breakout

December 4, 2017

```
In [1]: import numpy as np
        import matplotlib.pyplot as plt
        import matplotlib.animation as animation
        import matplotlib.patches as patches
        import random
        from breakout_env import *
        from wait import *
        import tensorflow as tf
```

```
In [2]: tf.flags.DEFINE_boolean("restore", False, "Print scores performance")
        FLAGS = tf.flags.FLAGS

        env = breakout_environment(nx = 5, ny = 8, nb = 3, nt = 1, nf = 2)
```

1 DQN description

I experimented with 3 different model stuctures:

1. Two CNN layers with f1_shape=[3x2x2x25] and f2_shape=[2x1x25x50] plus two fully connected layers fc1_shape=[500x100] and fc2_shape=[100x3]
2. One CNN layer with f1_shape=[2x1x2x80] plus two fully connected layers fc1_shape=[2800x150] and fc2_shape=[150x3]
3. Two fully connected layers fc1_shape=[80x80] and fc2_shape=[80x3]

The latter model exhibited the most stable performance, most frequently achieving the maximum reward of 15 during the test game. The reason can be that the input state has a very small size and convolutions are not much helpful in such cases.

```
In [3]: class DQN:
            def __init__(self, env):
                # state size [ny, nx, nf]
                self.s = tf.placeholder(tf.float32, shape=[None, env.ny, env.nx, env.nf])
                self.a = tf.placeholder(tf.int32, shape=[None])
                self.batch_size = tf.placeholder(tf.int32, shape=[])
                self.bootstraped = tf.placeholder(tf.float32, shape=[None])
                self.ch1 = 80
                self.env = env
                # network parameters
```

```
        W_fc1 = tf.Variable(tf.truncated_normal([env.nx*env.ny*env.nf, self.ch1],\
                                                stddev=0.1))
        b_fc1 = tf.Variable(tf.constant(0.1, shape=[self.ch1]))
        W_fc2 = tf.Variable(tf.truncated_normal([self.ch1, env.na], stddev=0.1))
        b_fc2 = tf.Variable(tf.constant(0.1, shape=[env.na]))
        # Q network
        h_flat = tf.reshape(self.s, [self.batch_size, -1])
        fc1 = tf.matmul(h_flat, W_fc1) + b_fc1
        self.q = tf.matmul(tf.nn.relu(fc1), W_fc2) + b_fc2
        # find Q values for particular actions
        action_one_hot = tf.one_hot(self.a, env.na, 1.0, 0.0, name='action_one_hot')
        self.q_a = tf.reduce_sum(self.q * action_one_hot, reduction_indices=1, \
                                                                name='q_acted')

        self.optim = tf.train.RMSPropOptimizer(0.0002, momentum=0.95, epsilon=0.01)
        self.theta = [W_fc1, b_fc1, W_fc2, b_fc2]
        self.target_init()
        # minimize MSE between bootstraped value of target network and
        # approximated value of behaviour network
        losses = tf.squared_difference(self.bootstraped, self.q_a)
        self.loss = tf.reduce_mean(losses)
        self.train_step = self.optim.minimize(self.loss)

    def copy_parameters(self):
        for i in range(len(self.theta)):
            self.theta_[i].assign(self.theta[i]).eval()

    def target_init(self):
        self.theta_ = []
        for param in self.theta:
            self.theta_ += [tf.Variable(tf.truncated_normal(tf.shape(param), stddev=0.1)
        W_fc1, b_fc1, W_fc2, b_fc2 = self.theta_

        h_flat = tf.reshape(self.s, [self.batch_size, -1])
        fc1 = tf.matmul(h_flat, W_fc1) + b_fc1
        self.q_ = tf.matmul(tf.nn.relu(fc1), W_fc2) + b_fc2
        self.q_max_ = tf.reduce_max(self.q_, axis=1)

    def train_iter(self, s, a, bootstraped):
        loss = self.loss.eval(feed_dict={self.s: s, self.a: a, self.batch_size:\
                                    s.shape[0], self.bootstraped:bootstraped})
        self.train_step.run(feed_dict={self.s: s, self.a: a, self.batch_size:\
                                    s.shape[0], self.bootstraped:bootstraped})
        return loss

    def target_q(self, s):
        return self.q_max_.eval(feed_dict={self.s: s, self.batch_size: s.shape[0]})
```

```
        def behav_q(self, s):
            return self.q.eval(feed_dict={self.s: np.expand_dims(s, axis=0), \
                                          self.batch_size: 1})
```

2 Hyperparameters

Were found empirically

```
In [4]: max_steps = 200      # max number of steps to run in each episode
        gamma = 0.85
        batch_size = 30
        replay_size = 2000
        replay_start = 100
        n_episodes = 4500 + replay_start
        target_update = 100

        class epsilon_profile: pass
        epsilon_profile = epsilon_profile()
        epsilon_profile.init = 1.    # initial epsilon in e-greedy
        epsilon_profile.final = 0.1   # final epsilon in e-greedy
        epsilon_profile.dec_episode = 1. / n_episodes  # amount of decrement in each episode
        epsilon_profile.dec_step = 0.   # amount of decrement in each step

In [5]: sess = tf.InteractiveSession()

In [6]: agent = DQN(env)
        tf.group(tf.global_variables_initializer(), tf.local_variables_initializer()).run()
        # copy behaviour network parameters to target network
        agent.copy_parameters()
        saver = tf.train.Saver()

In [7]: epsilon = epsilon_profile.init
        losses, ep_r, ep_st, replay = [], [], [], []

In [8]: if not FLAGS.restore:
            for episode in range(n_episodes):
                env_s = env.reset()
                env_done = 0
                ep_r += [0]
                for t in range(max_steps):
                    if np.random.rand() < epsilon:
                        env_a = np.random.randint(env.na)
                    else:
                        env_q = agent.behav_q(env_s)
                        env_a = np.random.choice(np.where(env_q[0] == np.max(env_q))[0])

                    env_sn, env_r, env_done, _,_,_,_,_,_,_,_ = env.run(env_a - 1)
                    if len(replay) == replay_size:
```

```
                    replay.pop(0)
                ep_r[-1] += env_r
                replay += [(env_s, env_a, env_r, env_sn, env_done)]

                if len(replay) >= replay_start:
                    samples = random.sample(replay, batch_size)
                    s, a, r, sn, done = map(np.array, zip(*samples))
                    # training behaviour network parameters by Q learning
                    q_max_ = agent.target_q(sn)
                    bootstraped = r + (1. - done)*gamma*q_max_
                    loss = agent.train_iter(s, a, bootstraped)
                    losses += [loss]
                    epsilon = max(epsilon - epsilon_profile.dec_step, epsilon_profile.final)
                if env_done == 1:
                    ep_st += [t]
                    break
                env_s = env_sn

            if env_done != 1:
                ep_st += [max_steps]

            if len(replay) >= replay_start:
                if episode % target_update == 0:
                    # copy behaviour network parameters to target network
                    agent.copy_parameters()
                print_rate =50
                if episode % print_rate == 0:
                    print('loss = %5.4f  av_r = %2.4f  r = %2d  av_steps = %3.1f  episode =
                                    % (loss, np.mean(ep_r[:print_rate]), ep_r[-1],\
                                    np.mean(ep_st[:print_rate]), episode, epsilon))
                    ep_r, ep_st = [], []
                epsilon = max(epsilon - epsilon_profile.dec_episode, epsilon_profile.final)

        save_path = saver.save(sess, "./breakout.ckpt")
    else:
        saver.restore(sess, "./breakout.ckpt")
```

```
loss = 0.0723  av_r = 0.7000  r =  2  av_steps = 6.4  episode = 50  epsilon=0.99
loss = 0.0551  av_r = 1.0200  r =  1  av_steps = 8.6  episode = 100  epsilon=0.98
loss = 0.0467  av_r = 0.8200  r =  0  av_steps = 7.2  episode = 150  epsilon=0.97
loss = 0.0141  av_r = 0.8800  r =  1  av_steps = 7.4  episode = 200  epsilon=0.96
loss = 0.0444  av_r = 0.8200  r =  0  av_steps = 7.1  episode = 250  epsilon=0.95
loss = 0.0223  av_r = 0.7800  r =  2  av_steps = 7.0  episode = 300  epsilon=0.94
loss = 0.0378  av_r = 1.0000  r =  3  av_steps = 8.1  episode = 350  epsilon=0.93
loss = 0.0662  av_r = 1.2200  r =  1  av_steps = 10.0  episode = 400  epsilon=0.91
loss = 0.0254  av_r = 1.0200  r =  0  av_steps = 8.4  episode = 450  epsilon=0.90
loss = 0.0117  av_r = 1.2200  r =  2  av_steps = 9.8  episode = 500  epsilon=0.89
loss = 0.0410  av_r = 0.8800  r =  1  av_steps = 7.4  episode = 550  epsilon=0.88
```

```
loss = 0.0168  av_r = 0.7000  r =  1  av_steps = 6.5  episode = 600  epsilon=0.87
loss = 0.0149  av_r = 0.9400  r =  1  av_steps = 8.2  episode = 650  epsilon=0.86
loss = 0.0095  av_r = 1.0800  r =  2  av_steps = 8.8  episode = 700  epsilon=0.85
loss = 0.0210  av_r = 1.1000  r =  1  av_steps = 8.9  episode = 750  epsilon=0.84
loss = 0.0075  av_r = 1.1000  r =  2  av_steps = 8.8  episode = 800  epsilon=0.83
loss = 0.0090  av_r = 0.6200  r =  1  av_steps = 5.9  episode = 850  epsilon=0.82
loss = 0.0071  av_r = 0.9200  r =  5  av_steps = 7.8  episode = 900  epsilon=0.81
loss = 0.0046  av_r = 1.0200  r =  0  av_steps = 8.4  episode = 950  epsilon=0.80
loss = 0.0058  av_r = 1.1000  r =  1  av_steps = 9.0  episode = 1000  epsilon=0.78
loss = 0.0096  av_r = 1.4200  r =  1  av_steps = 10.9  episode = 1050  epsilon=0.77
loss = 0.0039  av_r = 1.1200  r =  1  av_steps = 9.1  episode = 1100  epsilon=0.76
loss = 0.0022  av_r = 1.5600  r =  1  av_steps = 12.0  episode = 1150  epsilon=0.75
loss = 0.0029  av_r = 1.4000  r =  0  av_steps = 11.2  episode = 1200  epsilon=0.74
loss = 0.0041  av_r = 1.3000  r =  3  av_steps = 10.4  episode = 1250  epsilon=0.73
loss = 0.0022  av_r = 1.3200  r =  0  av_steps = 10.5  episode = 1300  epsilon=0.72
loss = 0.0063  av_r = 1.3600  r =  0  av_steps = 10.7  episode = 1350  epsilon=0.71
loss = 0.0051  av_r = 1.3400  r =  3  av_steps = 10.5  episode = 1400  epsilon=0.70
loss = 0.0027  av_r = 1.2600  r =  2  av_steps = 10.0  episode = 1450  epsilon=0.69
loss = 0.0028  av_r = 1.9200  r =  2  av_steps = 14.6  episode = 1500  epsilon=0.68
loss = 0.0023  av_r = 1.6000  r =  0  av_steps = 12.3  episode = 1550  epsilon=0.66
loss = 0.0027  av_r = 1.6400  r =  1  av_steps = 12.3  episode = 1600  epsilon=0.65
loss = 0.0021  av_r = 1.7000  r =  2  av_steps = 12.9  episode = 1650  epsilon=0.64
loss = 0.0024  av_r = 1.8200  r =  4  av_steps = 13.7  episode = 1700  epsilon=0.63
loss = 0.0036  av_r = 2.1400  r =  1  av_steps = 16.2  episode = 1750  epsilon=0.62
loss = 0.0079  av_r = 2.2000  r =  2  av_steps = 16.6  episode = 1800  epsilon=0.61
loss = 0.0110  av_r = 1.9200  r =  1  av_steps = 14.8  episode = 1850  epsilon=0.60
loss = 0.0067  av_r = 2.1800  r =  2  av_steps = 16.1  episode = 1900  epsilon=0.59
loss = 0.0093  av_r = 1.8400  r =  1  av_steps = 14.2  episode = 1950  epsilon=0.58
loss = 0.0060  av_r = 1.9800  r =  0  av_steps = 15.0  episode = 2000  epsilon=0.57
loss = 0.0048  av_r = 2.0600  r =  0  av_steps = 15.9  episode = 2050  epsilon=0.56
loss = 0.0011  av_r = 1.8800  r =  2  av_steps = 14.1  episode = 2100  epsilon=0.55
loss = 0.0093  av_r = 2.5000  r =  0  av_steps = 18.6  episode = 2150  epsilon=0.53
loss = 0.0022  av_r = 2.5200  r =  7  av_steps = 19.4  episode = 2200  epsilon=0.52
loss = 0.0036  av_r = 2.5800  r =  0  av_steps = 19.4  episode = 2250  epsilon=0.51
loss = 0.0066  av_r = 2.2400  r =  4  av_steps = 16.9  episode = 2300  epsilon=0.50
loss = 0.0031  av_r = 2.7000  r =  3  av_steps = 21.2  episode = 2350  epsilon=0.49
loss = 0.0053  av_r = 2.8000  r =  1  av_steps = 21.4  episode = 2400  epsilon=0.48
loss = 0.0029  av_r = 3.5000  r =  1  av_steps = 24.7  episode = 2450  epsilon=0.47
loss = 0.0036  av_r = 3.7600  r =  6  av_steps = 28.3  episode = 2500  epsilon=0.46
loss = 0.0025  av_r = 3.1200  r =  0  av_steps = 23.0  episode = 2550  epsilon=0.45
loss = 0.0045  av_r = 3.3000  r =  4  av_steps = 25.1  episode = 2600  epsilon=0.44
loss = 0.0044  av_r = 3.4000  r =  0  av_steps = 25.9  episode = 2650  epsilon=0.43
loss = 0.0052  av_r = 4.4400  r =  2  av_steps = 34.0  episode = 2700  epsilon=0.41
loss = 0.0044  av_r = 3.4600  r =  1  av_steps = 26.2  episode = 2750  epsilon=0.40
loss = 0.0098  av_r = 3.9200  r =  1  av_steps = 30.2  episode = 2800  epsilon=0.39
loss = 0.0144  av_r = 4.0800  r =  1  av_steps = 30.1  episode = 2850  epsilon=0.38
loss = 0.0060  av_r = 3.9800  r =  0  av_steps = 32.6  episode = 2900  epsilon=0.37
loss = 0.0220  av_r = 3.5200  r =  3  av_steps = 28.9  episode = 2950  epsilon=0.36
```

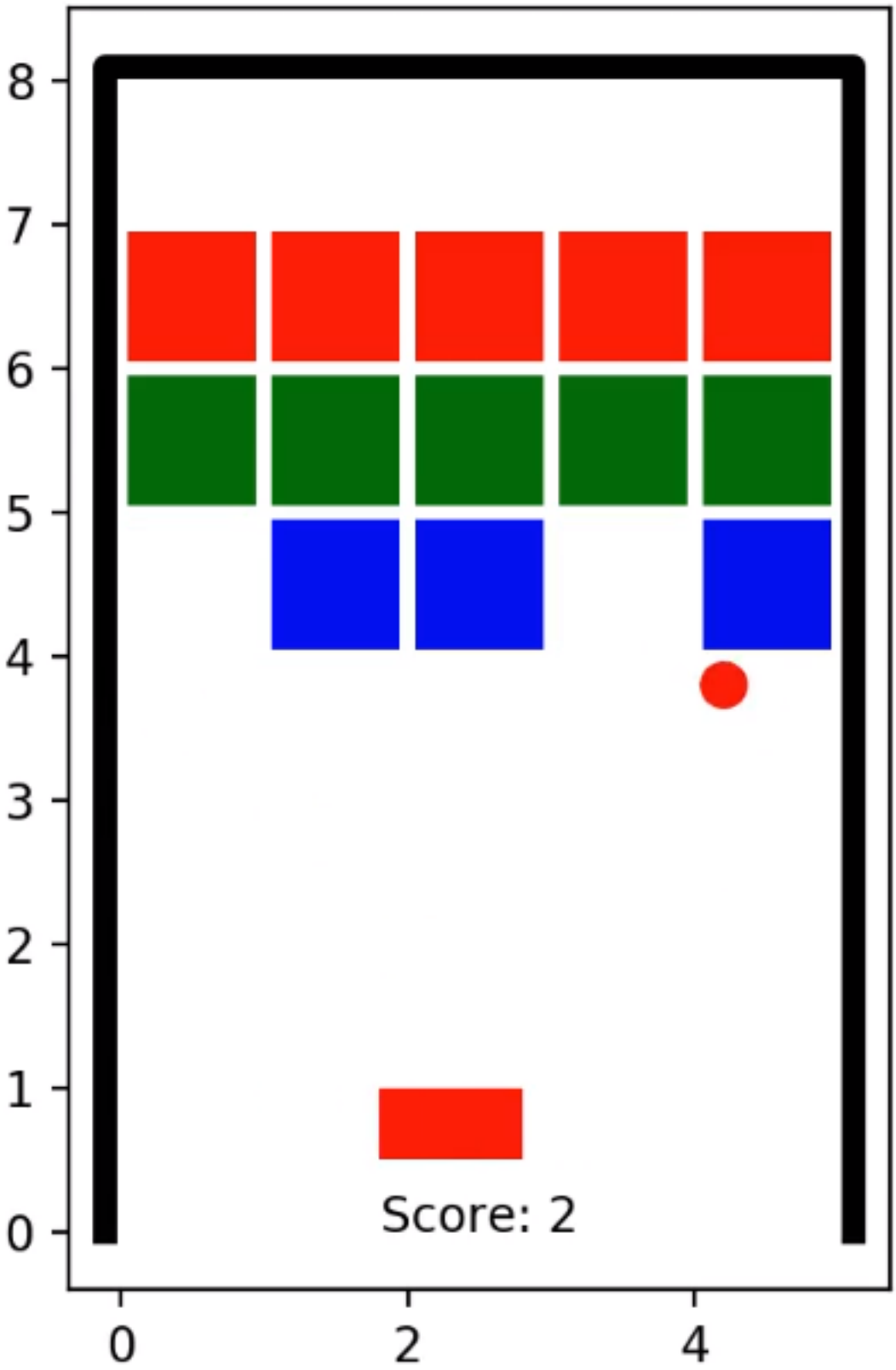
```
loss = 0.0032  av_r = 3.2400  r =  9  av_steps = 25.1  episode = 3000  epsilon=0.35
loss = 0.0161  av_r = 3.7600  r =  0  av_steps = 28.8  episode = 3050  epsilon=0.34
loss = 0.0030  av_r = 4.1000  r = 10  av_steps = 30.6  episode = 3100  epsilon=0.33
loss = 0.0040  av_r = 4.2800  r = 12  av_steps = 31.9  episode = 3150  epsilon=0.32
loss = 0.0031  av_r = 4.0800  r =  1  av_steps = 30.6  episode = 3200  epsilon=0.31
loss = 0.0082  av_r = 6.0200  r = 14  av_steps = 47.8  episode = 3250  epsilon=0.30
loss = 0.0224  av_r = 4.9400  r = 10  av_steps = 39.9  episode = 3300  epsilon=0.28
loss = 0.0078  av_r = 4.6400  r =  4  av_steps = 35.5  episode = 3350  epsilon=0.27
loss = 0.0039  av_r = 4.9400  r =  9  av_steps = 36.7  episode = 3400  epsilon=0.26
loss = 0.0113  av_r = 4.7400  r =  4  av_steps = 38.8  episode = 3450  epsilon=0.25
loss = 0.0020  av_r = 5.7200  r =  4  av_steps = 44.7  episode = 3500  epsilon=0.24
loss = 0.0024  av_r = 5.9600  r =  1  av_steps = 46.5  episode = 3550  epsilon=0.23
loss = 0.0058  av_r = 5.1800  r =  0  av_steps = 45.0  episode = 3600  epsilon=0.22
loss = 0.0085  av_r = 6.6600  r =  8  av_steps = 54.2  episode = 3650  epsilon=0.21
loss = 0.0017  av_r = 7.0600  r = 11  av_steps = 61.4  episode = 3700  epsilon=0.20
loss = 0.0025  av_r = 7.1000  r =  2  av_steps = 60.4  episode = 3750  epsilon=0.19
loss = 0.0025  av_r = 7.9200  r = 15  av_steps = 67.2  episode = 3800  epsilon=0.18
loss = 0.0032  av_r = 7.8200  r = 15  av_steps = 68.2  episode = 3850  epsilon=0.16
loss = 0.0078  av_r = 8.2600  r =  5  av_steps = 76.0  episode = 3900  epsilon=0.15
loss = 0.0008  av_r = 8.3200  r =  0  av_steps = 76.2  episode = 3950  epsilon=0.14
loss = 0.0015  av_r = 6.6200  r = 10  av_steps = 54.5  episode = 4000  epsilon=0.13
loss = 0.0012  av_r = 7.1800  r =  3  av_steps = 61.1  episode = 4050  epsilon=0.12
loss = 0.0003  av_r = 9.1000  r = 11  av_steps = 79.6  episode = 4100  epsilon=0.11
loss = 0.0012  av_r = 9.6800  r = 15  av_steps = 100.1  episode = 4150  epsilon=0.10
loss = 0.0003  av_r = 9.9600  r = 12  av_steps = 100.9  episode = 4200  epsilon=0.10
loss = 0.0031  av_r = 9.7200  r = 13  av_steps = 90.2  episode = 4250  epsilon=0.10
loss = 0.0119  av_r = 9.6600  r = 14  av_steps = 85.6  episode = 4300  epsilon=0.10
loss = 0.0038  av_r = 8.6400  r = 14  av_steps = 71.7  episode = 4350  epsilon=0.10
loss = 0.0014  av_r = 10.6000  r = 15  av_steps = 98.2  episode = 4400  epsilon=0.10
loss = 0.0020  av_r = 10.2600  r =  1  av_steps = 98.6  episode = 4450  epsilon=0.10
loss = 0.0003  av_r = 9.6200  r =  1  av_steps = 79.5  episode = 4500  epsilon=0.10
loss = 0.0038  av_r = 9.4400  r =  0  av_steps = 82.8  episode = 4550  epsilon=0.10
```

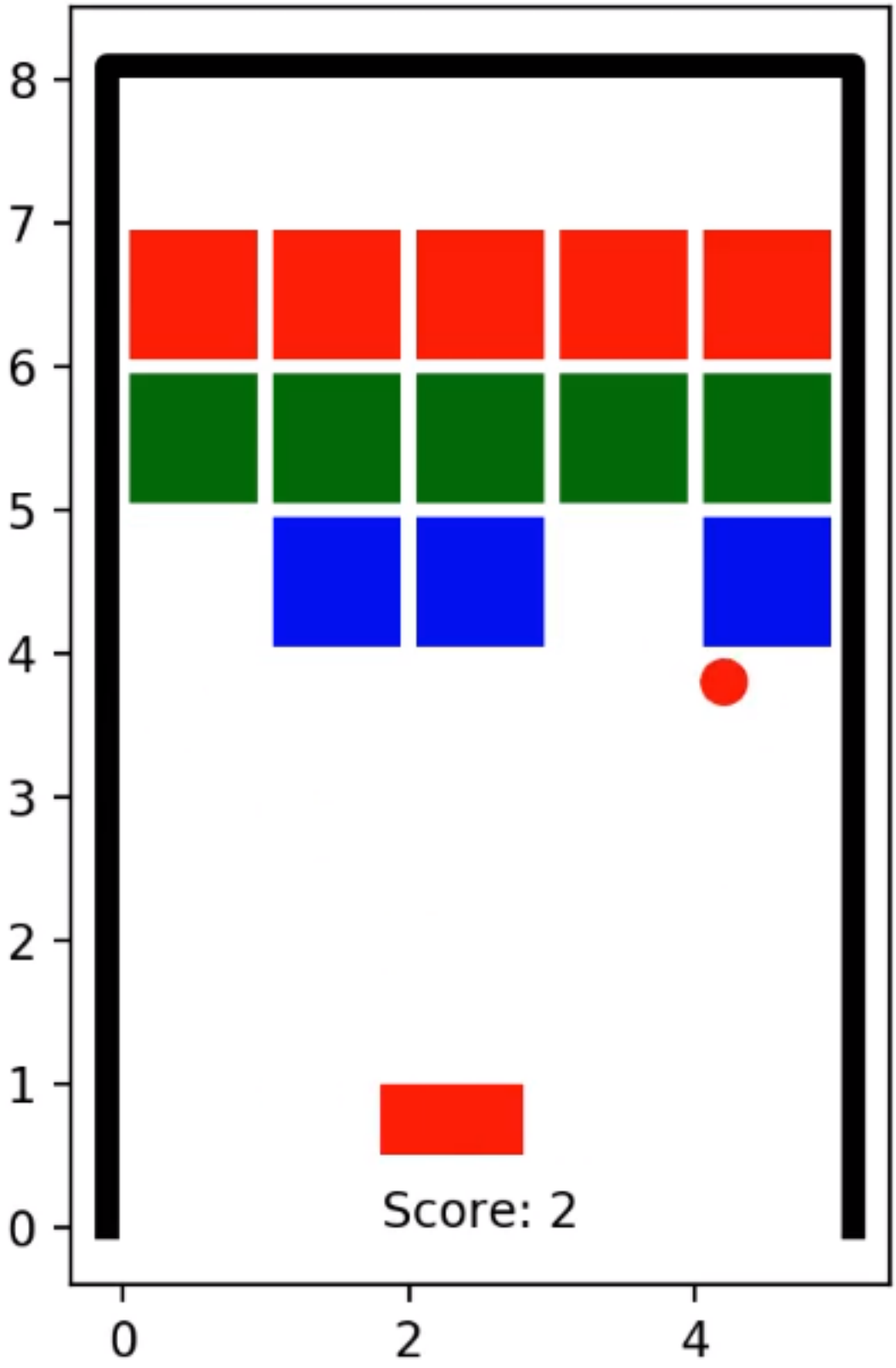
```
In [9]: print("\nTesting \n")
        env_s = env.reset()
        ep_r = []
        env_done = 0
        for t in range(max_steps):
            env_q = agent.behav_q(env_s)
            env_a = np.random.choice(np.where(env_q[0] == np.max(env_q))[0])
            env_sn, env_r, env_done, _,_,_,_,_,_,_,_ = env.run(env_a - 1)
            ep_r += [env_r]
            if env_done == 1:
                break
            env_s = env_sn

        print("obtained reward = %2d in %3d steps" % (np.sum(ep_r), len(ep_r)))
```

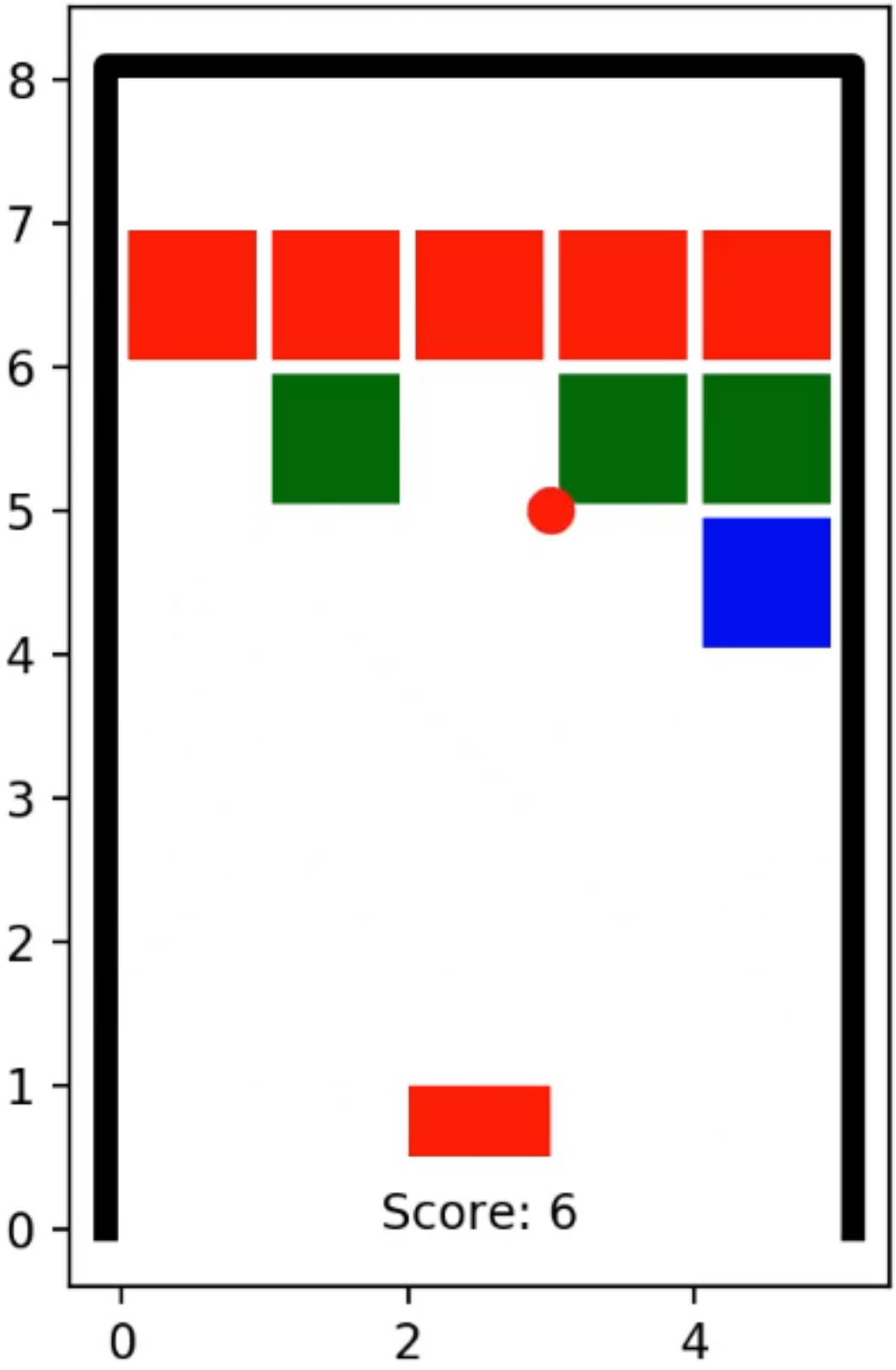
```
Testing

obtained reward = 15 in 115 steps
```

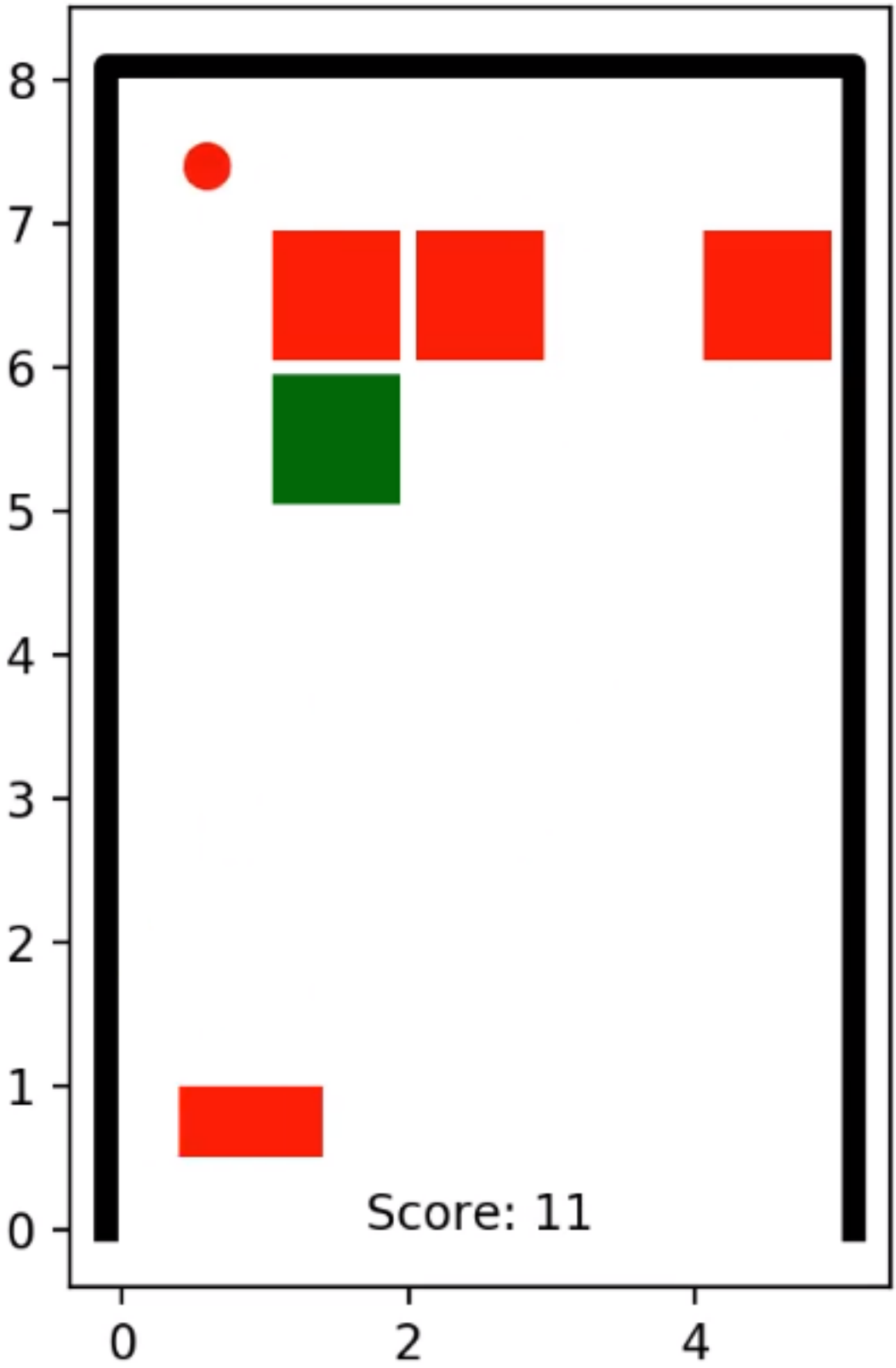
3 Screentshots from the game

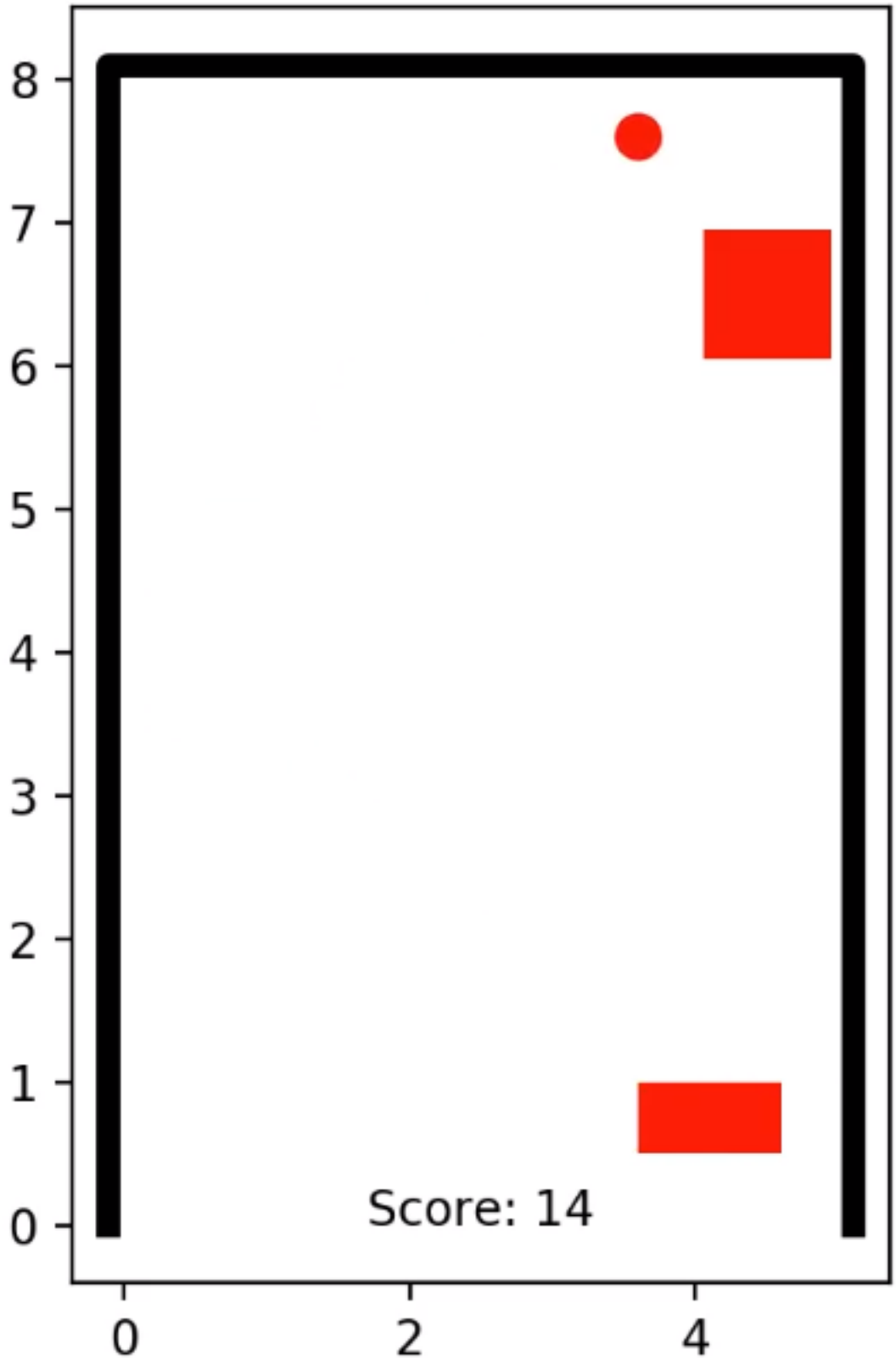
```
In [26]: from IPython.display import Image
         from IPython.display import display
         res = []
         #for ima in ['br1.png','br2.png','br3.png','br4.png','br5.png']:
         x1 = Image(filename='br1.png', width=250)
         x2 = Image(filename='br2.png', width=250)
         x3 = Image(filename='br3.png', width=250)
         x4 = Image(filename='br4.png', width=250)
         x5 = Image(filename='br5.png', width=250)
         display(x1,x2,x3,x4,x5)
```


8
7
6
5
4
3
2
1
0
0
2
4
Score: 2


8
7
6
5
4
3
2
1
0
0
2
4
Score: 2


8
7
6
5
4
3
2
1
0
0
2
4
Score: 6


8
7
6
5
4
3
2
1
0
0
2
4
Score: 11


8
7
6
5
4
3
2
1
0
0
2
4
Score: 14

4 Breakout Animation

```
In [ ]: import numpy as np
        import matplotlib.pyplot as plt
        import matplotlib.animation as animation
        import matplotlib.patches as patches
        import tensorflow as tf


        class breakout_animation(animation.TimedAnimation):
            def __init__(self, env, max_steps, frames_per_step = 5):
                self.env = env
                self.agent = self.initialize_agent()
                self.max_steps = max_steps

                fig = plt.figure()
                ax = fig.add_subplot(111)
                ax.set_aspect('equal')
                self.objs = []

                # boundary
                w = 0.1
                ax.plot([-w,-w,env.nx+w,env.nx+w],[0,env.ny+w,env.ny+w,0],'k-',linewidth=5)

                # bricks
                wb = 0.05
                self.bricks = []
                self.brick_colors = [['red'], ['blue','red'], ['blue','green','red'], \
                        ['blue','green','yellow','red'], ['blue','green','yellow',\
                        'orange','red'], ['purple','blue','green','yellow','brown',\
                        'orange','red'], ['purple','blue','green','yellow','brown',\
                                                                'orange','red']]
                for y in range(self.env.nb):
                    b = []
                    yp = y + (self.env.ny - self.env.nt - self.env.nb)
                    for x in range(self.env.nx):
                        b.append(patches.Rectangle((x + wb, yp + wb), 1-2*wb, 1-2*wb, \
                        edgecolor='none', facecolor=self.brick_colors[self.env.nb-1][y]))
                        ax.add_patch(b[x])
                        self.objs.append(b[x])
                    self.bricks.append(b)

                # ball
                self.ball = patches.Circle(env.get_ball_pos(0.), radius = 0.15, color = 'red')
```

```
        ax.add_patch(self.ball)
        self.objs.append(self.ball)

        # score text
        self.text = ax.text(0.5 * env.nx, 0, '', ha='center')
        self.objs.append(self.text)

        # game over text
        self.gameover_text = ax.text(0.5 * env.nx, 0.5 * env.ny, '', ha='center')
        self.objs.append(self.gameover_text)

        self.frames_per_step = frames_per_step
        self.total_frames = self.frames_per_step * self.max_steps

        # paddle
        self.paddle = patches.Rectangle((env.p, 0.5), 1, 0.5, edgecolor='none', facecolo
        ax.add_patch(self.paddle)

        # for early termination of animation
        self.iter_objs = []
        self.iter_obj_cnt = 0

        # interval = 50msec
        animation.TimedAnimation.__init__(self, fig, interval=50, repeat=False, blit=Fal

    def initialize_agent(self):
        sess = tf.InteractiveSession()
        agent = DQN(env)
        tf.group(tf.global_variables_initializer(), tf.local_variables_initializer()).ru
        agent.copy_parameters()
        saver = tf.train.Saver()
        saver.restore(sess, "./breakout.ckpt")
        return agent

    def _draw_frame(self, k):
        if self.terminal:
            return
        if k == 0:
            self.iter_obj_cnt -= 1
        if k % self.frames_per_step == 0:
            # take action to maximize Q value
            env_q = self.agent.behav_q(self.env.s)
            env_a = np.random.choice(np.where(env_q[0] == np.max(env_q))[0])
            self.a = env_a - 1
            self.p = self.env.p
            self.pn = min(max(self.p + self.a, 0), self.env.nx - 1)

        t = (k % self.frames_per_step) * 1. / self.frames_per_step
```

```
            self.ball.center = self.env.get_ball_pos(t)
            self.paddle.set_x(t * self.pn + (1-t) * self.p)

            if k % self.frames_per_step == self.frames_per_step - 1:
                sn, reward, terminal, p0, p, bx0, by0, vx0, vy0, rx, ry = \
                                                        self.env.run(self.a)
                self.sum_reward += reward
                if reward > 0.:
                    self.bricks[ry][rx].set_facecolor('none')
                    self.text.set_text('Score: %d' % self.sum_reward)
                if terminal:
                    self.terminal = terminal
                    self.gameover_text.set_text('Game Over')
                    for _ in range(self.total_frames - k - 1):
                        self.iter_objs[self.iter_obj_cnt].next()

            self._drawn_artists = self.objs

        def new_frame_seq(self):
            iter_obj = iter(range(self.total_frames))
            self.iter_objs.append(iter_obj)
            self.iter_obj_cnt += 1
            return iter_obj

        def _init_draw(self):
            _ = self.env.reset()
            self.sum_reward = 0.
            self.p = self.env.p     # current paddle position
            self.pn = self.p        # next paddle position
            self.a = 0              # action
            self.terminal = 0

            for y in range(self.env.nb):
                for x in range(self.env.nx):
                    self.bricks[y][x].set_facecolor(self.brick_colors[self.env.nb-1][y])

            self.ball.center = self.env.get_ball_pos(0.)
            self.paddle.set_x(self.p)

            self.text.set_text('Score: 0')
            self.gameover_text.set_text('')


    class DQN:
        def __init__(self, env):
            # state size [ny, nx, nf]
            self.s = tf.placeholder(tf.float32, shape=[None, env.ny, env.nx, env.nf])
            self.a = tf.placeholder(tf.int32, shape=[None])
```

```
        self.batch_size = tf.placeholder(tf.int32, shape=[])
        self.bootstraped = tf.placeholder(tf.float32, shape=[None])
        self.ch1 = 80
        self.env = env

        W_fc1 = tf.Variable(tf.truncated_normal([env.nx*env.ny*env.nf, self.ch1], \
                                                stddev=0.1))
        b_fc1 = tf.Variable(tf.constant(0.1, shape=[self.ch1]))
        W_fc2 = tf.Variable(tf.truncated_normal([self.ch1, env.na], stddev=0.1))
        b_fc2 = tf.Variable(tf.constant(0.1, shape=[env.na]))

        h_flat = tf.reshape(self.s, [self.batch_size, -1])
        fc1 = tf.matmul(h_flat, W_fc1) + b_fc1
        self.q = tf.matmul(tf.nn.relu(fc1), W_fc2) + b_fc2
        action_one_hot = tf.one_hot(self.a, env.na, 1.0, 0.0, name='action_one_hot')
        self.q_a = tf.reduce_sum(self.q * action_one_hot, reduction_indices=1, name='q_a

        self.optim = tf.train.RMSPropOptimizer(0.0002, momentum=0.95, epsilon=0.01)
        self.theta = [W_fc1, b_fc1, W_fc2, b_fc2]
        self.target_init()

        losses = tf.squared_difference(self.bootstraped, self.q_a)
        self.loss = tf.reduce_mean(losses)
        self.train_step = self.optim.minimize(self.loss)

    def copy_parameters(self):
        for i in range(len(self.theta)):
            self.theta_[i].assign(self.theta[i]).eval()

    def target_init(self):
        self.theta_ = []
        for param in self.theta:
            self.theta_ += [tf.Variable(tf.truncated_normal(tf.shape(param), \
                                                            stddev=0.1))]
        W_fc1, b_fc1, W_fc2, b_fc2 = self.theta_

        h_flat = tf.reshape(self.s, [self.batch_size, -1])
        fc1 = tf.matmul(h_flat, W_fc1) + b_fc1
        self.q_ = tf.matmul(tf.nn.relu(fc1), W_fc2) + b_fc2
        self.q_max_ = tf.reduce_max(self.q_, axis=1)

    def train_iter(self, s, a, bootstraped):
        loss = self.loss.eval(feed_dict={self.s: s, self.a: a, self.batch_size: \
                                         s.shape[0],self.bootstraped:bootstraped})
        self.train_step.run(feed_dict={self.s: s, self.a: a, self.batch_size: \
                                       s.shape[0], self.bootstraped:bootstraped})
        return loss
```

```
    def target_q(self, s):
        return self.q_max_.eval(feed_dict={self.s: s, self.batch_size: s.shape[0]})

    def behav_q(self, s):
        return self.q.eval(feed_dict={self.s: np.expand_dims(s, axis=0), \
                                      self.batch_size: 1})



from breakout_env import *
from wait import *

env = breakout_environment(nx = 5, ny = 8, nb = 3, nt = 1, nf = 2)
ani = breakout_animation(env, 200)
#ani.save('breakout.mp4', dpi=200)
plt.show(block=False)
wait('Press enter to quit')
```