```
import gym
import numpy as np
import random

env = gym.make("FrozenLake-v0", map_name='4x4', is_slippery=False)
```

Funkcja generująca politykę deterministyczną:

```
def create_random_det_policy(env):
    policy = {}
    for key in range(0, env.observation_space.n):
        policy[key] = np.random.randint(4);
    return policy
```

Testujemy:

```
policy = create_random_det_policy(env)
policy
```

```
     {0: 1,
      1: 3,
      2: 0,
      3: 2,
      4: 2,
      5: 1,
      6: 0,
      7: 1,
      8: 0,
      9: 3,
      10: 3,
      11: 0,
      12: 0,
      13: 1,
```

```
      14: 1,
      15: 2}
```

Wygenerowanie słownika reprezentującego funkcję Q:

```
def create_state_action_dictionary(env, policy):
    Q = {}
    for key in policy.keys():
         Q[key] = {a: 0.0 for a in range(0, env.action_space.n)}
    return Q


Q = create_state_action_dictionary(env, policy)


Q
```

```
     {0: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      1: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      2: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      3: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      4: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      5: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      6: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      7: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      8: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      9: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      10: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      11: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      12: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      13: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      14: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0},
      15: {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0}}
```

Funkcja generująca epizod:

```
def generate_episode_det(env, policy):
    env.reset()
```

```
    episode = []
    finished = False

    while not finished:
        s = env.s
        #s = np.random.randint(16)
        #print(s)

        timestep = []
        timestep.append(s)

        action = policy[s]

        _, reward, finished, _ = env.step(action)

        timestep.append(action)
        timestep.append(reward)

        episode.append(timestep)

    return episode
```

Testujemy:

```
print("LEFT = 0 DOWN = 1 RIGHT = 2 UP = 3")
for i in range(10):
  print("Epizod ",i,": ",generate_episode_det(env, policy))
```

```
LEFT = 0 DOWN = 1 RIGHT = 2 UP = 3
Epizod  0 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  1 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  2 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  3 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  4 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  5 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  6 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
```

```
Epizod  7 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  8 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
Epizod  9 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.
```

Czy pierwsza wizyta w danym stanie?

Unless the pair S_t, A_t appears in $S_0, A_0, S_1, A_1 \ldots, S_{t-1}, A_{t-1}$:

```
policy = create_random_det_policy(env)
episode = generate_episode_det(env, policy)
print(episode)

for time_step in reversed(range(0, len(episode))):

  S_t, A_t, R_t = episode[time_step]
  state_action = (S_t, A_t)

  if not state_action in [(x[0], x[1]) for x in episode[0:time_step]]:
      print("t=",time_step," pierwsza wizyta w (s,a): ",state_action)
```

```
[[0, 2, 0.0], [1, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 2, 0.0], [1, 0, 0.
t= 1  pierwsza wizyta w (s,a):  (1, 0)
t= 0  pierwsza wizyta w (s,a):  (0, 2)
```

Słownik, którego kluczami są pary (stan,akcja) tzn. (S,A) a wartościami listy zwrotów G

Append G to $Returns(S_t, A_t)$

```
Returns = {(3,2):[4,5,-1],(1,1):[2,3,6,7,1],(6,3):[2,-1,3,1]}
```

```
Returns = {}

Returns[(3,1)]=[3]
print(Returns)

Returns[(3,1)].append(4)
print(Returns)

Returns[(3,1)].append(8)
print(Returns)
```

```
     {(3, 1): [3]}
     {(3, 1): [3, 4]}
     {(3, 1): [3, 4, 8]}
```

```
Returns[(4,2)]=[7]
print(Returns)

Returns[(4,2)].append(-4)
print(Returns)

Returns[(4,2)].append(2)
print(Returns)
```

```
     {(3, 1): [3, 4, 8], (4, 2): [7]}
     {(3, 1): [3, 4, 8], (4, 2): [7, -4]}
     {(3, 1): [3, 4, 8], (4, 2): [7, -4, 2]}
```

```
#Q = np.zeros((env.nS,env.nA))
Pi = np.zeros(env.nS)
Returns = {}
for u in range(10000):
  y=1

  policy = create_random_det_policy(env)
  episode = generate_episode_det(env, policy)
```

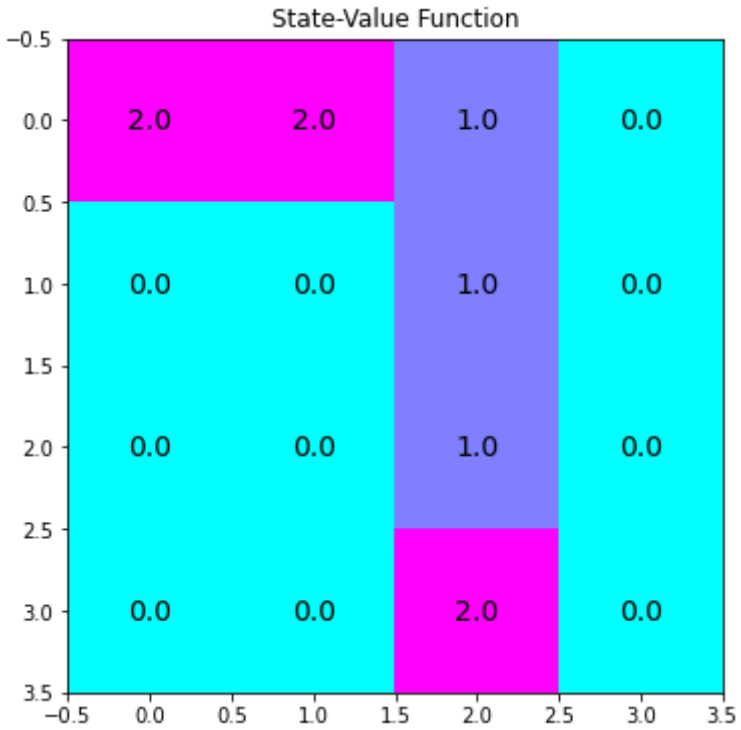
```
  episode = generate_episode_det(env, policy)
  #print(episode)
  G=0
  for time_step in reversed(range(0, len(episode))):

   S_t, A_t, R_t = episode[time_step]
   state_action = (S_t, A_t)
   G = y*G + R_t


   if not state_action in [(x[0], x[1]) for x in episode[0:time_step]]:
       #print("t=",time_step," pierwsza wizyta w (s,a): ",state_action)
       if not state_action in Returns.keys():
        Returns[state_action]=[G]
       else :
        Returns[state_action].append(G)
       Q[state_action] = np.average(Returns[state_action])
       # Pi[state_action[0]] = np.argmax([state_action])

       # Q[S_t][A_t] = sum(Returns[state_action]) / len(Returns[state_action]) # Average reward across episodes

            # Finding the action with maximum value.
       Q_list = list(map(lambda x: x[1], Q[S_t].items()))
       max_Q = np.argmax(Q_list)
       Pi[S_t]=max_Q


Q_list

     [0.0, 0.0024459845087647777, 0.0003961965134706815, 0.0]


Returns


Q

     array([[0.        , 0.0011957 , 0.00197006, 0.        ],
            [0.        , 0.        , 0.00777605, 0.        ],
```

```
       [0.        , 0.02840909, 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        ],
       [0.        , 0.00505902, 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        ],
       [0.        , 0.09433962, 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.0234375 , 0.        ],
       [0.        , 0.04166667, 0.06451613, 0.        ],
       [0.        , 0.31818182, 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.25      , 0.        ],
       [0.        , 0.        , 1.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        ]])
```

```
Pi
```

```
array([1., 2., 1., 0., 1., 0., 1., 0., 2., 2., 1., 0., 0., 2., 2., 0.])
```

```
from plot_utils import plot_values
plot_values(Pi)
```



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