In [ ]:
```
# MACHADO, JOHN; HOME WORK 4
```

In [1]:
```
# IMPORTS AND SETTINGS

import matplotlib.pyplot as plt
import numpy as np
import os
import pandas as pd
from random import randint, seed
from scipy import linalg
import seaborn
from sklearn.cluster import KMeans
from sklearn.decomposition import TruncatedSVD
from sklearn.metrics import rand_score, mean_squared_error
from sklearn.metrics.pairwise import cosine_similarity
from sklearn.preprocessing import scale
from time import time
pd.set_option('display.expand_frame_repr', False)
pd.set_option('precision',2)
```

In [736…
```
# QUESTION 1: SET UP DATAFRAME
df = pd.read_csv(
    '../assignment/question_1_data/cleaned_data.csv',
    sep=',',
    header=None
)
df.columns = [
    'area',
    'perimeter',
    'compactness',
    'kernal_length',
    'kernal_width',
    'assymetry_coefficient',
    'groove_length',
    'kernal_type'
]
```

In [737…
```
 # QUESTION 1: INITIAL VISUALIZATION

# seaborn.pairplot(
#     df,
#     corner=True,
#     hue='kernal_type',
#     palette=['red', 'green', 'blue']
# )
```

In [738…
```
# QUESTION 1: FUNCTION

def q1(df):
    _k_means_df = df[df.columns[:-1]]
    _actual_df = pd.DataFrame(df[df.columns[-1]])
    _actual_df.columns = ['actual']
    _clusters = [2, 3, 4, 5]
    _ri_values = []
    _sse_values = []
    for _c in _clusters:
        _k_means = KMeans(
            n_clusters = _c,
            random_state = 2
        )
        _model = _k_means.fit(_k_means_df)
        _sse_values.append(_k_means.inertia_)
        _predicted_df = pd.DataFrame(_model.predict(_k_means_df))
        _predicted_df.columns = ['predicted']
        _ri = rand_score(_actual_df['actual'], _predicted_df['predicted'])
        _ri_values.append(_ri)

    _df_data = {
        'k_values': [2, 3, 4, 5],
        'SEE': _sse_values,
        'RI': _ri_values
    }

    return pd.DataFrame(_df_data)
```

In [739…
```
# QUESTION 1: NOT NORMALIZED
```

```
_not_normalized = q1(df)
_not_normalized
```

Out[739…

	k_values	SEE	RI
0	2	1011.61	0.73
1	3	587.32	0.87
2	4	471.03	0.84
3	5	386.16	0.82

In [740…

```
# QUESTION 1: NORMALIZED

_normalized = pd.DataFrame(scale(df[df.columns[:-1]]))
_normalized.columns = df.columns[:-1]
_normalized['kernal_type'] = df['kernal_type']
_normalized = q1(_normalized)
_normalized
```

Out[740…

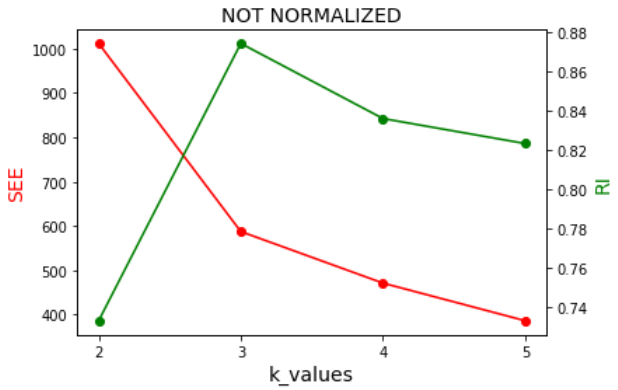
	k_values	SEE	RI
0	2	659.17	0.73
1	3	430.66	0.90
2	4	371.30	0.86
3	5	326.31	0.81

In [741…

```
# QUESTION 1: PLOT FUNCTION

def plotQ1(df, label):
    fig, ax1 = plt.subplots()
    ax2 = ax1.twinx()
    ax1.plot(
        df['k_values'],
        df['SEE'],
        'r-',
        marker='o'
    )
    ax2.plot(
        df['k_values'],
        df['RI'],
        'g-',
        marker='o'
    )
    ax1.set_xticks(df['k_values'])
    ax1.set_xlabel('k_values', fontsize=14)
    ax1.set_ylabel('SEE', color='r', fontsize=14)
    ax2.set_ylabel('RI', color='g', fontsize=14)
    plt.title('{}'.format(label), fontsize=14)
    plt.show()
```

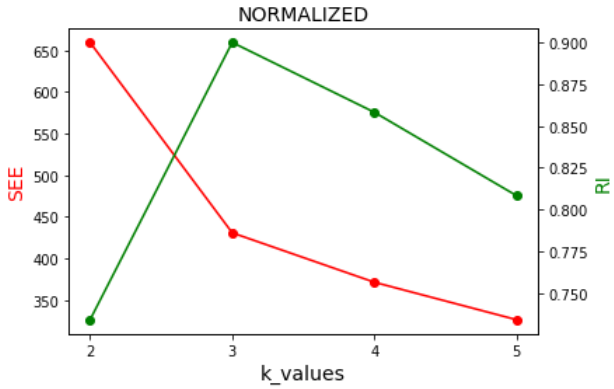
In [742…

```
# QUESTION 1: NOT NORMALIZED PLOT

plotQ1(_not_normalized, 'NOT NORMALIZED')
```



In [743…

```
# QUESTION 1: PLOT NORMALIZED

plotQ1(_normalized, 'NORMALIZED')
```



In [744…

```
# QUESTION 2: SET UP DATAFRAMED

df = pd.read_csv(
    '../assignment/question_2_data/cleaned_data.csv',
    sep=','
)
```

In [745…

```
scaled_df = pd.DataFrame(scale(df))
scaled_df.columns = df.columns
```

In [746…

```
# QUESTION 2: LINEAR PREDICTION FUNCTION
# code below is a modified version of code from Regression Modeling Slide Deck, Slide 19

def q2(x, y, learn_rate, iterations):
    _x0 = np.ones((len(x), 1))
    X = np.hstack((_x0, x))
    w = np.random.randn(X.shape[1])
    result = []
    _loss = 0
    for _t in range(iterations):
        _y_pred = X.dot(w)
        _loss = np.square(_y_pred - y).sum()
        result.append(_loss)
        _grad_y_pred = 2.0 * (_y_pred - y)
        _grad_w = X.T.dot(_grad_y_pred)
        w -= learn_rate * _grad_w
    return w, result
```

In [747…

```
# QUESTION 2: PREDICT FUNCTION

def q2predict(x, w):
    _x0 = np.ones((len(x), 1))
    X = np.hstack((_x0, x))
    return X.dot(w)
```

In [748…

```
# QUESTION 2: TEST LOOP

_features = ['police_funding', 'over_25_hs', 'under_19_no_hs', 'college_students', 'over_25_college']
_x = scaled_df[_features]
_y = scaled_df['violent_crime']
_learning_rates = [1e-3, 1E-4, 1e-5]
_iteration_list = [1_000]
_test_rates = []
_test_iterations = []
_ellapsed_times = []
_w_list = []
_error_list = []
_mse_list=[]

for _rate in _learning_rates:
    for _iterations in _iteration_list:
        print('Testing learining rate {} with {} iterations.'.format(_rate, _iterations))
        if _rate == 1e-5: _iterations = 10_000
        start_time = time()
        _w, _error = q2(_x, _y, _rate, _iterations)
        stop_time = time()
        _test_rates.append(_rate)
        _test_iterations.append(_iterations)
        _ellapsed_times.append(stop_time - start_time)
        _w_list.append(_w)
        _error_list.append(_error)
```

```
        _mse_list.append(mean_squared_error(_y, q2predict(_x, _w)))

_result = {
    'learning_rates': _test_rates,
    'iteration_list': _test_iterations,
    'ellapsed_time': _ellapsed_times,
    'mse': _mse_list,
    'w': _w_list,
    'error': _error_list
}

result = pd.DataFrame(_result)
```

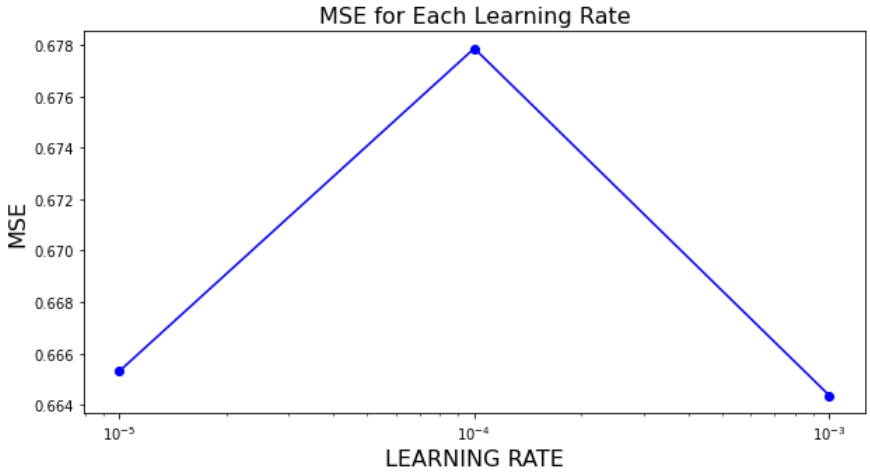
```
Testing learining rate 0.001 with 1000 iterations.
Testing learining rate 0.0001 with 1000 iterations.
Testing learining rate 1e-05 with 1000 iterations.
```

In [749…

```
# QUESTION 2: SAVE RESULTS

result.to_csv('result.csv')
```

In [750…

```
# QUESTION 2: MSE PLOT

_x = result['learning_rates']
_y = result['mse']
plt.figure(figsize=(10,5))
plt.plot(
    _x,
    _y,
    'b-',
    marker='o'
)
# for _lr, _et, _it in zip(_x,_y, result['iteration_list']):
#     label = '{:,} iterations'.format(_it)
#     plt.annotate(
#         text=label,
#         xy=(_lr,_et),
#         xytext=(5,2),
#         textcoords=('offset pixels')
#     )
plt.xscale('log')
plt.ylabel('MSE', fontsize=16)
plt.xlabel('LEARNING RATE', fontsize=16)
plt.xticks(_x)
plt.title('MSE for Each Learning Rate', fontsize=16)
plt.show()
```



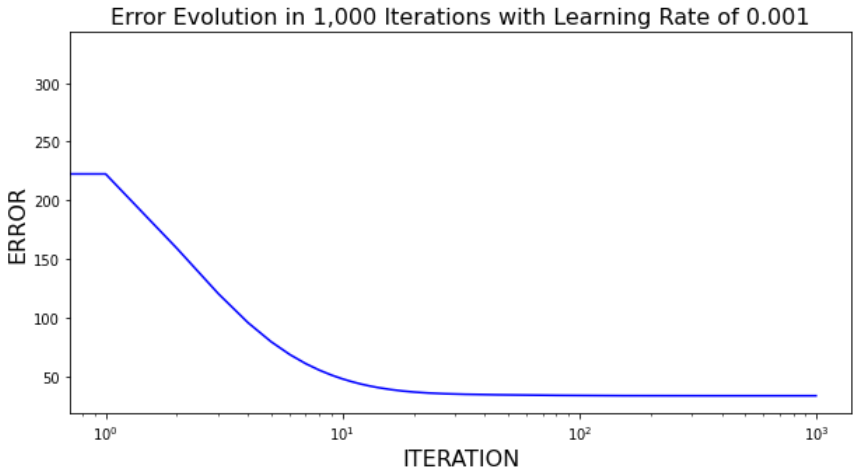
In [751…

```
# QUESTION 2: ERROR VS ITERATION PLOT FUNCTION

def q2ErrorPlot(test):
    _x = np.arange(len(result.iloc[test,5]))
    _y = result.iloc[test,5]
    plt.figure(figsize=(10,5))
    plt.plot(
        _x,
        _y,
        'b-',
    )
    plt.xscale('log')
    plt.ylabel('ERROR', fontsize=16)
    plt.xlabel('ITERATION', fontsize=16)
```

```
    plt.title('Error Evolution in {:,} Iterations with Learning Rate of {}'.format(result.iloc[test,1], result.iloc[test,
    plt.show()
```

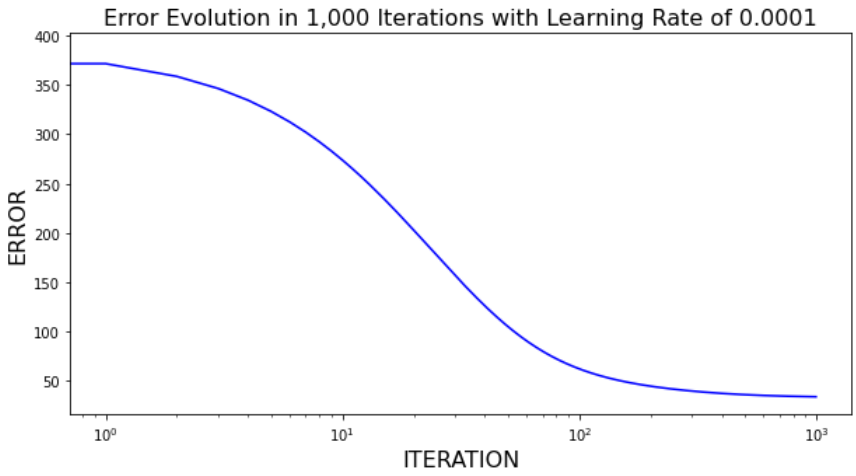
In [752…

```
# QUESTION 2: PLOT LEARNING RATE 0.1, ITERATIONS 1,000

q2ErrorPlot(0)
```



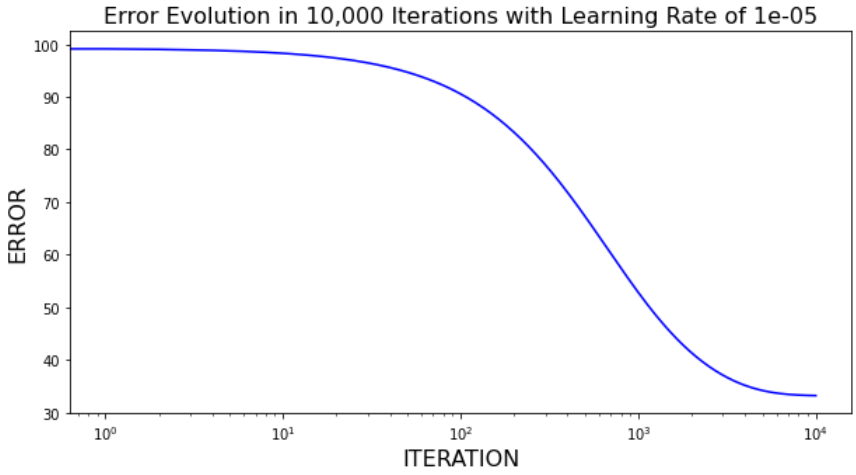
In [753…

```
# QUESTION 2: PLOT LEARNING RATE 0.01, ITERATIONS 1,000

q2ErrorPlot(1)
```



In [754…

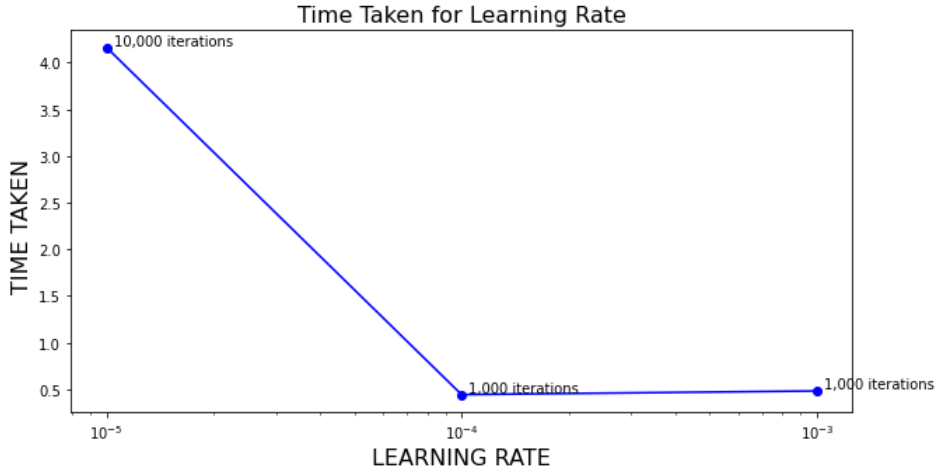
```
# QUESTION 2: PLOT LEARNING RATE 0.001, ITERATIONS 1,000

q2ErrorPlot(2)
```



In [755…

```
# QUESTION 2: TIME TAKEN FOR EACH TEST
```

```
_x = result['learning_rates']
_y = result['ellapsed_time']
plt.figure(figsize=(10,5))
plt.plot(
    _x,
    _y,
    'b-',
    marker='o'
)
for _lr, _et, _it in zip(_x,_y, result['iteration_list']):
    label = '{:,} iterations'.format(_it)
    plt.annotate(
        text=label,
        xy=(_lr,_et),
        xytext=(5,2),
        textcoords=('offset pixels')
    )
plt.xscale('log')
plt.ylabel('TIME TAKEN ', fontsize=16)
plt.xlabel('LEARNING RATE', fontsize=16)
plt.xticks(_x)
plt.title('Time Taken for Learning Rate', fontsize=16)
plt.show()
```



In [756…

```
# QUESTIN 3: SETUP COUNT DATAFRAME
# put all questio 3 cells into a loop if there is time

A = 'A'
B = 'B'
C = 'C'
D = 'D'
E = 'E'
_items_bought_list = [
    {A, B, D, E},
    {B, C, D},
    {A, B, D, E},
    {A, C, D, E},
    {B, C, D, E},
    {B, D, E},
    {C, D},
    {A, B, C},
    {A, D, E},
    {B, D},
]

_tid_df_list = []
_items_df_list = []
for _i,_row in enumerate(_items_bought_list):
    for _item in _row:
        _tid_df_list.append(_i+1)
        _items_df_list.append(_item)
_df_data = {
    'TID': _tid_df_list,
    'items': _items_df_list
}
_count_df = pd.DataFrame(_df_data)
```

In [757…

```
# QUESTION 3: SET UP SET DATAFRAME

A = 'A'
B = 'B'
```

```
C = 'C'
D = 'D'
E = 'E'
_items_bought_list = [
    {A, B, D, E},
    {B, C, D},
    {A, B, D, E},
    {A, C, D, E},
    {B, C, D, E},
    {B, D, E},
    {C, D},
    {A, B, C},
    {A, D, E},
    {B, D},
]
_tid_list = np.arange(len(_items_bought_list)) + 1
_df_data = {
    'TID': _tid_list,
    'items': _items_bought_list
}
_set_df = pd.DataFrame(_df_data)
_set_df
```

Out[757…

	TID	items
0	1	{A, B, D, E}
1	2	{C, B, D}
2	3	{A, B, D, E}
3	4	{A, C, D, E}
4	5	{C, B, D, E}
5	6	{B, D, E}
6	7	{C, D}
7	8	{A, C, B}
8	9	{A, D, E}
9	10	{B, D}

In [758…

```
# QUESTION 3: INITIAL COUNTS
_min_support = 2
_c = _count_df['items'].value_counts()
_c
_l = _c[_c >= _min_support]
_l
```

Out[758…

```
D    9
B    7
E    6
A    5
C    5
Name: items, dtype: int64
```

In [759…

```
# QUESTION 3: INITIAL COMBINATIONS
_comb = []
_keys = _l.keys()
_len = len(_keys)
for _i in range(_len):
    for _j in range(_i+1, _len):
        _comb.append({_keys[_i], _keys[_j]})
```

In [760…

```
# QUESTION 3: COUNT OCCURANCES

_count_list = []
for _comb_row in _comb:
    _count = 0
    for _df_row in _set_df.iterrows():
        if _comb_row.issubset(_df_row[1][1]):
            _count += 1
    _count_list.append(_count)
```

In [761…

```
# QUESTION 3: SAVE TO DF FOR LOW COUNT REMOVAL

_df_data = {'combinations': _comb, 'occurances': _count_list}
_df = pd.DataFrame(_df_data)
```

In [762…

```
# QUESTION 3: LOW COUNT REMOVAL
```

```
_df = _df[_df['occurances'] >= 3]
_df
```

Out[762…

	combinations	occurances
0	{B, D}	6
1	{D, E}	6
2	{A, D}	4
3	{C, D}	4
4	{B, E}	4
5	{A, B}	3
6	{C, B}	3
7	{A, E}	4

In [763…

```
# QUESTION 3: NEW COMBINATIONS

_n = []
_combs = _df['combinations']
_len = len(_combs)
for _i in range(_len):
    for _j in range(_i+1,_len):
        _n.append(_combs[_i].union(_combs[_j]))
_comb = []
[_comb.append(x) for x in _n if x not in _comb]
_comb
```

Out[763…

```
[{'B', 'D', 'E'},
 {'A', 'B', 'D'},
 {'B', 'C', 'D'},
 {'A', 'B', 'D', 'E'},
 {'A', 'D', 'E'},
 {'C', 'D', 'E'},
 {'B', 'C', 'D', 'E'},
 {'A', 'C', 'D'},
 {'A', 'B', 'C', 'D'},
 {'A', 'C', 'D', 'E'},
 {'A', 'B', 'E'},
 {'B', 'C', 'E'},
 {'A', 'B', 'C'},
 {'A', 'B', 'C', 'E'}]
```

In [764…

```
# QUESTION 3: COUNT OCCURANCES

_count_list = []
for _comb_row in _comb:
    _count = 0
    for _df_row in _set_df.iterrows():
        if _comb_row.issubset(_df_row[1][1]):
            _count += 1
    _count_list.append(_count)
```

In [765…

```
# QUESTION 3: SAVE TO DF FOR LOW COUNT REMOVAL

_df_data = {'combinations': _comb, 'occurances': _count_list}
_df = pd.DataFrame(_df_data)
```

In [766…

```
# QUESTION 3: FINAL ANSWER
_df = _df[_df['occurances'] >= 3]
_df
```

Out[766…

	combinations	occurances
0	{B, D, E}	4
4	{A, D, E}	4

In [767…

```
# QUESTION 4: SETUP DATA

_data = {
    'KEYS': ['K1', 'K2', 'K3', 'K4', 'K5'],
    'D1': [True, False, True, True, False],
    'D2': [False, True, True, False, False],
    'D3': [True, False, False, False, False],
    'D4': [False, False, False, True, True],
```

```
    'D5': [False, False, False, True, False],
    'D6': [False, False, False, False, True]
}
df = pd.DataFrame(_data)
df
```

Out[767…

	KEYS	D1	D2	D3	D4	D5	D6
0	K1	True	False	True	False	False	False
1	K2	False	True	False	False	False	False
2	K3	True	True	False	False	False	False
3	K4	True	False	False	True	True	False
4	K5	False	False	False	True	False	True

In [768…

```
# QUESTION 4: GET SVD SPECIFIC DATA

np.set_printoptions(precision=2)
_svd_df = df.iloc[:,1:]
```

In [769…

```
# QUESTION 4: (i) Obtain the singular value decomposition of F.

U, s, V = linalg.svd(_svd_df)
s_print = pd.DataFrame(s)
s_print
```

Out[769…

	0
0	2.16
1	1.59
2	1.28
3	1.00
4	0.39

In [770…

```
# QUESTION 4: (ii) Reconstruct F using only the toptwo singular values.

_lsa = TruncatedSVD(
    2,
    algorithm='arpack'
)
Fa = _lsa.fit_transform(_svd_df)
Fa_print = pd.DataFrame(Fa)
Fa_print.columns = ['s[0]*U[:,0]', 's[1]*U[:,1]']
Fa_print
```

Out[770…

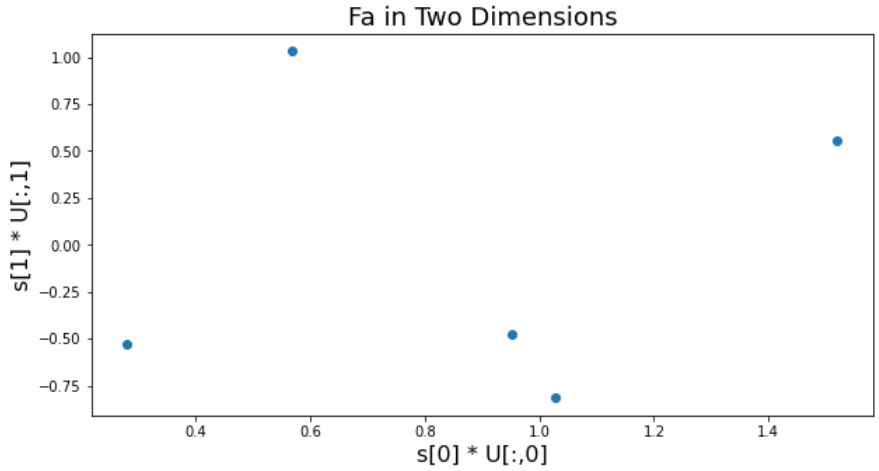
	s[0]*U[:,0]	s[1]*U[:,1]
0	0.95	-0.47
1	0.28	-0.53
2	1.03	-0.81
3	1.52	0.56
4	0.57	1.03

In [771…

```
# QUESTION 4: (iii) Show the representation of the documents and the keywords in the 2-D space after SVD application.

plt.figure(figsize=(10,5))
plt.scatter(
    Fa_print.iloc[:,0],
    Fa_print.iloc[:,1]
)
plt.xlabel('s[0] * U[:,0]', fontsize=16)
plt.ylabel('s[1] * U[:,1]', fontsize=16)
plt.title('Fa in Two Dimensions', fontsize=18)
```

Out[771…

```
Text(0.5, 1.0, 'Fa in Two Dimensions')
```



In [772…

```
# QUESTIN 4: (iv) Using the cosine similarity measure in the LSI space, calculate the document similarity matrix.

cos_sim_print = pd.DataFrame(cosine_similarity(_svd_df))
cos_sim_print
```

Out[772…

	0	1	2	3	4
0	1.00	0.00	0.50	0.41	0.00
1	0.00	1.00	0.71	0.00	0.00
2	0.50	0.71	1.00	0.41	0.00
3	0.41	0.00	0.41	1.00	0.41
4	0.00	0.00	0.00	0.41	1.00