In [1]:

```
# install required system dependencies
!apt-get install -y xvfb x11-utils
!apt-get install x11-utils > /dev/null 2>&1
!pip install PyVirtualDisplay==2.0.* \
  PyOpenGL==3.1.* \
  PyOpenGL-accelerate==3.1.* \
  gym[box2d]==0.17.*
!pip install pyglet
```

```
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libxxf86dga1
Suggested packages:
  mesa-utils
The following NEW packages will be installed:
  libxxf86dga1 x11-utils xvfb
0 upgraded, 3 newly installed, 0 to remove and 30 not upgraded.
Need to get 993 kB of archives.
After this operation, 2,981 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu (http://archive.ubuntu.com/ubuntu) bio
nic/main amd64 libxxf86dga1 amd64 2:1.1.4-1 [13.7 kB]
Get:2 http://archive.ubuntu.com/ubuntu (http://archive.ubuntu.com/ubuntu) bio
nic/main amd64 x11-utils amd64 7.7+3build1 [196 kB]
Get:3 http://archive.ubuntu.com/ubuntu (http://archive.ubuntu.com/ubuntu) bio
nic-updates/universe amd64 xvfb amd64 2:1.19.6-1ubuntu4.8 [784 kB]
Fetched 993 kB in 0s (8,110 kB/s)
Selecting previously unselected package libxxf86dga1:amd64.
(Reading database ... 160980 files and directories currently installed.)
Preparing to unpack .../libxxf86dga1_2%3a1.1.4-1_amd64.deb ...
Unpacking libxxf86dga1:amd64 (2:1.1.4-1) ...
Selecting previously unselected package x11-utils.
Preparing to unpack .../x11-utils_7.7+3build1_amd64.deb ...
Unpacking x11-utils (7.7+3build1) ...
Selecting previously unselected package xvfb.
Preparing to unpack .../xvfb_2%3a1.19.6-1ubuntu4.8_amd64.deb ...
Unpacking xvfb (2:1.19.6-1ubuntu4.8) ...
Setting up xvfb (2:1.19.6-1ubuntu4.8) ...
Setting up libxxf86dga1:amd64 (2:1.1.4-1) ...
Setting up x11-utils (7.7+3build1) ...
Processing triggers for man-db (2.8.3-2ubuntu0.1) ...
Processing triggers for libc-bin (2.27-3ubuntu1.2) ...
/sbin/ldconfig.real: /usr/local/lib/python3.7/dist-packages/ideep4py/lib/libm
kldnn.so.0 is not a symbolic link

Collecting PyVirtualDisplay==2.0.*
  Downloading https://files.pythonhosted.org/packages/ad/05/6568620fed440941b
704664b9cfe5f836ad699ac7694745e7787fbdc8063/PyVirtualDisplay-2.0-py2.py3-none
-any.whl (https://files.pythonhosted.org/packages/ad/05/6568620fed440941b7046
64b9cfe5f836ad699ac7694745e7787fbdc8063/PyVirtualDisplay-2.0-py2.py3-none-an
y.whl)
Requirement already satisfied: PyOpenGL==3.1.* in /usr/local/lib/python3.7/di
st-packages (3.1.5)
Collecting PyOpenGL-accelerate==3.1.*
  Downloading https://files.pythonhosted.org/packages/a2/3c/f42a62b7784c04b20
```

```
f8b88d6c8ad04f4f20b0767b721102418aad94d8389/PyOpenGL-accelerate-3.1.5.tar.gz
 (https://files.pythonhosted.org/packages/a2/3c/f42a62b7784c04b20f8b88d6c8ad0
4f4f20b0767b721102418aad94d8389/PyOpenGL-accelerate-3.1.5.tar.gz) (538kB)
     |████████████████████████████████| 542kB 14.4MB/s
Requirement already satisfied: gym[box2d]==0.17.* in /usr/local/lib/python3.
7/dist-packages (0.17.3)
Collecting EasyProcess
  Downloading https://files.pythonhosted.org/packages/48/3c/75573613641c90c6d
094059ac28adb748560d99bd27ee6f80cce398f404e/EasyProcess-0.3-py2.py3-none-any.
whl (https://files.pythonhosted.org/packages/48/3c/75573613641c90c6d094059ac2
8adb748560d99bd27ee6f80cce398f404e/EasyProcess-0.3-py2.py3-none-any.whl)
Requirement already satisfied: cloudpickle<1.7.0,>=1.2.0 in /usr/local/lib/py
thon3.7/dist-packages (from gym[box2d]==0.17.*) (1.3.0)
Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-package
s (from gym[box2d]==0.17.*) (1.4.1)
Requirement already satisfied: pyglet<=1.5.0,>=1.4.0 in /usr/local/lib/python
3.7/dist-packages (from gym[box2d]==0.17.*) (1.5.0)
Requirement already satisfied: numpy>=1.10.4 in /usr/local/lib/python3.7/dist
-packages (from gym[box2d]==0.17.*) (1.19.5)
Collecting box2d-py~=2.3.5; extra == "box2d"
  Downloading https://files.pythonhosted.org/packages/87/34/da5393985c3ff9a76
351df6127c275dcb5749ae0abbe8d5210f06d97405d/box2d_py-2.3.8-cp37-cp37m-manylin
ux1_x86_64.whl (https://files.pythonhosted.org/packages/87/34/da5393985c3ff9a
76351df6127c275dcb5749ae0abbe8d5210f06d97405d/box2d_py-2.3.8-cp37-cp37m-manyl
inux1_x86_64.whl) (448kB)
     |████████████████████████████████| 450kB 35.1MB/s
Requirement already satisfied: future in /usr/local/lib/python3.7/dist-packag
es (from pyglet<=1.5.0,>=1.4.0->gym[box2d]==0.17.*) (0.16.0)
Building wheels for collected packages: PyOpenGL-accelerate
  Building wheel for PyOpenGL-accelerate (setup.py) ... done
  Created wheel for PyOpenGL-accelerate: filename=PyOpenGL_accelerate-3.1.5-c
p37-cp37m-linux_x86_64.whl size=1599120 sha256=e42d1a5d3434c83cc1dd8e4e218fe8
b45faad8360d6776a24e5769b41c1ceefb
  Stored in directory: /root/.cache/pip/wheels/bd/21/77/99670ceca25fddb3c2b60
a7ae44644b8253d1006e8ec417bcc
Successfully built PyOpenGL-accelerate
Installing collected packages: EasyProcess, PyVirtualDisplay, PyOpenGL-accele
rate, box2d-py
Successfully installed EasyProcess-0.3 PyOpenGL-accelerate-3.1.5 PyVirtualDis
play-2.0 box2d-py-2.3.8
Requirement already satisfied: pyglet in /usr/local/lib/python3.7/dist-packag
es (1.5.0)
Requirement already satisfied: future in /usr/local/lib/python3.7/dist-packag
es (from pyglet) (0.16.0)
```

In [2]:

```python
import gym
import numpy as np
import base64
import io
import IPython
import random
```

In [89]:

```
import gym
from gym import spaces
import random
import numpy as np

class CustomTaxiEnv(gym.Env):

  def __init__(self):
    self.action_space = gym.spaces.Discrete(6) #Representing 0-5
    self.observation_space = gym.spaces.Discrete(4) #(taxi_row, taxi_col, passeng
    initial_state = np.array([2,3,2,0])
    reward =  0
    done = False
    print(initial_state)
    pickup = False

  def step(self, action):
    state = initial_state
    if action == 0:
      reward -= 1
    elif action == 1:
      reward -= 1
    elif action == 2:
      reward -= 1
    elif action == 3:
      reward -= 1
    elif action == 4:
      if initial_state[2] == state:
        pickup = True
        reward -= 1
      else:
        reward -= 10  #Illegal Pickup
    elif action == 5:
      if(pickup == True):
       reward += 20  #Goal Achieved
       return state, reward, done, info
       done = True
      else:
        reward -= 10  #Illegal drop
    info = {}
    return state, done, info

  def reset(self):
    state = 0

    return state
```

In [90]:

```
env = CustomTaxiEnv()
```

```
[2 3 2 0]
```

Policy Formulation

In [91]:

```
streets = CustomTaxiEnv()
```

```
[2 3 2 0]
```

In [94]:

```
import numpy as np

q_table = np.zeros([streets.observation_space.n, streets.action_space.n])
learning_rate = 0.1
discount_factor = 0.6
exploration = 0.1
epochs = 10000

for taxi_run in range(epochs):
    state = streets.reset()
    done = False

    while not done:
        random_value = random.uniform(0, 1)
        if (random_value < exploration):
            action = streets.action_space.sample() # Explore a random action
        else:
            action = np.argmax(q_table[state]) # Use the action with the highest

        next_state, reward, done = streets.step(action)

        prev_q = q_table[state, action]
        next_max_q = np.max(q_table[next_state])
        new_q = (1 - learning_rate) * prev_q + learning_rate * (reward + discount
        q_table[state, action] = new_q

        state = next_state
```

In [ ]:

```
from IPython.display import clear_output
from time import sleep
lengths=[]
for tripnum in range(1, 11):
    state = streets.reset()

    done = False
    trip_length = 0

    while not done and trip_length < 25:
        action = np.argmax(q_table[state])
        next_state, reward, done, info = streets.step(action)
        clear_output(wait=True)
        print("Trip number " + str(tripnum) + " Step " + str(trip_length))
        print(streets.render(mode='ansi'))
        sleep(.2)
        state = next_state
        trip_length += 1
    lengths.append(trip_length)

    sleep(.2)
avg_len=sum(lengths)/10
print(avg_len)
```