

Report

October 22, 2019

1 Navigation

For this project, you will train an agent to navigate (and collect bananas!) in a large, square world.

If running on the Udacity Workspace, the environment is already saved in the Workspace and can be accessed at the file path provided below. When running locally change the os variable (MACOS, LINUX, WINDOWS_32, WINDOWS_64) to match your OS

```
[1]: from unityagents import UnityEnvironment
import numpy as np
import timeit

os = 'MACOS'
os_env = {
    'LINUX_X86': "./envs/VisualBanana_Linux/Banana.x86",
    'LINUX_X86_64': "./envs/VisualBanana_Linux/Banana.x86_64",
    'MACOS': "./envs/Banana.app",
    'WINDOWS_X86_32': "./envs/VisualBanana_Windows_x86/Banana.exe",
    'WINDOWS_X86_64': "./envs/VisualBanana_Windows_x86_64/Banana.exe",
}

print('Running on self built enviroment')
env = UnityEnvironment(file_name=os_env[os])
```

Running on self built enviroment

INFO:unityagents:

'Academy' started successfully!

Unity Academy name: Academy

Number of Brains: 1

Number of External Brains : 1

Lesson number : 0

Reset Parameters :

Unity brain name: BananaBrain

Number of Visual Observations (per agent): 0

Vector Observation space type: continuous

```
Vector Observation space size (per agent): 37
Number of stacked Vector Observation: 1
Vector Action space type: discrete
Vector Action space size (per agent): 4
Vector Action descriptions: , , ,
```

1.1 Environment and Brains

Environments contain *brains* which are responsible for deciding the actions of their associated agents. Here we check for the first brain available, and set it as the default brain we will be controlling from Python.

```
[2]: # get the default brain
brain_name = env.brain_names[0]
brain = env.brains[brain_name]
```

1.2 Examine the State and Action Spaces

Run the code cell below to print some information about the environment.

```
[3]: # reset the environment
env_info = env.reset(train_mode=True)[brain_name]

# number of agents in the environment
print('Number of agents:', len(env_info.agents))

# number of actions
action_size = brain.vector_action_space_size
print('Number of actions:', action_size)

# examine the state space
state = env_info.vector_observations[0]
print('States look like:', state)
state_size = len(state)
print('States have length:', state_size)
```

```
Number of agents: 1
Number of actions: 4
States look like: [1.          0.          0.          0.          0.84408134 0.
 0.          1.          0.          0.0748472 0.          1.
 0.          0.          0.25755   1.          0.          0.
 0.          0.74177343 0.          1.          0.          0.
 0.25854847 0.          0.          1.          0.          0.09355672
 0.          1.          0.          0.          0.31969345 0.
 0.          ]
States have length: 37
```

1.2.1 Architecture

Agent The Agent uses 2 FeedForward Networks and a ReplayBuffer to interact with the environment to accomplish the episodic tasks. It uses the Epsilon Greedy method to select the action with a starting epsilon of 1.0. The epsilon is decayed over the episodes using a decay rate of 0.995 with an ending epsilon of 0.01. - Replay Buffer: It stores the experience that the agent observes, allowing us to reuse this data later. This allows the agent to sample the transitions randomly reducing the correlation in a batch. This has been shown to stabilize and improve the DQN training. The buffer is a cyclic buffer of bounded size that holds the experiences observed recently. It also implements a `.sample()` method for selecting a random batch of experiences for training. Each experience stored is actually a NamedTuple containing a single named tuple representing a single interaction with the environment. It essentially maps (state, action) pairs to their (next_state, reward, done) result. - Target network: This network is compared to the local network minimize the error better the 2 to maximize the reward to solve the task. The agent randomly initialized it at a start and it is updated everytime the buffer hits the batch size. The update is performed by picking random samples from the Replay Buffer to get the best action for a given state. - Local network: This network takes a state as input and outputs an action, it uses the epsilon, to perform epsilon-greedy action selection

It takes in the following parameters during construction: 1. device - Allows the training to switch between running on the CPU or GPU 2. memory - ReplayBuffer instance use for experience replay. This allows the ReplayBuffer class to be abstracted from the network and agent implementation. 3. action_size - Possible actions for action 4. state_size - Number of states in the environment 5. batch_size - Variable used to control the number of random samples to select for training 6. gamma - Discount factor used to calculate the targetted rewards 7. lr - Learning rate used by the optimizer for training 8. update_every - Indicates the number of time steps to occur before the agent attempts to learn 9. tau - weighting factor used to update the target network 10. hidden_layer_lengths - Allows the customization of the size in the full connected layers

Constructor The constructor of the agent takes care of creating the local network, target network and an Adam optimizer.

Methods

1. act This method is called with the current state which the agent uses with the epsilon-greedy action selector to get the next action to perform.
2. step This method takes in the `state`, `action`, `reward`, `next_state`, `done` values that were obtained from performing the action obtained from the act method previously. Internally it stores the inputs into the ReplayBuffer. And during every `update_every` step it will trigger the learn method on a random sample of responses if the memory capacity is greater than the `batch_size`
3. learn This method will calculate the target rewards and calculate the loss against the Q values in the local network using the `MSELoss` function. It will then perform any required optimization using the optimizer. And it will trigger the `soft_update` method
4. soft_update This method will perform an update on the parameters in the target network.

Network The network has 3 feed forward layers: 1. fc1 - in:state_size, out:hidden_layer_lengths
2. relu: activation for adding nonlinearity 3. fc2 - in:hidden_layer_lengths,

out:hidden_layer_lengths 4. relu: activation for adding nonlinearity 5. fc3:
in:hidden_layer_lengths, out:action_size

```
[4]: class ReplayBuffer:
    '''Fixed-size buffer to store experience tuples.'''

    def __init__(self, device, action_size, buffer_size, batch_size):
        '''Initialize a ReplayBuffer object.

        Params
        =====
            action_size (int): dimension of each action
            buffer_size (int): maximum size of buffer
            batch_size (int): size of each training batch
        '''
        self.action_size = action_size
        self.memory = deque(maxlen=buffer_size)
        self.batch_size = batch_size
        self.device = device
        self.experience = namedtuple('Experience', field_names=['state', '
        ↪'action', 'reward', 'next_state', 'done'])

    def add(self, state, action, reward, next_state, done):
        '''Add a new experience to memory.'''
        e = self.experience(state, action, reward, next_state, done)
        self.memory.append(e)

    def sample(self):
        '''Randomly sample a batch of experiences from memory.'''
        experiences = random.sample(self.memory, k=self.batch_size)

        states = torch.from_numpy(np.vstack([e.state for e in experiences if e
        ↪is not None])).float().to(self.device)
        actions = torch.from_numpy(np.vstack([e.action for e in experiences if
        ↪e is not None])).long().to(self.device)
        rewards = torch.from_numpy(np.vstack([e.reward for e in experiences if
        ↪e is not None])).float().to(self.device)
        next_states = torch.from_numpy(np.vstack([e.next_state for e in
        ↪experiences if e is not None])).float().to(self.device)
        dones = torch.from_numpy(np.vstack([e.done for e in experiences if e is
        ↪not None])).astype(np.uint8).float().to(self.device)

        return (states, actions, rewards, next_states, dones)

    def __len__(self):
        '''Return the current size of internal memory.'''
        return len(self.memory)
```

1.2.2 Training

The training method has been abstracted and it takes the following arguments: - `checkpoint_filename` (string): name to store the saved state of successful agent action - `agent`: agent that implements the methods `act` and `step` with a `qnetwork_local` property - `n_episodes` (int): maximum number of training episodes - `max_t` (int): maximum number of timesteps per episode - `eps_start` (float): starting value of epsilon, for epsilon-greedy action selection - `eps_end` (float): minimum value of epsilon - `eps_decay` (float): multiplicative factor (per episode) for decreasing epsilon

This follows different types of agents to use the same training method as follows: 1. Obtain the next action to perform against the environment from the agent 2. Perform the action against the environment and obtained the new `reward`, `next_state`, `done` values 3. Call `step` on the agent with `state`, `action`, `reward`, `next_state`, `done` to perform the learn operation from the new parameters obtained from the environment 4. Calculate the rewards accumulated and persist the state of the model if the target accumulated reward is obtained

```
[5]: import numpy as np
from collections import namedtuple, deque

import random
import torch
from qnetwork.agent import Agent as QNetwork_Agent

import matplotlib.pyplot as plt
%matplotlib inline

device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
BUFFER_SIZE = int(1e5) # replay buffer size
BATCH_SIZE = 64 # minibatch size
GAMMA = 0.99 # discount factor
TAU = 1e-3 # for soft update of target parameters
LR = 5e-4 # learning rate
UPDATE_EVERY = 4 # how often to update the network

def train(checkpoint_filename, agent, n_episodes=2000, max_t=1000, eps_start=1.
    ↪0, eps_end=0.01, eps_decay=0.995):
    """
    Params
    =====
        checkpoint_filename (string): name to store the saved state of
    ↪successful agent action
        agent: agent that implements the methods act and step with a
    ↪qnetwork_local property
        n_episodes (int): maximum number of training episodes
        max_t (int): maximum number of timesteps per episode
        eps_start (float): starting value of epsilon, for epsilon-greedy action
    ↪selection
        eps_end (float): minimum value of epsilon
```

```

        eps_decay (float): multiplicative factor (per episode) for decreasing_
→epsilon
        """
        scores = [] # list to store scores from each episode
        scores_window = deque(maxlen=100) # last 100 scores
        eps = eps_start # initialize epsilon

        average_score = 0.0
        best_average_score = 0.0
        for i_episode in range(1, n_episodes + 1):
            env_info = env.reset(train_mode=True)[brain_name]
            state = env_info.vector_observations[0]
            score = 0
            for t in range(max_t):
                action = agent.act(state, eps)
                env_info = env.step(action)[brain_name] # send the action_
→to the environment
                next_state = env_info.vector_observations[0] # get the next state
                reward = env_info.rewards[0] # get the reward
                done = env_info.local_done[0] # see if episode_
→has finished
                agent.step(state, action, reward, next_state, done)
                state = next_state # update the score
                score += reward
                if done:
                    break

            scores_window.append(score) # save most recent score
            scores.append(score) # save most recent score
            eps = max(eps_end, eps_decay * eps) # decrease epsilon

            average_score = np.mean(scores_window)
            print(f'\rEpisode {i_episode}\tAverage Score: {average_score:.2f}',_
→end="")
            if i_episode % 100 == 0:
                print(f'\rEpisode {i_episode}\tAverage Score: {average_score:.2f}')

            if average_score >= 13.0 and average_score > best_average_score:
                best_average_score = average_score
                print('\nEnvironment solved in {:d} episodes!\tAverage Score: {:.
→2f}'.format(i_episode, average_score))
                torch.save(agent.qnetwork_local.state_dict(), checkpoint_filename)

        return scores

```

Setup variables and utility functions for using Q Network. `testWrapper` is a utility method for timing the training process.

```
[6]: def runQNetworkTest(checkpoint_filename, buffer_size, batch_size, gamma, lr,
    ↪update_every, tau, hidden_layer_lengths):
    memory = ReplayBuffer(device, action_size, buffer_size, batch_size)
    agent = QNetwork_Agent(
        device, memory, action_size, state_size,
        batch_size, gamma, lr, update_every, tau, hidden_layer_lengths
    )

    scores = train(checkpoint_filename, agent)

    # plot the scores
    fig = plt.figure()
    ax = fig.add_subplot(111)
    plt.plot(np.arange(len(scores)), scores)
    plt.ylabel('Score')
    plt.xlabel('Episode #')
    plt.show()

def testWrapper(func, *args, **kwargs):
    def wrapped():
        return func(*args, **kwargs)
    return wrapped
```

Test Case BUFFER_SIZE = 100,000 BATCH_SIZE = 64

GAMMA = 0.99

TAU = 1e-3

LR = 5e-4

UPDATE_EVERY = 4

Run using Buffer Size of 100,000

```
[7]: # 64 Hidden Layers
wrapped = testWrapper(runQNetworkTest, 'checkpoint-100000.pth', BUFFER_SIZE,
    ↪BATCH_SIZE, GAMMA, LR, UPDATE_EVERY, TAU, { 'fc1': 64, 'fc2': 64 })
print(f'Time Taken: {timeit.timeit(wrapped, number=1)}')
```

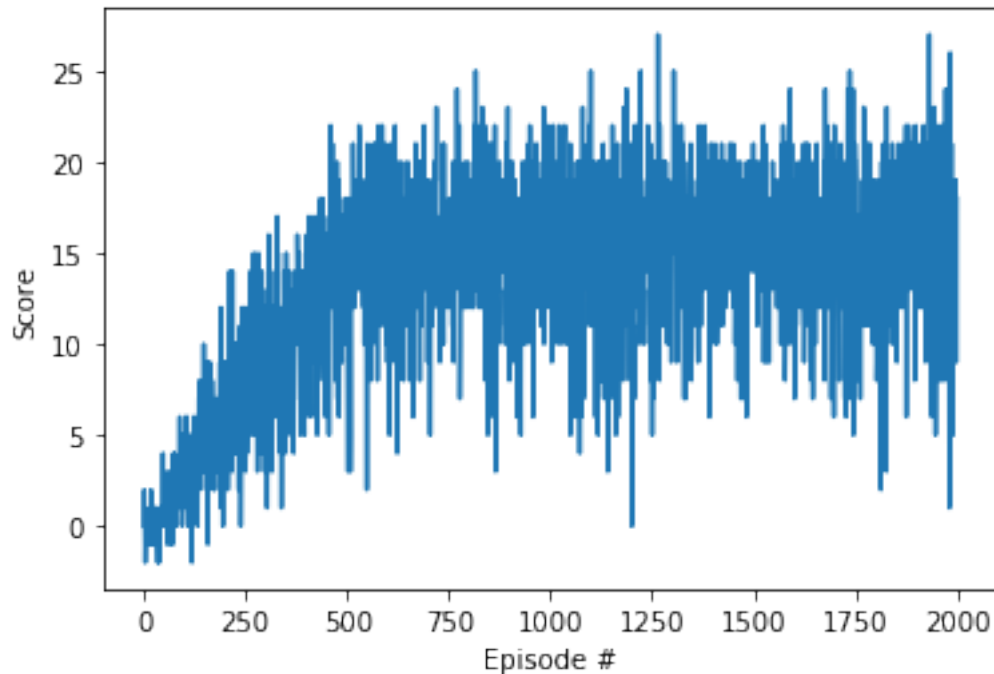
Episode 100	Average Score: 0.85	
Episode 200	Average Score: 4.52	
Episode 300	Average Score: 8.10	
Episode 400	Average Score: 10.11	
Episode 500	Average Score: 12.92	
Episode 525	Average Score: 13.02	
Environment solved in 525 episodes!	Average Score: 13.02	
Episode 526	Average Score: 13.03	
Environment solved in 526 episodes!	Average Score: 13.03	
Episode 527	Average Score: 13.16	
Environment solved in 527 episodes!	Average Score: 13.16	

Episode 528	Average Score: 13.22	
Environment solved in 528 episodes!		Average Score: 13.22
Episode 529	Average Score: 13.23	
Environment solved in 529 episodes!		Average Score: 13.23
Episode 530	Average Score: 13.35	
Environment solved in 530 episodes!		Average Score: 13.35
Episode 531	Average Score: 13.45	
Environment solved in 531 episodes!		Average Score: 13.45
Episode 532	Average Score: 13.49	
Environment solved in 532 episodes!		Average Score: 13.49
Episode 533	Average Score: 13.51	
Environment solved in 533 episodes!		Average Score: 13.51
Episode 534	Average Score: 13.53	
Environment solved in 534 episodes!		Average Score: 13.53
Episode 536	Average Score: 13.55	
Environment solved in 536 episodes!		Average Score: 13.55
Episode 537	Average Score: 13.57	
Environment solved in 537 episodes!		Average Score: 13.57
Episode 538	Average Score: 13.61	
Environment solved in 538 episodes!		Average Score: 13.61
Episode 539	Average Score: 13.63	
Environment solved in 539 episodes!		Average Score: 13.63
Episode 542	Average Score: 13.67	
Environment solved in 542 episodes!		Average Score: 13.67
Episode 545	Average Score: 13.71	
Environment solved in 545 episodes!		Average Score: 13.71
Episode 546	Average Score: 13.75	
Environment solved in 546 episodes!		Average Score: 13.75
Episode 548	Average Score: 13.82	
Environment solved in 548 episodes!		Average Score: 13.82
Episode 552	Average Score: 13.86	
Environment solved in 552 episodes!		Average Score: 13.86
Episode 554	Average Score: 13.87	
Environment solved in 554 episodes!		Average Score: 13.87
Episode 556	Average Score: 13.99	
Environment solved in 556 episodes!		Average Score: 13.99
Episode 557	Average Score: 14.00	
Environment solved in 557 episodes!		Average Score: 14.00
Episode 574	Average Score: 14.04	
Environment solved in 574 episodes!		Average Score: 14.04
Episode 578	Average Score: 14.15	
Environment solved in 578 episodes!		Average Score: 14.15
Episode 579	Average Score: 14.18	
Environment solved in 579 episodes!		Average Score: 14.18
Episode 580	Average Score: 14.19	
Environment solved in 580 episodes!		Average Score: 14.19
Episode 581	Average Score: 14.28	
Environment solved in 581 episodes!		Average Score: 14.28

Episode 582	Average Score: 14.32	
Environment solved in 582 episodes!		Average Score: 14.32
Episode 583	Average Score: 14.35	
Environment solved in 583 episodes!		Average Score: 14.35
Episode 584	Average Score: 14.37	
Environment solved in 584 episodes!		Average Score: 14.37
Episode 585	Average Score: 14.42	
Environment solved in 585 episodes!		Average Score: 14.42
Episode 587	Average Score: 14.50	
Environment solved in 587 episodes!		Average Score: 14.50
Episode 588	Average Score: 14.53	
Environment solved in 588 episodes!		Average Score: 14.53
Episode 590	Average Score: 14.54	
Environment solved in 590 episodes!		Average Score: 14.54
Episode 592	Average Score: 14.57	
Environment solved in 592 episodes!		Average Score: 14.57
Episode 593	Average Score: 14.58	
Environment solved in 593 episodes!		Average Score: 14.58
Episode 595	Average Score: 14.61	
Environment solved in 595 episodes!		Average Score: 14.61
Episode 599	Average Score: 14.62	
Environment solved in 599 episodes!		Average Score: 14.62
Episode 600	Average Score: 14.56	
Episode 603	Average Score: 14.67	
Environment solved in 603 episodes!		Average Score: 14.67
Episode 608	Average Score: 14.69	
Environment solved in 608 episodes!		Average Score: 14.69
Episode 609	Average Score: 14.80	
Environment solved in 609 episodes!		Average Score: 14.80
Episode 610	Average Score: 14.91	
Environment solved in 610 episodes!		Average Score: 14.91
Episode 611	Average Score: 14.96	
Environment solved in 611 episodes!		Average Score: 14.96
Episode 612	Average Score: 15.01	
Environment solved in 612 episodes!		Average Score: 15.01
Episode 614	Average Score: 15.04	
Environment solved in 614 episodes!		Average Score: 15.04
Episode 620	Average Score: 15.08	
Environment solved in 620 episodes!		Average Score: 15.08
Episode 700	Average Score: 14.88	
Episode 724	Average Score: 15.11	
Environment solved in 724 episodes!		Average Score: 15.11
Episode 758	Average Score: 15.13	
Environment solved in 758 episodes!		Average Score: 15.13
Episode 759	Average Score: 15.16	
Environment solved in 759 episodes!		Average Score: 15.16
Episode 764	Average Score: 15.18	
Environment solved in 764 episodes!		Average Score: 15.18

Episode 766	Average Score: 15.22	
Environment solved in 766 episodes!		Average Score: 15.22
Episode 767	Average Score: 15.24	
Environment solved in 767 episodes!		Average Score: 15.24
Episode 768	Average Score: 15.26	
Environment solved in 768 episodes!		Average Score: 15.26
Episode 774	Average Score: 15.27	
Environment solved in 774 episodes!		Average Score: 15.27
Episode 775	Average Score: 15.32	
Environment solved in 775 episodes!		Average Score: 15.32
Episode 780	Average Score: 15.34	
Environment solved in 780 episodes!		Average Score: 15.34
Episode 800	Average Score: 15.31	
Episode 805	Average Score: 15.43	
Environment solved in 805 episodes!		Average Score: 15.43
Episode 809	Average Score: 15.45	
Environment solved in 809 episodes!		Average Score: 15.45
Episode 817	Average Score: 15.50	
Environment solved in 817 episodes!		Average Score: 15.50
Episode 818	Average Score: 15.52	
Environment solved in 818 episodes!		Average Score: 15.52
Episode 825	Average Score: 15.53	
Environment solved in 825 episodes!		Average Score: 15.53
Episode 826	Average Score: 15.56	
Environment solved in 826 episodes!		Average Score: 15.56
Episode 827	Average Score: 15.58	
Environment solved in 827 episodes!		Average Score: 15.58
Episode 828	Average Score: 15.64	
Environment solved in 828 episodes!		Average Score: 15.64
Episode 829	Average Score: 15.69	
Environment solved in 829 episodes!		Average Score: 15.69
Episode 832	Average Score: 15.74	
Environment solved in 832 episodes!		Average Score: 15.74
Episode 833	Average Score: 15.84	
Environment solved in 833 episodes!		Average Score: 15.84
Episode 836	Average Score: 15.85	
Environment solved in 836 episodes!		Average Score: 15.85
Episode 837	Average Score: 15.87	
Environment solved in 837 episodes!		Average Score: 15.87
Episode 838	Average Score: 15.91	
Environment solved in 838 episodes!		Average Score: 15.91
Episode 839	Average Score: 15.92	
Environment solved in 839 episodes!		Average Score: 15.92
Episode 840	Average Score: 15.93	
Environment solved in 840 episodes!		Average Score: 15.93
Episode 859	Average Score: 15.95	
Environment solved in 859 episodes!		Average Score: 15.95
Episode 864	Average Score: 15.98	

Environment solved in 864 episodes!	Average Score: 15.98
Episode 900	Average Score: 15.72
Episode 1000	Average Score: 15.44
Episode 1036	Average Score: 16.00
Environment solved in 1036 episodes!	Average Score: 16.00
Episode 1038	Average Score: 16.04
Environment solved in 1038 episodes!	Average Score: 16.04
Episode 1100	Average Score: 15.39
Episode 1200	Average Score: 14.99
Episode 1300	Average Score: 15.29
Episode 1400	Average Score: 15.71
Episode 1500	Average Score: 15.74
Episode 1519	Average Score: 16.05
Environment solved in 1519 episodes!	Average Score: 16.05
Episode 1525	Average Score: 16.10
Environment solved in 1525 episodes!	Average Score: 16.10
Episode 1575	Average Score: 16.14
Environment solved in 1575 episodes!	Average Score: 16.14
Episode 1577	Average Score: 16.17
Environment solved in 1577 episodes!	Average Score: 16.17
Episode 1600	Average Score: 15.73
Episode 1700	Average Score: 15.42
Episode 1800	Average Score: 15.59
Episode 1900	Average Score: 15.88
Episode 1914	Average Score: 16.20
Environment solved in 1914 episodes!	Average Score: 16.20
Episode 1915	Average Score: 16.22
Environment solved in 1915 episodes!	Average Score: 16.22
Episode 1923	Average Score: 16.25
Environment solved in 1923 episodes!	Average Score: 16.25
Episode 1927	Average Score: 16.41
Environment solved in 1927 episodes!	Average Score: 16.41
Episode 1933	Average Score: 16.45
Environment solved in 1933 episodes!	Average Score: 16.45
Episode 1935	Average Score: 16.48
Environment solved in 1935 episodes!	Average Score: 16.48
Episode 1938	Average Score: 16.51
Environment solved in 1938 episodes!	Average Score: 16.51
Episode 2000	Average Score: 15.84



Time Taken: 1651.8256685069937

5.b Run using Buffer Size of 200,000

```
[8]: wrapped = testWrapper(runQNetworkTest, 'checkpoint-200000.pth', int(2e5),
    ↪ BATCH_SIZE, GAMMA, LR, UPDATE_EVERY, TAU, { 'fc1': 64, 'fc2': 64 })
    print(f'Time Taken: {timeit.timeit(wrapped, number=1)}')
```

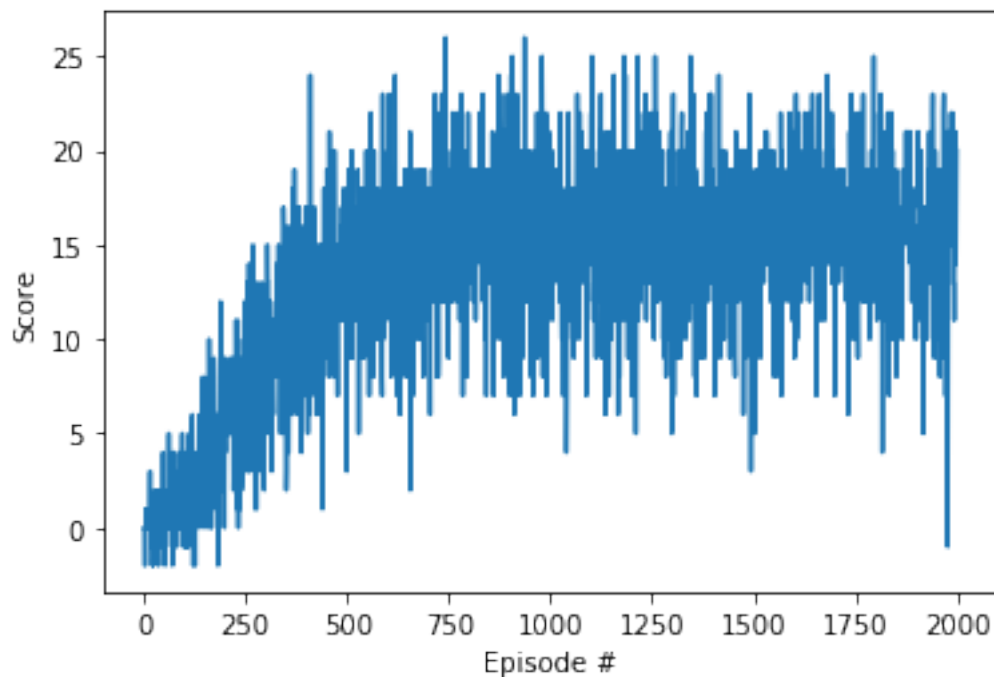
Episode 100	Average Score: 0.69	
Episode 200	Average Score: 3.45	
Episode 300	Average Score: 6.95	
Episode 400	Average Score: 10.54	
Episode 500	Average Score: 12.34	
Episode 538	Average Score: 13.01	
Environment solved in 538 episodes!		Average Score: 13.01
Episode 539	Average Score: 13.02	
Environment solved in 539 episodes!		Average Score: 13.02
Episode 540	Average Score: 13.16	
Environment solved in 540 episodes!		Average Score: 13.16
Episode 542	Average Score: 13.17	
Environment solved in 542 episodes!		Average Score: 13.17
Episode 546	Average Score: 13.24	
Environment solved in 546 episodes!		Average Score: 13.24
Episode 547	Average Score: 13.30	
Environment solved in 547 episodes!		Average Score: 13.30
Episode 548	Average Score: 13.40	

Environment solved in 548 episodes!	Average Score: 13.40
Episode 549 Average Score: 13.44	
Environment solved in 549 episodes!	Average Score: 13.44
Episode 550 Average Score: 13.50	
Environment solved in 550 episodes!	Average Score: 13.50
Episode 559 Average Score: 13.51	
Environment solved in 559 episodes!	Average Score: 13.51
Episode 560 Average Score: 13.53	
Environment solved in 560 episodes!	Average Score: 13.53
Episode 561 Average Score: 13.56	
Environment solved in 561 episodes!	Average Score: 13.56
Episode 562 Average Score: 13.60	
Environment solved in 562 episodes!	Average Score: 13.60
Episode 563 Average Score: 13.64	
Environment solved in 563 episodes!	Average Score: 13.64
Episode 567 Average Score: 13.69	
Environment solved in 567 episodes!	Average Score: 13.69
Episode 568 Average Score: 13.74	
Environment solved in 568 episodes!	Average Score: 13.74
Episode 577 Average Score: 13.76	
Environment solved in 577 episodes!	Average Score: 13.76
Episode 578 Average Score: 13.78	
Environment solved in 578 episodes!	Average Score: 13.78
Episode 579 Average Score: 13.81	
Environment solved in 579 episodes!	Average Score: 13.81
Episode 582 Average Score: 13.84	
Environment solved in 582 episodes!	Average Score: 13.84
Episode 584 Average Score: 13.88	
Environment solved in 584 episodes!	Average Score: 13.88
Episode 599 Average Score: 13.94	
Environment solved in 599 episodes!	Average Score: 13.94
Episode 600 Average Score: 14.10	
Environment solved in 600 episodes!	Average Score: 14.10
Episode 601 Average Score: 14.19	
Environment solved in 601 episodes!	Average Score: 14.19
Episode 602 Average Score: 14.21	
Environment solved in 602 episodes!	Average Score: 14.21
Episode 605 Average Score: 14.22	
Environment solved in 605 episodes!	Average Score: 14.22
Episode 606 Average Score: 14.24	
Environment solved in 606 episodes!	Average Score: 14.24
Episode 607 Average Score: 14.28	
Environment solved in 607 episodes!	Average Score: 14.28
Episode 608 Average Score: 14.34	
Environment solved in 608 episodes!	Average Score: 14.34
Episode 611 Average Score: 14.37	
Environment solved in 611 episodes!	Average Score: 14.37

Episode 613	Average Score: 14.43	
Environment solved in 613 episodes!		Average Score: 14.43
Episode 619	Average Score: 14.49	
Environment solved in 619 episodes!		Average Score: 14.49
Episode 620	Average Score: 14.50	
Environment solved in 620 episodes!		Average Score: 14.50
Episode 629	Average Score: 14.54	
Environment solved in 629 episodes!		Average Score: 14.54
Episode 630	Average Score: 14.58	
Environment solved in 630 episodes!		Average Score: 14.58
Episode 700	Average Score: 14.32	
Episode 737	Average Score: 14.60	
Environment solved in 737 episodes!		Average Score: 14.60
Episode 739	Average Score: 14.68	
Environment solved in 739 episodes!		Average Score: 14.68
Episode 740	Average Score: 14.70	
Environment solved in 740 episodes!		Average Score: 14.70
Episode 741	Average Score: 14.78	
Environment solved in 741 episodes!		Average Score: 14.78
Episode 743	Average Score: 14.86	
Environment solved in 743 episodes!		Average Score: 14.86
Episode 744	Average Score: 14.91	
Environment solved in 744 episodes!		Average Score: 14.91
Episode 745	Average Score: 14.97	
Environment solved in 745 episodes!		Average Score: 14.97
Episode 746	Average Score: 15.07	
Environment solved in 746 episodes!		Average Score: 15.07
Episode 747	Average Score: 15.08	
Environment solved in 747 episodes!		Average Score: 15.08
Episode 748	Average Score: 15.11	
Environment solved in 748 episodes!		Average Score: 15.11
Episode 749	Average Score: 15.18	
Environment solved in 749 episodes!		Average Score: 15.18
Episode 756	Average Score: 15.22	
Environment solved in 756 episodes!		Average Score: 15.22
Episode 757	Average Score: 15.32	
Environment solved in 757 episodes!		Average Score: 15.32
Episode 758	Average Score: 15.33	
Environment solved in 758 episodes!		Average Score: 15.33
Episode 760	Average Score: 15.42	
Environment solved in 760 episodes!		Average Score: 15.42
Episode 762	Average Score: 15.47	
Environment solved in 762 episodes!		Average Score: 15.47
Episode 763	Average Score: 15.49	
Environment solved in 763 episodes!		Average Score: 15.49
Episode 764	Average Score: 15.52	
Environment solved in 764 episodes!		Average Score: 15.52
Episode 765	Average Score: 15.57	

Environment solved in 765 episodes!	Average Score: 15.57
Episode 766 Average Score: 15.65	
Environment solved in 766 episodes!	Average Score: 15.65
Episode 767 Average Score: 15.71	
Environment solved in 767 episodes!	Average Score: 15.71
Episode 768 Average Score: 15.76	
Environment solved in 768 episodes!	Average Score: 15.76
Episode 771 Average Score: 15.78	
Environment solved in 771 episodes!	Average Score: 15.78
Episode 774 Average Score: 15.79	
Environment solved in 774 episodes!	Average Score: 15.79
Episode 775 Average Score: 15.85	
Environment solved in 775 episodes!	Average Score: 15.85
Episode 776 Average Score: 15.90	
Environment solved in 776 episodes!	Average Score: 15.90
Episode 777 Average Score: 15.94	
Environment solved in 777 episodes!	Average Score: 15.94
Episode 781 Average Score: 15.99	
Environment solved in 781 episodes!	Average Score: 15.99
Episode 782 Average Score: 16.03	
Environment solved in 782 episodes!	Average Score: 16.03
Episode 788 Average Score: 16.09	
Environment solved in 788 episodes!	Average Score: 16.09
Episode 791 Average Score: 16.15	
Environment solved in 791 episodes!	Average Score: 16.15
Episode 800 Average Score: 16.21	
Environment solved in 800 episodes!	Average Score: 16.21
Episode 801 Average Score: 16.22	
Environment solved in 801 episodes!	Average Score: 16.22
Episode 802 Average Score: 16.26	
Environment solved in 802 episodes!	Average Score: 16.26
Episode 804 Average Score: 16.27	
Environment solved in 804 episodes!	Average Score: 16.27
Episode 805 Average Score: 16.40	
Environment solved in 805 episodes!	Average Score: 16.40
Episode 806 Average Score: 16.46	
Environment solved in 806 episodes!	Average Score: 16.46
Episode 808 Average Score: 16.47	
Environment solved in 808 episodes!	Average Score: 16.47
Episode 809 Average Score: 16.50	
Environment solved in 809 episodes!	Average Score: 16.50
Episode 810 Average Score: 16.53	
Environment solved in 810 episodes!	Average Score: 16.53
Episode 824 Average Score: 16.55	
Environment solved in 824 episodes!	Average Score: 16.55
Episode 825 Average Score: 16.64	
Environment solved in 825 episodes!	Average Score: 16.64

Episode 826	Average Score: 16.70	
Environment solved in 826 episodes!		Average Score: 16.70
Episode 827	Average Score: 16.73	
Environment solved in 827 episodes!		Average Score: 16.73
Episode 900	Average Score: 16.27	
Episode 1000	Average Score: 15.79	
Episode 1100	Average Score: 15.53	
Episode 1200	Average Score: 15.79	
Episode 1300	Average Score: 15.80	
Episode 1400	Average Score: 16.02	
Episode 1500	Average Score: 15.42	
Episode 1600	Average Score: 15.75	
Episode 1683	Average Score: 16.74	
Environment solved in 1683 episodes!		Average Score: 16.74
Episode 1692	Average Score: 16.81	
Environment solved in 1692 episodes!		Average Score: 16.81
Episode 1696	Average Score: 16.84	
Environment solved in 1696 episodes!		Average Score: 16.84
Episode 1700	Average Score: 16.63	
Episode 1800	Average Score: 16.04	
Episode 1900	Average Score: 15.89	
Episode 2000	Average Score: 15.72	



Time Taken: 1728.554216582008

5.c Run using Buffer Size of 250,000

```
[9]: wrapped = testWrapper(runQNetworkTest, 'checkpoint-250000.pth', int(2.5e5),  
    ↪ BATCH_SIZE, GAMMA, LR, UPDATE_EVERY, TAU, { 'fc1': 64, 'fc2': 64 })  
    print(f'Time Taken: {timeit.timeit(wrapped, number=1)}')
```

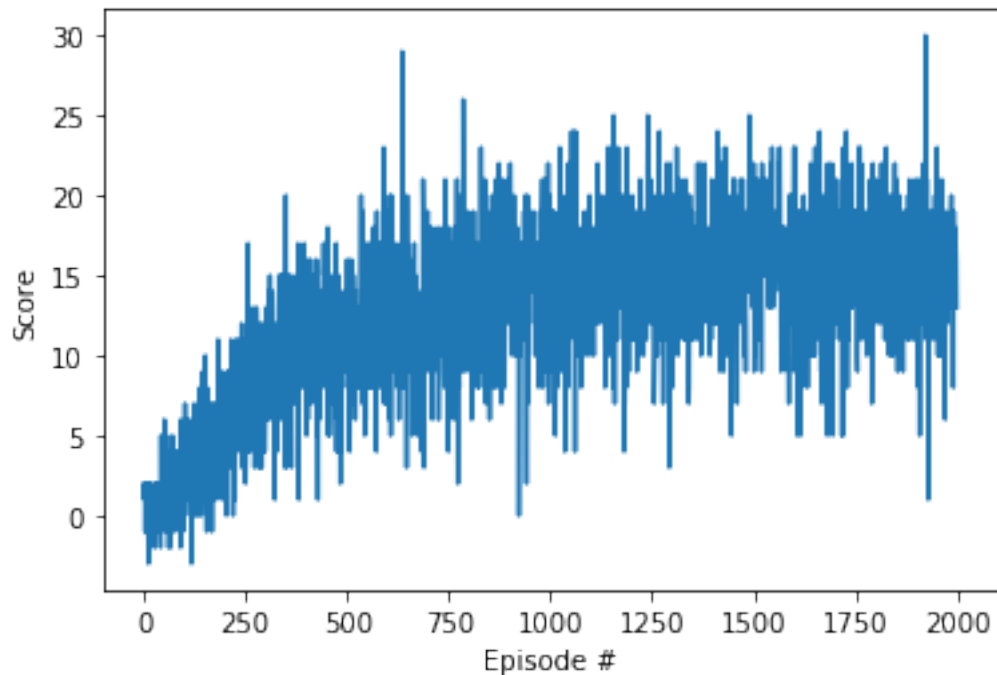
Episode 100	Average Score: 0.97	
Episode 200	Average Score: 4.04	
Episode 300	Average Score: 7.39	
Episode 400	Average Score: 10.55	
Episode 500	Average Score: 10.72	
Episode 600	Average Score: 11.75	
Episode 700	Average Score: 12.65	
Episode 780	Average Score: 13.01	
Environment solved in 780 episodes!	Average Score: 13.01	
Episode 781	Average Score: 13.09	
Environment solved in 781 episodes!	Average Score: 13.09	
Episode 782	Average Score: 13.19	
Environment solved in 782 episodes!	Average Score: 13.19	
Episode 783	Average Score: 13.20	
Environment solved in 783 episodes!	Average Score: 13.20	
Episode 784	Average Score: 13.26	
Environment solved in 784 episodes!	Average Score: 13.26	
Episode 786	Average Score: 13.43	
Environment solved in 786 episodes!	Average Score: 13.43	
Episode 790	Average Score: 13.55	
Environment solved in 790 episodes!	Average Score: 13.55	
Episode 800	Average Score: 13.40	
Episode 830	Average Score: 13.59	
Environment solved in 830 episodes!	Average Score: 13.59	
Episode 831	Average Score: 13.65	
Environment solved in 831 episodes!	Average Score: 13.65	
Episode 835	Average Score: 13.67	
Environment solved in 835 episodes!	Average Score: 13.67	
Episode 837	Average Score: 13.68	
Environment solved in 837 episodes!	Average Score: 13.68	
Episode 838	Average Score: 13.74	
Environment solved in 838 episodes!	Average Score: 13.74	
Episode 839	Average Score: 13.86	
Environment solved in 839 episodes!	Average Score: 13.86	
Episode 840	Average Score: 13.90	
Environment solved in 840 episodes!	Average Score: 13.90	
Episode 841	Average Score: 13.91	
Environment solved in 841 episodes!	Average Score: 13.91	
Episode 877	Average Score: 13.97	
Environment solved in 877 episodes!	Average Score: 13.97	
Episode 878	Average Score: 14.06	
Environment solved in 878 episodes!	Average Score: 14.06	

Episode 879	Average Score: 14.14	
Environment solved in 879 episodes!		Average Score: 14.14
Episode 900	Average Score: 14.01	
Episode 907	Average Score: 14.16	
Environment solved in 907 episodes!		Average Score: 14.16
Episode 908	Average Score: 14.19	
Environment solved in 908 episodes!		Average Score: 14.19
Episode 910	Average Score: 14.20	
Environment solved in 910 episodes!		Average Score: 14.20
Episode 911	Average Score: 14.27	
Environment solved in 911 episodes!		Average Score: 14.27
Episode 919	Average Score: 14.31	
Environment solved in 919 episodes!		Average Score: 14.31
Episode 920	Average Score: 14.32	
Environment solved in 920 episodes!		Average Score: 14.32
Episode 921	Average Score: 14.35	
Environment solved in 921 episodes!		Average Score: 14.35
Episode 960	Average Score: 14.36	
Environment solved in 960 episodes!		Average Score: 14.36
Episode 961	Average Score: 14.37	
Environment solved in 961 episodes!		Average Score: 14.37
Episode 962	Average Score: 14.46	
Environment solved in 962 episodes!		Average Score: 14.46
Episode 981	Average Score: 14.54	
Environment solved in 981 episodes!		Average Score: 14.54
Episode 984	Average Score: 14.61	
Environment solved in 984 episodes!		Average Score: 14.61
Episode 988	Average Score: 14.74	
Environment solved in 988 episodes!		Average Score: 14.74
Episode 989	Average Score: 14.79	
Environment solved in 989 episodes!		Average Score: 14.79
Episode 994	Average Score: 14.81	
Environment solved in 994 episodes!		Average Score: 14.81
Episode 995	Average Score: 14.85	
Environment solved in 995 episodes!		Average Score: 14.85
Episode 1000	Average Score: 14.82	
Episode 1024	Average Score: 14.96	
Environment solved in 1024 episodes!		Average Score: 14.96
Episode 1025	Average Score: 15.00	
Environment solved in 1025 episodes!		Average Score: 15.00
Episode 1027	Average Score: 15.01	
Environment solved in 1027 episodes!		Average Score: 15.01
Episode 1028	Average Score: 15.04	
Environment solved in 1028 episodes!		Average Score: 15.04
Episode 1029	Average Score: 15.05	
Environment solved in 1029 episodes!		Average Score: 15.05
Episode 1033	Average Score: 15.07	
Environment solved in 1033 episodes!		Average Score: 15.07

Episode 1034	Average Score: 15.08	
Environment solved in 1034 episodes!		Average Score: 15.08
Episode 1035	Average Score: 15.10	
Environment solved in 1035 episodes!		Average Score: 15.10
Episode 1045	Average Score: 15.14	
Environment solved in 1045 episodes!		Average Score: 15.14
Episode 1053	Average Score: 15.17	
Environment solved in 1053 episodes!		Average Score: 15.17
Episode 1056	Average Score: 15.18	
Environment solved in 1056 episodes!		Average Score: 15.18
Episode 1057	Average Score: 15.21	
Environment solved in 1057 episodes!		Average Score: 15.21
Episode 1058	Average Score: 15.26	
Environment solved in 1058 episodes!		Average Score: 15.26
Episode 1059	Average Score: 15.31	
Environment solved in 1059 episodes!		Average Score: 15.31
Episode 1063	Average Score: 15.32	
Environment solved in 1063 episodes!		Average Score: 15.32
Episode 1064	Average Score: 15.34	
Environment solved in 1064 episodes!		Average Score: 15.34
Episode 1065	Average Score: 15.38	
Environment solved in 1065 episodes!		Average Score: 15.38
Episode 1066	Average Score: 15.40	
Environment solved in 1066 episodes!		Average Score: 15.40
Episode 1067	Average Score: 15.43	
Environment solved in 1067 episodes!		Average Score: 15.43
Episode 1100	Average Score: 14.84	
Episode 1179	Average Score: 15.50	
Environment solved in 1179 episodes!		Average Score: 15.50
Episode 1191	Average Score: 15.51	
Environment solved in 1191 episodes!		Average Score: 15.51
Episode 1192	Average Score: 15.54	
Environment solved in 1192 episodes!		Average Score: 15.54
Episode 1194	Average Score: 15.55	
Environment solved in 1194 episodes!		Average Score: 15.55
Episode 1196	Average Score: 15.61	
Environment solved in 1196 episodes!		Average Score: 15.61
Episode 1200	Average Score: 15.51	
Episode 1202	Average Score: 15.65	
Environment solved in 1202 episodes!		Average Score: 15.65
Episode 1204	Average Score: 15.68	
Environment solved in 1204 episodes!		Average Score: 15.68
Episode 1206	Average Score: 15.69	
Environment solved in 1206 episodes!		Average Score: 15.69
Episode 1207	Average Score: 15.70	
Environment solved in 1207 episodes!		Average Score: 15.70
Episode 1210	Average Score: 15.73	
Environment solved in 1210 episodes!		Average Score: 15.73

Episode 1212	Average Score: 15.76	
Environment solved in 1212 episodes!		Average Score: 15.76
Episode 1255	Average Score: 15.79	
Environment solved in 1255 episodes!		Average Score: 15.79
Episode 1300	Average Score: 15.52	
Episode 1400	Average Score: 15.51	
Episode 1424	Average Score: 15.80	
Environment solved in 1424 episodes!		Average Score: 15.80
Episode 1426	Average Score: 15.84	
Environment solved in 1426 episodes!		Average Score: 15.84
Episode 1428	Average Score: 15.86	
Environment solved in 1428 episodes!		Average Score: 15.86
Episode 1431	Average Score: 15.91	
Environment solved in 1431 episodes!		Average Score: 15.91
Episode 1432	Average Score: 15.98	
Environment solved in 1432 episodes!		Average Score: 15.98
Episode 1469	Average Score: 16.01	
Environment solved in 1469 episodes!		Average Score: 16.01
Episode 1471	Average Score: 16.03	
Environment solved in 1471 episodes!		Average Score: 16.03
Episode 1472	Average Score: 16.04	
Environment solved in 1472 episodes!		Average Score: 16.04
Episode 1476	Average Score: 16.06	
Environment solved in 1476 episodes!		Average Score: 16.06
Episode 1477	Average Score: 16.07	
Environment solved in 1477 episodes!		Average Score: 16.07
Episode 1493	Average Score: 16.09	
Environment solved in 1493 episodes!		Average Score: 16.09
Episode 1494	Average Score: 16.11	
Environment solved in 1494 episodes!		Average Score: 16.11
Episode 1495	Average Score: 16.14	
Environment solved in 1495 episodes!		Average Score: 16.14
Episode 1496	Average Score: 16.19	
Environment solved in 1496 episodes!		Average Score: 16.19
Episode 1500	Average Score: 16.13	
Episode 1508	Average Score: 16.21	
Environment solved in 1508 episodes!		Average Score: 16.21
Episode 1530	Average Score: 16.23	
Environment solved in 1530 episodes!		Average Score: 16.23
Episode 1535	Average Score: 16.24	
Environment solved in 1535 episodes!		Average Score: 16.24
Episode 1536	Average Score: 16.30	
Environment solved in 1536 episodes!		Average Score: 16.30
Episode 1537	Average Score: 16.31	
Environment solved in 1537 episodes!		Average Score: 16.31
Episode 1538	Average Score: 16.34	
Environment solved in 1538 episodes!		Average Score: 16.34
Episode 1539	Average Score: 16.43	

Environment solved in 1539 episodes!	Average Score: 16.43
Episode 1543	Average Score: 16.49
Environment solved in 1543 episodes!	Average Score: 16.49
Episode 1544	Average Score: 16.51
Environment solved in 1544 episodes!	Average Score: 16.51
Episode 1546	Average Score: 16.67
Environment solved in 1546 episodes!	Average Score: 16.67
Episode 1547	Average Score: 16.77
Environment solved in 1547 episodes!	Average Score: 16.77
Episode 1561	Average Score: 16.82
Environment solved in 1561 episodes!	Average Score: 16.82
Episode 1562	Average Score: 16.88
Environment solved in 1562 episodes!	Average Score: 16.88
Episode 1563	Average Score: 16.91
Environment solved in 1563 episodes!	Average Score: 16.91
Episode 1565	Average Score: 16.92
Environment solved in 1565 episodes!	Average Score: 16.92
Episode 1566	Average Score: 16.96
Environment solved in 1566 episodes!	Average Score: 16.96
Episode 1600	Average Score: 16.53
Episode 1700	Average Score: 15.24
Episode 1800	Average Score: 16.14
Episode 1900	Average Score: 15.94
Episode 2000	Average Score: 15.33



Time Taken: 1790.1120206429914

5.d Run using Buffer Size of 100,000 and Batch Size 32

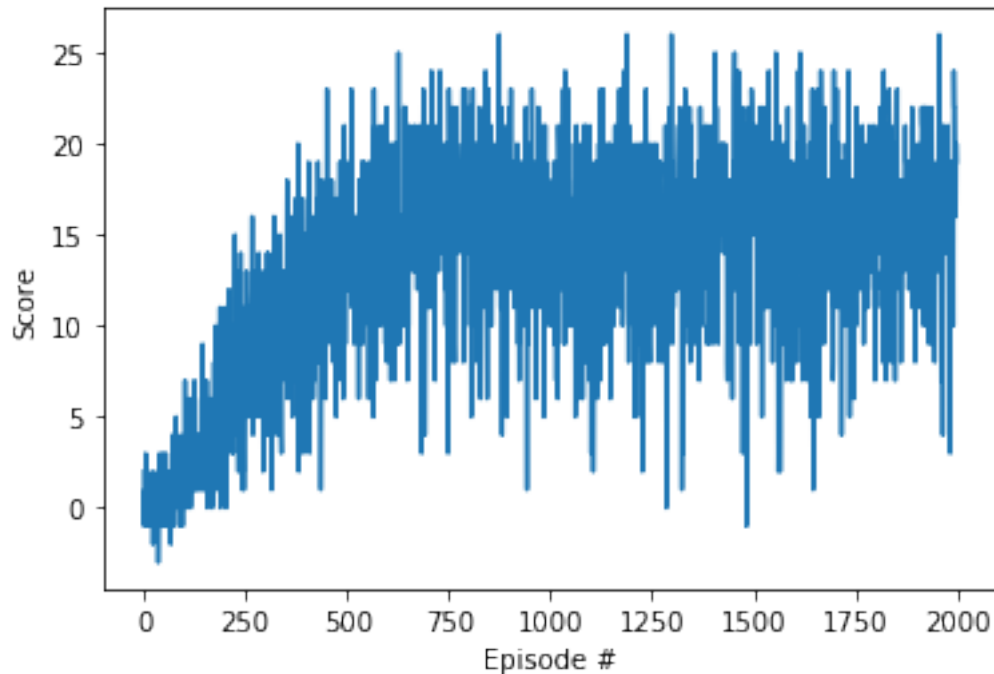
```
[10]: wrapped = testWrapper(runQNetworkTest, 'checkpoint-100000x32.pth', int(1e5),  
    ↪32, GAMMA, LR, UPDATE_EVERY, TAU, { 'fc1': 64, 'fc2': 64 })  
    print(f'Time Taken: {timeit.timeit(wrapped, number=1)}')
```

Episode 100	Average Score: 0.61	
Episode 200	Average Score: 3.78	
Episode 300	Average Score: 8.00	
Episode 400	Average Score: 10.56	
Episode 500	Average Score: 12.57	
Episode 520	Average Score: 13.02	
Environment solved in 520 episodes!		Average Score: 13.02
Episode 521	Average Score: 13.06	
Environment solved in 521 episodes!		Average Score: 13.06
Episode 522	Average Score: 13.08	
Environment solved in 522 episodes!		Average Score: 13.08
Episode 523	Average Score: 13.14	
Environment solved in 523 episodes!		Average Score: 13.14
Episode 524	Average Score: 13.17	
Environment solved in 524 episodes!		Average Score: 13.17
Episode 525	Average Score: 13.19	
Environment solved in 525 episodes!		Average Score: 13.19
Episode 536	Average Score: 13.29	
Environment solved in 536 episodes!		Average Score: 13.29
Episode 537	Average Score: 13.40	
Environment solved in 537 episodes!		Average Score: 13.40
Episode 538	Average Score: 13.43	
Environment solved in 538 episodes!		Average Score: 13.43
Episode 547	Average Score: 13.50	
Environment solved in 547 episodes!		Average Score: 13.50
Episode 548	Average Score: 13.57	
Environment solved in 548 episodes!		Average Score: 13.57
Episode 553	Average Score: 13.59	
Environment solved in 553 episodes!		Average Score: 13.59
Episode 561	Average Score: 13.63	
Environment solved in 561 episodes!		Average Score: 13.63
Episode 562	Average Score: 13.65	
Environment solved in 562 episodes!		Average Score: 13.65
Episode 567	Average Score: 13.72	
Environment solved in 567 episodes!		Average Score: 13.72
Episode 568	Average Score: 13.78	
Environment solved in 568 episodes!		Average Score: 13.78
Episode 569	Average Score: 13.85	
Environment solved in 569 episodes!		Average Score: 13.85
Episode 571	Average Score: 13.87	

Environment solved in 571 episodes!	Average Score: 13.87
Episode 572 Average Score: 13.93	
Environment solved in 572 episodes!	Average Score: 13.93
Episode 574 Average Score: 14.00	
Environment solved in 574 episodes!	Average Score: 14.00
Episode 575 Average Score: 14.05	
Environment solved in 575 episodes!	Average Score: 14.05
Episode 578 Average Score: 14.08	
Environment solved in 578 episodes!	Average Score: 14.08
Episode 581 Average Score: 14.16	
Environment solved in 581 episodes!	Average Score: 14.16
Episode 585 Average Score: 14.17	
Environment solved in 585 episodes!	Average Score: 14.17
Episode 586 Average Score: 14.24	
Environment solved in 586 episodes!	Average Score: 14.24
Episode 587 Average Score: 14.29	
Environment solved in 587 episodes!	Average Score: 14.29
Episode 590 Average Score: 14.36	
Environment solved in 590 episodes!	Average Score: 14.36
Episode 591 Average Score: 14.46	
Environment solved in 591 episodes!	Average Score: 14.46
Episode 592 Average Score: 14.49	
Environment solved in 592 episodes!	Average Score: 14.49
Episode 598 Average Score: 14.50	
Environment solved in 598 episodes!	Average Score: 14.50
Episode 600 Average Score: 14.46	
Episode 603 Average Score: 14.52	
Environment solved in 603 episodes!	Average Score: 14.52
Episode 619 Average Score: 14.55	
Environment solved in 619 episodes!	Average Score: 14.55
Episode 627 Average Score: 14.60	
Environment solved in 627 episodes!	Average Score: 14.60
Episode 628 Average Score: 14.63	
Environment solved in 628 episodes!	Average Score: 14.63
Episode 629 Average Score: 14.66	
Environment solved in 629 episodes!	Average Score: 14.66
Episode 658 Average Score: 14.68	
Environment solved in 658 episodes!	Average Score: 14.68
Episode 660 Average Score: 14.70	
Environment solved in 660 episodes!	Average Score: 14.70
Episode 661 Average Score: 14.74	
Environment solved in 661 episodes!	Average Score: 14.74
Episode 663 Average Score: 14.76	
Environment solved in 663 episodes!	Average Score: 14.76
Episode 664 Average Score: 14.78	
Environment solved in 664 episodes!	Average Score: 14.78
Episode 665 Average Score: 14.91	
Environment solved in 665 episodes!	Average Score: 14.91

Episode 666	Average Score: 15.02	
Environment solved in 666 episodes!		Average Score: 15.02
Episode 679	Average Score: 15.06	
Environment solved in 679 episodes!		Average Score: 15.06
Episode 680	Average Score: 15.07	
Environment solved in 680 episodes!		Average Score: 15.07
Episode 683	Average Score: 15.13	
Environment solved in 683 episodes!		Average Score: 15.13
Episode 700	Average Score: 14.87	
Episode 716	Average Score: 15.15	
Environment solved in 716 episodes!		Average Score: 15.15
Episode 721	Average Score: 15.22	
Environment solved in 721 episodes!		Average Score: 15.22
Episode 722	Average Score: 15.26	
Environment solved in 722 episodes!		Average Score: 15.26
Episode 723	Average Score: 15.34	
Environment solved in 723 episodes!		Average Score: 15.34
Episode 724	Average Score: 15.39	
Environment solved in 724 episodes!		Average Score: 15.39
Episode 729	Average Score: 15.42	
Environment solved in 729 episodes!		Average Score: 15.42
Episode 730	Average Score: 15.44	
Environment solved in 730 episodes!		Average Score: 15.44
Episode 731	Average Score: 15.46	
Environment solved in 731 episodes!		Average Score: 15.46
Episode 732	Average Score: 15.49	
Environment solved in 732 episodes!		Average Score: 15.49
Episode 734	Average Score: 15.52	
Environment solved in 734 episodes!		Average Score: 15.52
Episode 735	Average Score: 15.59	
Environment solved in 735 episodes!		Average Score: 15.59
Episode 736	Average Score: 15.65	
Environment solved in 736 episodes!		Average Score: 15.65
Episode 737	Average Score: 15.72	
Environment solved in 737 episodes!		Average Score: 15.72
Episode 738	Average Score: 15.78	
Environment solved in 738 episodes!		Average Score: 15.78
Episode 740	Average Score: 15.81	
Environment solved in 740 episodes!		Average Score: 15.81
Episode 742	Average Score: 15.88	
Environment solved in 742 episodes!		Average Score: 15.88
Episode 784	Average Score: 15.93	
Environment solved in 784 episodes!		Average Score: 15.93
Episode 785	Average Score: 16.01	
Environment solved in 785 episodes!		Average Score: 16.01
Episode 786	Average Score: 16.17	
Environment solved in 786 episodes!		Average Score: 16.17
Episode 795	Average Score: 16.23	

Environment solved in 795 episodes!	Average Score: 16.23
Episode 798	Average Score: 16.31
Environment solved in 798 episodes!	Average Score: 16.31
Episode 800	Average Score: 16.31
Episode 801	Average Score: 16.37
Environment solved in 801 episodes!	Average Score: 16.37
Episode 802	Average Score: 16.43
Environment solved in 802 episodes!	Average Score: 16.43
Episode 819	Average Score: 16.45
Environment solved in 819 episodes!	Average Score: 16.45
Episode 820	Average Score: 16.47
Environment solved in 820 episodes!	Average Score: 16.47
Episode 867	Average Score: 16.50
Environment solved in 867 episodes!	Average Score: 16.50
Episode 869	Average Score: 16.51
Environment solved in 869 episodes!	Average Score: 16.51
Episode 900	Average Score: 15.95
Episode 1000	Average Score: 15.18
Episode 1100	Average Score: 15.04
Episode 1200	Average Score: 15.17
Episode 1300	Average Score: 15.17
Episode 1400	Average Score: 15.45
Episode 1500	Average Score: 16.19
Episode 1600	Average Score: 15.41
Episode 1700	Average Score: 15.25
Episode 1800	Average Score: 15.31
Episode 1900	Average Score: 15.83
Episode 2000	Average Score: 15.99



Time Taken: 1593.5201363289962

5.e Run using Buffer Size of 200,000 and Batch Size 32

```
[11]: wrapped = testWrapper(runQNetworkTest, 'checkpoint-200000x32.pth', int(2e5), 32, GAMMA, LR, UPDATE_EVERY, TAU, { 'fc1': 64, 'fc2': 64 })
print(f'Time Taken: {timeit.timeit(wrapped, number=1)}')
```

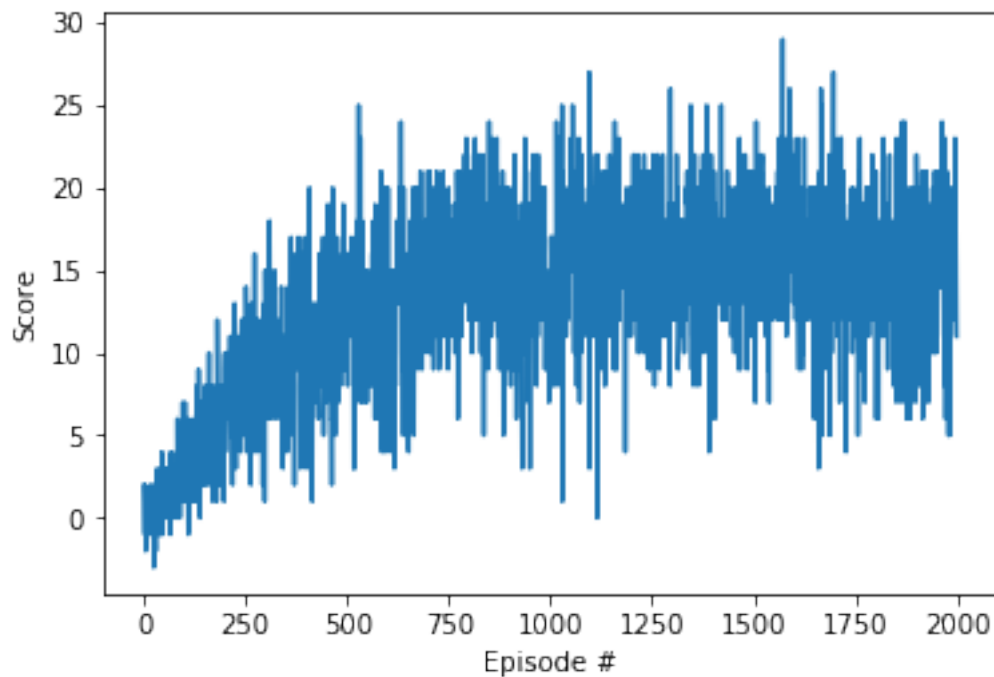
Episode 100	Average Score: 1.02	
Episode 200	Average Score: 4.39	
Episode 300	Average Score: 7.98	
Episode 400	Average Score: 9.943	
Episode 500	Average Score: 11.08	
Episode 600	Average Score: 12.77	
Episode 664	Average Score: 13.05	
Environment solved in 664 episodes!		Average Score: 13.05
Episode 670	Average Score: 13.06	
Environment solved in 670 episodes!		Average Score: 13.06
Episode 671	Average Score: 13.10	
Environment solved in 671 episodes!		Average Score: 13.10
Episode 672	Average Score: 13.12	
Environment solved in 672 episodes!		Average Score: 13.12
Episode 673	Average Score: 13.17	
Environment solved in 673 episodes!		Average Score: 13.17
Episode 675	Average Score: 13.24	
Environment solved in 675 episodes!		Average Score: 13.24

Episode 677	Average Score: 13.28	
Environment solved in 677 episodes!		Average Score: 13.28
Episode 678	Average Score: 13.42	
Environment solved in 678 episodes!		Average Score: 13.42
Episode 693	Average Score: 13.48	
Environment solved in 693 episodes!		Average Score: 13.48
Episode 697	Average Score: 13.52	
Environment solved in 697 episodes!		Average Score: 13.52
Episode 698	Average Score: 13.54	
Environment solved in 698 episodes!		Average Score: 13.54
Episode 699	Average Score: 13.61	
Environment solved in 699 episodes!		Average Score: 13.61
Episode 700	Average Score: 13.61	
Episode 704	Average Score: 13.75	
Environment solved in 704 episodes!		Average Score: 13.75
Episode 705	Average Score: 13.91	
Environment solved in 705 episodes!		Average Score: 13.91
Episode 708	Average Score: 13.93	
Environment solved in 708 episodes!		Average Score: 13.93
Episode 711	Average Score: 13.97	
Environment solved in 711 episodes!		Average Score: 13.97
Episode 712	Average Score: 14.02	
Environment solved in 712 episodes!		Average Score: 14.02
Episode 714	Average Score: 14.07	
Environment solved in 714 episodes!		Average Score: 14.07
Episode 715	Average Score: 14.12	
Environment solved in 715 episodes!		Average Score: 14.12
Episode 716	Average Score: 14.20	
Environment solved in 716 episodes!		Average Score: 14.20
Episode 717	Average Score: 14.32	
Environment solved in 717 episodes!		Average Score: 14.32
Episode 718	Average Score: 14.38	
Environment solved in 718 episodes!		Average Score: 14.38
Episode 719	Average Score: 14.41	
Environment solved in 719 episodes!		Average Score: 14.41
Episode 720	Average Score: 14.44	
Environment solved in 720 episodes!		Average Score: 14.44
Episode 721	Average Score: 14.51	
Environment solved in 721 episodes!		Average Score: 14.51
Episode 722	Average Score: 14.53	
Environment solved in 722 episodes!		Average Score: 14.53
Episode 725	Average Score: 14.55	
Environment solved in 725 episodes!		Average Score: 14.55
Episode 739	Average Score: 14.57	
Environment solved in 739 episodes!		Average Score: 14.57
Episode 741	Average Score: 14.58	
Environment solved in 741 episodes!		Average Score: 14.58
Episode 742	Average Score: 14.63	

Environment solved in 742 episodes!	Average Score: 14.63
Episode 746 Average Score: 14.69	
Environment solved in 746 episodes!	Average Score: 14.69
Episode 747 Average Score: 14.75	
Environment solved in 747 episodes!	Average Score: 14.75
Episode 748 Average Score: 14.83	
Environment solved in 748 episodes!	Average Score: 14.83
Episode 750 Average Score: 14.92	
Environment solved in 750 episodes!	Average Score: 14.92
Episode 751 Average Score: 14.94	
Environment solved in 751 episodes!	Average Score: 14.94
Episode 752 Average Score: 15.08	
Environment solved in 752 episodes!	Average Score: 15.08
Episode 753 Average Score: 15.10	
Environment solved in 753 episodes!	Average Score: 15.10
Episode 754 Average Score: 15.12	
Environment solved in 754 episodes!	Average Score: 15.12
Episode 759 Average Score: 15.13	
Environment solved in 759 episodes!	Average Score: 15.13
Episode 760 Average Score: 15.17	
Environment solved in 760 episodes!	Average Score: 15.17
Episode 761 Average Score: 15.21	
Environment solved in 761 episodes!	Average Score: 15.21
Episode 765 Average Score: 15.28	
Environment solved in 765 episodes!	Average Score: 15.28
Episode 790 Average Score: 15.32	
Environment solved in 790 episodes!	Average Score: 15.32
Episode 792 Average Score: 15.34	
Environment solved in 792 episodes!	Average Score: 15.34
Episode 793 Average Score: 15.36	
Environment solved in 793 episodes!	Average Score: 15.36
Episode 794 Average Score: 15.41	
Environment solved in 794 episodes!	Average Score: 15.41
Episode 795 Average Score: 15.46	
Environment solved in 795 episodes!	Average Score: 15.46
Episode 797 Average Score: 15.52	
Environment solved in 797 episodes!	Average Score: 15.52
Episode 800 Average Score: 15.44	
Episode 802 Average Score: 15.60	
Environment solved in 802 episodes!	Average Score: 15.60
Episode 806 Average Score: 15.67	
Environment solved in 806 episodes!	Average Score: 15.67
Episode 807 Average Score: 15.75	
Environment solved in 807 episodes!	Average Score: 15.75
Episode 811 Average Score: 15.76	
Environment solved in 811 episodes!	Average Score: 15.76
Episode 812 Average Score: 15.81	
Environment solved in 812 episodes!	Average Score: 15.81

Episode 813	Average Score: 15.88	
Environment solved in 813 episodes!		Average Score: 15.88
Episode 820	Average Score: 15.89	
Environment solved in 820 episodes!		Average Score: 15.89
Episode 828	Average Score: 15.92	
Environment solved in 828 episodes!		Average Score: 15.92
Episode 831	Average Score: 15.98	
Environment solved in 831 episodes!		Average Score: 15.98
Episode 834	Average Score: 16.07	
Environment solved in 834 episodes!		Average Score: 16.07
Episode 870	Average Score: 16.12	
Environment solved in 870 episodes!		Average Score: 16.12
Episode 874	Average Score: 16.17	
Environment solved in 874 episodes!		Average Score: 16.17
Episode 875	Average Score: 16.25	
Environment solved in 875 episodes!		Average Score: 16.25
Episode 900	Average Score: 15.91	
Episode 1000	Average Score: 14.54	
Episode 1100	Average Score: 16.16	
Episode 1107	Average Score: 16.27	
Environment solved in 1107 episodes!		Average Score: 16.27
Episode 1111	Average Score: 16.29	
Environment solved in 1111 episodes!		Average Score: 16.29
Episode 1112	Average Score: 16.34	
Environment solved in 1112 episodes!		Average Score: 16.34
Episode 1200	Average Score: 15.84	
Episode 1236	Average Score: 16.36	
Environment solved in 1236 episodes!		Average Score: 16.36
Episode 1253	Average Score: 16.37	
Environment solved in 1253 episodes!		Average Score: 16.37
Episode 1254	Average Score: 16.41	
Environment solved in 1254 episodes!		Average Score: 16.41
Episode 1256	Average Score: 16.42	
Environment solved in 1256 episodes!		Average Score: 16.42
Episode 1264	Average Score: 16.46	
Environment solved in 1264 episodes!		Average Score: 16.46
Episode 1265	Average Score: 16.47	
Environment solved in 1265 episodes!		Average Score: 16.47
Episode 1300	Average Score: 16.18	
Episode 1400	Average Score: 15.31	
Episode 1500	Average Score: 15.96	
Episode 1600	Average Score: 16.43	
Episode 1601	Average Score: 16.48	
Environment solved in 1601 episodes!		Average Score: 16.48
Episode 1604	Average Score: 16.51	
Environment solved in 1604 episodes!		Average Score: 16.51
Episode 1605	Average Score: 16.56	
Environment solved in 1605 episodes!		Average Score: 16.56

Episode 1606	Average Score: 16.62	
Environment solved in 1606 episodes!		Average Score: 16.62
Episode 1608	Average Score: 16.65	
Environment solved in 1608 episodes!		Average Score: 16.65
Episode 1609	Average Score: 16.71	
Environment solved in 1609 episodes!		Average Score: 16.71
Episode 1700	Average Score: 15.88	
Episode 1800	Average Score: 15.85	
Episode 1900	Average Score: 15.02	
Episode 2000	Average Score: 15.49	



Time Taken: 1621.5029886100092

5.f Run using Buffer Size of 250,000 and Batch Size 32

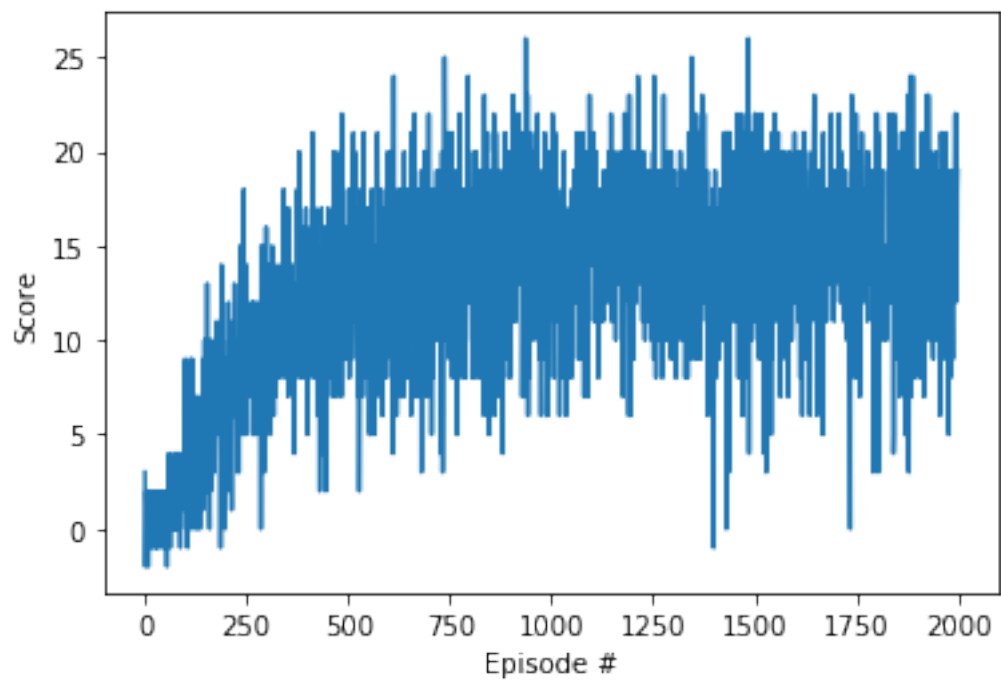
```
[12]: wrapped = testWrapper(runQNetworkTest, 'checkpoint-250000x32.pth', int(2.5e5),
    ↪ 32, GAMMA, LR, UPDATE_EVERY, TAU, { 'fc1': 64, 'fc2': 64 })
    print(f'Time Taken: {timeit.timeit(wrapped, number=1)}')
```

Episode 100	Average Score: 1.08
Episode 200	Average Score: 5.17
Episode 300	Average Score: 8.73
Episode 400	Average Score: 11.28
Episode 500	Average Score: 11.93
Episode 600	Average Score: 12.74
Episode 613	Average Score: 13.02

Environment solved in 613 episodes!	Average Score: 13.02
Episode 654 Average Score: 13.08	
Environment solved in 654 episodes!	Average Score: 13.08
Episode 656 Average Score: 13.12	
Environment solved in 656 episodes!	Average Score: 13.12
Episode 663 Average Score: 13.16	
Environment solved in 663 episodes!	Average Score: 13.16
Episode 664 Average Score: 13.28	
Environment solved in 664 episodes!	Average Score: 13.28
Episode 665 Average Score: 13.38	
Environment solved in 665 episodes!	Average Score: 13.38
Episode 666 Average Score: 13.47	
Environment solved in 666 episodes!	Average Score: 13.47
Episode 667 Average Score: 13.53	
Environment solved in 667 episodes!	Average Score: 13.53
Episode 670 Average Score: 13.63	
Environment solved in 670 episodes!	Average Score: 13.63
Episode 671 Average Score: 13.68	
Environment solved in 671 episodes!	Average Score: 13.68
Episode 685 Average Score: 13.72	
Environment solved in 685 episodes!	Average Score: 13.72
Episode 686 Average Score: 13.74	
Environment solved in 686 episodes!	Average Score: 13.74
Episode 688 Average Score: 13.82	
Environment solved in 688 episodes!	Average Score: 13.82
Episode 689 Average Score: 13.83	
Environment solved in 689 episodes!	Average Score: 13.83
Episode 697 Average Score: 13.84	
Environment solved in 697 episodes!	Average Score: 13.84
Episode 699 Average Score: 13.85	
Environment solved in 699 episodes!	Average Score: 13.85
Episode 700 Average Score: 13.86	
Environment solved in 700 episodes!	Average Score: 13.86
Episode 701 Average Score: 13.92	
Environment solved in 701 episodes!	Average Score: 13.92
Episode 725 Average Score: 13.93	
Environment solved in 725 episodes!	Average Score: 13.93
Episode 726 Average Score: 13.95	
Environment solved in 726 episodes!	Average Score: 13.95
Episode 727 Average Score: 13.98	
Environment solved in 727 episodes!	Average Score: 13.98
Episode 732 Average Score: 14.01	
Environment solved in 732 episodes!	Average Score: 14.01
Episode 739 Average Score: 14.03	
Environment solved in 739 episodes!	Average Score: 14.03
Episode 745 Average Score: 14.07	
Environment solved in 745 episodes!	Average Score: 14.07

Episode 747	Average Score: 14.09	
Environment solved in 747 episodes!		Average Score: 14.09
Episode 748	Average Score: 14.12	
Environment solved in 748 episodes!		Average Score: 14.12
Episode 749	Average Score: 14.24	
Environment solved in 749 episodes!		Average Score: 14.24
Episode 755	Average Score: 14.25	
Environment solved in 755 episodes!		Average Score: 14.25
Episode 800	Average Score: 14.15	
Episode 810	Average Score: 14.29	
Environment solved in 810 episodes!		Average Score: 14.29
Episode 816	Average Score: 14.32	
Environment solved in 816 episodes!		Average Score: 14.32
Episode 817	Average Score: 14.35	
Environment solved in 817 episodes!		Average Score: 14.35
Episode 823	Average Score: 14.38	
Environment solved in 823 episodes!		Average Score: 14.38
Episode 828	Average Score: 14.43	
Environment solved in 828 episodes!		Average Score: 14.43
Episode 833	Average Score: 14.48	
Environment solved in 833 episodes!		Average Score: 14.48
Episode 834	Average Score: 14.57	
Environment solved in 834 episodes!		Average Score: 14.57
Episode 858	Average Score: 14.65	
Environment solved in 858 episodes!		Average Score: 14.65
Episode 859	Average Score: 14.78	
Environment solved in 859 episodes!		Average Score: 14.78
Episode 860	Average Score: 14.83	
Environment solved in 860 episodes!		Average Score: 14.83
Episode 866	Average Score: 14.87	
Environment solved in 866 episodes!		Average Score: 14.87
Episode 869	Average Score: 14.90	
Environment solved in 869 episodes!		Average Score: 14.90
Episode 874	Average Score: 14.95	
Environment solved in 874 episodes!		Average Score: 14.95
Episode 900	Average Score: 14.26	
Episode 983	Average Score: 15.00	
Environment solved in 983 episodes!		Average Score: 15.00
Episode 984	Average Score: 15.13	
Environment solved in 984 episodes!		Average Score: 15.13
Episode 986	Average Score: 15.17	
Environment solved in 986 episodes!		Average Score: 15.17
Episode 999	Average Score: 15.23	
Environment solved in 999 episodes!		Average Score: 15.23
Episode 1000	Average Score: 15.22	
Episode 1003	Average Score: 15.29	
Environment solved in 1003 episodes!		Average Score: 15.29
Episode 1004	Average Score: 15.32	

Environment solved in 1004 episodes!	Average Score: 15.32
Episode 1100	Average Score: 14.42
Episode 1182	Average Score: 15.33
Environment solved in 1182 episodes!	Average Score: 15.33
Episode 1187	Average Score: 15.38
Environment solved in 1187 episodes!	Average Score: 15.38
Episode 1188	Average Score: 15.40
Environment solved in 1188 episodes!	Average Score: 15.40
Episode 1189	Average Score: 15.45
Environment solved in 1189 episodes!	Average Score: 15.45
Episode 1190	Average Score: 15.57
Environment solved in 1190 episodes!	Average Score: 15.57
Episode 1192	Average Score: 15.61
Environment solved in 1192 episodes!	Average Score: 15.61
Episode 1200	Average Score: 15.43
Episode 1217	Average Score: 15.64
Environment solved in 1217 episodes!	Average Score: 15.64
Episode 1218	Average Score: 15.65
Environment solved in 1218 episodes!	Average Score: 15.65
Episode 1220	Average Score: 15.67
Environment solved in 1220 episodes!	Average Score: 15.67
Episode 1223	Average Score: 15.68
Environment solved in 1223 episodes!	Average Score: 15.68
Episode 1300	Average Score: 14.96
Episode 1376	Average Score: 15.70
Environment solved in 1376 episodes!	Average Score: 15.70
Episode 1400	Average Score: 15.36
Episode 1500	Average Score: 15.33
Episode 1600	Average Score: 14.96
Episode 1647	Average Score: 15.71
Environment solved in 1647 episodes!	Average Score: 15.71
Episode 1648	Average Score: 15.76
Environment solved in 1648 episodes!	Average Score: 15.76
Episode 1649	Average Score: 15.77
Environment solved in 1649 episodes!	Average Score: 15.77
Episode 1700	Average Score: 15.57
Episode 1713	Average Score: 15.80
Environment solved in 1713 episodes!	Average Score: 15.80
Episode 1718	Average Score: 15.83
Environment solved in 1718 episodes!	Average Score: 15.83
Episode 1719	Average Score: 15.84
Environment solved in 1719 episodes!	Average Score: 15.84
Episode 1800	Average Score: 14.78
Episode 1900	Average Score: 14.83
Episode 2000	Average Score: 15.20



Time Taken: 1667.0391814080067