In [1]:

```
import numpy as np
from numpy.random import default_rng
from sklearn.cluster import KMeans
import matplotlib.pyplot as plt
import math
import numpy as np
import random
import pandas as pd
from datetime import datetime
import seaborn as sns
import matplotlib.pyplot as plt
from matplotlib.pyplot import figure
from sklearn import preprocessing
```

Part 1 - Defining the environment.

In [2]:

```
class StockTradingEnv:
    """
        Specifying the action and observation componenets that would help the agent

    """
    def __init__(self,
                 fee=0.1,
                 starting_date="2015-01-24",
                 max_training_date = '2020-12-31',
                 inital_cash_balance = 50000,
                 initial_number_shares = 10):

        # Defining the parameters specific to the environment
        self.df = pd.read_excel("Quantitative Trading2.xls", sheet_name='SPY (1)')
        self.action_list = ['Buy','Sell','Hold']
        self.feature_list = ['Daily Close Returns ', 'Open','High','Low','Close', 'W
        #setup
        self.fee = fee #Stock trading commission fee per trade
        self.start_date = starting_date
        self.current_step = 0
        self.eventlog = [] #eventlog to keep track
        self.max_training_date = max_training_date

        #used to calculate portfoliovalue
        self.initial_number_shares = initial_number_shares
        self.inital_cash_balance = inital_cash_balance
        self.cash_balance = self.inital_cash_balance
        self.number_shares = self.initial_number_shares

        #To_review

        self.df = self.df[self.df['Date']>=datetime.strptime(self.start_date, '%Y-%m
        self.training_data = self.df[self.df['Date']<datetime.strptime(self.max_trai
        self.start_date = self.df['Date'].min()

        #maybe needed.
        self.initial_value = self.cash_balance + self.number_shares* self.df[self.df
        self.wallet = [self.initial_value]

        #self.training_data,self.observations, self.states, self.transition_matrix,
        #data preprocessing
```

```
    def reward_function(self,action, step):
        ''' Reward Policy, if :
        - Sell : Next day return *-100
        - Buy : Next day return *100
        - Hold : if held and movement superior to 4% negative reward : abs(next day
        while if movement undertrading fee, positive reward
        '''

        #Check the line below
        if action == 'Buy':
            reward = (self.df.iloc[step + 1]['Daily Close Returns '])*100

        if action == 'Sell':
            reward = (self.df.iloc[step + 1]['Daily Close Returns '])*-100

        if action == 'Hold':
            if abs(self.df.iloc[step + 1]['Daily Close Returns ']*100) >4:
                reward = abs(self.df.iloc[step + 1]['Daily Close Returns '])*-100/2

            elif abs(self.df.iloc[step + 1]['Daily Close Returns '])*100 <self.fee:
                reward = abs(self.df.iloc[step + 1]['Daily Close Returns '])*200

            else :
                reward = 0

        return reward

    def step(self,action):
        """
        Move the step and recalculate portfolio Value
        """

        #Check the line below
        self._state = self.df.iloc[self.current_step]
        current_price = self.df.iloc[self.current_step]['Close']

        ## Add condition if buy but enough cash -> hold (bump example) and similarly
        if action == 'Buy':
            #transition function
            if current_price > self.cash_balance:
                self.wallet.append(self.cash_balance + self.number_shares* current_p
                comment = 'Not Enough Cash to Buy'
            else :
                self.number_shares +=1
                self.cash_balance = self.cash_balance -self.fee - current_price
                self.wallet.append(self.cash_balance + self.number_shares* current_p
                comment = ''

        if action == 'Sell':
            if self.number_shares ==0 :
                self.wallet.append(self.cash_balance + self.number_shares* current_p
                comment = 'Not Enough Shares to Sell '

            else:
                self.number_shares -=1
                self.cash_balance = self.cash_balance -self.fee + current_price
                self.wallet.append(self.cash_balance + self.number_shares* current_p
                comment = ''

        if action == 'Hold':
            self.wallet.append(self.cash_balance + self.number_shares* current_price
            comment = ''
```

```
        #create pandas or array of array which will include = step, action, state, w
        self.eventlog.append([self.current_step, self.number_shares,self.cash_balanc
        self.current_step+=1


    def display(self):
        print ('Portfolio contains :' + str(self.number_shares ))
        print ('Initial Portfolio Value was : '+ str(self.initial_value))
        print (self.wallet)
        #to add
        print ('total reward')

    def reset(self):
        self.current_step = 0
        self.cash_balance = self.inital_cash_balance
        self.number_shares = self.initial_number_shares
        self.eventlog = []
        self.initial_value = self.cash_balance + self.number_shares* self.df[self.df

    def qlearning_preprocessing (self):

        #kmeans
        print('Clustering')
        kmeans = KMeans(n_clusters=7)

        standard = preprocessing.scale(self.training_data[self.feature_list])
        standard = pd.DataFrame(standard, columns =self.feature_list)

        y = kmeans.fit_predict(standard)
        self.training_data['Cluster'] = y
        centroid = kmeans.cluster_centers_


        fig, ax = plt.subplots()
        plt.scatter(kmeans.cluster_centers_[:, 0], kmeans.cluster_centers_[:, 6], s
        for i,txt in enumerate(['state_0', 'state_1', 'state_2','state_3','state_4',
            ax.annotate(txt, (kmeans.cluster_centers_[i, 0]+0.08, kmeans.cluster_cen
        plt.title('State Representation')

        ax.set_xlim(xmin=(kmeans.cluster_centers_[:, 0]).min()-0.2, xmax=(kmeans.clu
        plt.xlabel(self.feature_list[0])
        plt.ylabel(self.feature_list[6])
        plt.show()
        plt.clf()

        print('Calculating historical expected transition matrix')
        self.training_data['next_cluster']=self.training_data['Cluster'].shift(-1)
        self.training_data['Count'] = 1
        transition_matrix = pd.pivot_table(self.training_data, values='Count', index
        transition_matrix = transition_matrix/sum(self.training_data['Count'])
        transition_matrix =transition_matrix.fillna(0)*100

        sns.heatmap(transition_matrix, cmap = 'Blues',annot=True, fmt ='.2f')
        plt.title('State Transition Matrix')
        plt.show()
        plt.clf()

        print('Calculating historical expected return matrix for state-action')
        matrix_rewards =  np.zeros((7, 3))
        simulated_er = []
        n=0

        #In order to descretise the return, we looked at expected return by simulati
```

```
        for i in range(len(self.training_data.index)-1) :
            for action in range (3):
                reward = self.reward_function(self.action_list[action],i)
                simulated_er.append([i,self.action_list[action],reward, self.trainin

        simulated_er= pd.DataFrame(simulated_er, columns = ['i','Action', 'Reward','
        #to debug : simulated_er.to_csv('histreward.csv')
        reward_matrix = pd.pivot_table(simulated_er, values='Reward', index=['State'
        reward_matrix=reward_matrix[ self.action_list]
        sns.heatmap(reward_matrix, cmap = 'Blues',annot=True, fmt ='.2f')
        plt.title('reward_matrix')
        plt.show()
        plt.clf()
        print('End of Preprocessing')
        return self.training_data, transition_matrix, reward_matrix
```

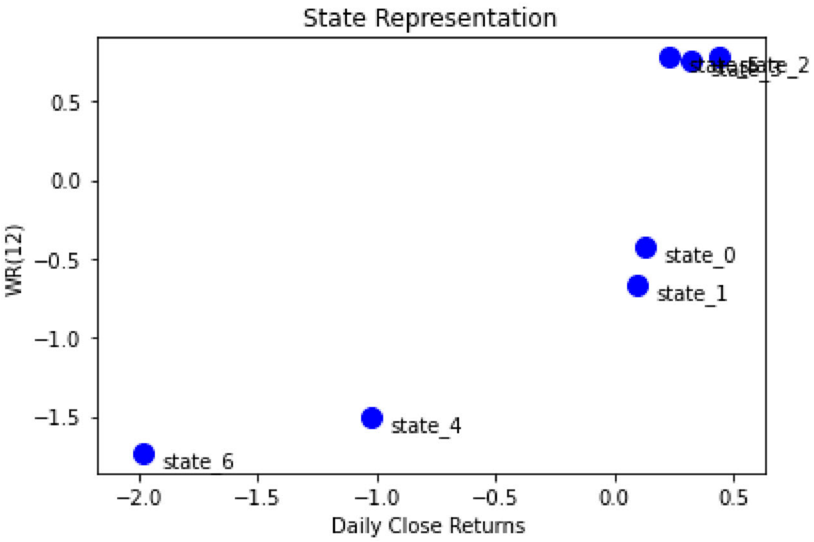
Part 2 - Q-Learning Agent.

Setting up the environment

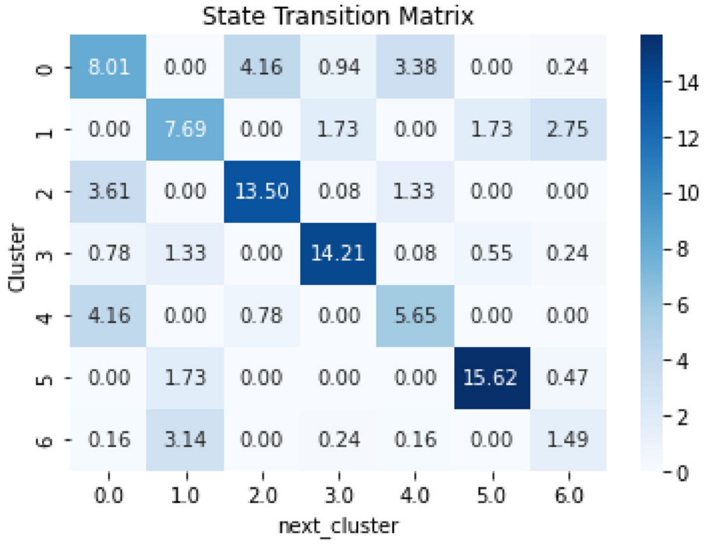
In [3]:

```
trading = StockTradingEnv()
print ('Extracting time period, Defining State, and returning transition Matrix annd
trading.training_data, transition_matrix, reward_matrix = trading.qlearning_preproce
```

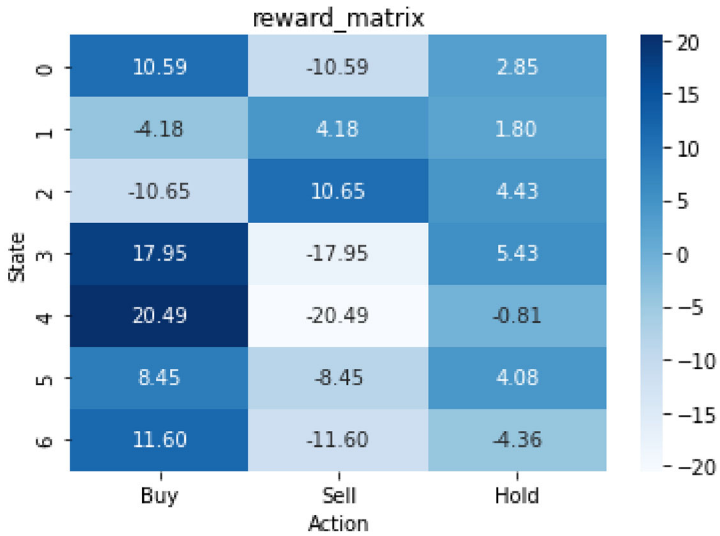
```
Extracting time period, Defining State, and returning transition Matrix annd state t
ransition function
Clustering
```




```
Calculating historical expected transition matrix
```




```
Calculating historical expected return matrix for state-action
```




```
End of Preprocessing
<Figure size 432x288 with 0 Axes>
```

Setting up the Q-Learning Agent

In [38]:

```
#each episode are training on 1 year of data as we are trying to maximize our return
def Qlearning_Agent(epsilon,alpha, gamma, reward_matrix, is_eps_decay = False,episod
    episode_log =[]
    emptyDict = {}
    decay = 0.99
    epsilon_min = 0.1


    Q = np.zeros(reward_matrix.shape)

    for episode in range (episoden):
        rewardlist =[]
        cumulative_reward = 0
        trading.reset()

        for i in range(len(trading.training_data.index)-1):
            #to add code
            possible_action = trading.action_list


            state = trading.training_data.iloc[trading.current_step]['Cluster']
            q_values = [Q[state,possible_action.index(a)] for a in possible_action]
```

```
            best_actions =  np.array(possible_action)[np.where(q_values == np.max(q_
            best_actions_q_values = [Q[state,possible_action.index(x)] for x in best

            #Policy Epsilon-greedy


            is_greedy = random.random() > epsilon

            if is_greedy :
            # we select greedy action
                a = np.random.choice(best_actions)
            else:
            # we sample a random action
                 a = np.random.choice(possible_action)


            # Environment updating
            r = reward_matrix.iloc[state][a]
            cumulative_reward += r
            rewardlist.append(r)
            s_old = state
            state = trading.training_data.iloc[trading.current_step+1]['Cluster']

            # here, the transition function is stochastic. Next state is dependend o
            q_values = [Q[state,possible_action.index(a)] for a in possible_action]
            q_updated = Q[s_old,possible_action.index(a)] + alpha * ( r + gamma * np
            Q[s_old,possible_action.index(a)] = q_updated
            trading.step(a)

        episode_log.append([episode,cumulative_reward])
        if is_eps_decay == True:
            epsilon = epsilon*decay
        if epsilon < epsilon_min:
            epsilon = epsilon_min

    episode_log_df = pd.DataFrame(episode_log,columns=['episode','Cumulative Rewards



    return episode_log_df,Q
```

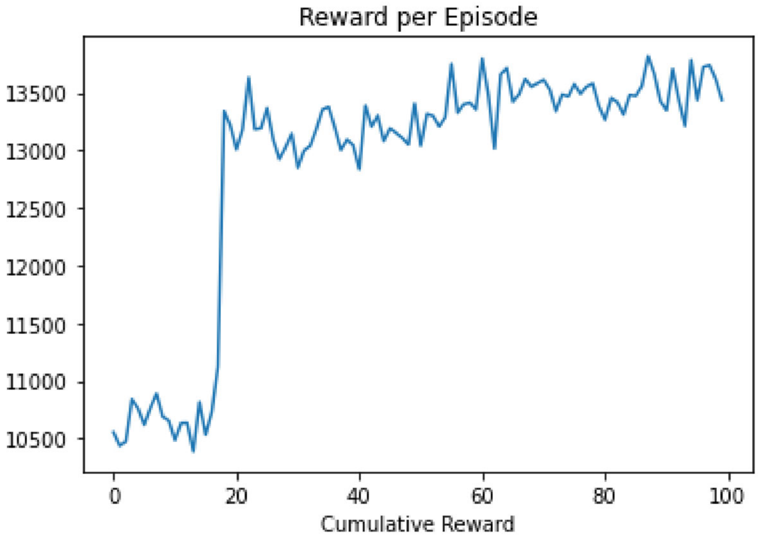
Selected Alpha, Beta and policy

In [43]:

```
ep_log, Qlearned = Qlearning_Agent(0.1,0.01,0.8, reward_matrix)
```

In [44]:

```
plt.plot(ep_log['Cumulative Rewards'])
plt.title('Reward per Episode')
plt.xlabel('Episodes')
plt.xlabel('Cumulative Reward')
plt.show()
```



In [61]:

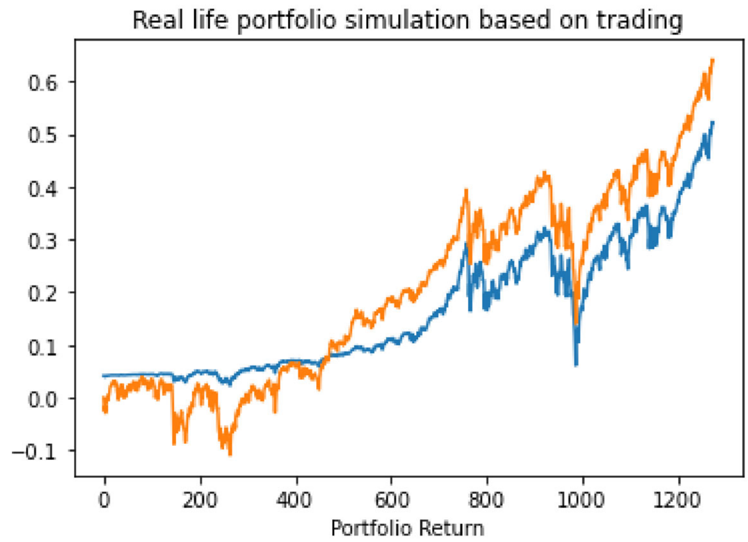
```
last_episode = pd.DataFrame(trading.eventlog,columns =['episode', 'shares', 'cash','
last_episode['NAV'] = last_episode['cash'] + last_episode['shares']*last_episode['pr
last_episode['Return'] = last_episode['NAV']/trading.inital_cash_balance - 1
last_episode['Price Return'] = last_episode['price']/trading.df[trading.df['Date']==
last_episode['Cash%'] = last_episode['cash'] /last_episode['NAV'] *100
last_episode.head(5)
```

Out[61]:

	episode	shares	cash	price	action	comment	NAV	Return	Price Return
0	0	9	50205.349997	205.449997	Sell		52054.399970	0.041088	0.000000
1	1	10	50002.509992	202.740005	Buy		52029.910042	0.040598	-0.013191
2	2	11	49802.269993	200.139999	Buy		52003.809982	0.040076	-0.025846
3	3	12	49600.179988	201.990005	Buy		52024.060048	0.040481	-0.016841
4	4	13	49400.629991	199.449997	Buy		51993.479952	0.039870	-0.029204

In [62]:

```
#Real life portfolio simulation based on signal
plt.plot(last_episode['Return'], label = 'Strategy Return')
plt.plot(last_episode['Price Return'], label = 'ETF Return')
plt.title('Real life portfolio simulation based on trading')
plt.xlabel('Days cumulated')
plt.xlabel('Portfolio Return')
plt.show()
```



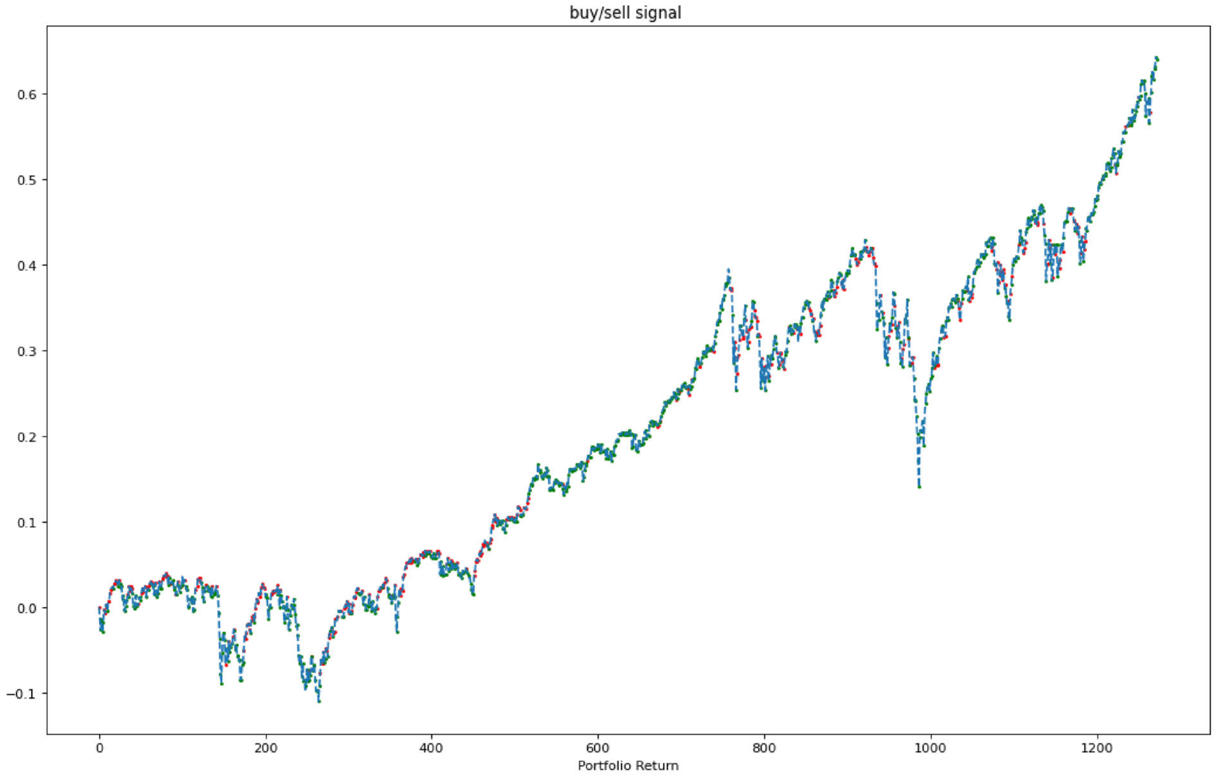
In [60]:

```
#Real life portfolio simulation based on signal
plt.plot(last_episode['Cash%'])
plt.title('Cash % Weight')
plt.xlabel('Days cumulated')
plt.xlabel('Cash%')
plt.show()
```

In [82]:

```
figure(figsize=(16,10), dpi=80)
plt.plot(last_episode['episode'],last_episode['Price Return'], linestyle='dashed', l

plt.scatter(last_episode[last_episode['action']=='Sell']['episode']
            ,last_episode[last_episode['action']=='Sell']['Price Return']
            ,marker="."
            ,color = 'red'
            , label = 'Sell',s = 10)

plt.scatter(last_episode[last_episode['action']=='Buy']['episode']
            ,last_episode[last_episode['action']=='Buy']['Price Return']
            ,marker="."
            ,color = 'green'
            , label = 'Buy'
           , s =10)

plt.title('buy/sell signal ')
plt.xlabel('Days cumulated')
```

```
plt.xlabel('Portfolio Return')
plt.show()
```



Other combination

In [5]:

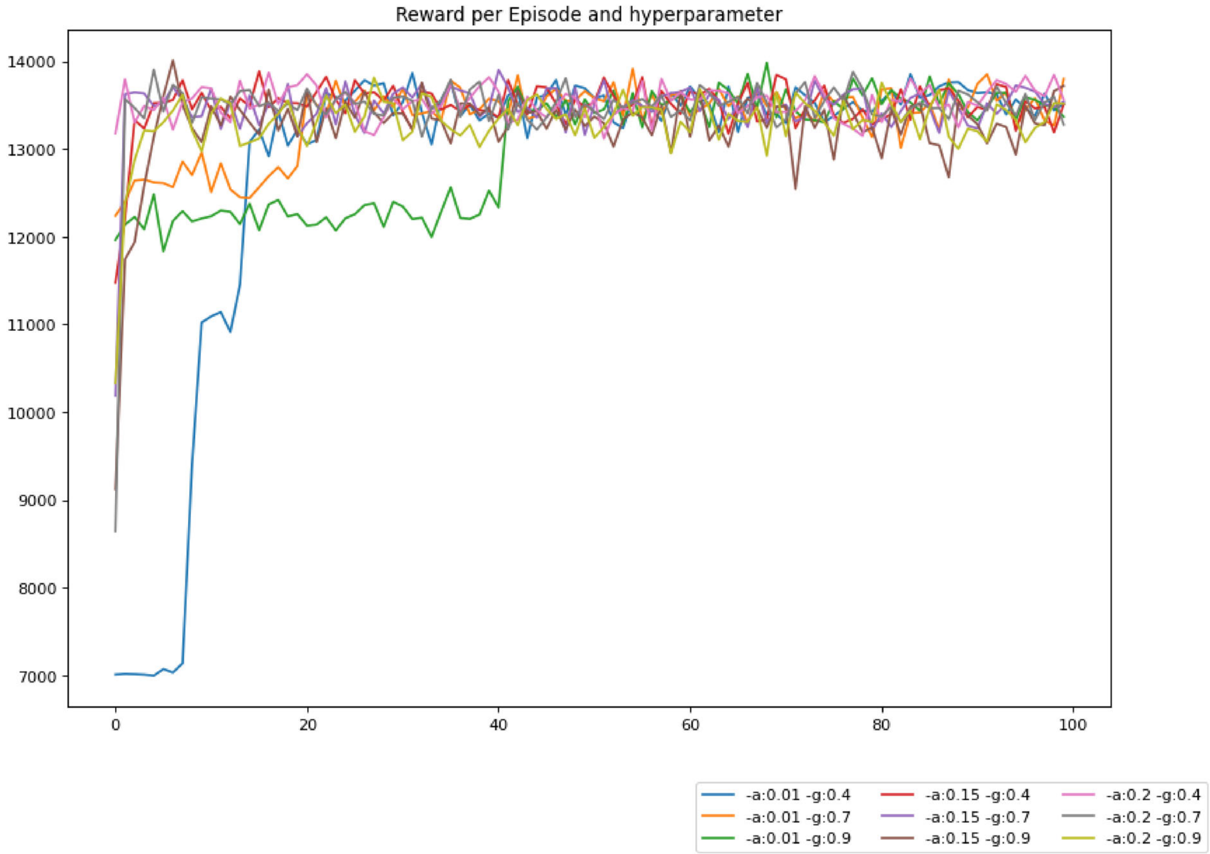
```
alpha_test = [0.01, 0.15, 0.2]
gamma_test = [0.4,0.7,0.9]
epsilon = 0.1

fulllog = None
QLdictionary = {}
for alpha in alpha_test :
    for g in gamma_test :
        hypcomb ='-a:'+str(round(alpha,2))+' -g:'+str(round(g,1))
        print ('-a:'+str(round(alpha,2))+' -g:'+str(round(g,1)))
        ep_log, Qlearned = Qlearning_Agent(epsilon,alpha,g, reward_matrix)
        ep_log['Hyperparameter'] = hypcomb
        QLdictionary[hypcomb] = Qlearned
        if fulllog is None :
            fulllog =ep_log
        else:
            fulllog =fulllog.append(ep_log)
```

```
-a:0.01 -g:0.4
-a:0.01 -g:0.7
-a:0.01 -g:0.9
-a:0.15 -g:0.4
-a:0.15 -g:0.7
-a:0.15 -g:0.9
-a:0.2 -g:0.4
-a:0.2 -g:0.7
-a:0.2 -g:0.9
```

In [6]:

```
figure(figsize=(12,8), dpi=80)
for h in fulllog['Hyperparameter'].drop_duplicates():
    temp =  fulllog[fulllog['Hyperparameter'] == h]
    plt.plot(temp['Cumulative Rewards'], label = h)
```

```
plt.title('Reward per Episode and hyperparameter')
plt.xlabel('Episodes')
plt.xlabel('Cumulative Reward')
plt.legend(fancybox = True, bbox_to_anchor=(1.1, -0.1), ncol = 3 )
plt.show()
```



In [7]:

```
hyperparametergrid = []
for h in fulllog['Hyperparameter'].drop_duplicates():
    temp =  fulllog[fulllog['Hyperparameter'] == h]
    maxreward = temp['Cumulative Rewards'].max()
    minreward = temp['Cumulative Rewards'].min()
    stdreward = temp['Cumulative Rewards'].std()
    meanreward = temp['Cumulative Rewards'].mean()
    print ('For ' +h + ' max,min,std reward : ' + str(round(maxreward,2)) +', '+str(
           +str(round(stdreward,2))+', '+str(round(meanreward,2)))
```

```
For -a:0.01 -g:0.4 max,min,std reward : 13867.75, 6994.93, 1845.22, 12821.49
For -a:0.01 -g:0.7 max,min,std reward : 13915.17, 12238.25, 398.42, 13343.74
For -a:0.01 -g:0.9 max,min,std reward : 13984.6, 11833.2, 659.44, 13001.18
For -a:0.15 -g:0.4 max,min,std reward : 13888.66, 11475.95, 292.65, 13489.37
For -a:0.15 -g:0.7 max,min,std reward : 13903.51, 10186.32, 373.52, 13475.98
For -a:0.15 -g:0.9 max,min,std reward : 14012.58, 9123.96, 526.78, 13257.69
For -a:0.2 -g:0.4 max,min,std reward : 13870.5, 13121.0, 179.55, 13536.49
For -a:0.2 -g:0.7 max,min,std reward : 13905.45, 8643.47, 509.36, 13466.48
For -a:0.2 -g:0.9 max,min,std reward : 13814.42, 10332.82, 373.68, 13305.18
```

In [33]:

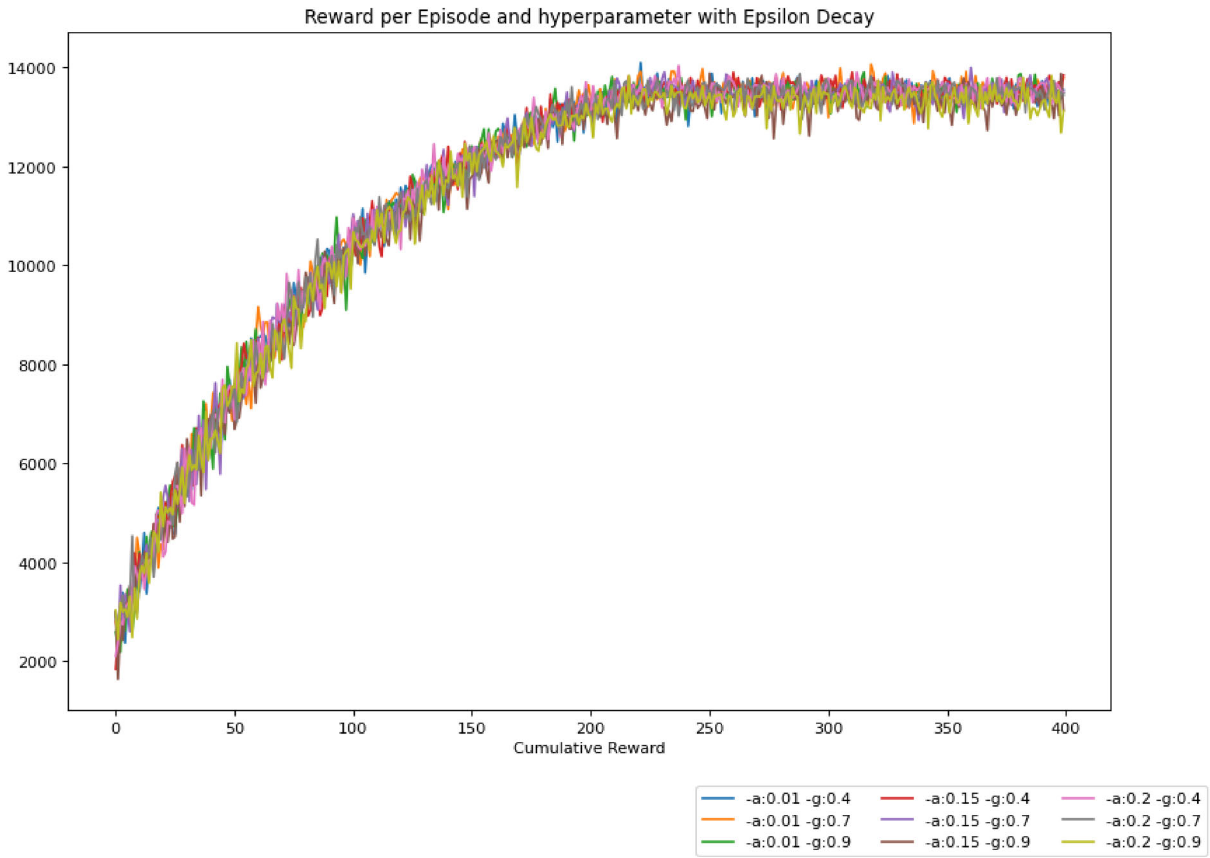
```
alpha_test = [0.01, 0.15, 0.2]
gamma_test = [0.4,0.7,0.9]
starting_epsilon = 0.9


fulllogd = None
QLdictionaryd = {}
for alpha in alpha_test :
```

```
    for g in gamma_test :
            hypcomb ='-a:'+str(round(alpha,2))+' -g:'+str(round(g,1))
            print ('-a:'+str(round(alpha,2))+' -g:'+str(round(g,1)))
            ep_log, Qlearned = Qlearning_Agent(starting_epsilon,alpha,g, reward_matr
            ep_log['Hyperparameter'] = hypcomb
            QLdictionaryd[hypcomb] = Qlearned
            if fulllogd is None :
                fulllogd =ep_log
            else:
                fulllogd =fulllogd.append(ep_log)
```

```
-a:0.01 -g:0.4
-a:0.01 -g:0.7
-a:0.01 -g:0.9
-a:0.15 -g:0.4
-a:0.15 -g:0.7
-a:0.15 -g:0.9
-a:0.2 -g:0.4
-a:0.2 -g:0.7
-a:0.2 -g:0.9
```

In [34]:

```
figure(figsize=(12,8), dpi=80)
for h in fulllogd['Hyperparameter'].drop_duplicates():
    temp =  fulllogd[fulllogd['Hyperparameter'] == h]
    plt.plot(temp['Cumulative Rewards'], label = h)

plt.title('Reward per Episode and hyperparameter with Epsilon Decay')
plt.xlabel('Episodes')
plt.xlabel('Cumulative Reward')
plt.legend(fancybox = True, bbox_to_anchor=(1.1, -0.1), ncol = 3 )
plt.show()
```



In [35]:

```
for h in fulllogd['Hyperparameter'].drop_duplicates():
    temp =  fulllogd[fulllogd['Hyperparameter'] == h]
    maxreward = temp['Cumulative Rewards'].max()
```

```
    minreward = temp['Cumulative Rewards'].min()
    stdreward = temp['Cumulative Rewards'].std()
    meanreward = temp['Cumulative Rewards'].mean()
    print ('For ' +h + ' max,min,std reward : ' + str(round(maxreward,2)) +', '+str(
           +str(round(stdreward,2))+', '+str(round(meanreward,2)))
```

```
For -a:0.01 -g:0.4 max,min,std reward : 14095.11, 2367.69, 2913.97, 11527.4
For -a:0.01 -g:0.7 max,min,std reward : 14059.42, 2362.89, 2910.2, 11566.36
For -a:0.01 -g:0.9 max,min,std reward : 13904.62, 2186.37, 2910.79, 11521.41
For -a:0.15 -g:0.4 max,min,std reward : 13901.55, 1837.71, 2891.83, 11543.85
For -a:0.15 -g:0.7 max,min,std reward : 13991.14, 2429.46, 2891.02, 11512.42
For -a:0.15 -g:0.9 max,min,std reward : 13881.99, 1636.86, 2889.41, 11368.69
For -a:0.2 -g:0.4 max,min,std reward : 14034.55, 2103.49, 2928.78, 11538.98
For -a:0.2 -g:0.7 max,min,std reward : 13870.39, 2536.28, 2911.06, 11490.7
For -a:0.2 -g:0.9 max,min,std reward : 13835.43, 2434.76, 2883.79, 11378.11
```

In [ ]: