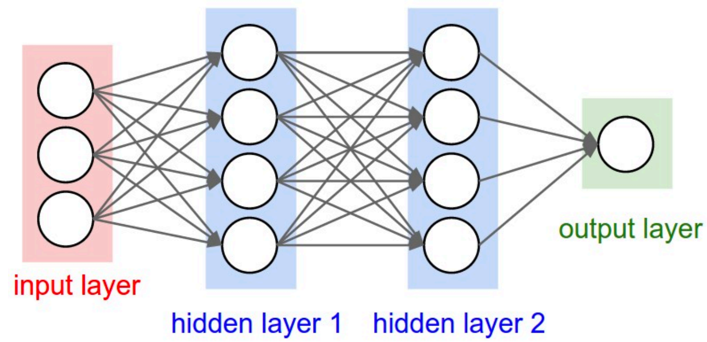

Lab 6-2: Q Network for Cart Pole

Reinforcement Learning with TensorFlow&OpenAI Gym

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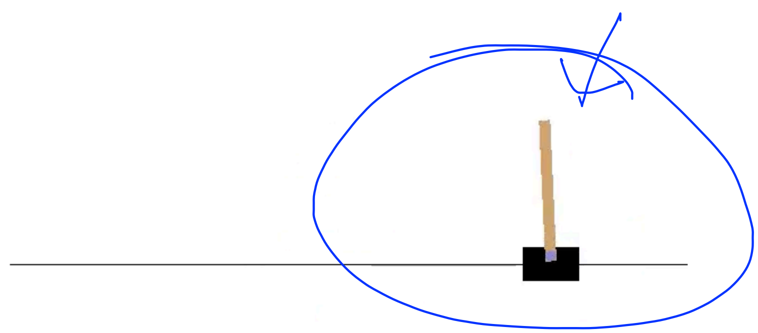
Cart Pole

```
import gym
env = gym.make('CartPole-v0')
env.reset()
for _ in range(1000):
    env.render()
    env.step(env.action_space.sample()) # take a random action
```

It should look something like this:



https://gym.openai.com/docs

Random trials

State reward Done

```
[-0.01760681 -0.21040623  0.0050548   0.33178224] 1.0 False
[-0.02181493 -0.40559977  0.01169044  0.6260549 ] 1.0 False
[-0.02992693 -0.60088294  0.02421154  0.92239656] 1.0 False
[-0.04194459 -0.79632351  0.04265947  1.22258898] 1.0 False
[-0.05787106 -0.60177631  0.06711125  0.94357177] 1.0 False
[-0.06990658 -0.79773512  0.08598269  1.25656419] 1.0 False
[-0.08586128 -0.60381257  0.11111397  0.99200273] 1.0 False
[-0.09793754 -0.41033868  0.13095402  0.7361819 ] 1.0 False
[-0.10614431 -0.60700289  0.14567766  1.06704293] 1.0 False
[-0.11828437 -0.80372008  0.16701852  1.40167111] 1.0 False
[-0.13435877 -0.61102015  0.19505194  1.16551887] 1.0 False
[-0.14657917 -0.41889634  0.21836232  0.93978019] 1.0 True
Reward for this episode was: 12.0
```

```python
import gym

env = gym.make('CartPole-v0')
env.reset()
random_episodes = 0
reward_sum = 0
while random_episodes < 10:
    env.render()
    action = env.action_space.sample()
    observation, reward, done, _ = env.step(action)
    print(observation, reward, done)
    reward_sum += reward
    if done:
        random_episodes += 1
        print("Reward for this episode was:",reward_sum)
        reward_sum = 0
        env.reset()
```

Rewards

```
[-0.01760681 -0.21040623  0.0050548   0.33178224] 1.0 False
[-0.02181493 -0.40559977  0.01169044  0.6260549 ] 1.0 False
[-0.02992693 -0.60088294  0.02421154  0.92239656] 1.0 False
[-0.04194459 -0.79632351  0.04265947  1.22258898] 1.0 False
[-0.05787106 -0.60177631  0.06711125  0.94357177] 1.0 False
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[-0.11828437 -0.80372008  0.16701852  1.40167111] 1.0 False
[-0.13435877 -0.61102015  0.19505194  1.16551887] 1.0 False
[-0.14657917 -0.41889634  0.21836232  0.93978019] 1.0 True
Reward for this episode was: 12.0
```
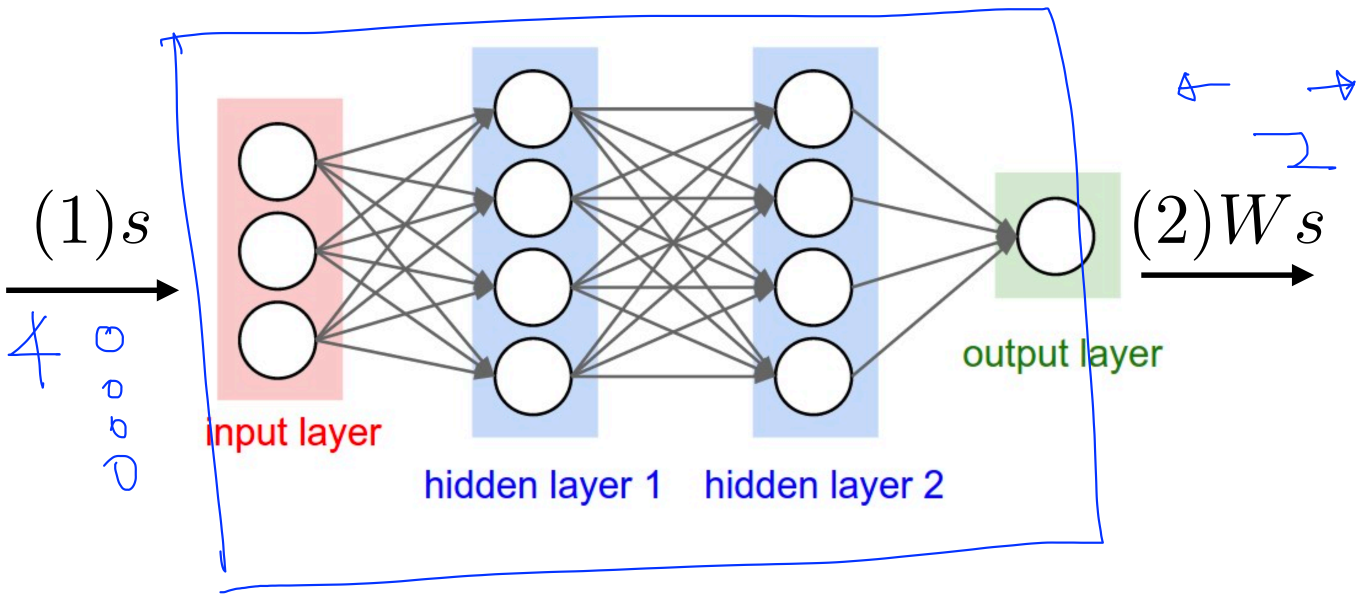
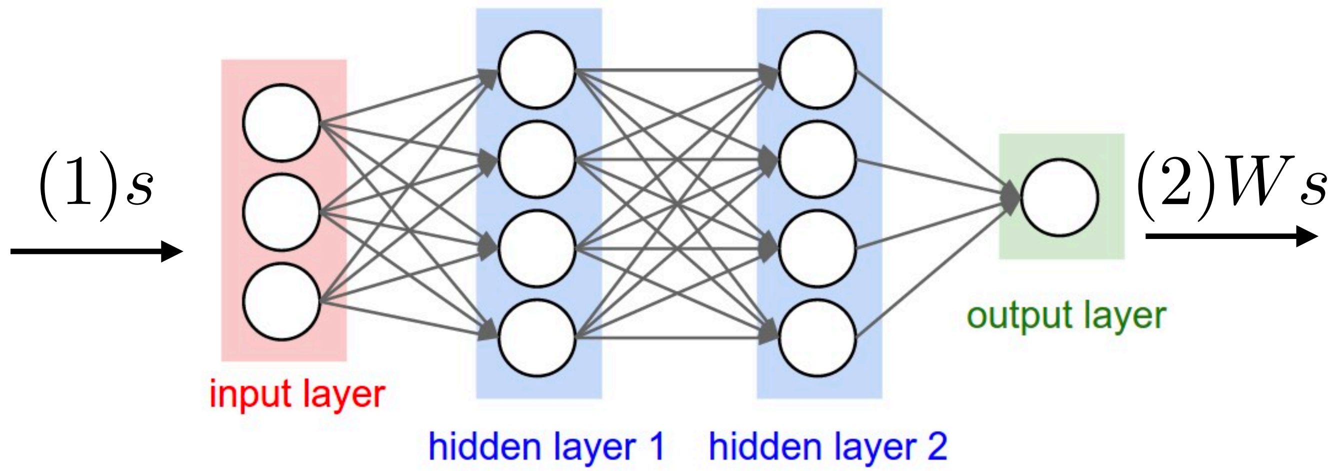

```python
# Get new state and reward from environment
s1, reward, done, _ = env.step(a)
if done:
    Qs[0, a] = -100
else:
    x1 = np.reshape(s1, [1, input_size])
    # Obtain the Q' values by feeding the new state through our network
    Qs1 = sess.run(Qpred, feed_dict={X: x1})
    Qs[0, a] = reward + dis * np.max(Qs1)
```

Cart Pole Q-network



Q-Network training (Network construction)

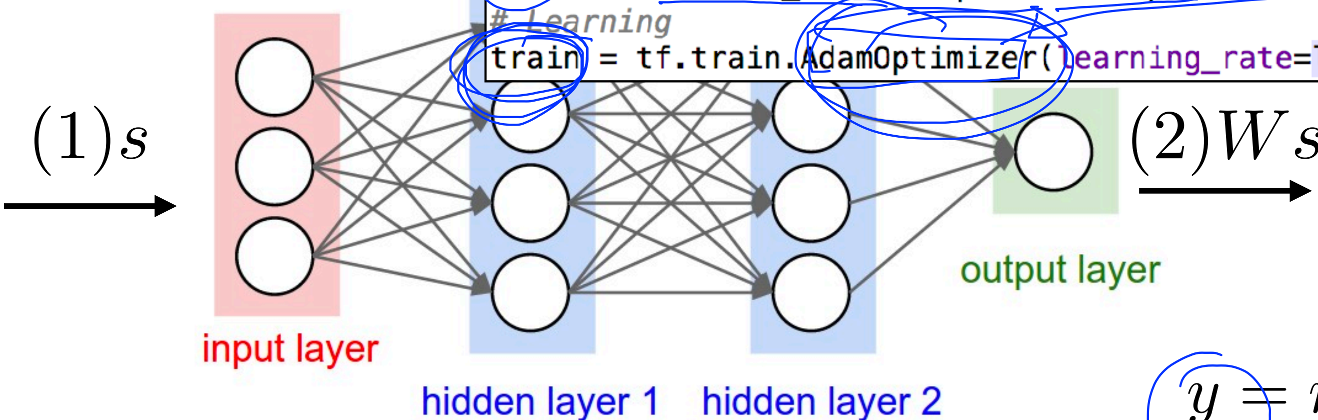



```
input_size = env.observation_space.shape[0]
output_size = env.action_space.n

X = tf.placeholder(tf.float32, [None, input_size], name="input_x")

# First layer of weights
W1 = tf.get_variable("W1", shape=[input_size, output_size],
                     initializer=tf.contrib.layers.xavier_initializer())
Qpred = tf.matmul(X, W1)
```

Q-Network training (linear regression)

$$cost(W) = (Ws - y)^2$$

```
Qpred = tf.matmul(X, W1)

# We need to define the parts of the network needed for learning a policy
Y = tf.placeholder(shape=[None, output_size],dtype=tf.float32)

# Loss function
loss = tf.reduce_sum(tf.square(Y - Qpred))
# Learning
train = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(loss)
```



$$y = r + \gamma \max Q(s')$$

```
    Qs[0, a] = reward + dis * np.max(Qs1)

# Train our network using target and predicted Q values on each episode
sess.run(train, feed_dict={X: x, Y: Qs})
```

Code: Network and setup

```
import numpy as np
import tensorflow as tf

import gym
env = gym.make('CartPole-v0')

# Constants defining our neural network
learning_rate = 1e-1
input_size = env.observation_space.shape[0]
output_size = env.action_space.n

X = tf.placeholder(tf.float32, [None, input_size], name="input_x")

# First layer of weights
W1 = tf.get_variable("W1", shape=[input_size, output_size],
                     initializer=tf.contrib.layers.xavier_initializer())
Qpred = tf.matmul(X, W1)

# We need to define the parts of the network needed for learning a policy
Y = tf.placeholder(shape=[None, output_size],dtype=tf.float32)

# Loss function
loss = tf.reduce_sum(tf.square(Y - Qpred))
# Learning
train = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(loss)

# Values for q learning
num_episodes = 2000
dis = 0.9
rList = []
```

gradient descent step on $\left(y_j - Q(\phi_j, a_j; \theta)\right)^2$

Code: Training

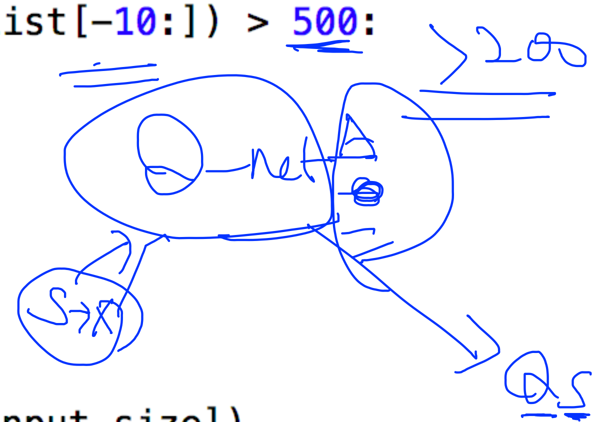
$$\text{preprocess } \phi_{t+1} = \phi(s_{t+1})$$

$$\text{Set } y_j = \begin{cases} r_j & \text{for terminal } \phi_{j+1} \\ r_j + \gamma \max_{a'} Q(\phi_{j+1}, a'; \theta) & \text{for non-terminal } \phi_{j+1} \end{cases}$$

```
for i in range(num_episodes):
    e = 1. / ((i / 10) + 1)
    rAll = 0
    step_count = 0
    s = env.reset()
    done = False

    # The Q-Network training
    while not done:
        step_count += 1
        x = np.reshape(s, [1, input_size])
        # Choose an action by greedily (with e chance of random action) from the Q-network
        Qs = sess.run(Qpred, feed_dict={X: x})
        if np.random.rand(1) < e:
            a = env.action_space.sample()
        else:
            a = np.argmax(Qs)

        # Get new state and reward from environment
        s1, reward, done, _ = env.step(a)
        if done:
            Qs[0, a] = -100
        else:
            x1 = np.reshape(s1, [1, input_size])
            # Obtain the Q' values by feeding the new state through our network
            Qs1 = sess.run(Qpred, feed_dict={X: x1})
            Qs[0, a] = reward + dis * np.max(Qs1)

        # Train our network using target and predicted Q values on each episode
        sess.run(train, feed_dict={X: x, Y: Qs})
        s = s1

    rList.append(step_count)
    print("Episode: {}  steps: {}".format(i, step_count))
    # If last 10's avg steps are 500, it's good enough
    if len(rList) > 10 and np.mean(rList[-10:]) > 500:
        break
```

Code: apply

```
    rList.append(step_count)
    print("Episode: {}  steps: {}".format(i, step_count))
    # If last 10's avg steps are 500, it's good enough
    if len(rList) > 10 and np.mean(rList[-10:]) > 500:
        break

# See our trained network in action
observation = env.reset()
reward_sum = 0
while True:
    env.render()

    x = np.reshape(observation, [1, input_size])
    Qs = sess.run(Qpred, feed_dict={X: x})
    a = np.argmax(Qs)

    observation, reward, done, _ = env.step(a)
    reward_sum += reward
    if done:
        print("Total score: {}".format(reward_sum))
        break
```



Results: really poor!

```
Episode: 1988  steps: 14
Episode: 1989  steps: 25
Episode: 1990  steps: 15
Episode: 1991  steps: 23
Episode: 1992  steps: 19
Episode: 1993  steps: 17
Episode: 1994  steps: 46
Episode: 1995  steps: 20
Episode: 1996  steps: 17
Episode: 1997  steps: 15
Episode: 1998  steps: 33
Episode: 1999  steps: 22
2017-02-08 16:59:31.216 Python[7525:2769691
Total score: 15.0
```

Why does not work? Too shallow?

```
X = tf.placeholder(tf.float32, [None, input_size], name="input_x")

# First layer of weights
W1 = tf.get_variable("W1", shape=[input_size, output_size],
                     initializer=tf.contrib.layers.xavier_initializer())
Qpred = tf.matmul(X, W1)
```

- But diverges using neural networks due to:
  - Correlations between samples
  - Non-stationary targets

Excise

- Why does not work?
- Hint: DQN