```
import gym
import numpy as np
import random

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

Funkcja generująca politykę stochastyczną:

```
def create_random_sto_policy(env):
    policy = {}
    for key in range(0, env.observation_space.n):
        p = {}
        for action in range(0, env.action_space.n):
            p[action] = 1 / env.action_space.n
        policy[key] = p
    return policy
```

Testujemy:

```
policy = create_random_sto_policy(env)
policy
```

```
     {0: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      1: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      2: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      3: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      4: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      5: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      6: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      7: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      8: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      9: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      10: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
      11: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
```

```
  12: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
  13: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
  14: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25},
  15: {0: 0.25, 1: 0.25, 2: 0.25, 3: 0.25}}
```

Funkcja generująca epizod:


```
    finished = False

    while not finished:
        s = env.s

        timestep = []
        timestep.append(s)

        n = random.uniform(0, sum(policy[s].values()))

        top_range = 0
        for prob in policy[s].items():
            top_range += prob[1]
            if n < top_range:
                action = prob[0]
                break

        #observation, reward, done, info
        _, 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(100):
  print("Epizod ",i,": ",generate_episode(env, policy))
```



```
Epizod  42 :  [[0, 1, 0.0], [4, 2, 0.0]]
                                                2, 0.0], [1, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
                                                2, 0.0], [1, 1, 0.0]]
                                                3, 0.0], [0, 1, 0.0], [4, 1, 0.0], [8, 1, 0.0]]
Epizod  46 :  [[0, 2, 0.0], [1, 1, 0.0]]
Epizod  47 :  [[0, 3, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 3,
Epizod  48 :  [[0, 3, 0.0], [0, 2, 0.0], [1, 3, 0.0], [1, 2, 0.0], [2, 3, 0.0], [2, 3, 0.0], [2, 2, 0.0], [3, 0, 0.0], [2, 1,
Epizod  49 :  [[0, 1, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 2, 0.0]]
Epizod  50 :  [[0, 0, 0.0], [0, 2, 0.0], [1, 1, 0.0]]
Epizod  51 :  [[0, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 1, 0.0]]
Epizod  52 :  [[0, 2, 0.0], [1, 1, 0.0]]
Epizod  53 :  [[0, 3, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 3,
Epizod  54 :  [[0, 3, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  55 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  56 :  [[0, 0, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 3, 0.0], [0, 2, 0.0], [1, 1, 0.0]]
Epizod  57 :  [[0, 2, 0.0], [1, 3, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 2,
Epizod  58 :  [[0, 2, 0.0], [1, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  59 :  [[0, 1, 0.0], [4, 2, 0.0]]
Epizod  60 :  [[0, 1, 0.0], [4, 3, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 2, 0.0], [3, 1, 0.0]]
Epizod  61 :  [[0, 0, 0.0], [0, 3, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  62 :  [[0, 1, 0.0], [4, 2, 0.0]]
Epizod  63 :  [[0, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  64 :  [[0, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 2,
Epizod  65 :  [[0, 3, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 3, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 3, 0.0], [2, 0, 0.0], [1, 3,
Epizod  66 :  [[0, 1, 0.0], [4, 1, 0.0], [8, 3, 0.0], [4, 2, 0.0]]
Epizod  67 :  [[0, 3, 0.0], [0, 1, 0.0], [4, 3, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 1,
Epizod  68 :  [[0, 2, 0.0], [1, 2, 0.0], [2, 0, 0.0], [1, 2, 0.0], [2, 1, 0.0], [6, 1, 0.0], [10, 0, 0.0], [9, 0, 0.0], [8, 1
Epizod  69 :  [[0, 1, 0.0], [4, 3, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 3, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 3,
Epizod  70 :  [[0, 3, 0.0], [0, 1, 0.0], [4, 1, 0.0], [8, 0, 0.0], [8, 1, 0.0]]
Epizod  71 :  [[0, 2, 0.0], [1, 1, 0.0]]
Epizod  72 :  [[0, 3, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 2, 0.0], [3, 1, 0.0]]
Epizod  73 :  [[0, 1, 0.0], [4, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  74 :  [[0, 0, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
```

```
Epizod  75 :  [[0, 2, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 1, 0.0], [8, 0, 0.0], [8, 2, 0.0], [9, 1, 0.0], [13, 2
Epizod  76 :  [[0, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 2, 0.0]]
Epizod  77 :  [[0, 1, 0.0], [4, 2, 0.0]]
Epizod  78 :  [[0, 1, 0.0], [4, 1, 0.0], [8, 3, 0.0], [4, 0, 0.0], [4, 1, 0.0], [8, 3, 0.0], [4, 2, 0.0]]
Epizod  79 :  [[0, 2, 0.0], [1, 2, 0.0], [2, 1, 0.0], [6, 3, 0.0], [2, 1, 0.0], [6, 0, 0.0]]
Epizod  80 :  [[0, 0, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 2, 0.0]]
Epizod  81 :  [[0, 1, 0.0], [4, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 1,
Epizod  82 :  [[0, 0, 0.0], [0, 2, 0.0], [1, 3, 0.0], [1, 2, 0.0], [2, 3, 0.0], [2, 2, 0.0], [3, 3, 0.0], [3, 1, 0.0]]
Epizod  83 :  [[0, 3, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 3, 0.0], [0, 0, 0.0], [0, 2,
              [[0, 3, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 1, 0.0], [4, 1, 0.0], [8, 2, 0.0], [9, 2, 0.0], [10, 2
              1, 0.0]]
              0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 1, 0.0], [6, 1, 0.0], [10, 0, 0.0], [9, 3
Epizod  87 :  [[0, 1, 0.0], [4, 3, 0.0], [0, 3, 0.0], [0, 1, 0.0], [4, 1, 0.0], [8, 0, 0.0], [8, 0, 0.0], [8, 3, 0.0], [4, 3,
Epizod  88 :  [[0, 0, 0.0], [0, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 3,
Epizod  89 :  [[0, 0, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 3, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  90 :  [[0, 0, 0.0], [0, 1, 0.0], [4, 1, 0.0], [8, 3, 0.0], [4, 2, 0.0]]
Epizod  91 :  [[0, 3, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 0, 0.0], [1, 0, 0.0], [0, 1, 0.0], [4, 2, 0.0]]
Epizod  92 :  [[0, 1, 0.0], [4, 1, 0.0], [8, 2, 0.0], [9, 3, 0.0]]
Epizod  93 :  [[0, 0, 0.0], [0, 3, 0.0], [0, 2, 0.0], [1, 1, 0.0]]
Epizod  94 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 3, 0.0], [2, 3, 0.0], [2, 1, 0.0], [6, 1,
Epizod  95 :  [[0, 2, 0.0], [1, 0, 0.0], [0, 2, 0.0], [1, 1, 0.0]]
Epizod  96 :  [[0, 1, 0.0], [4, 3, 0.0], [0, 2, 0.0], [1, 3, 0.0], [1, 3, 0.0], [1, 3, 0.0], [1, 2, 0.0], [2, 2, 0.0], [3, 3,
Epizod  97 :  [[0, 3, 0.0], [0, 3, 0.0], [0, 0, 0.0], [0, 1, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 0, 0.0], [4, 2, 0.0]]
Epizod  98 :  [[0, 0, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 2, 0.0], [3, 0, 0.0], [2, 2, 0.0], [3, 0, 0.0], [2, 1, 0.0], [6, 2,
Epizod  99 :  [[0, 3, 0.0], [0, 2, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 3, 0.0], [1, 1,
```

Zapisano pomyślnie.

Przeglądanie epizodu od końca

Generate an episode following π: $S_0, A_0, R_1, S_1, A_1, R_2, \ldots, S_{T-1}, A_{T-1}, R_T$
$G \leftarrow 0$
Loop for each step of episode, $t = T-1, T-2, \ldots, 0$:

```
policy = create_random_sto_policy(env)
episode = generate_episode(env, policy)
print(episode)
```

```
for i in reversed(range(0, len(episode))):
    S_t, A_t, R_t = episode[i]
    print(S_t," ",A_t," ",R_t)
```

```
 [[0, 2, 0.0], [1, 0, 0.0], [0, 0, 0.0], [0, 2, 0.0], [1, 2, 0.0], [2, 3, 0.0], [2, 3, 0.0], [2, 3, 0.0], [2, 0, 0.0], [1, 0, 0.
 1   1   0.0
 2   0   0.0
 2   3   0.0
```

Zapisano pomyślnie.

```
 0   2   0.0
 1   0   0.0
 2   0   0.0
 3   0   0.0
 2   2   0.0
 2   3   0.0
 1   2   0.0
 0   2   0.0
 0   3   0.0
 4   3   0.0
 4   0   0.0
 0   1   0.0
 0   3   0.0
 1   0   0.0
 2   0   0.0
 2   3   0.0
 2   3   0.0
 2   3   0.0
 1   2   0.0
 0   2   0.0
 0   0   0.0
 1   0   0.0
 0   2   0.0
```

Czy pierwsza wizyta w danym stanie?

Unless S_t appears in $S_0, S_1, \ldots, S_{t-1}$:

```
policy = create_random_sto_policy(env)
episode = generate_episode(env, policy)
print(episode)
```

Zapisano pomyślnie.

```
en(episode))):
  state = episode[time_step][0]

  if not state in [x[0] for x in episode[0:time_step]]:
    print("t=",time_step," pierwsza wizyta w stanie: ",state)

     [[0, 1, 0.0], [4, 1, 0.0], [8, 1, 0.0]]
     t= 2  pierwsza wizyta w stanie:  8
     t= 1  pierwsza wizyta w stanie:  4
     t= 0  pierwsza wizyta w stanie:  0
```

Słowniki (https://oprojektowaniu.pl/python-dla-inzynierow-slowniki/)

```
moj_slownik = {'klucz1': 'wartosc1', 'klucz2': 'wartosc2'}
```

Słownik, którego kluczami są stany S, a wartościami listy zwrotów G

Append G to $Returns(S_t)$
$V(S_t) \leftarrow \text{average}(Returns(S_t))$

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

```
Returns = {}

Returns[2]=[3]
print(Returns)

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



```
     {2: [3]}
     {2: [3, 4]}
     {2: [3, 4, 8]}



Returns[5]=[7]
print(Returns)

Returns[5].append(-4)
print(Returns)

Returns[5].append(2)
print(Returns)

     {2: [3, 4, 8], 5: [7]}
     {2: [3, 4, 8], 5: [7, -4]}
     {2: [3, 4, 8], 5: [7, -4, 2]}
```

Sprawdzenie czy dany klucz istnieje w słowniku:

```
state = 2
if state in Returns.keys():
    print("Stan był już odwiedzony!")
else:
    print("Stan nie był jeszcze odwiedzony!")
```

```
Stan był już odwiedzony!
```

Policzenie **średniej zwrotów** dla pewnego stanu

$$V(S_t) \leftarrow \text{average}(Returns(S_t))$$

Zapisano pomyślnie.

```
np.mean(Returns[2])
```

```
5.0
```

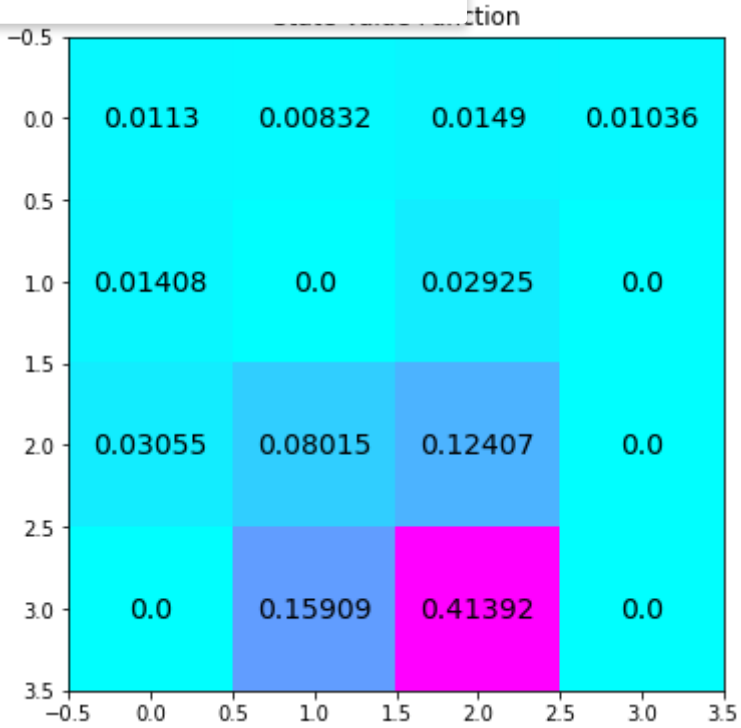
```
V = np.zeros(env.nS)
Returns = {}
for u in range(10000):
  y=1
  policy = create_random_sto_policy(env)
  episode = generate_episode(env, policy)
  #print(episode)
  G = 0

  for p in reversed(range(0, len(episode))):
    state, A_t, R = episode[p]
    #print(S_t," ",A_t," ",R_t)
    G = y*G + R


    if not state in [x[0] for x in episode[0:p]]:
     #print("t=",time_step," pierwsza wizyta w stanie: ",state)
     if not state in Returns.keys():
      Returns[state]=[G]
     else :
      Returns[state].append(G)
      V[state] = np.average(Returns[state])
```

```
from plot_utils import plot_values
```

Zapisano pomyślnie.



Zapisano pomyślnie.