SolvingMazes: Q-Learning Agent

[Achi's Projects (https://github.com/QuantumNano-AI/PROJECTS)](https://github.com/QuantumNano-AI/PROJECTS)

The difference between SARSA and Q-Learning is in the selection of action in the next state. While SARSA follows the current policy, Q-Learning selects the next state's action in a way that maximizes utility.

In [1]:
```
import numpy as np
import sklearn.preprocessing as sc
import matplotlib.pyplot as plt
import cv2
import pandas as pd
import operator

class Maze:
    def __init__(self, maze, rewards = {'goal':1000000,'wall':-15, 'other':-1}):

        """# Read file and set height and width of maze
        with open(filename) as f:
            maze = f.read()"""
        self.rewards=rewards
        # Validate start and goal
        if maze.count("A") != 1:
            raise Exception("maze must have exactly one start point")
        if maze.count("B") != 1:
            raise Exception("maze must have exactly one goal")

        self.actions =  ["up", "down", "left", "right"]

        # Determine height and width of maze
        maze = maze.splitlines()
        self.height = len(maze)
        self.width = max(len(line) for line in maze)
        self.states = []
        self.gamma = .9 # This is the discount factor
        self.theta = .00001 # Small number threshold to signal convergence of the value function
        self.probs = [round(1/len(self.actions),2)] * len(self.actions)
        self.policy = list(zip(self.actions,self.probs))

        # Keep track of walls
        self.walls = []
        self.wall_cords = []
        for i in range(self.height):
            row = []
            for j in range(self.width):
                try:
                    if maze[i][j] == "A":
                        self.start = (i, j)
                        row.append(False)
                        self.states.append((i,j))
                    elif maze[i][j] == "B":
                        self.goal = (i, j)
                        row.append(False)
                        self.states.append((i,j))
                    elif maze[i][j] == " ":
                        row.append(False)
                        self.states.append((i,j))
                    else:
                        row.append(True)
                        self.wall_cords.append((i,j))
                except IndexError:
                    row.append(False)
                    self.states.append((i,j))
            self.walls.append(row)


        self.state_count = len(self.states)
        self.solution = None
        self.V = dict(zip(self.states, self.state_count*[0]))
        self.pi = dict(zip(self.states, self.state_count*[0]))
        for s in self.states:
            avail_actions = self.actions
            self.pi[s] = avail_actions[0]
        self.pi1 = dict(zip(self.states, self.state_count*[0]))

    def print(self):
        solution = self.solution[1] if self.solution is not None else None
        print()
        for i, row in enumerate(self.walls):
            for j, col in enumerate(row):
                if col:
                    print("#", end="")
                elif (i, j) == self.start:
                    print("A", end="")
                elif (i, j) == self.goal:
                    print("B", end="")
                elif solution is not None and (i, j) in solution:
                    print("*", end="")
                else:
                    print(" ", end="")
            print()
        print()

    def neighbors(self, state, a = None):
        """This function takes in a state and returns all available actions for that state the next state
            and reward if each action is take, with a specific transition probability"""
        row, col = state
        candidates = [
            ("up", (row - 1, col)),
            ("down", (row + 1, col)),
            ("left", (row, col - 1)),
```

```python
            ("right", (row, col + 1))
        ]
        terminal = False
        result = []
        for action, (r, c) in candidates:
            if (r,c) == self.goal: terminal = True
            if 0 <= r < self.height and 0 <= c < self.width and not self.walls[r][c]:
                if (row, col) == self.goal:
                    (r, c) = self.goal; terminal = True
                reward = self.rewards['goal'] if ((r,c) == self.goal) or (state == self.goal) else self.rewards['other']
                trans_prob = 1
                result.append((action, (r, c), reward, trans_prob, terminal))

        actions = [tup[0] for tup in result]

        if a:
            R = []
            if a in actions:
                inx = actions.index(a)
                R.append((result[inx]))
                return R
            else:
                R.append((a, (row,col), self.rewards['wall'], 1, terminal))
                return R
        return result

    def plot_state_values(self):
        val = np.array(list(self.V.values())).reshape(-1,1)
        va = sc.MinMaxScaler(feature_range=(0, 255)).fit_transform(val).flatten()
        V = {}
        for i in range(len(va)):
            V[list(self.V.keys())[i]] = va[i]

        # create a black image
        img  = np.ones((self.height,self.width,3), np.uint8)

        for item in V.items():
            (r,c),vx = item
            img[r,c] = [0,vx,0]

        for r,c in self.wall_cords:
            img[r,c] = [150,5,150]

        img[self.start[0],self.start[1]] = [255,0,0]
        img[self.goal[0],self.goal[1]] = [100,100,255]
        def showimg(img):
            plt.figure(figsize = (15,15))
            plt.imshow(img, cmap='viridis')
            plt.xticks([])
            plt.yticks([])
            #plt.colorbar()
            plt.show()
        showimg(img)

        def policy_(s):
            row, col = s
            candidates = [
                ("up", (row - 1, col)),
                ("down", (row + 1, col)),
                ("left", (row, col - 1)),
                ("right", (row, col + 1))
            ]


            if s in self.wall_cords:
                return ('WALL!!!')
            else:
                values = {a:self.V[r,c] for a,(r,c) in candidates if 0 <= r < self.height and 0 <= c < self.width and not self.walls[r][c]}
                values = {v:k for k,v in values.items()}
                best = values[max(values)]
            return best

        pi = np.zeros((self.height, self.width)).astype('str')
        pi = np.where(pi=='0.0', 'wall', pi)
        candidates = {
                    "up": [255,0,0],
                    "down": [0,0,255],
                    "left": [0,255,0],
                    "right": [255,255,0]
        }
        for item in self.pi.keys():
            action = policy_(item)
            r,c = item
            pi[r,c] = action
            img[r,c] = candidates[action]

        img[self.start[0],self.start[1]] = [255,0,0]
        img[self.goal[0],self.goal[1]] = [100,100,255]
        def showimg(img):
            plt.figure(figsize = (15,15))
            plt.imshow(img, cmap='viridis', )
            plt.yticks(list(range(self.height)))
            plt.xticks(list(range(self.width)))
            plt.title("POLICY\n\nRED  =>  up\nBLUE  =>  down\nGREEN  =>  left\nYELLOW  =>  right")
            #plt.colorbar()
```

```python
            plt.show()
        showimg(img)
        return img

class QLearning_agent(Maze):
    def __init__(self, maze, rewards = {'goal':1000000,
                                        'wall':-15,
                                        'other':-1},

                                 info = {'episodes': 200,
                                         'max_steps': 1500,
                                         'alpha': 0.4,
                                         'epsilon': 0.9} ):

        Maze.__init__(self, maze, rewards)
        self.epsilon = info['epsilon']
        self.r = np.random.RandomState(seed=12345)
        self.episodes =info['episodes']
        self.max_steps =info['max_steps']
        self.alpha = info['alpha']
        self.epsilon = info['epsilon']

    def func_q(self, states,n_states,n_actions,kind = 'random'):
        if kind=='ones':
            return dict(zip(states,np.ones((n_states,n_actions)).tolist()))
        elif kind == 'zeros':
            return dict(zip(states,np.zeros((n_states,n_actions)).tolist()))
        elif kind =='random':
            return dict(zip(states,np.round(self.r.randn(n_states,n_actions),2).tolist()))
        else :  raise NameError("Wrong input: please use ['ones', 'zeros', 'random']")

    def argmax(self, test_array):
        return self.r.choice(np.flatnonzero(np.array(test_array)==np.array(test_array).max()))

    def epsilon_greedy(self, Q, epsilon, actions, state, train=False):
        current_q = Q[state]
        if self.r.rand() < epsilon:
            action = self.r.choice(actions)
            return action
        else:
            action = self.argmax(current_q)
        return actions[action]

    def run(self):
        self.Q = self.func_q(self.states,self.state_count,len(self.actions),kind = 'random')
        self.time_steps = pd.DataFrame()
        for episode in range(self.episodes):
            total_reward = 0 # This sets the total reward obtained during this episode
            s = self.states[self.r.randint(len(self.states))]
            a = self.epsilon_greedy(Q=self.Q, epsilon=self.epsilon, actions=self.actions, state=s,train=False)
            t = 0
            terminal = False
            while t < self.max_steps:
                t+=1
                _,s_, reward, p,terminal = self.neighbors(s,a)[0]
                total_reward += reward
                q_ = self.Q[s_] # Action values in the next state
                a_ = self.actions[self.argmax(q_)] # Action in the next state does not follow policy. It is rather selected to maximise utility.
                if terminal:
                    self.Q[s][self.actions.index(a)] += self.alpha * (reward - self.Q[s][self.actions.index(a)])
                else:
                    self.Q[s][self.actions.index(a)] += self.alpha * (reward + self.gamma*self.Q[s_][self.actions.index(a_)]  - \
                                                                     self.Q[s][self.actions.index(a)])
                s, a = s_, a_
                if terminal:
                    self.time_steps = self.time_steps.append(pd.Series({
                        'episode':int(episode), 'steps':t, 'rewards':total_reward
                                                                       }), ignore_index=True)
                    break
            if terminal and t%10==0:
                print(f'.',end='')
        self.pi = {}
        self.V = {}
        for k,v in self.Q.items():
            self.pi[(k)] = self.actions[self.argmax(v)]
            self.V[(k)] = max(v)
        max_r = max([v for k,v in self.V.items()])
        self.V[self.goal] = max_r
        img = self.plot_state_values()
        #return V,pi
```

In [2]:

```python
maze0 = """####################
##                 #
## ####### ###### # #
##A              #B#"""
```

In [3]:

```python
print(maze0)
```

```
####################
##                 #
## ####### ###### # #
##A              #B#
```

In [4]:
```python
info = {'episodes': 10000,'max_steps': 500,'alpha': 0.2,'epsilon': 0.999}
rewards = {'goal':10000,'wall':-5, 'other':-1}
m = QLearning_agent(maze = maze0, rewards = rewards, info = info)
m.run()
t = m.time_steps; t[t.rewards!=0]
```

```
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```
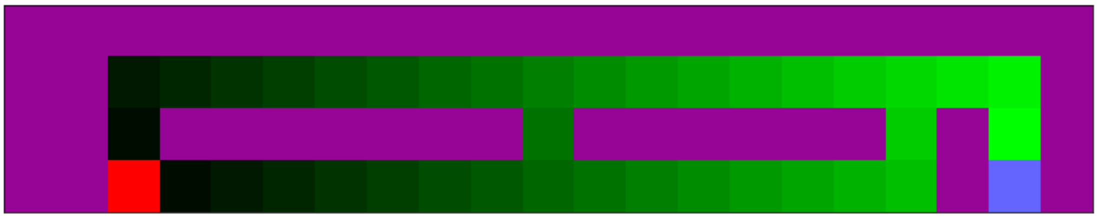
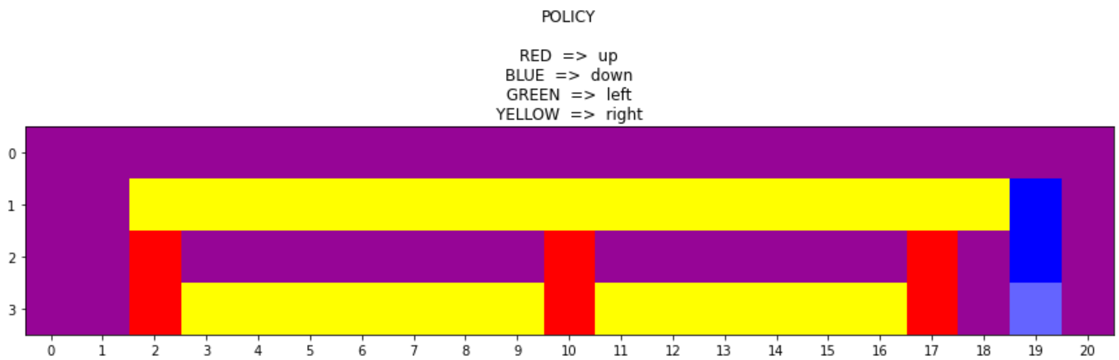





Out[4]:

	episode	rewards	steps
0	0.0	9999.0	2.0
1	1.0	-5.0	1.0
2	4.0	9683.0	186.0
3	5.0	9885.0	68.0
4	6.0	9571.0	278.0
...	...	...	...
9993	9995.0	9983.0	18.0
9994	9996.0	9998.0	3.0
9995	9997.0	9994.0	7.0
9996	9998.0	9989.0	12.0
9997	9999.0	9988.0	9.0

9998 rows × 3 columns

In [ ]:

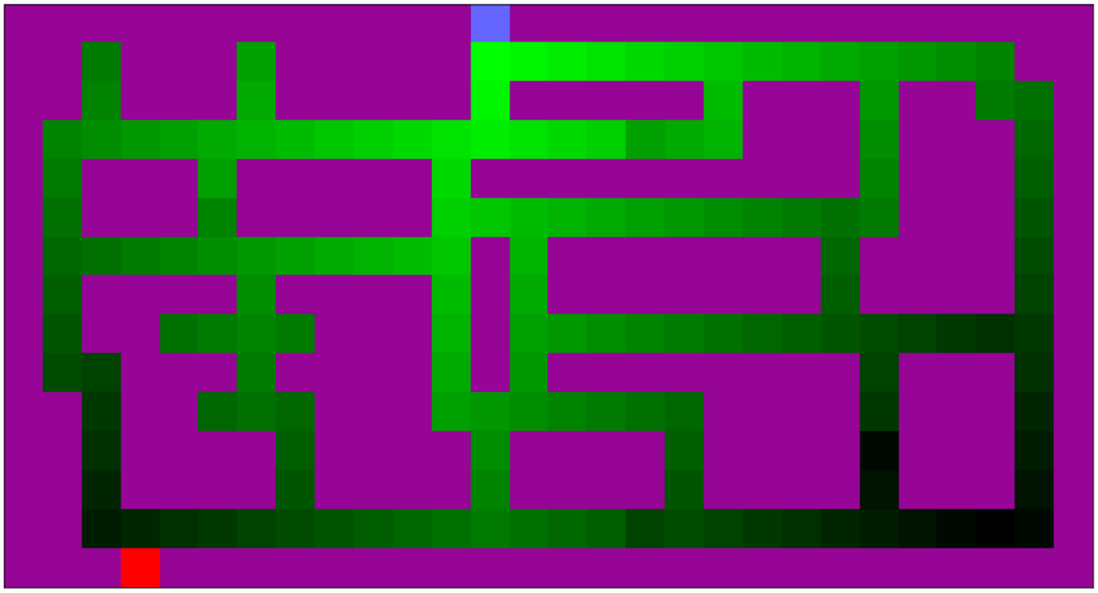
In [5]:
```python
maze = """############B###############
## ### #####              ##
## ### ##### ##### ### ##  #
#                  ### ### #
# ### ##### ########## ### #
# ### #####            ### #
#           # ####### #### #
# #### #### # ####### #### #
# ##    ### #              #
#  ### #### # ######## ### #
## ##   ###       #### ### #
## #### #### #### #### ### #
## #### #### #### #### ### #
##                         #
###A########################"""
```

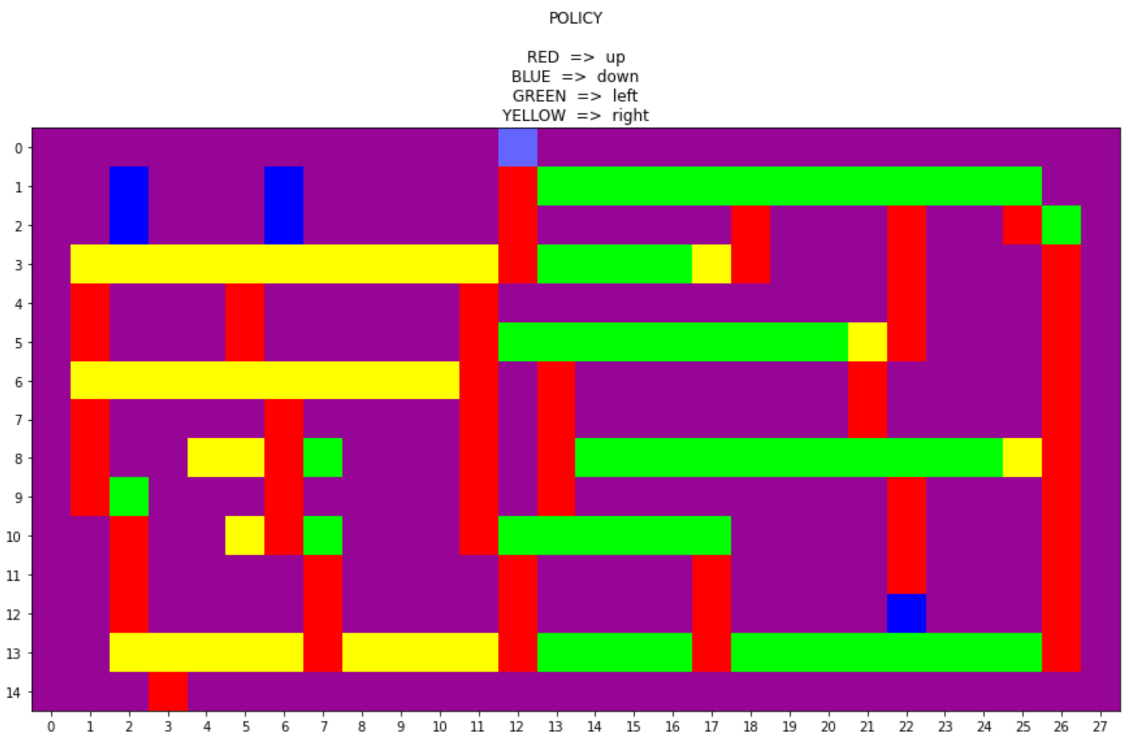
In [6]:
```python
print(maze)
```

```
############B###############
## ### #####              ##
## ### ##### ##### ### ##  #
#                  ### ### #
# ### ##### ########## ### #
# ### #####            ### #
#           # ####### #### #
# #### #### # ####### #### #
# ##    ### #              #
#  ### #### # ######## ### #
## ##   ###       #### ### #
## #### #### #### #### ### #
## #### #### #### #### ### #
##                         #
###A########################
```

In [7]:
```
info = {'episodes': 10000,'max_steps': 500,'alpha': 0.4,'epsilon': 0.999}
rewards = {'goal':10000,'wall':-5, 'other':-1}
m = QLearning_agent(maze = maze, rewards = rewards, info = info)
m.run()
t = m.time_steps; t[t.rewards!=0]
```

....





Out[7]:

	episode	rewards	steps
0	3.0	-926.0	498.0
1	5.0	-166.0	82.0
2	6.0	9735.0	130.0
3	7.0	9883.0	78.0
4	8.0	9881.0	84.0
...	...	...	...
9991	9995.0	9988.0	13.0
9992	9996.0	9981.0	20.0
9993	9997.0	9968.0	29.0
9994	9998.0	9992.0	5.0
9995	9999.0	10000.0	1.0

9996 rows × 3 columns

In [ ]:

```python

```

In [8]:

```python
maze1 = """###################B#
##                  #
## ### ############ #
##              ### #
## ### ############ #
###### ##############
##         ######## #
## #### ## ######## #
## ####             #
## ############ ### #
## #      ##### ### #
## # ####       ### #
## # ############## #
##                  #
## ################ #
##A##################"""
```

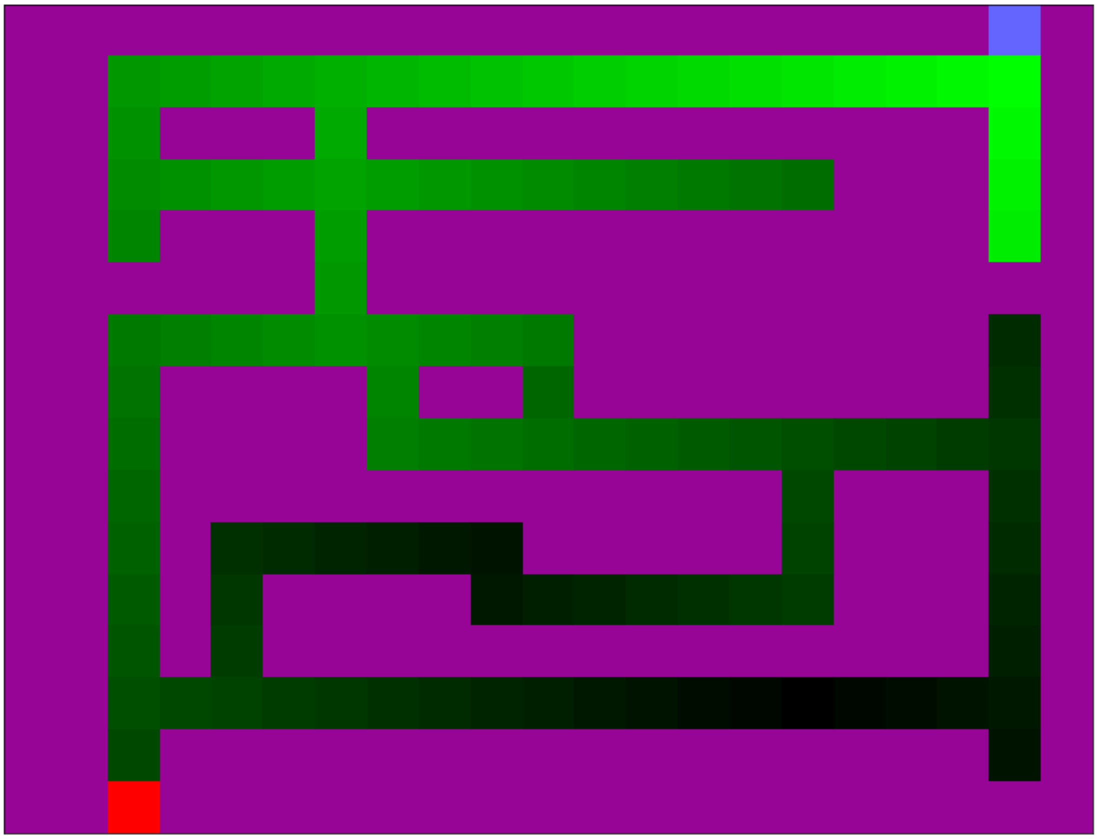
In [9]:

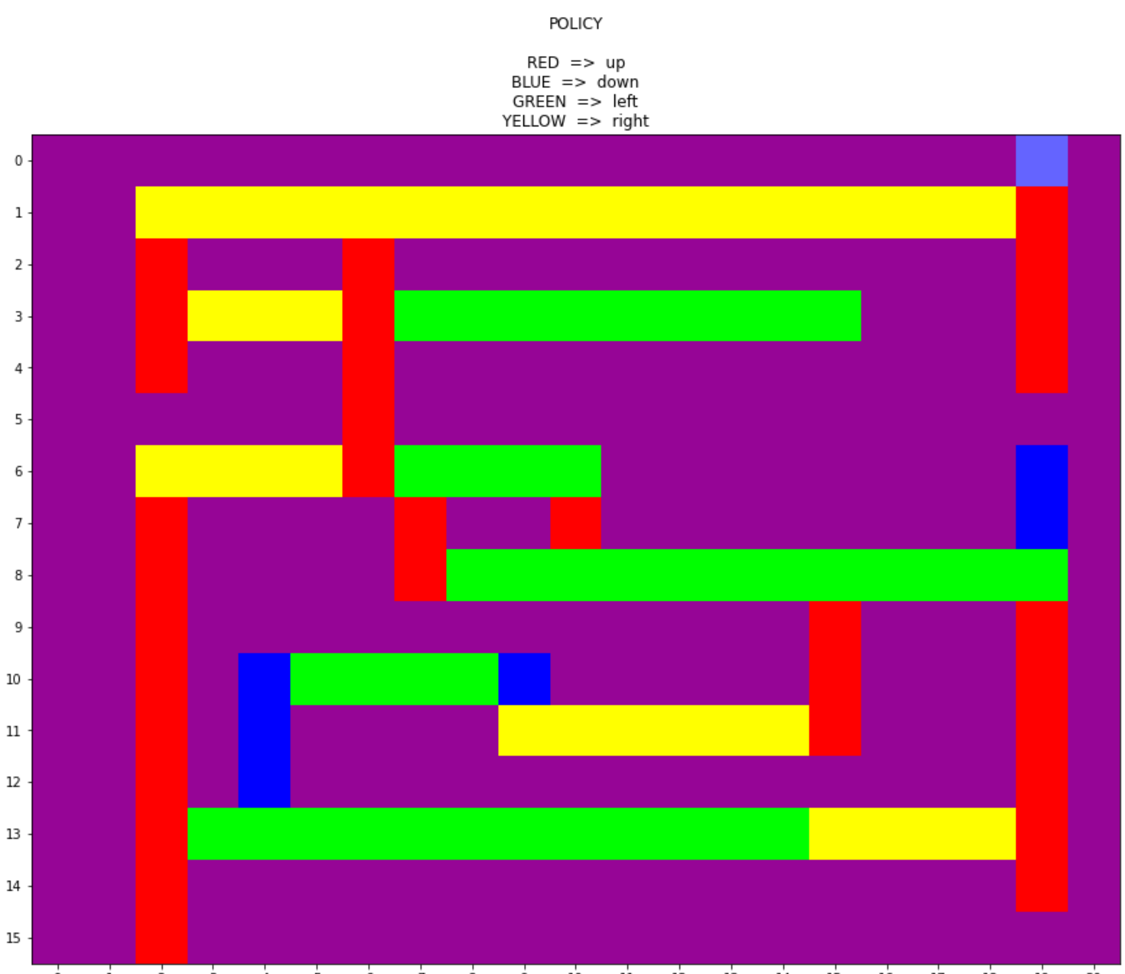
```python
print(maze1)
```

```
###################B#
##                  #
## ### ############ #
##              ### #
## ### ############ #
###### ##############
##         ######## #
## #### ## ######## #
## ####             #
## ############ ### #
## #      ##### ### #
## # ####       ### #
## # ############## #
##                  #
## ################ #
##A##################
```

In [10]:
```python
info = {'episodes': 10000,'max_steps': 500,'alpha': 0.2,'epsilon': 0.999}
rewards = {'goal':10000,'wall':-5, 'other':-1}
m = QLearning_agent(maze = maze1, rewards = rewards, info = info)
m.run()
t = m.time_steps; t[t.rewards!=0]
```

....





Out[10]:

episode	rewards	steps

	episode	rewards	steps
0	7.0	-268.0	164.0
1	10.0	9685.0	184.0
2	12.0	9341.0	380.0
3	15.0	9903.0	58.0
4	18.0	9362.0	367.0
...	...	...	...
9974	9995.0	9977.0	24.0
9975	9996.0	9969.0	32.0
9976	9997.0	9982.0	15.0
9977	9998.0	9983.0	18.0
9978	9999.0	9992.0	5.0

In [ ]:

In [ ]: