424H_CW1

November 22, 2018

1 CW1 - Reinforcement Learning

Import usefull libraries.

```
In [2]: import numpy as np
        import matplotlib.pyplot as plt
        plt.rcParams["figure.figsize"] = (8,5)
```

1.1 Part 1 - Understanding of MDPs

```
In [3]: CID = "1594572"
        #CID = "12345678"
        CID = np.array([int(CID[i]) for i in range(len(CID))])
        CID

Out[3]: array([1, 5, 9, 4, 5, 7, 2])

In [4]: s = np.mod(CID + 1 ,3)
        s

Out[4]: array([2, 0, 1, 2, 0, 2, 0])

In [5]: r = np.mod(CID[1:] ,2)
        r

Out[5]: array([1, 1, 0, 1, 1, 0])

In [6]: tau = np.array([ [s[i],r[i]] for i in range(len(r))]).flatten()
        tau

Out[6]: array([2, 1, 0, 1, 1, 0, 2, 1, 0, 1, 2, 0])

In [7]: x = CID[-3]
        y = CID[-2]
        z = CID[-1]

        #Generation of personalized Data :
        j = np.mod(z+1,3)+1
        print(j)
```

```
        p= 0.25 + 0.5 *x/10.
        print(p)
        gamma = 0.3+0.5* y /10.
        print(gamma)
```

```
1
0.5
0.6499999999999999
```

1.2 Part 2 - Understanding of Grid Worlds

```
In [8]: class GridWorld(object):
            def __init__(self):

                ### Attributes defining the Gridworld #######
                # Shape of the gridworld
                self.shape = (4,4)

                # Locations of the obstacles
                self.obstacle_locs = [(2,0),(3,0),(3,1),(3,1),(3,3),(1,2)]

                # Locations for the absorbing states
                self.absorbing_locs = [(0,0),(3,2)]

                # Rewards for each of the absorbing states
                self.special_rewards = [10, -100 ] #corresponds to each of the absorbing_locs

                # Reward for all the other states
                self.default_reward = -1

                # Starting location
                self.starting_loc = (0,3)

                # Action names
                self.action_names = ['N','E','S','W']

                # Number of actions
                self.action_size = len(self.action_names)


                # Randomizing action results: [1 0 0 0] to no Noise in the action results.
                self.action_randomizing_array = [ p, (1-p)/3, (1-p)/3 , (1-p)/3]

                ############################################
```

```python
#### Internal State  ####


# Get attributes defining the world
state_size, T, R, absorbing, locs = self.build_grid_world()

# Number of valid states in the gridworld (there are 11 of them)
self.state_size = state_size

# Transition operator (3D tensor)
self.T = T

# Reward function (3D tensor)
self.R = R

# Absorbing states
self.absorbing = absorbing

# The locations of the valid states
self.locs = locs

# Number of the starting state
self.starting_state = self.loc_to_state(self.starting_loc, locs);

# Locating the initial state
self.initial = np.zeros((1,len(locs)))
self.initial[0,self.starting_state] = 1


# Placing the walls on a bitmap
self.walls = np.zeros(self.shape);
for ob in self.obstacle_locs:
    self.walls[ob]=1

# Placing the absorbers on a grid for illustration
self.absorbers = np.zeros(self.shape)
for ab in self.absorbing_locs:
    self.absorbers[ab] = -1

# Placing the rewarders on a grid for illustration
self.rewarders = np.zeros(self.shape)
for i, rew in enumerate(self.absorbing_locs):
    self.rewarders[rew] = self.special_rewards[i]

#Illustrating the grid world
self.paint_maps()
################################
```

```
####### Getters ###########

def get_transition_matrix(self):
    return self.T

def get_reward_matrix(self):
    return self.R


########################

####### Methods #########
def policy_evaluation(self, policy, threshold, discount):

    # Make sure delta is bigger than the threshold to start with
    delta= 2*threshold

    #Get the reward and transition matrices
    R = self.get_reward_matrix()
    T = self.get_transition_matrix()

    # The value is initialised at 0
    V = np.zeros(policy.shape[0])
    # Make a deep copy of the value array to hold the update during the evaluation
    Vnew = np.copy(V)

    # While the Value has not yet converged do:
    while delta>threshold:
        for state_idx in range(policy.shape[0]):
            # If it is one of the absorbing states, ignore
            if(self.absorbing[0,state_idx]):
                continue

            # Accumulator variable for the Value of a state
            tmpV = 0
            for action_idx in range(policy.shape[1]):
                # Accumulator variable for the State-Action Value
                tmpQ = 0
                for state_idx_prime in range(policy.shape[0]):
                    tmpQ = tmpQ + T[state_idx_prime,state_idx,action_idx] * (R[sta

                tmpV += policy[state_idx,action_idx] * tmpQ

            # Update the value of the state
```

```
                Vnew[state_idx] = tmpV

            # After updating the values of all states, update the delta
            delta =  max(abs(Vnew-V))
            # and save the new value into the old
            V=np.copy(Vnew)

        return V

    def draw_deterministic_policy(self, Policy):
        # Draw a deterministic policy
        # The policy needs to be a np array of 22 values between 0 and 3 with
        # 0 -> N, 1->E, 2->S, 3->W
        plt.figure()

        plt.imshow(self.walls+self.rewarders +self.absorbers)
        #plt.hold('on')
        for state, action in enumerate(Policy):
            if(self.absorbing[0,state]):
                continue
            arrows = [r"$\uparrow$",r"$\rightarrow$", r"$\downarrow$", r"$\leftarrow$"]
            action_arrow = arrows[action]
            location = self.locs[state]
            plt.text(location[1], location[0], action_arrow, ha='center', va='center')

        plt.show()
    ##########################


    ########### Internal Helper Functions #####################
    def paint_maps(self):
        plt.figure()
        plt.subplot(1,3,1)
        plt.imshow(self.walls)
        plt.subplot(1,3,2)
        plt.imshow(self.absorbers)
        plt.subplot(1,3,3)
        plt.imshow(self.rewarders)
        plt.show()

    def build_grid_world(self):
        # Get the locations of all the valid states, the neighbours of each state (by
        # and the absorbing states (array of 0's with ones in the absorbing states)
        locations, neighbours, absorbing = self.get_topology()

        # Get the number of states
        S = len(locations)
```

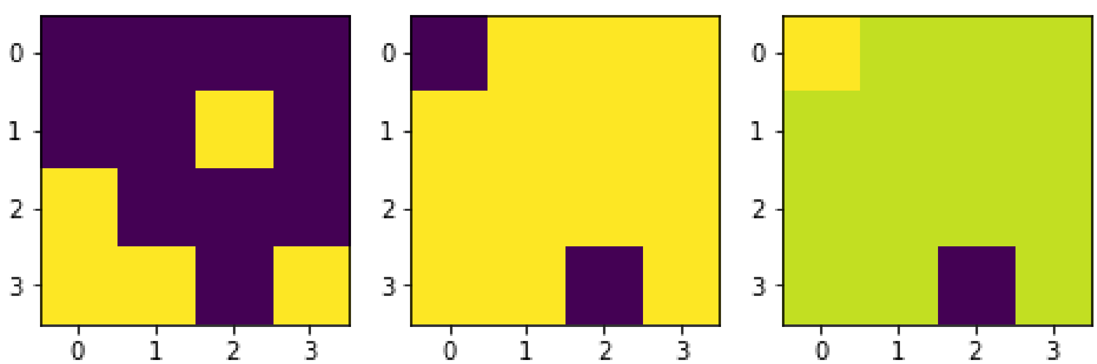
```
        # Initialise the transition matrix
        T = np.zeros((S,S,4))

        for action in range(4):
            for effect in range(4):

                # Randomize the outcome of taking an action
                outcome = (action+effect+1) % 4
                if outcome == 0:
                    outcome = 3
                else:
                    outcome -= 1

                # Fill the transition matrix
                prob = self.action_randomizing_array[effect]
                for prior_state in range(S):
                    post_state = neighbours[prior_state, outcome]
                    post_state = int(post_state)
                    T[post_state,prior_state,action] = T[post_state,prior_state,action]


        # Build the reward matrix
        R = self.default_reward*np.ones((S,S,4))
        for i, sr in enumerate(self.special_rewards):
            post_state = self.loc_to_state(self.absorbing_locs[i],locations)
            R[post_state,:,:]= sr

        return S, T,R,absorbing,locations

    def get_topology(self):
        height = self.shape[0]
        width = self.shape[1]

        index = 1
        locs = []
        neighbour_locs = []

        for i in range(height):
            for j in range(width):
                # Get the locaiton of each state
                loc = (i,j)

                #And append it to the valid state locations if it is a valid state (ie
                if(self.is_location(loc)):
                    locs.append(loc)

                    # Get an array with the neighbours of each state, in terms of loca
                    local_neighbours = [self.get_neighbour(loc,direction) for directio
```

```
                neighbour_locs.append(local_neighbours)

        # translate neighbour lists from locations to states
        num_states = len(locs)
        state_neighbours = np.zeros((num_states,4))

        for state in range(num_states):
            for direction in range(4):
                # Find neighbour location
                nloc = neighbour_locs[state][direction]

                # Turn location into a state number
                nstate = self.loc_to_state(nloc,locs)

                # Insert into neighbour matrix
                state_neighbours[state,direction] = nstate;


        # Translate absorbing locations into absorbing state indices
        absorbing = np.zeros((1,num_states))
        for a in self.absorbing_locs:
            absorbing_state = self.loc_to_state(a,locs)
            absorbing[0,absorbing_state] =1

        return locs, state_neighbours, absorbing





    def loc_to_state(self,loc,locs):
        #takes list of locations and gives index corresponding to input loc
        return locs.index(tuple(loc))


    def is_location(self, loc):
        # It is a valid location if it is in grid and not obstacle
        if(loc[0]<0 or loc[1]<0 or loc[0]>self.shape[0]-1 or loc[1]>self.shape[1]-1):
            return False
        elif(loc in self.obstacle_locs):
            return False
        else:
             return True

    def get_neighbour(self,loc,direction):
        #Find the valid neighbours (ie that are in the grif and not obstacle)
        i = loc[0]
        j = loc[1]
```

```
        nr = (i-1,j)
        ea = (i,j+1)
        so = (i+1,j)
        we = (i,j-1)

        # If the neighbour is a valid location, accept it, otherwise, stay put
        if(direction == 'nr' and self.is_location(nr)):
            return nr
        elif(direction == 'ea' and self.is_location(ea)):
            return ea
        elif(direction == 'so' and self.is_location(so)):
            return so
        elif(direction == 'we' and self.is_location(we)):
            return we
        else:
            #default is to return to the same location
            return loc

    def optimal_value_policy(self, threshold, discount):
        # Computes the Optimal Value and Policy with the Value Itteration Algorithm

        # Make sure delta is bigger than the threshold to start with
        delta= 2*threshold

        #Get the reward and transition matrices
        R = self.get_reward_matrix()
        T = self.get_transition_matrix()

        # The value is initialised at 0
        V = np.zeros(self.state_size)
        # The policy is initialised at 0
        policy = np.zeros((self.state_size,), dtype=np.int)

        # Make a deep copy of the value array to hold the update during the evaluation
        Vnew = np.copy(V)

        # While the Value has not yet converged do:
        while delta>threshold:
            for state_idx in range(self.state_size):
                # If it is one of the absorbing states, ignore
                if(self.absorbing[0,state_idx]):
                    continue

                # List variable for the Value of a state
                tmpQ_list = []
                for action_idx in range(self.action_size):
                    # Accumulator variable for the State-Action Value
```

```
                    tmpQ = 0
                    for state_idx_prime in range(self.state_size):
                        tmpQ = tmpQ +
                            T[state_idx_prime,state_idx,action_idx] *
                            (R[state_idx_prime,state_idx, action_idx] +
                            discount * V[state_idx_prime])

                    tmpQ_list.append(tmpQ)

                # Update the value of the state
                 # Choosing the largest valued Policy (greedy)

                policy[state_idx] = int(np.argmax(tmpQ_list))
                Vnew[state_idx] = tmpQ_list[policy[state_idx]]

            # After updating the values of all states, update the delta
            delta =  max(abs(Vnew-V))
            # and save the new value into the old
            V=np.copy(Vnew)

        return policy, V

    #########################################
```

In [9]:
```
myWorld = GridWorld()
```



In [10]:
```
optPolicy, optV = myWorld.optimal_value_policy(0.0001,gamma)
```

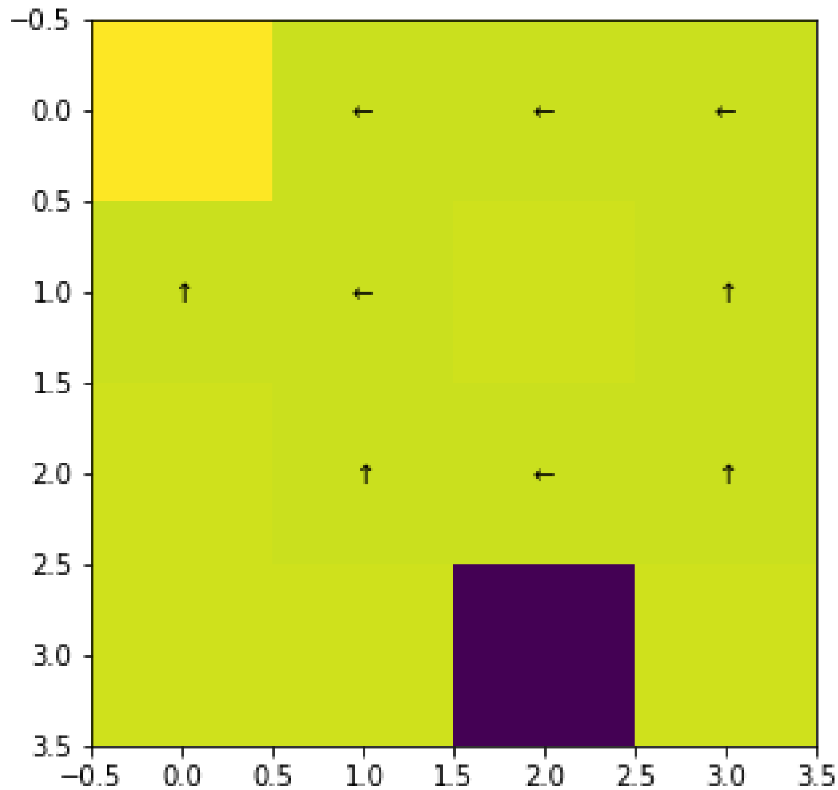
In [11]:
```
optPolicy
```

Out[11]:
```
array([0, 3, 3, 3, 0, 3, 0, 0, 3, 0, 0])
```

In [12]:
```
optV
```

```
Out[12]: array([  0.        ,   5.28366338,   0.73191542,  -1.32774645,
                  5.91316542,   1.21829509,  -2.56530113,  -3.76482201,
                -21.64655263,  -5.33465824,   0.        ])
```

```
In [13]: myWorld.draw_deterministic_policy(optPolicy)
```




```
In [ ]:
```