

Report

November 1, 2020

1 Continuous Control Project Report

1.0.1 1.Examination of State and Action Spaces

In this environment, a double-jointed arm can move to target locations. A reward of +0.1 is provided for each step that the agent's hand is in the goal location. Thus, the goal of your agent is to maintain its position at the target location for as many time steps as possible.

The observation space consists of 33 variables corresponding to position, rotation, velocity, and angular velocities of the arm. Each action is a vector with four numbers, corresponding to torque applicable to two joints. Every entry in the action vector should be a number between -1 and 1.

1.0.2 2. Algorithm

Algorithm is DDPG. DDPG algorithm uses two separate network which are working collaboratively; actor and critic. Actor network does policy approximation where critic does value estimation. Training of this network composed out of two steps; acting and learning. In acting step, agent gives state vector as an input to Actor network and receives actions to be taken. In learning step, Critic network evaluates correctness of action taken and gives feed to Actor network so Actor network adjust its weights accordingly.

```
In [7]: from model import Actor, Critic
        from agent import Agent

        import pandas as pd
        import matplotlib.pyplot as plt
        import random
        import copy
        from collections import namedtuple, deque
        import torch
        import torch.nn as nn
        import torch.nn.functional as F
        import torch.optim as optim

In [8]: agent = Agent(state_size=state_size,
                      action_size=action_size,
                      random_seed=10)
```

```

In [9]: def ddpg(n_episodes=2000, max_t=10000):

    scores = []
    scores_deque = deque(maxlen=100)

    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)

            env_info = env.step(action)[brain_name]
            next_state = env_info.vector_observations[0]
            reward = env_info.rewards[0]
            done = env_info.local_done[0]
            agent.step(state, action, reward, next_state, done)
            score += reward
            state = next_state
            if done:
                break

        scores_deque.append(score)
        scores.append(score)

        print('\rEpisode {} score: {:.2f}\tAverage Score: {:.2f}'.format(i_episode, score, np.mean(scores_deque)))

        print('\rAfter Episode {} average score is: {:.2f}'.format(i_episode, np.mean(scores_deque)))
        torch.save(agent.actor_local.state_dict(), 'checkpoint_actor.pth')
        torch.save(agent.critic_local.state_dict(), 'checkpoint_critic.pth')

        if np.mean(scores_deque) >= 30.0:
            print('\nEnvironment solved in {:d} episodes and average score is: {:.2f}'.format(i_episode, np.mean(scores_deque)))
            torch.save(agent.actor_local.state_dict(), 'checkpoint_actor.pth')
            torch.save(agent.critic_local.state_dict(), 'checkpoint_critic.pth')
            break

    return scores

```

1.0.3 3. Networks

Actor Network input size = 33 output size = 4 2 hidden layers and one output layer each hidden layer has 256 hidden units and is followed by a ReLU activation layer A batch normalization layer after the first layer Output layer is followed by a tanh activation layer

Critic Network input size = 4 output size = 1 2 hidden layers and one output layer each hidden layer has 256 hidden units and is followed by a ReLU activation layer A batch normalization layer

after the first layer Output layer is followed by a linear activation unit

```
Hyperparameters  BUFFER_SIZE = int(1e5)
BATCH_SIZE = 128
GAMMA = 0.99
TAU = 0.001
LR_ACTOR = 0.0001
LR_CRITIC = 0.0001
WEIGHT_DECAY = 0
```

```
In [10]: scores = ddpq(n_episodes=5000)
```

```
Episode 1 score: 0.16      Average Score: 0.16
After Episode 1 average score is: 0.16
Episode 2 score: 0.30      Average Score: 0.23
After Episode 2 average score is: 0.23
Episode 3 score: 0.80      Average Score: 0.42
After Episode 3 average score is: 0.42
Episode 4 score: 1.28      Average Score: 0.63
After Episode 4 average score is: 0.63
Episode 5 score: 1.65      Average Score: 0.84
After Episode 5 average score is: 0.84
Episode 6 score: 0.63      Average Score: 0.80
After Episode 6 average score is: 0.80
Episode 7 score: 0.62      Average Score: 0.78
After Episode 7 average score is: 0.78
Episode 8 score: 0.83      Average Score: 0.78
After Episode 8 average score is: 0.78
Episode 9 score: 0.45      Average Score: 0.75
After Episode 9 average score is: 0.75
Episode 10 score: 1.75     Average Score: 0.85
After Episode 10 average score is: 0.85
Episode 11 score: 0.77     Average Score: 0.84
After Episode 11 average score is: 0.84
Episode 12 score: 0.12     Average Score: 0.78
After Episode 12 average score is: 0.78
Episode 13 score: 0.96     Average Score: 0.79
After Episode 13 average score is: 0.79
Episode 14 score: 1.64     Average Score: 0.85
After Episode 14 average score is: 0.85
Episode 15 score: 1.83     Average Score: 0.92
After Episode 15 average score is: 0.92
Episode 16 score: 0.70     Average Score: 0.91
After Episode 16 average score is: 0.91
Episode 17 score: 1.29     Average Score: 0.93
After Episode 17 average score is: 0.93
Episode 18 score: 0.90     Average Score: 0.93
After Episode 18 average score is: 0.93
```

Episode 19 score: 0.80 Average Score: 0.92
After Episode 19 average score is: 0.92
Episode 20 score: 0.25 Average Score: 0.89
After Episode 20 average score is: 0.89
Episode 21 score: 1.92 Average Score: 0.94
After Episode 21 average score is: 0.94
Episode 22 score: 2.57 Average Score: 1.01
After Episode 22 average score is: 1.01
Episode 23 score: 1.26 Average Score: 1.02
After Episode 23 average score is: 1.02
Episode 24 score: 1.06 Average Score: 1.02
After Episode 24 average score is: 1.02
Episode 25 score: 2.55 Average Score: 1.08
After Episode 25 average score is: 1.08
Episode 26 score: 1.55 Average Score: 1.10
After Episode 26 average score is: 1.10
Episode 27 score: 1.61 Average Score: 1.12
After Episode 27 average score is: 1.12
Episode 28 score: 2.39 Average Score: 1.17
After Episode 28 average score is: 1.17
Episode 29 score: 2.02 Average Score: 1.20
After Episode 29 average score is: 1.20
Episode 30 score: 1.78 Average Score: 1.21
After Episode 30 average score is: 1.21
Episode 31 score: 2.38 Average Score: 1.25
After Episode 31 average score is: 1.25
Episode 32 score: 2.59 Average Score: 1.29
After Episode 32 average score is: 1.29
Episode 33 score: 2.32 Average Score: 1.33
After Episode 33 average score is: 1.33
Episode 34 score: 2.47 Average Score: 1.36
After Episode 34 average score is: 1.36
Episode 35 score: 3.11 Average Score: 1.41
After Episode 35 average score is: 1.41
Episode 36 score: 2.43 Average Score: 1.44
After Episode 36 average score is: 1.44
Episode 37 score: 3.59 Average Score: 1.50
After Episode 37 average score is: 1.50
Episode 38 score: 4.04 Average Score: 1.56
After Episode 38 average score is: 1.56
Episode 39 score: 3.51 Average Score: 1.61
After Episode 39 average score is: 1.61
Episode 40 score: 2.03 Average Score: 1.62
After Episode 40 average score is: 1.62
Episode 41 score: 4.24 Average Score: 1.69
After Episode 41 average score is: 1.69
Episode 42 score: 3.49 Average Score: 1.73
After Episode 42 average score is: 1.73

Episode 43 score: 3.30 Average Score: 1.77
After Episode 43 average score is: 1.77
Episode 44 score: 3.28 Average Score: 1.80
After Episode 44 average score is: 1.80
Episode 45 score: 3.45 Average Score: 1.84
After Episode 45 average score is: 1.84
Episode 46 score: 2.26 Average Score: 1.85
After Episode 46 average score is: 1.85
Episode 47 score: 2.55 Average Score: 1.86
After Episode 47 average score is: 1.86
Episode 48 score: 2.28 Average Score: 1.87
After Episode 48 average score is: 1.87
Episode 49 score: 2.60 Average Score: 1.88
After Episode 49 average score is: 1.88
Episode 50 score: 2.71 Average Score: 1.90
After Episode 50 average score is: 1.90
Episode 51 score: 3.12 Average Score: 1.93
After Episode 51 average score is: 1.93
Episode 52 score: 1.21 Average Score: 1.91
After Episode 52 average score is: 1.91
Episode 53 score: 4.19 Average Score: 1.95
After Episode 53 average score is: 1.95
Episode 54 score: 2.04 Average Score: 1.96
After Episode 54 average score is: 1.96
Episode 55 score: 4.39 Average Score: 2.00
After Episode 55 average score is: 2.00
Episode 56 score: 1.75 Average Score: 2.00
After Episode 56 average score is: 2.00
Episode 57 score: 3.23 Average Score: 2.02
After Episode 57 average score is: 2.02
Episode 58 score: 2.21 Average Score: 2.02
After Episode 58 average score is: 2.02
Episode 59 score: 2.68 Average Score: 2.03
After Episode 59 average score is: 2.03
Episode 60 score: 6.84 Average Score: 2.11
After Episode 60 average score is: 2.11
Episode 61 score: 3.57 Average Score: 2.14
After Episode 61 average score is: 2.14
Episode 62 score: 1.63 Average Score: 2.13
After Episode 62 average score is: 2.13
Episode 63 score: 2.98 Average Score: 2.14
After Episode 63 average score is: 2.14
Episode 64 score: 6.68 Average Score: 2.21
After Episode 64 average score is: 2.21
Episode 65 score: 6.17 Average Score: 2.27
After Episode 65 average score is: 2.27
Episode 66 score: 3.67 Average Score: 2.29
After Episode 66 average score is: 2.29

Episode 67 score: 5.42 Average Score: 2.34
After Episode 67 average score is: 2.34
Episode 68 score: 2.56 Average Score: 2.34
After Episode 68 average score is: 2.34
Episode 69 score: 4.88 Average Score: 2.38
After Episode 69 average score is: 2.38
Episode 70 score: 3.41 Average Score: 2.40
After Episode 70 average score is: 2.40
Episode 71 score: 4.10 Average Score: 2.42
After Episode 71 average score is: 2.42
Episode 72 score: 2.24 Average Score: 2.42
After Episode 72 average score is: 2.42
Episode 73 score: 5.09 Average Score: 2.45
After Episode 73 average score is: 2.45
Episode 74 score: 2.84 Average Score: 2.46
After Episode 74 average score is: 2.46
Episode 75 score: 5.52 Average Score: 2.50
After Episode 75 average score is: 2.50
Episode 76 score: 6.67 Average Score: 2.55
After Episode 76 average score is: 2.55
Episode 77 score: 4.15 Average Score: 2.58
After Episode 77 average score is: 2.58
Episode 78 score: 4.96 Average Score: 2.61
After Episode 78 average score is: 2.61
Episode 79 score: 4.12 Average Score: 2.63
After Episode 79 average score is: 2.63
Episode 80 score: 4.94 Average Score: 2.65
After Episode 80 average score is: 2.65
Episode 81 score: 5.49 Average Score: 2.69
After Episode 81 average score is: 2.69
Episode 82 score: 3.73 Average Score: 2.70
After Episode 82 average score is: 2.70
Episode 83 score: 7.73 Average Score: 2.76
After Episode 83 average score is: 2.76
Episode 84 score: 3.62 Average Score: 2.77
After Episode 84 average score is: 2.77
Episode 85 score: 5.19 Average Score: 2.80
After Episode 85 average score is: 2.80
Episode 86 score: 4.54 Average Score: 2.82
After Episode 86 average score is: 2.82
Episode 87 score: 4.28 Average Score: 2.84
After Episode 87 average score is: 2.84
Episode 88 score: 8.30 Average Score: 2.90
After Episode 88 average score is: 2.90
Episode 89 score: 4.61 Average Score: 2.92
After Episode 89 average score is: 2.92
Episode 90 score: 9.15 Average Score: 2.99
After Episode 90 average score is: 2.99

Episode 91 score: 3.51 Average Score: 2.99
After Episode 91 average score is: 2.99
Episode 92 score: 7.21 Average Score: 3.04
After Episode 92 average score is: 3.04
Episode 93 score: 3.32 Average Score: 3.04
After Episode 93 average score is: 3.04
Episode 94 score: 6.29 Average Score: 3.08
After Episode 94 average score is: 3.08
Episode 95 score: 4.54 Average Score: 3.09
After Episode 95 average score is: 3.09
Episode 96 score: 4.50 Average Score: 3.11
After Episode 96 average score is: 3.11
Episode 97 score: 9.24 Average Score: 3.17
After Episode 97 average score is: 3.17
Episode 98 score: 4.56 Average Score: 3.19
After Episode 98 average score is: 3.19
Episode 99 score: 4.90 Average Score: 3.20
After Episode 99 average score is: 3.20
Episode 100 score: 4.40 Average Score: 3.21
After Episode 100 average score is: 3.21
Episode 101 score: 3.37 Average Score: 3.25
After Episode 101 average score is: 3.25
Episode 102 score: 6.61 Average Score: 3.31
After Episode 102 average score is: 3.31
Episode 103 score: 4.67 Average Score: 3.35
After Episode 103 average score is: 3.35
Episode 104 score: 6.45 Average Score: 3.40
After Episode 104 average score is: 3.40
Episode 105 score: 6.56 Average Score: 3.45
After Episode 105 average score is: 3.45
Episode 106 score: 6.86 Average Score: 3.51
After Episode 106 average score is: 3.51
Episode 107 score: 5.33 Average Score: 3.56
After Episode 107 average score is: 3.56
Episode 108 score: 7.62 Average Score: 3.63
After Episode 108 average score is: 3.63
Episode 109 score: 7.14 Average Score: 3.69
After Episode 109 average score is: 3.69
Episode 110 score: 4.06 Average Score: 3.72
After Episode 110 average score is: 3.72
Episode 111 score: 4.28 Average Score: 3.75
After Episode 111 average score is: 3.75
Episode 112 score: 5.83 Average Score: 3.81
After Episode 112 average score is: 3.81
Episode 113 score: 7.92 Average Score: 3.88
After Episode 113 average score is: 3.88
Episode 114 score: 7.90 Average Score: 3.94
After Episode 114 average score is: 3.94

Episode 115 score: 7.70 Average Score: 4.00
After Episode 115 average score is: 4.00
Episode 116 score: 5.68 Average Score: 4.05
After Episode 116 average score is: 4.05
Episode 117 score: 6.07 Average Score: 4.10
After Episode 117 average score is: 4.10
Episode 118 score: 7.92 Average Score: 4.17
After Episode 118 average score is: 4.17
Episode 119 score: 9.96 Average Score: 4.26
After Episode 119 average score is: 4.26
Episode 120 score: 10.82 Average Score: 4.36
After Episode 120 average score is: 4.36
Episode 121 score: 10.51 Average Score: 4.45
After Episode 121 average score is: 4.45
Episode 122 score: 10.52 Average Score: 4.53
After Episode 122 average score is: 4.53
Episode 123 score: 6.39 Average Score: 4.58
After Episode 123 average score is: 4.58
Episode 124 score: 8.54 Average Score: 4.66
After Episode 124 average score is: 4.66
Episode 125 score: 8.78 Average Score: 4.72
After Episode 125 average score is: 4.72
Episode 126 score: 12.21 Average Score: 4.82
After Episode 126 average score is: 4.82
Episode 127 score: 15.17 Average Score: 4.96
After Episode 127 average score is: 4.96
Episode 128 score: 10.39 Average Score: 5.04
After Episode 128 average score is: 5.04
Episode 129 score: 9.91 Average Score: 5.12
After Episode 129 average score is: 5.12
Episode 130 score: 12.72 Average Score: 5.23
After Episode 130 average score is: 5.23
Episode 131 score: 5.51 Average Score: 5.26
After Episode 131 average score is: 5.26
Episode 132 score: 11.32 Average Score: 5.35
After Episode 132 average score is: 5.35
Episode 133 score: 5.31 Average Score: 5.38
After Episode 133 average score is: 5.38
Episode 134 score: 9.03 Average Score: 5.44
After Episode 134 average score is: 5.44
Episode 135 score: 10.76 Average Score: 5.52
After Episode 135 average score is: 5.52
Episode 136 score: 13.23 Average Score: 5.63
After Episode 136 average score is: 5.63
Episode 137 score: 8.85 Average Score: 5.68
After Episode 137 average score is: 5.68
Episode 138 score: 4.77 Average Score: 5.69
After Episode 138 average score is: 5.69

Episode 139 score: 11.30 Average Score: 5.77
After Episode 139 average score is: 5.77
Episode 140 score: 9.89 Average Score: 5.84
After Episode 140 average score is: 5.84
Episode 141 score: 6.71 Average Score: 5.87
After Episode 141 average score is: 5.87
Episode 142 score: 9.72 Average Score: 5.93
After Episode 142 average score is: 5.93
Episode 143 score: 11.90 Average Score: 6.02
After Episode 143 average score is: 6.02
Episode 144 score: 11.30 Average Score: 6.10
After Episode 144 average score is: 6.10
Episode 145 score: 14.49 Average Score: 6.21
After Episode 145 average score is: 6.21
Episode 146 score: 12.03 Average Score: 6.31
After Episode 146 average score is: 6.31
Episode 147 score: 18.48 Average Score: 6.46
After Episode 147 average score is: 6.46
Episode 148 score: 13.35 Average Score: 6.58
After Episode 148 average score is: 6.58
Episode 149 score: 10.51 Average Score: 6.65
After Episode 149 average score is: 6.65
Episode 150 score: 9.93 Average Score: 6.73
After Episode 150 average score is: 6.73
Episode 151 score: 11.23 Average Score: 6.81
After Episode 151 average score is: 6.81
Episode 152 score: 15.57 Average Score: 6.95
After Episode 152 average score is: 6.95
Episode 153 score: 14.64 Average Score: 7.06
After Episode 153 average score is: 7.06
Episode 154 score: 10.76 Average Score: 7.14
After Episode 154 average score is: 7.14
Episode 155 score: 12.71 Average Score: 7.23
After Episode 155 average score is: 7.23
Episode 156 score: 8.97 Average Score: 7.30
After Episode 156 average score is: 7.30
Episode 157 score: 11.52 Average Score: 7.38
After Episode 157 average score is: 7.38
Episode 158 score: 10.31 Average Score: 7.46
After Episode 158 average score is: 7.46
Episode 159 score: 8.01 Average Score: 7.52
After Episode 159 average score is: 7.52
Episode 160 score: 12.91 Average Score: 7.58
After Episode 160 average score is: 7.58
Episode 161 score: 18.86 Average Score: 7.73
After Episode 161 average score is: 7.73
Episode 162 score: 8.27 Average Score: 7.80
After Episode 162 average score is: 7.80

Episode 163 score: 14.10 Average Score: 7.91
After Episode 163 average score is: 7.91
Episode 164 score: 14.04 Average Score: 7.98
After Episode 164 average score is: 7.98
Episode 165 score: 18.21 Average Score: 8.10
After Episode 165 average score is: 8.10
Episode 166 score: 2.86 Average Score: 8.09
After Episode 166 average score is: 8.09
Episode 167 score: 9.87 Average Score: 8.14
After Episode 167 average score is: 8.14
Episode 168 score: 14.50 Average Score: 8.26
After Episode 168 average score is: 8.26
Episode 169 score: 16.88 Average Score: 8.38
After Episode 169 average score is: 8.38
Episode 170 score: 15.54 Average Score: 8.50
After Episode 170 average score is: 8.50
Episode 171 score: 26.19 Average Score: 8.72
After Episode 171 average score is: 8.72
Episode 172 score: 11.56 Average Score: 8.81
After Episode 172 average score is: 8.81
Episode 173 score: 13.65 Average Score: 8.90
After Episode 173 average score is: 8.90
Episode 174 score: 13.71 Average Score: 9.01
After Episode 174 average score is: 9.01
Episode 175 score: 20.05 Average Score: 9.15
After Episode 175 average score is: 9.15
Episode 176 score: 20.93 Average Score: 9.29
After Episode 176 average score is: 9.29
Episode 177 score: 17.02 Average Score: 9.42
After Episode 177 average score is: 9.42
Episode 178 score: 9.08 Average Score: 9.46
After Episode 178 average score is: 9.46
Episode 179 score: 8.39 Average Score: 9.51
After Episode 179 average score is: 9.51
Episode 180 score: 12.75 Average Score: 9.58
After Episode 180 average score is: 9.58
Episode 181 score: 17.71 Average Score: 9.71
After Episode 181 average score is: 9.71
Episode 182 score: 15.09 Average Score: 9.82
After Episode 182 average score is: 9.82
Episode 183 score: 16.17 Average Score: 9.90
After Episode 183 average score is: 9.90
Episode 184 score: 10.93 Average Score: 9.98
After Episode 184 average score is: 9.98
Episode 185 score: 14.86 Average Score: 10.07
After Episode 185 average score is: 10.07
Episode 186 score: 16.03 Average Score: 10.19
After Episode 186 average score is: 10.19

Episode 187 score: 12.60 Average Score: 10.27
 After Episode 187 average score is: 10.27
 Episode 188 score: 13.21 Average Score: 10.32
 After Episode 188 average score is: 10.32
 Episode 189 score: 21.68 Average Score: 10.49
 After Episode 189 average score is: 10.49
 Episode 190 score: 16.32 Average Score: 10.56
 After Episode 190 average score is: 10.56
 Episode 191 score: 23.80 Average Score: 10.77
 After Episode 191 average score is: 10.77
 Episode 192 score: 20.61 Average Score: 10.90
 After Episode 192 average score is: 10.90
 Episode 193 score: 15.76 Average Score: 11.03
 After Episode 193 average score is: 11.03
 Episode 194 score: 12.19 Average Score: 11.08
 After Episode 194 average score is: 11.08
 Episode 195 score: 21.28 Average Score: 11.25
 After Episode 195 average score is: 11.25
 Episode 196 score: 24.20 Average Score: 11.45
 After Episode 196 average score is: 11.45
 Episode 197 score: 16.11 Average Score: 11.52
 After Episode 197 average score is: 11.52
 Episode 198 score: 19.83 Average Score: 11.67
 After Episode 198 average score is: 11.67
 Episode 199 score: 15.15 Average Score: 11.77
 After Episode 199 average score is: 11.77
 Episode 200 score: 20.92 Average Score: 11.94
 After Episode 200 average score is: 11.94
 Episode 201 score: 21.14 Average Score: 12.12
 After Episode 201 average score is: 12.12
 Episode 202 score: 25.61 Average Score: 12.31
 After Episode 202 average score is: 12.31
 Episode 203 score: 18.33 Average Score: 12.44
 After Episode 203 average score is: 12.44
 Episode 204 score: 25.79 Average Score: 12.64
 After Episode 204 average score is: 12.64
 Episode 205 score: 26.26 Average Score: 12.83
 After Episode 205 average score is: 12.83
 Episode 206 score: 21.69 Average Score: 12.98
 After Episode 206 average score is: 12.98
 Episode 207 score: 8.49 Average Score: 13.01
 After Episode 207 average score is: 13.01
 Episode 208 score: 15.65 Average Score: 13.09
 After Episode 208 average score is: 13.09
 Episode 209 score: 15.63 Average Score: 13.18
 After Episode 209 average score is: 13.18
 Episode 210 score: 31.70 Average Score: 13.45
 After Episode 210 average score is: 13.45

Episode 211 score: 23.30 Average Score: 13.64
 After Episode 211 average score is: 13.64
 Episode 212 score: 20.13 Average Score: 13.79
 After Episode 212 average score is: 13.79
 Episode 213 score: 32.63 Average Score: 14.03
 After Episode 213 average score is: 14.03
 Episode 214 score: 24.33 Average Score: 14.20
 After Episode 214 average score is: 14.20
 Episode 215 score: 22.58 Average Score: 14.35
 After Episode 215 average score is: 14.35
 Episode 216 score: 21.02 Average Score: 14.50
 After Episode 216 average score is: 14.50
 Episode 217 score: 11.28 Average Score: 14.55
 After Episode 217 average score is: 14.55
 Episode 218 score: 14.86 Average Score: 14.62
 After Episode 218 average score is: 14.62
 Episode 219 score: 35.44 Average Score: 14.88
 After Episode 219 average score is: 14.88
 Episode 220 score: 21.42 Average Score: 14.98
 After Episode 220 average score is: 14.98
 Episode 221 score: 28.92 Average Score: 15.17
 After Episode 221 average score is: 15.17
 Episode 222 score: 30.77 Average Score: 15.37
 After Episode 222 average score is: 15.37
 Episode 223 score: 19.40 Average Score: 15.50
 After Episode 223 average score is: 15.50
 Episode 224 score: 25.29 Average Score: 15.67
 After Episode 224 average score is: 15.67
 Episode 225 score: 32.81 Average Score: 15.91
 After Episode 225 average score is: 15.91
 Episode 226 score: 15.86 Average Score: 15.94
 After Episode 226 average score is: 15.94
 Episode 227 score: 32.02 Average Score: 16.11
 After Episode 227 average score is: 16.11
 Episode 228 score: 24.73 Average Score: 16.26
 After Episode 228 average score is: 16.26
 Episode 229 score: 28.25 Average Score: 16.44
 After Episode 229 average score is: 16.44
 Episode 230 score: 36.07 Average Score: 16.67
 After Episode 230 average score is: 16.67
 Episode 231 score: 34.36 Average Score: 16.96
 After Episode 231 average score is: 16.96
 Episode 232 score: 31.51 Average Score: 17.16
 After Episode 232 average score is: 17.16
 Episode 233 score: 24.80 Average Score: 17.36
 After Episode 233 average score is: 17.36
 Episode 234 score: 36.21 Average Score: 17.63
 After Episode 234 average score is: 17.63

Episode 235 score: 27.74 Average Score: 17.80
 After Episode 235 average score is: 17.80
 Episode 236 score: 39.20 Average Score: 18.06
 After Episode 236 average score is: 18.06
 Episode 237 score: 37.14 Average Score: 18.34
 After Episode 237 average score is: 18.34
 Episode 238 score: 27.95 Average Score: 18.57
 After Episode 238 average score is: 18.57
 Episode 239 score: 37.74 Average Score: 18.84
 After Episode 239 average score is: 18.84
 Episode 240 score: 37.48 Average Score: 19.11
 After Episode 240 average score is: 19.11
 Episode 241 score: 28.28 Average Score: 19.33
 After Episode 241 average score is: 19.33
 Episode 242 score: 35.20 Average Score: 19.59
 After Episode 242 average score is: 19.59
 Episode 243 score: 33.72 Average Score: 19.80
 After Episode 243 average score is: 19.80
 Episode 244 score: 36.73 Average Score: 20.06
 After Episode 244 average score is: 20.06
 Episode 245 score: 34.24 Average Score: 20.26
 After Episode 245 average score is: 20.26
 Episode 246 score: 37.12 Average Score: 20.51
 After Episode 246 average score is: 20.51
 Episode 247 score: 39.36 Average Score: 20.72
 After Episode 247 average score is: 20.72
 Episode 248 score: 39.17 Average Score: 20.97
 After Episode 248 average score is: 20.97
 Episode 249 score: 39.25 Average Score: 21.26
 After Episode 249 average score is: 21.26
 Episode 250 score: 39.60 Average Score: 21.56
 After Episode 250 average score is: 21.56
 Episode 251 score: 35.67 Average Score: 21.80
 After Episode 251 average score is: 21.80
 Episode 252 score: 31.41 Average Score: 21.96
 After Episode 252 average score is: 21.96
 Episode 253 score: 39.59 Average Score: 22.21
 After Episode 253 average score is: 22.21
 Episode 254 score: 36.77 Average Score: 22.47
 After Episode 254 average score is: 22.47
 Episode 255 score: 34.08 Average Score: 22.68
 After Episode 255 average score is: 22.68
 Episode 256 score: 34.68 Average Score: 22.94
 After Episode 256 average score is: 22.94
 Episode 257 score: 39.05 Average Score: 23.22
 After Episode 257 average score is: 23.22
 Episode 258 score: 36.34 Average Score: 23.48
 After Episode 258 average score is: 23.48

Episode 259 score: 39.52 Average Score: 23.79
 After Episode 259 average score is: 23.79
 Episode 260 score: 39.64 Average Score: 24.06
 After Episode 260 average score is: 24.06
 Episode 261 score: 34.49 Average Score: 24.21
 After Episode 261 average score is: 24.21
 Episode 262 score: 27.66 Average Score: 24.41
 After Episode 262 average score is: 24.41
 Episode 263 score: 24.21 Average Score: 24.51
 After Episode 263 average score is: 24.51
 Episode 264 score: 28.84 Average Score: 24.66
 After Episode 264 average score is: 24.66
 Episode 265 score: 39.27 Average Score: 24.87
 After Episode 265 average score is: 24.87
 Episode 266 score: 33.15 Average Score: 25.17
 After Episode 266 average score is: 25.17
 Episode 267 score: 22.61 Average Score: 25.30
 After Episode 267 average score is: 25.30
 Episode 268 score: 32.49 Average Score: 25.48
 After Episode 268 average score is: 25.48
 Episode 269 score: 35.64 Average Score: 25.67
 After Episode 269 average score is: 25.67
 Episode 270 score: 32.71 Average Score: 25.84
 After Episode 270 average score is: 25.84
 Episode 271 score: 30.41 Average Score: 25.88
 After Episode 271 average score is: 25.88
 Episode 272 score: 36.77 Average Score: 26.13
 After Episode 272 average score is: 26.13
 Episode 273 score: 38.69 Average Score: 26.38
 After Episode 273 average score is: 26.38
 Episode 274 score: 33.83 Average Score: 26.58
 After Episode 274 average score is: 26.58
 Episode 275 score: 39.48 Average Score: 26.78
 After Episode 275 average score is: 26.78
 Episode 276 score: 39.63 Average Score: 26.97
 After Episode 276 average score is: 26.97
 Episode 277 score: 36.41 Average Score: 27.16
 After Episode 277 average score is: 27.16
 Episode 278 score: 38.84 Average Score: 27.46
 After Episode 278 average score is: 27.46
 Episode 279 score: 38.72 Average Score: 27.76
 After Episode 279 average score is: 27.76
 Episode 280 score: 39.09 Average Score: 28.02
 After Episode 280 average score is: 28.02
 Episode 281 score: 39.68 Average Score: 28.24
 After Episode 281 average score is: 28.24
 Episode 282 score: 32.85 Average Score: 28.42
 After Episode 282 average score is: 28.42

```

Episode 283 score: 38.51      Average Score: 28.64
After Episode 283 average score is: 28.64
Episode 284 score: 28.66      Average Score: 28.82
After Episode 284 average score is: 28.82
Episode 285 score: 39.58      Average Score: 29.07
After Episode 285 average score is: 29.07
Episode 286 score: 39.52      Average Score: 29.30
After Episode 286 average score is: 29.30
Episode 287 score: 39.53      Average Score: 29.57
After Episode 287 average score is: 29.57
Episode 288 score: 32.53      Average Score: 29.77
After Episode 288 average score is: 29.77
Episode 289 score: 10.05      Average Score: 29.65
After Episode 289 average score is: 29.65
Episode 290 score: 39.02      Average Score: 29.88
After Episode 290 average score is: 29.88
Episode 291 score: 36.86      Average Score: 30.01
After Episode 291 average score is: 30.01

Environment solved in 291 episodes and average score is: 30.01

```

1.0.4 4. Plot of Reward

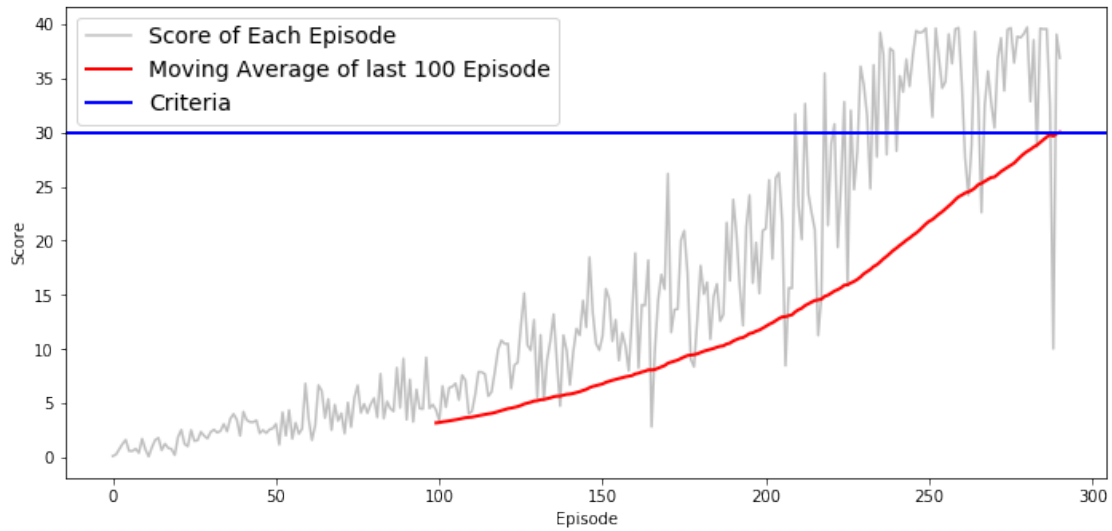
```

In [11]: fig, ax = plt.subplots(1, 1, figsize=[10, 5])
         plt.rcParams.update({'font.size': 14})

         scores_avg = pd.Series(scores).rolling(100).mean()
         ax.plot(scores, "-", c="black", alpha=0.25)
         ax.plot(scores_avg, "-", c="red", linewidth=2)
         ax.set_xlabel("Episode")
         ax.set_ylabel("Score")
         ax.axhline(30, c="blue", linewidth=2)
         ax.legend(["Score of Each Episode", "Moving Average of last 100 Episode", "Criteria"])

         fig.tight_layout()

```



```
In [12]: env.close()
```

1.0.5 5. Future Work

There are more network would be reasonable to try out if better performance can be observed like PPO, A3C, and D4PG. A3C can be tried first in order to do parallel training.

A3C: Waiting to experience the environment for a little longer before to calculate expected return of original state. Less bias, keep variance in control. Faster convergence with less experience. A3C replaces replay buffer with parallel training using parallel agents.