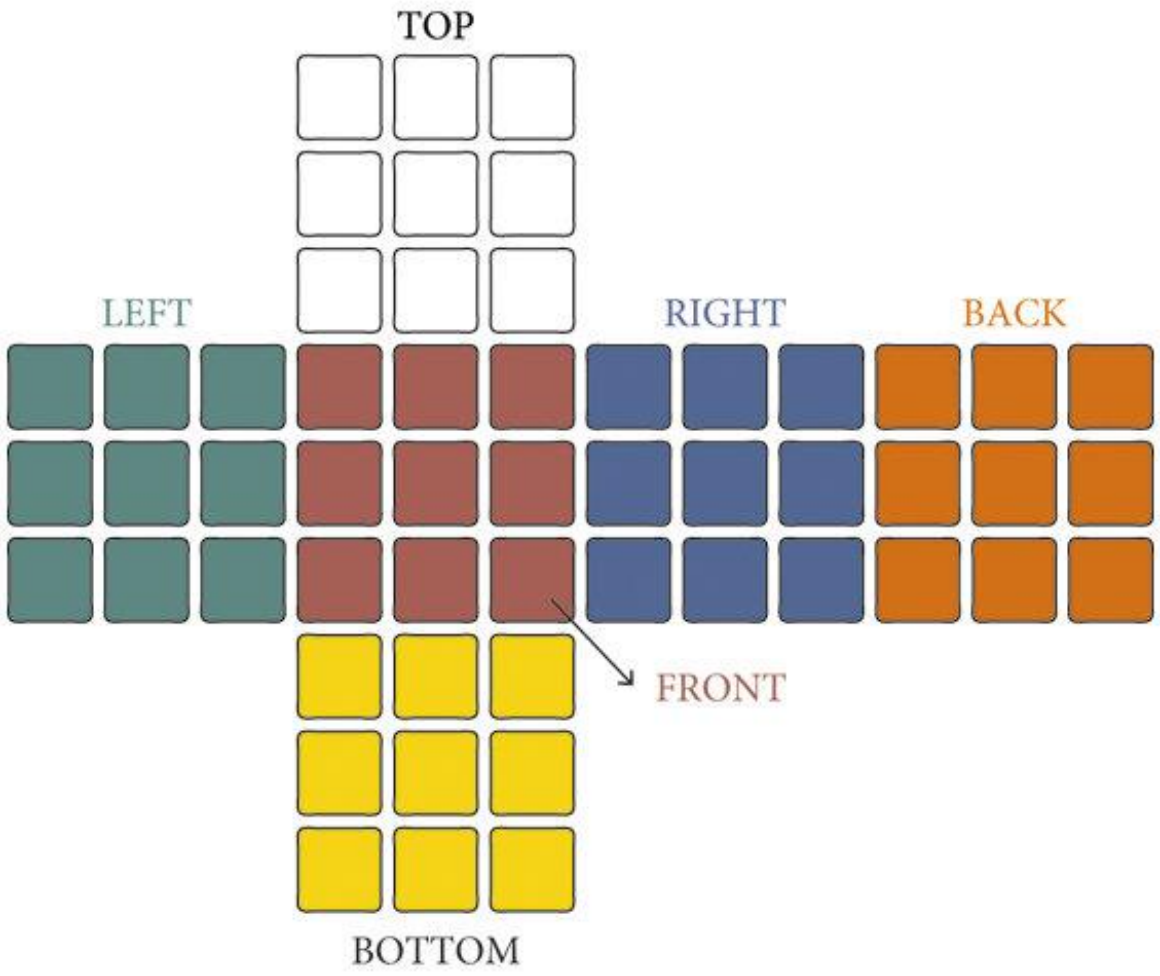
α = Learning Rate

Target Policy is always same as Behaviour Policy

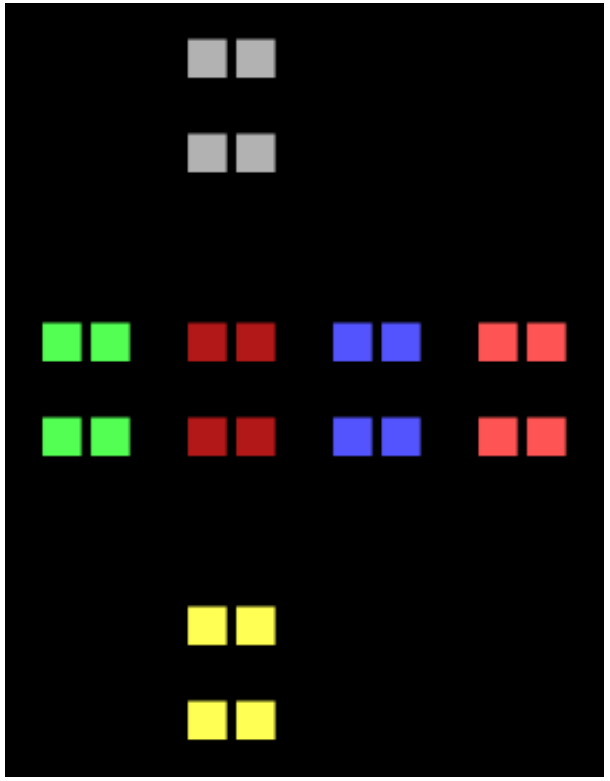
Code Review



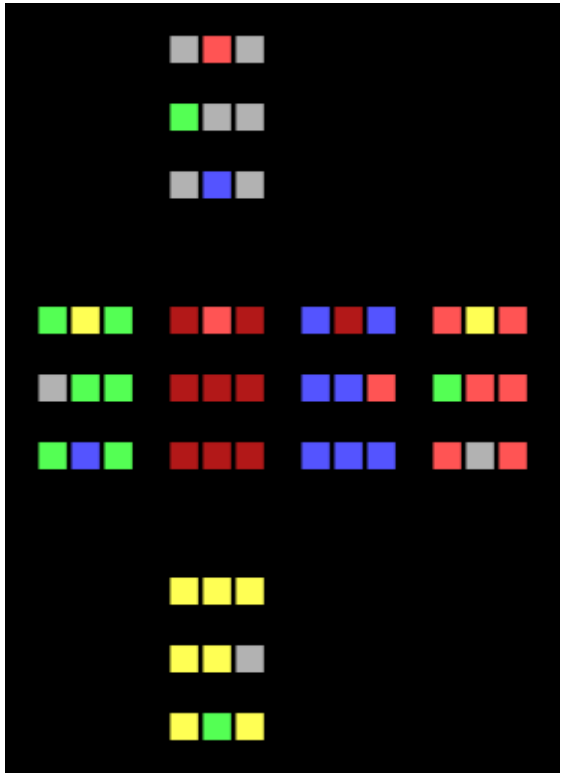
Cube Representation



Deep Q-Learning Stats



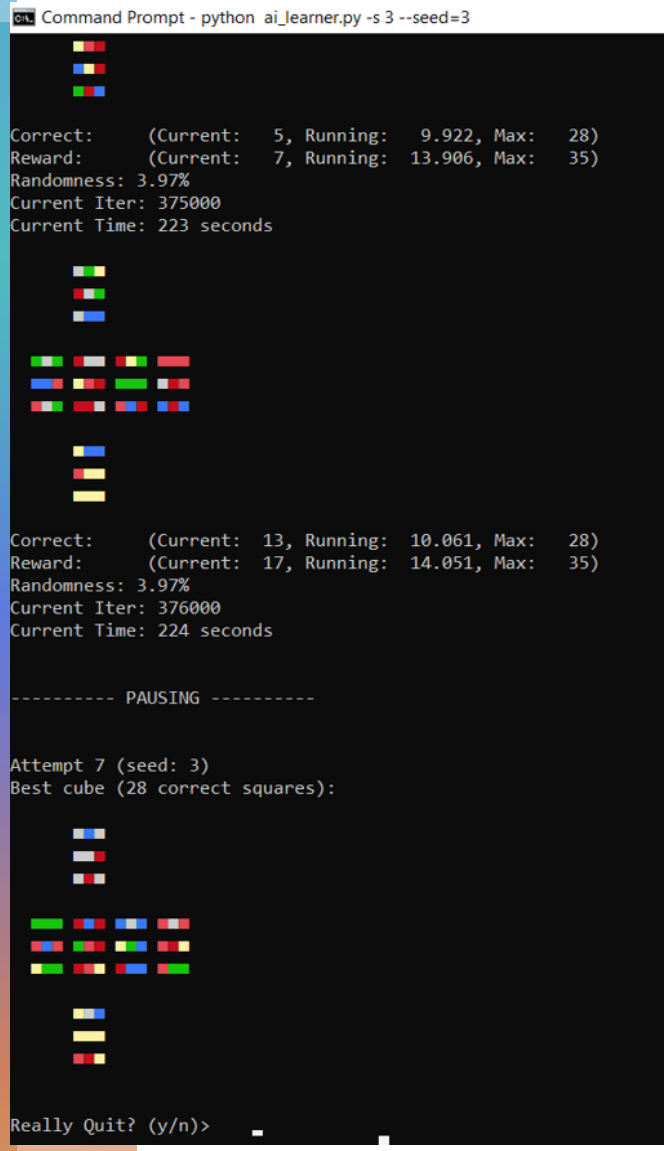
24 solved cubes in 45 min of training
2x2x2



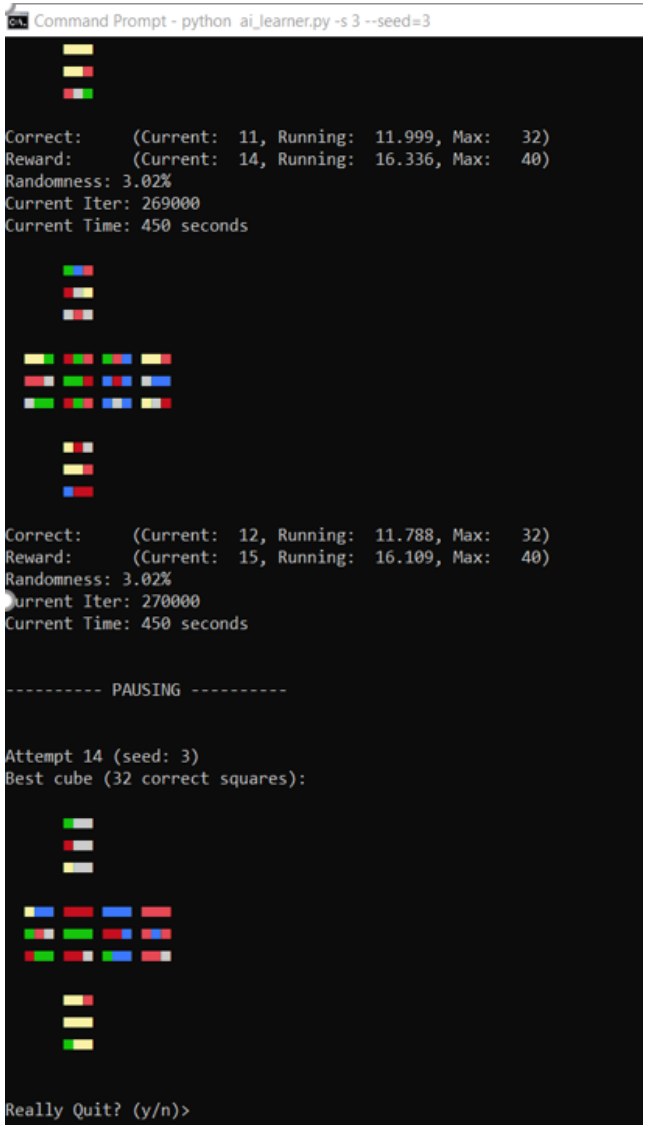
38 solved cubes in 3.5 hours of training
3x3x3

2x2x2 cube stats after 45 minutes of training

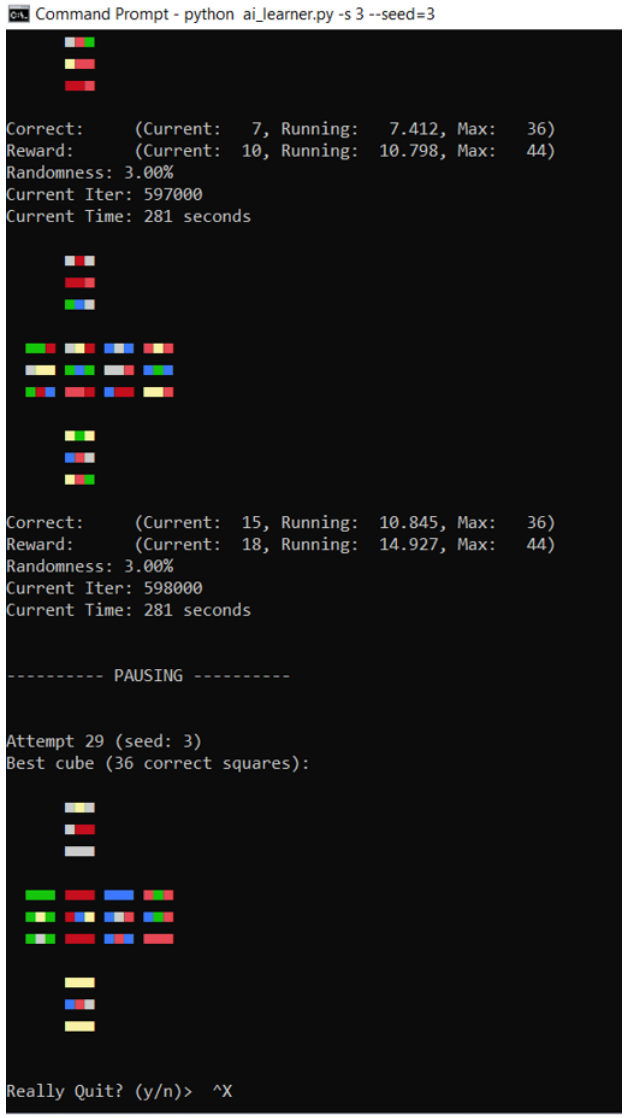
```
Cube 1034 (Attempt 1037): Rotations:    8781, Time:     3
Cube 1035 (Attempt 1038): Rotations:    5937, Time:     2
Cube 1036 (Attempt 1039): Rotations:    1591, Time:     0
Cube 1037 (Attempt 1040): Rotations:   11969, Time:     5
Cube 1038 (Attempt 1041): Rotations:    1615, Time:     0
Cube 1039 (Attempt 1042): Rotations:      77, Time:     0
Cube 1040 (Attempt 1043): Rotations:    6189, Time:     2
Cube 1041 (Attempt 1044): Rotations:   13945, Time:     5
Cube 1042 (Attempt 1045): Rotations:     497, Time:     0
Cube 1043 (Attempt 1046): Rotations:    9313, Time:     3
Cube 1044 (Attempt 1047): Rotations:   13473, Time:     5
Cube 1045 (Attempt 1048): Rotations:     353, Time:     0
Cube 1046 (Attempt 1049): Rotations:     649, Time:     0
Cube 1047 (Attempt 1050): Rotations:    4187, Time:     1
Cube 1048 (Attempt 1051): Rotations:    4793, Time:     2
Cube 1049 (Attempt 1052): Rotations:     177, Time:     0
Cube 1050 (Attempt 1053): Rotations:    3663, Time:     1
Cube 1051 (Attempt 1054): Rotations:     511, Time:     0
Cube 1052 (Attempt 1055): Rotations:    3375, Time:     1
Cube 1053 (Attempt 1056): Rotations:    7395, Time:     3
Cube 1054 (Attempt 1057): Rotations:     497, Time:     0
```



28 squares



32 squares



36 squares

SARSA Stats

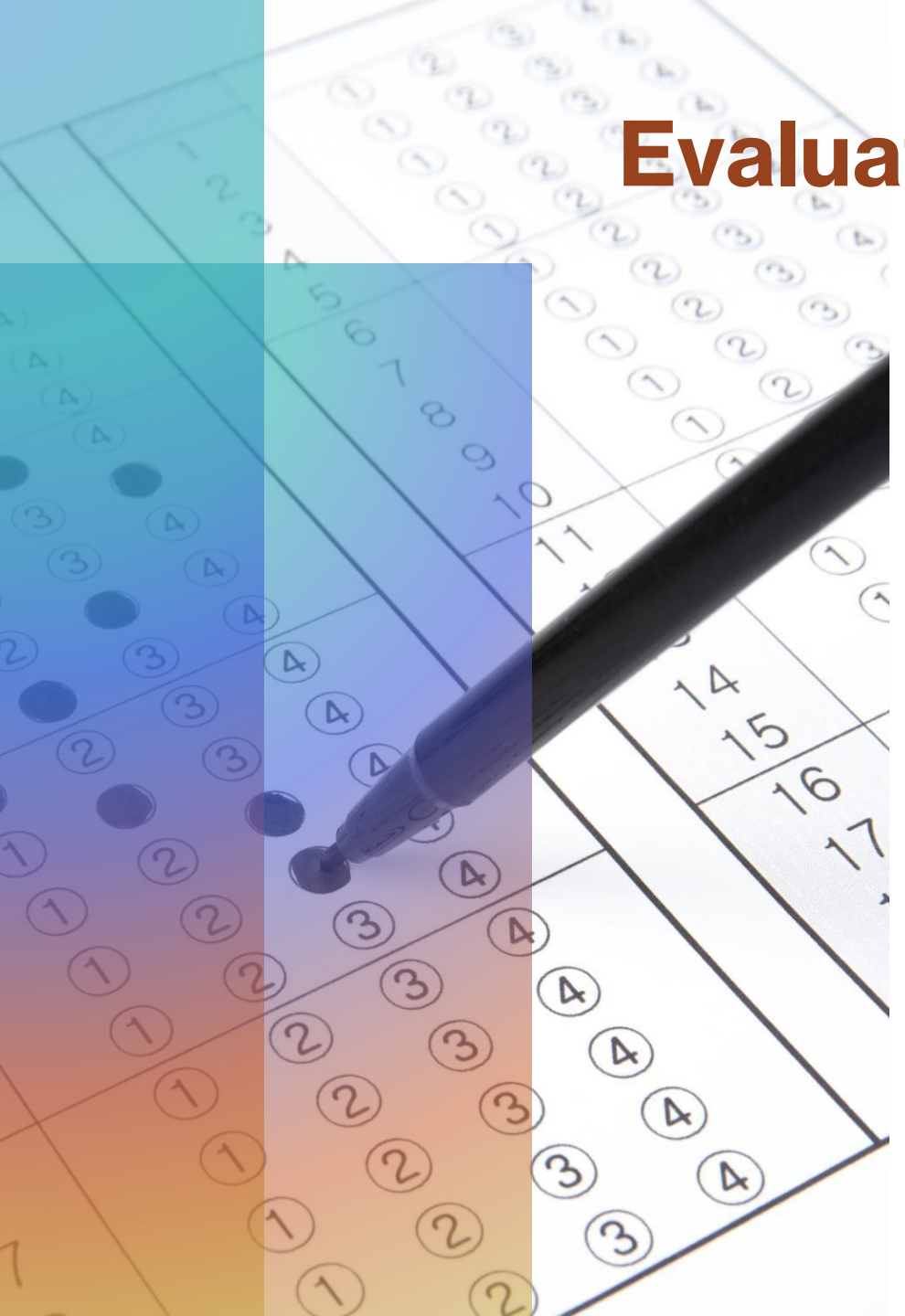
```
      [2  5]
      [1  5]

  [4  2]     [6  2]     [1  1]     [5  3]
  [4  2]     [6  1]     [3  3]     [5  4]

      [4  6]
      [3  6]

********* SARSA LEARNING *********
=====================================
```

```
      [2  2]
      [2  2]

  [4  4]     [6  6]     [1  1]     [5  5]
  [4  4]     [6  6]     [1  1]     [5  5]

      [3  3]
      [3  3]

The goal state was reached in  11 episodes.
```

```
Goal state reached for episode  73
Action taken to reach s'  front-face-right
Q value for (s, a)  9.504012637346158
Goal state reached
```

Deliverables

- ✓ Documentation Report (README.md)
- ✓ Python programming files (.py files) and the test results of the project.
- ✓ GitHub repository link
- ✓ YouTube video of the developed project



Evaluation Methodologies

- The success of the project is determined by the successful implementation of the RL algorithms Q-Learning and SARSA.
- The agent must be able to successfully solve the cube to its initial position or must be able to solve most of the pieces.
- SARSA is preferable over Q-Learning to minimize errors which is shown from the above statistics.

Thank You