spider

December 3, 2017

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In [1]: import matplotlib.pyplot as plt
        import numpy as np
        from qlearning import *
        from spider_ani import *
        from wait import *
```

1 Spider Environment

```
In [2]: class spider_environment:
            def __init__(self):
                # number of states: leg up/down, forward/backward
                self.n_states = pow(4,4)
                self.n_actions = pow(4,4)        # number of actions
                self.reward = np.zeros([self.n_states, self.n_actions])
                # 1 if terminal state, 0 otherwise
                self.terminal = np.zeros(self.n_states, dtype=np.int)
                self.next_state = np.zeros([self.n_states, self.n_actions], dtype=np.int)
                self.init_state = 0b00001010    # initial state
                n_legs = 4
                transition = [[1,0,2,0],[1,0,3,1],[3,2,2,0],[3,2,3,1]]
                class leg: pass
                # loop to calculate next state and rewards for each initial state
                for s in range(self.n_states):
                    legs_state = []
                    down_s = ""
                    # storing initial leg position
                    for l in range(n_legs):
                        leg_i = leg()
                        leg_i.up = (s >> 2*l) & 1
                        leg_i.fw = (s >> (2*l +1)) & 1
                        legs_state += [leg_i]
                        # initial arrangement of legs: 1 if up 0 if down
                        down_s = bin(leg_i.up ^ 0b1)[2:] + down_s
                    down_s = int("0b"+down_s, 2)
                    for a in range(self.n_actions):
                        legs_action = []
```

```
# storing actions for each leg
for l in range(n_legs):
    leg_i = leg()
    leg_i.action_up = ((a >> 2*l) & 3) == 0
    leg_i.action_dn = ((a >> 2*l) & 3) == 1
    leg_i.action_fw = ((a >> 2*l) & 3) == 2
    leg_i.action_bw = ((a >> 2*l) & 3) == 3
    legs_action += [leg_i]
next_s = 0
down_sn = "0b"
# start from MSB and move to LSB
# computing next state for each leg independently using
# the transition table
for l in reversed(range(n_legs)):
    s_i = (s >> 2*l) & 3
    a_i = (a >> 2*l) & 3
    next_s = (next_s << 2) + transition[s_i][a_i]
    # arrangement of legs in next state: 1 if up 0 if down
    down_sn += bin((transition[s_i][a_i] & 1) ^ 0b1)[2:]
down_sn = int(down_sn, 2)
self.next_state[s,a] = next_s
# total arrangement of legs which stay down at s and sn
product = (down_s) & (down_sn)
total_down = bin(product).count("1")
total_force = 0
for l in range(n_legs):
    total_force += (legs_state[l].up == 0 and legs_state[l].fw == 1 \
    and legs_action[l].action_bw == 1) - (legs_state[l].up == 0 and \
            legs_state[l].fw == 0 and legs_action[l].action_fw == 1)
# two diagonal legs stay down in two cases
# either product=0110 or product=1001
diagonal = ((product & 1) & ((product >> 3)& 1)) | \
                   (((product >> 2) & 1) & ((product >> 1)& 1))

if total_down == 0:
    self.reward[s,a] = 0
elif total_down >= 3:
    self.reward[s,a] = 1.0 * total_force / total_down
elif total_down == 2 and diagonal:
    self.reward[s,a] = 1.0 * total_force / total_down
else:
    self.reward[s,a] = 0.25 * total_force / total_down
```

2 Hyperparameters

Were chosen empirically such that $r_{test} > 9$

```
In [3]: env = spider_environment()

        n_episodes = 1       # number of episodes to run, 1 for continuing task
        max_steps = 5000000      # max number of steps to run in each episode
        alpha = 0.2          # learning rate
        gamma = 0.9

        class epsilon_profile: pass
        epsilon = epsilon_profile()
        epsilon.init = 1.    # initial epsilon in e-greedy
        epsilon.final = 0.0   # final epsilon in e-greedy
        epsilon.dec_episode = 0.  # amount of decrement in each episode
        epsilon.dec_step = 1. / max_steps   # amount of decrement in each step
```

3 Training and testing

First train agent for 5000000 steps and then reuse Q table for deterministic greedy policy w.r.t. state-action values

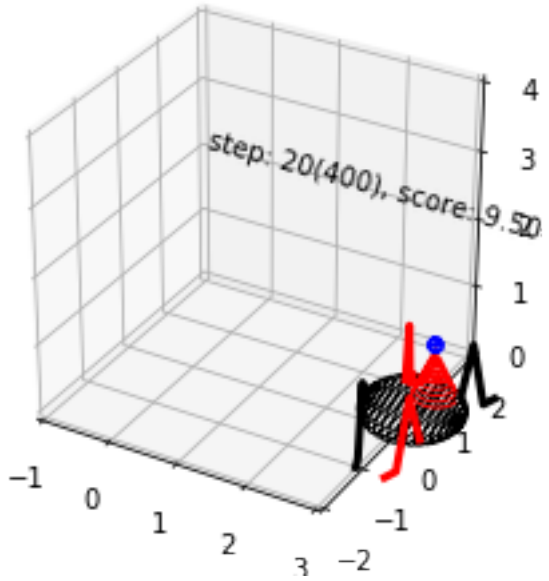
```
In [4]: Q, n_steps, sum_rewards = Q_learning_train(env, n_episodes, max_steps, alpha, \
                                                  gamma, epsilon)
        print("train_sum_rewards = %f"%sum_rewards[0])

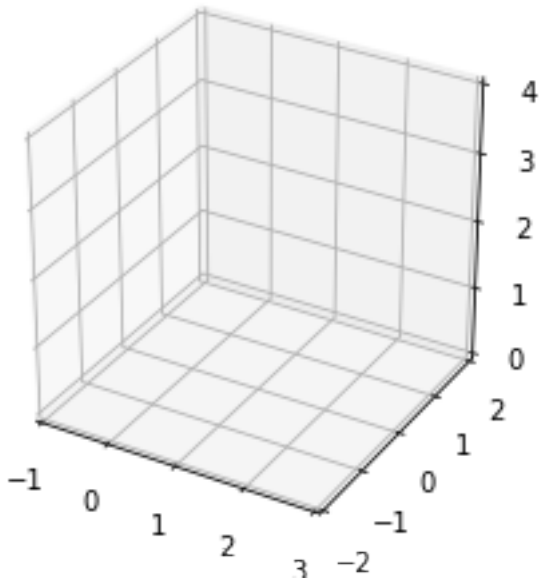
        test_n_episodes = 1  # number of episodes to run, 1 for continuing task
        test_max_steps = 20  # max. # of steps to run in each episode
        test_epsilon = 0.0    # test epsilon
        test_n_steps, test_sum_rewards, s, a, sn, r = Q_test(Q, env, test_n_episodes, \
                                                  test_max_steps, test_epsilon)
        print("Testing")
        print("s \t\t a \t sn \t r")
        for j in range(test_max_steps):
            print('%10s %10s %10s %5.2f' % (bin(s[0,j]), bin(a[0,j]), bin(sn[0,j]), r[0,j]))
        print("test_sum_rewards = %f"%test_sum_rewards[0])

        ani = spider_animation(Q, env, test_max_steps, test_epsilon, frames_per_step = 20)
        ani.save('spider.mp4', dpi=200)
        ani = spider_animation(Q, env, test_max_steps, test_epsilon, frames_per_step = 5)
        plt.show(block=False)
        wait('Press enter to quit')
```

```
train_sum_rewards = 1026679.958333
Testing
s                   a           sn          r
    0b1010 0b11000011    0b11100  0.50
   0b11100   0b101000  0b1111101  0.00
 0b1111101 0b10010110 0b11101011  0.00
0b11101011  0b1111101 0b10000010  1.00
0b10000010 0b11000011    0b10100  1.00
```

```
   0b10100   0b101000  0b1111101  0.00
 0b1111101 0b10010110 0b11101011  0.00
0b11101011  0b1111101 0b10000010  1.00
0b10000010 0b11000011    0b10100  1.00
   0b10100   0b101000  0b1111101  0.00
 0b1111101 0b10010110 0b11101011  0.00
0b11101011  0b1111101 0b10000010  1.00
0b10000010 0b11000011    0b10100  1.00
   0b10100   0b101000  0b1111101  0.00
 0b1111101 0b10010110 0b11101011  0.00
0b11101011  0b1111101 0b10000010  1.00
0b10000010 0b11000011    0b10100  1.00
   0b10100   0b101000  0b1111101  0.00
 0b1111101 0b10010110 0b11101011  0.00
0b11101011  0b1111101 0b10000010  1.00
test_sum_rewards = 9.500000
```



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Press enter to quit
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