matrix_factorizations_2

February 28, 2020

1 Matrix Factorization Visualizations - Method 2 (Code Modified from Homework 5)

Starter code written by: Fabian Boemer, Sid Murching, Suraj Nair, Alex Cui

```
In [1]: import numpy as np
        import matplotlib.pyplot as plt
        import pandas as pd
```

```
In [2]: def grad_U(Ui, Yij, Vj, mu, ai, bj, reg, eta):
            """
            Takes as input Ui (the ith row of U), a training point Yij, the column
            vector Vj (jth column of V^T), the average of all observations mu,
            ai (the ith entry of a), bj (the jth entry of b),
            reg (the regularization parameter lambda), and eta (the learning rate).

            Returns the gradient of the regularized loss function with
            respect to Ui multiplied by eta.
            """

            grad = reg*Ui - Vj*((Yij - mu) - (np.dot(Ui, Vj) + ai + bj))

            return eta*grad

        def grad_V(Vj, Yij, Ui, mu, ai, bj, reg, eta):
            """
            Takes as input the column vector Vj (jth column of V^T), a training point Yij,
            the average of all observations mu, ai (the ith entry of a),
            bj (the jth entry of b), Ui (the ith row of U),
            reg (the regularization parameter lambda), and eta (the learning rate).

            Returns the gradient of the regularized loss function with
            respect to Vj multiplied by eta.
            """

            grad = reg*Vj - Ui*((Yij - mu) - (np.dot(Ui, Vj) + ai + bj))
```

```python
    return eta*grad

def grad_a(ai, Yij, mu, Ui, Vj, bj, reg, eta):
    """
    Takes as input ai (the ith entry of a), a training point Yij,
    Ui (the ith row of U), the average of all observations mu,
    the column vector Vj (jth column of V^T), bj (the jth entry of b),
    reg (the regularization parameter lambda), and eta (the learning rate).

    Returns the gradient of the regularized loss function with
    respect to ai multiplied by eta.
    """

    grad = reg*ai - (Yij - mu) + (np.dot(Ui, Vj) + ai + bj)

    return eta*grad

def grad_b(bj, Yij, mu, Ui, Vj, ai, reg, eta):
    """
    Takes as input bj (the jth entry of b), a training point Yij,
    Ui (the ith row of U), the average of all observations mu,
    the column vector Vj (jth column of V^T), ai (the ith entry of a),
    reg (the regularization parameter lambda), and eta (the learning rate).

    Returns the gradient of the regularized loss function with
    respect to bj multiplied by eta.
    """

    grad = reg*bj - (Yij - mu) + (np.dot(Ui, Vj) + ai + bj)

    return eta*grad

def get_err(U, V, Y, mu, a, b, reg=0.0):
    """
    Takes as input a matrix Y of triples (i, j, Y_ij) where i is the index of a user,
    j is the index of a movie, and Y_ij is user i's rating of movie j;
    user/movie matrices U and V; bias vectors a and b;
    and mu, the average of all observations.

    Returns the mean regularized squared-error of predictions made by
    estimating Y_{ij} as the dot product of the ith row of U and the jth column of V^T
    """

    error = 0.5*reg*(np.linalg.norm(U, 'fro')**2 + np.linalg.norm(V, 'fro')**2 + np.li

    for k in range(len(Y)):
        Yij = Y[k][2]
        i = Y[k][0] - 1
        j = Y[k][1] - 1
        error += 0.5*((Yij - mu) - (np.dot(U[i,:], V[j,:]) + a[i] + b[j]))**2

    return error / len(Y) # mean error

def train_model(M, N, K, eta, reg, Y, mu, eps=0.0001, max_epochs=300):
    """
    Given a training data matrix Y containing rows (i, j, Y_ij)
    where Y_ij is user i's rating on movie j, and mu is the average of all Y_ij,
    learns an M x K matrix U and N x K matrix V such that rating Y_ij is approximated
    by (UV^T)_ij.

    Uses a learning rate of <eta> and regularization of <reg>. Stops after
    <max_epochs> epochs, or once the magnitude of the decrease in regularized
    MSE between epochs is smaller than a fraction <eps> of the decrease in
    MSE after the first epoch.

    Returns a tuple (U, V, err) consisting of U, V, and the unregularized MSE
    of the model.
    """

    # initialize entries of U, V, a, b uniformly and randomly in [-0.5, 0.5]
    U = np.random.rand(M, K) - 0.5*np.ones([M, K])
    V = np.random.rand(N, K) - 0.5*np.ones([N, K])
    a = np.zeros([M, 1]) # corresponds to users
    b = np.zeros([N, 1]) # corresponds to movies

    epochs = 0
    rel_red = np.inf
    err = get_err(U, V, Y, mu, a, b, reg)

    while epochs < max_epochs and rel_red > eps:
        # store previous error
        prev_err = np.copy(err)

        # shuffle training data
        order = np.random.permutation(len(Y))

        # perform SGD
        for o in order:
            i = Y[o][0] - 1
            j = Y[o][1] - 1
            Yij = Y[o][2]
            Ui = U[i,:]
            Vj = V[j,:]
            ai = a[i]
            bj = b[j]
```

```
                    # update U, V, a, b
                    U[i,:] -= grad_U(Ui, Yij, Vj, mu, ai, bj, reg, eta)
                    V[j,:] -= grad_V(Vj, Yij, Ui, mu, ai, bj, reg, eta)
                    a[i] -= grad_a(ai, Yij, mu, Ui, Vj, bj, reg, eta)
                    b[j] -= grad_b(bj, Yij, mu, Ui, Vj, ai, reg, eta)

                # compute error and loss reduction
                err = get_err(U, V, Y, mu, a, b, reg)
                loss_red = err - prev_err

                # store initial loss reduction for comparison
                if epochs == 0:
                    init_red = np.copy(loss_red)

                # compute relative loss reduction
                rel_red = loss_red/init_red
                epochs += 1
                print(epochs)

            return (U, V, err, a, b)
```

```
In [106]: # factorize using SGD as in Homework 5
          Y_train = np.loadtxt('./data/train2.txt').astype(int)
          Y_test = np.loadtxt('./data/test2.txt').astype(int)

          M = max(max(Y_train[:,0]), max(Y_test[:,0])).astype(int) # users
          N = max(max(Y_train[:,1]), max(Y_test[:,1])).astype(int) # movies
          k = 20
          mu = np.mean(Y_train[:,2])

          regs = [10**-4, 10**-3, 10**-2, 10**-1, 0.3, 0.5, 0.7, 1]
          eta = 0.03 # learning rate
          E_ins = []
          E_outs = []

          # Use to compute Ein and Eout
          for reg in regs:

              print("Training model with M = %s, N = %s, k = %s, eta = %s, reg = %s"%(M, N, k,
              U, V, e_in, a, b= train_model(M, N, k, eta, reg, Y_train, mu)
              e_out = get_err(U, V, Y_test, mu, a, b)

              E_ins.append(e_in)
              E_outs.append(e_out)
```

```
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.0001
1
2
```

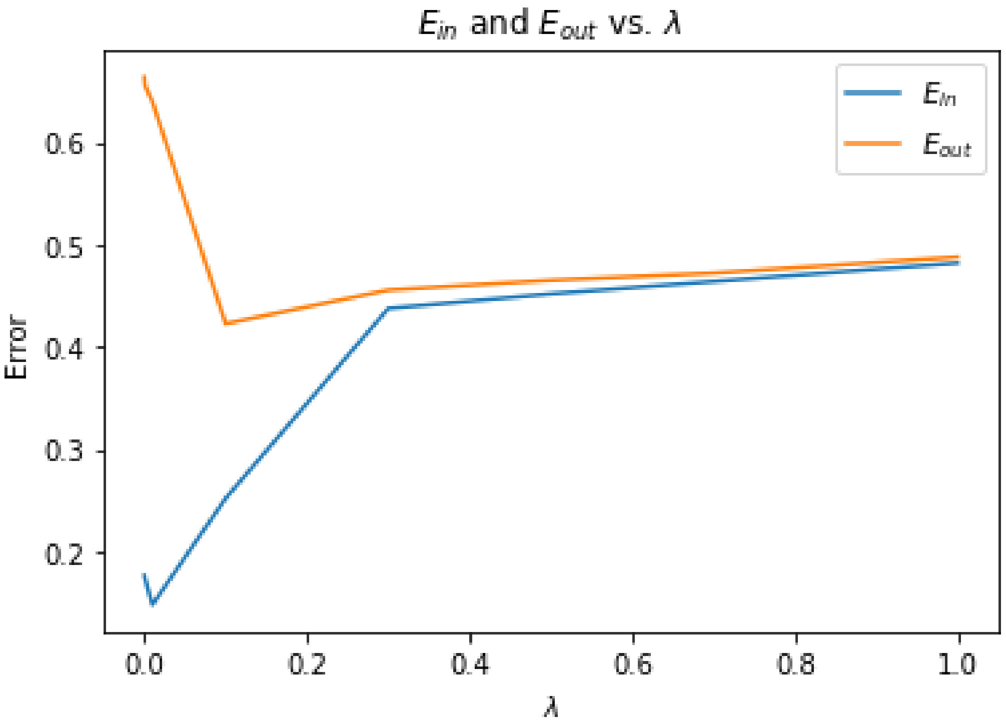
```
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.001
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.01
1
```

```
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.1
1
2
```

```
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.3
1
2
3
4
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.5
1
2
3
4
5
6
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 0.7
```

```
1
2
3
4
5
6
7
8
Training model with M = 943, N = 1664, k = 20, eta = 0.03, reg = 1
1
2
3
4
5
```

```
In [107]: # Plot values of E_in across k for each value of lambda
          plt.figure()
          plt.plot(regs, E_ins)
          plt.plot(regs, E_outs)
          plt.title('$E_{in}$ and $E_{out}$ vs. $\lambda$')
          plt.xlabel('$\lambda$')
          plt.ylabel('Error')
          plt.legend(['$E_{in}$', '$E_{out}$'])
          plt.savefig('matrix_2_reg.png')
```



```
In [108]: E_outs

Out[108]: [array([0.66362068]),
           array([0.65544063]),
           array([0.63991869]),
           array([0.4225576]),
           array([0.45544683]),
           array([0.46507973]),
           array([0.47208135]),
           array([0.4877622])]
```

```
In [17]: # load data from cleaned files
         movies = pd.read_csv('data/movies.csv')
         data = pd.read_csv('data/data.csv').astype(int)
         train_data = np.loadtxt('./data/data2.txt').astype(int)
```

```
In [95]: # train using best lambda on entire dataset
         M = max(data['User']) # users
         N = max(data['Movie']) # movies
         U, V, e_in, a, b = train_model(M, N, k, eta, 0.1, train_data, mu)

         # note that U is Mxk and V is Nxk, so we transpose them to be consistent
         # with the convention used in the Miniproject 2 pdf
         U = U.T
         V = V.T
```

```
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
```

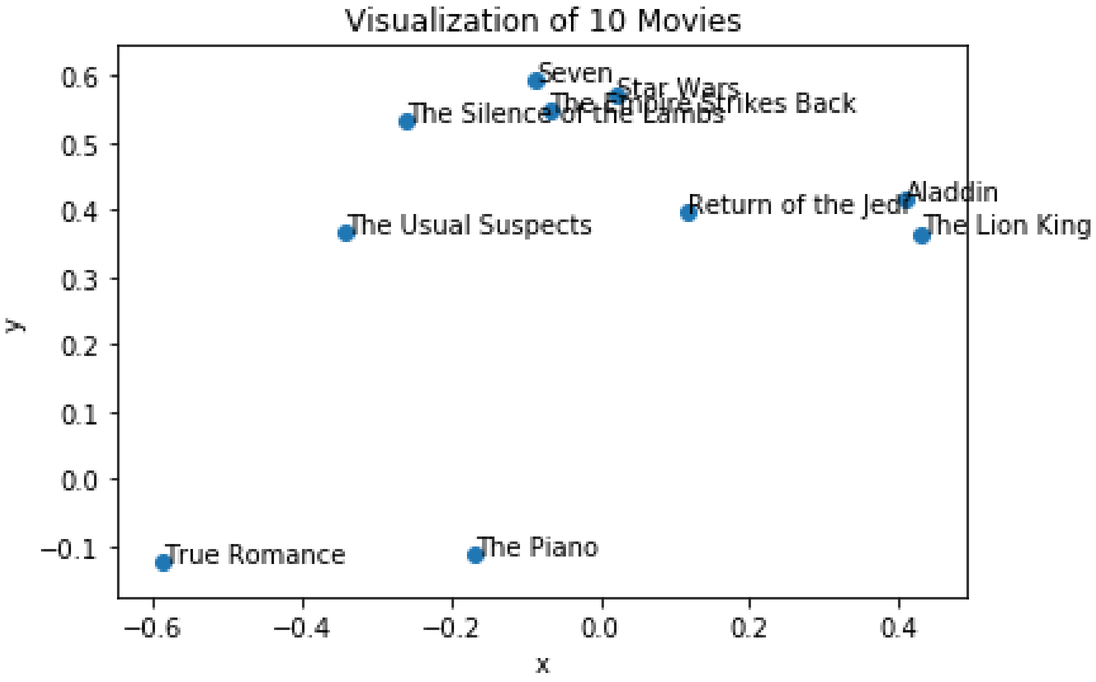
```
22
23
24
25
26
27
28
29
```

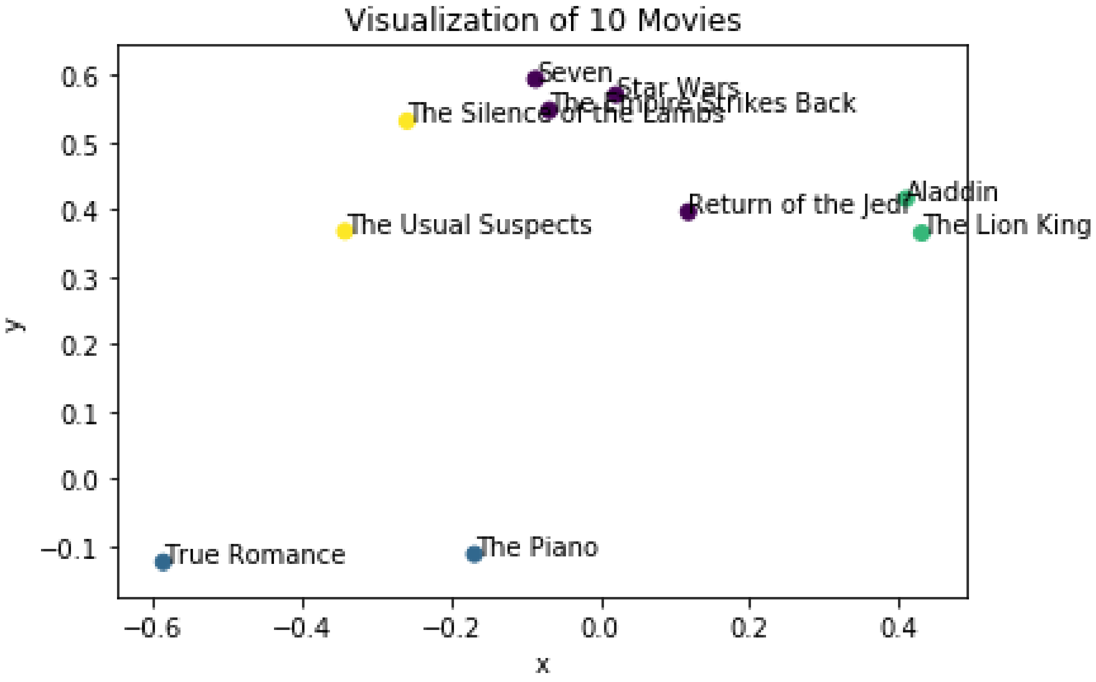
```
In [96]: # mean-centering
         V_mean = V.mean(axis=1)
         for i in range(N):
             V[:,i] -= V_mean
         for i in range(M):
             U[:,i] -= V_mean

         # get SVD of V
         A, S, B = np.linalg.svd(V)
```

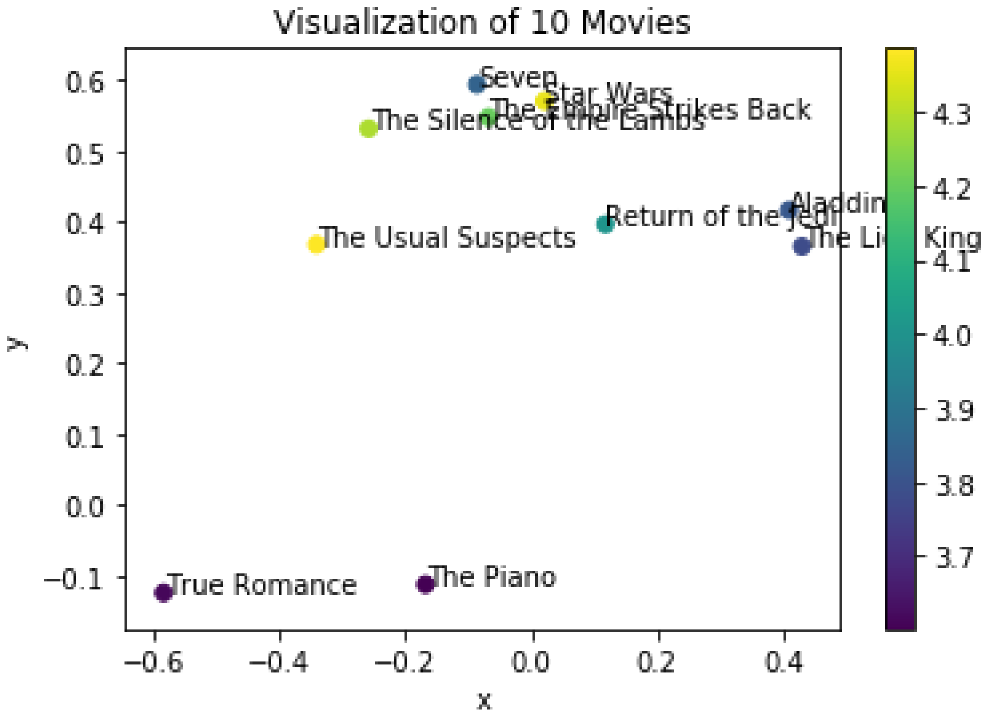
```
In [97]: # project U, V into K-dimensional space
         K = 2
         U_tilde = np.matmul(A.T[:K], U)
         V_tilde = np.matmul(A.T[:K], V)
```

```
In [124]: # visualize any 10 movies
          ids = [11, 12, 71, 95, 98, 92, 578, 181, 172, 50]

          titles = ['Seven', 'The Usual Suspects', 'The Lion King', 'Aladdin', 'The Silence of

          x = [0]*10
          y = [0]*10
          for i in range(len(ids)):
              x[i] = V_tilde[0][ids[i]-1]
              y[i] = V_tilde[1][ids[i]-1]

          fig, ax = plt.subplots()
          plt.scatter(x, y)

          for i, txt in enumerate(titles):
              ax.annotate(txt, (x[i], y[i]))

          plt.title('Visualization of 10 Movies')
          plt.xlabel('x')
          plt.ylabel('y')
          plt.savefig('matrix_2_a.png')

          # run k-means to cluster points
```

```
from sklearn.cluster import KMeans

X = np.column_stack((x, y))
labels = KMeans(n_clusters=4, random_state=0).fit_predict(X)

fig, ax = plt.subplots()
plt.scatter(x, y, c=labels)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.savefig('matrix_2_a_clusters.png')

# visualize movies by their average ratings
ratings = []
for i in ids:
    ratings.append(movies['avg_rating'][i-1])

fig, ax = plt.subplots()
plt.scatter(x, y, c=ratings)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.colorbar()
plt.savefig('matrix_2_a_ratings.png')
```


Visualization of 10 Movies
Seven
Star Wars
The Empire Strikes Back
The Silence of the Lambs
The Usual Suspects
Return of the Jedi
Aladdin
The Lion King
True Romance
The Piano
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
y
−0.6
−0.4
−0.2
0.0
0.2
0.4
x


Visualization of 10 Movies
Seven
Star Wars
The Empire Strikes Back
The Silence of the Lambs
The Usual Suspects
Return of the Jedi
Aladdin
The Lion King
True Romance
The Piano
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
y
−0.6
−0.4
−0.2
0.0
0.2
0.4
x

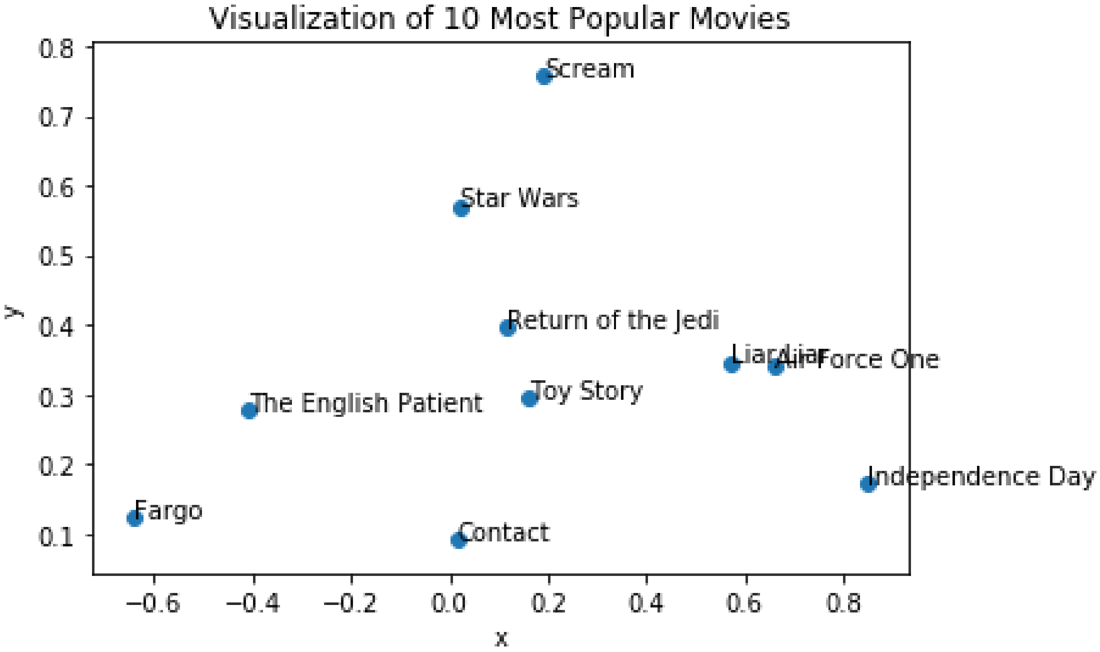


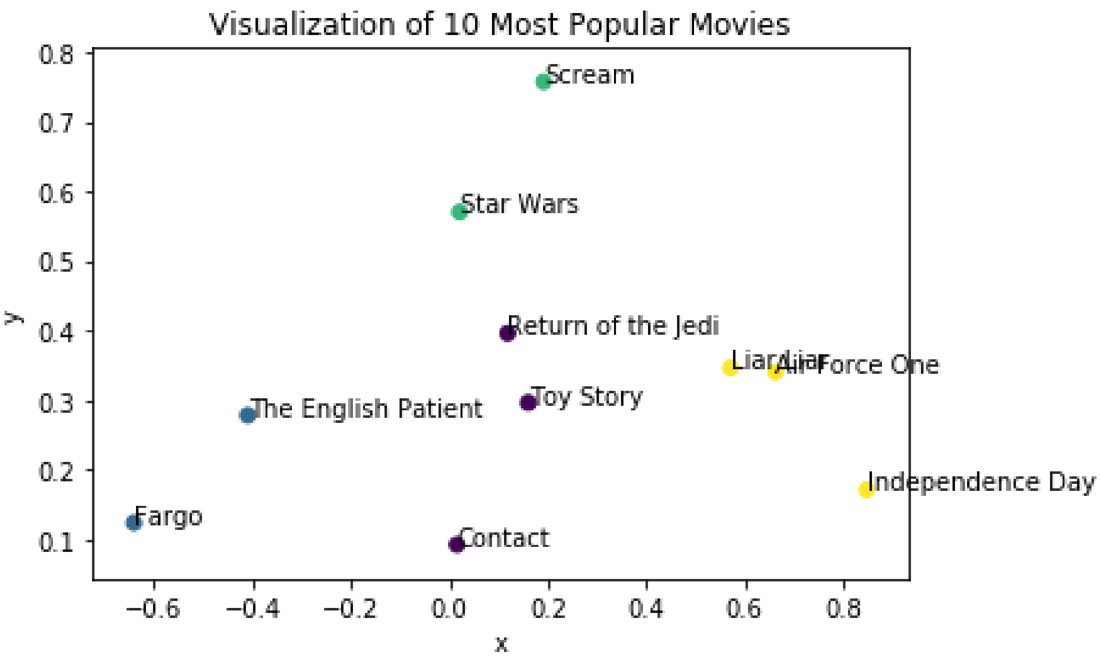
```
In [117]: # visualize 10 most popular movies
          pop = data['Movie'].value_counts().head(10).index

          for i in pop:
              print(movies[movies['ID'] == i]['Title'])

          titles = ['Star Wars', 'Contact', 'Fargo', 'Return of the Jedi', 'Liar Liar', 'The E

          x = [0]*10
          y = [0]*10
          for i in range(len(pop)):
              x[i] = V_tilde[0][pop[i]-1]
              y[i] = V_tilde[1][pop[i]-1]

          # clustering
          X = np.column_stack((x, y))
          labels = KMeans(n_clusters=4, random_state=0).fit_predict(X)

          # plot visualization
          fig, ax = plt.subplots()
          plt.scatter(x, y)

          for i, txt in enumerate(titles):
              ax.annotate(txt, (x[i], y[i]))
```

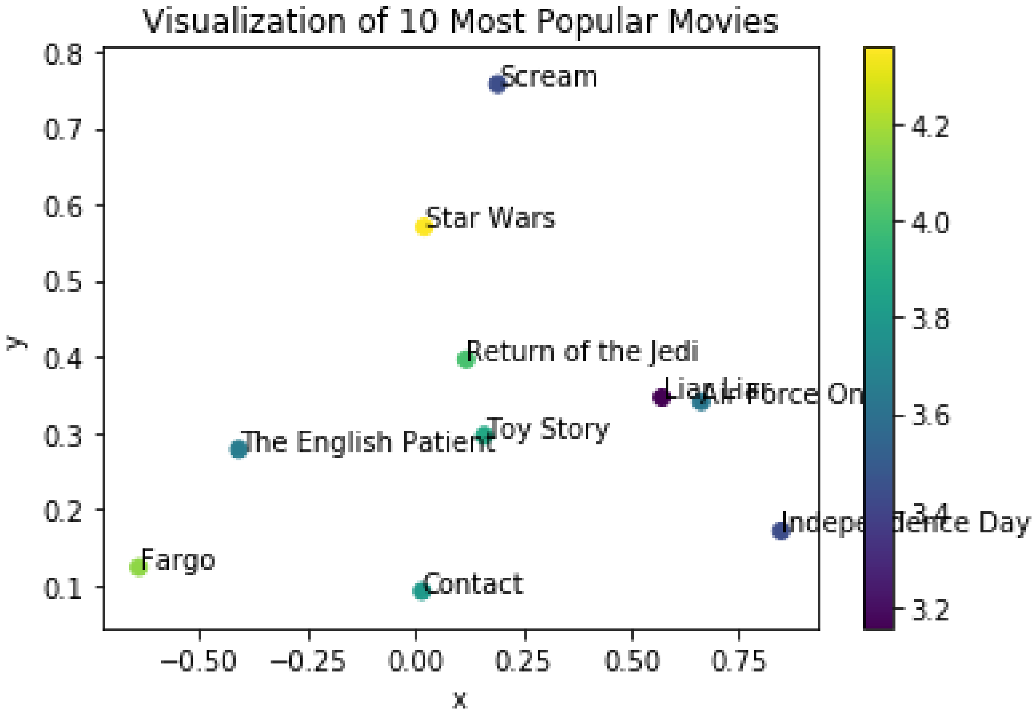
```
    plt.title('Visualization of 10 Most Popular Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.savefig('matrix_2_b.png')

    # plot clusters
    fig, ax = plt.subplots()
    plt.scatter(x, y, c=labels)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Most Popular Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.savefig('matrix_2_b_clusters.png')

    # visualize movies by their average ratings
    ratings = []
    for i in pop:
        ratings.append(movies['avg_rating'][i-1])

    fig, ax = plt.subplots()
    plt.scatter(x, y, c=ratings)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Most Popular Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.colorbar()
    plt.savefig('matrix_2_b_ratings.png')
```

```
49    Star Wars (1977)
Name: Title, dtype: object
257    Contact (1997)
Name: Title, dtype: object
99    Fargo (1996)
Name: Title, dtype: object
180    Return of the Jedi (1983)
Name: Title, dtype: object
292    Liar Liar (1997)
Name: Title, dtype: object
284    English Patient, The (1996)
Name: Title, dtype: object
286    Scream (1996)
```

```
Name: Title, dtype: object
0    Toy Story (1995)
Name: Title, dtype: object
298    Air Force One (1997)
Name: Title, dtype: object
120    Independence Day (ID4) (1996)
Name: Title, dtype: object
```





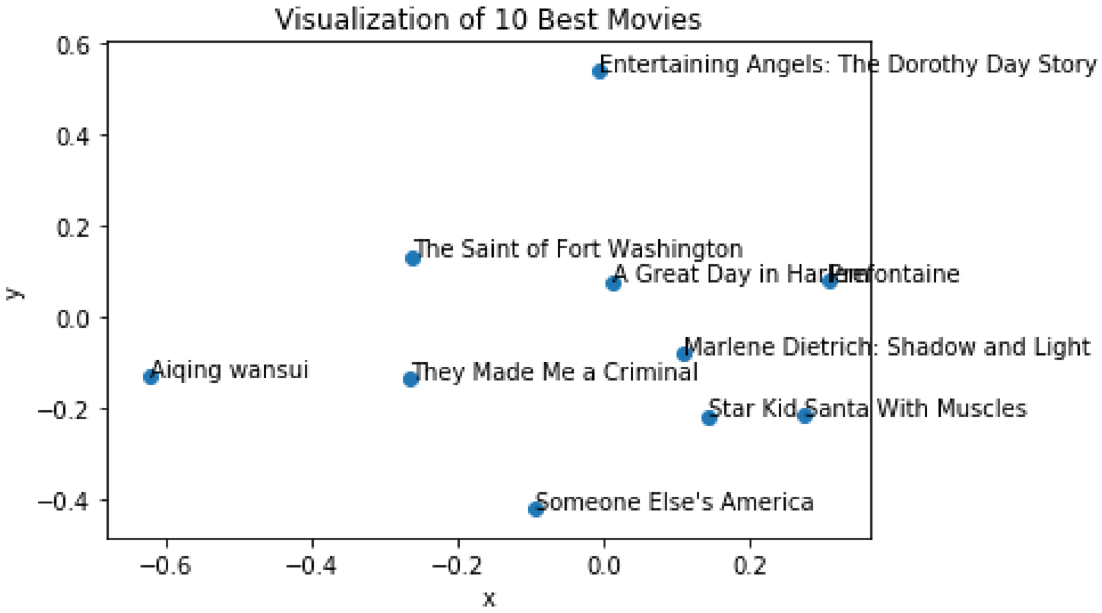


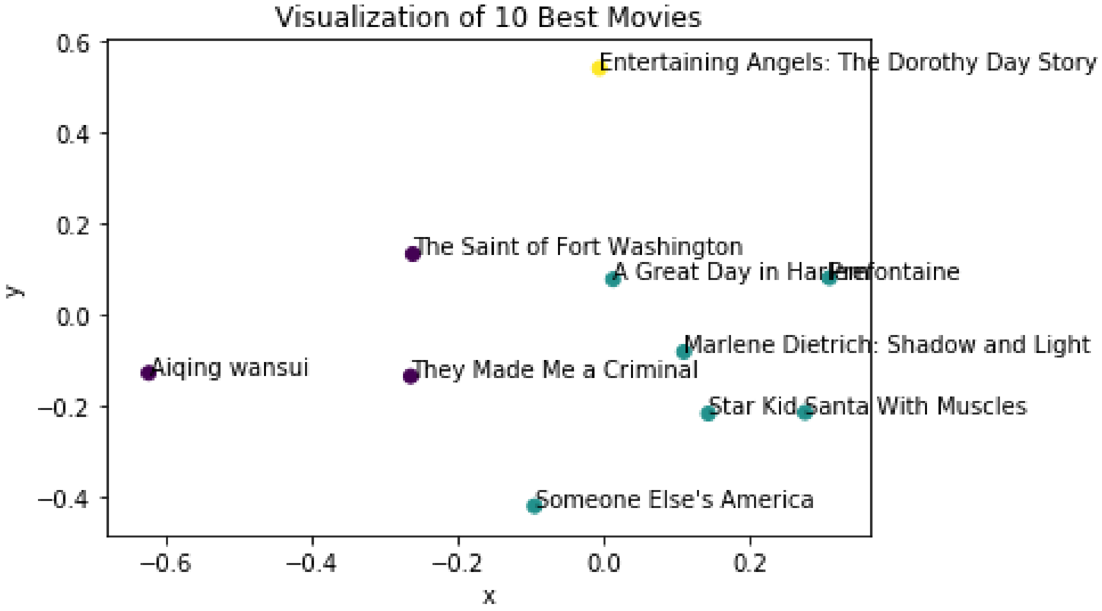
In [116]:
```
# visualize 10 best movies
sorted_df = movies.sort_values(by='avg_rating', ascending=False)
```

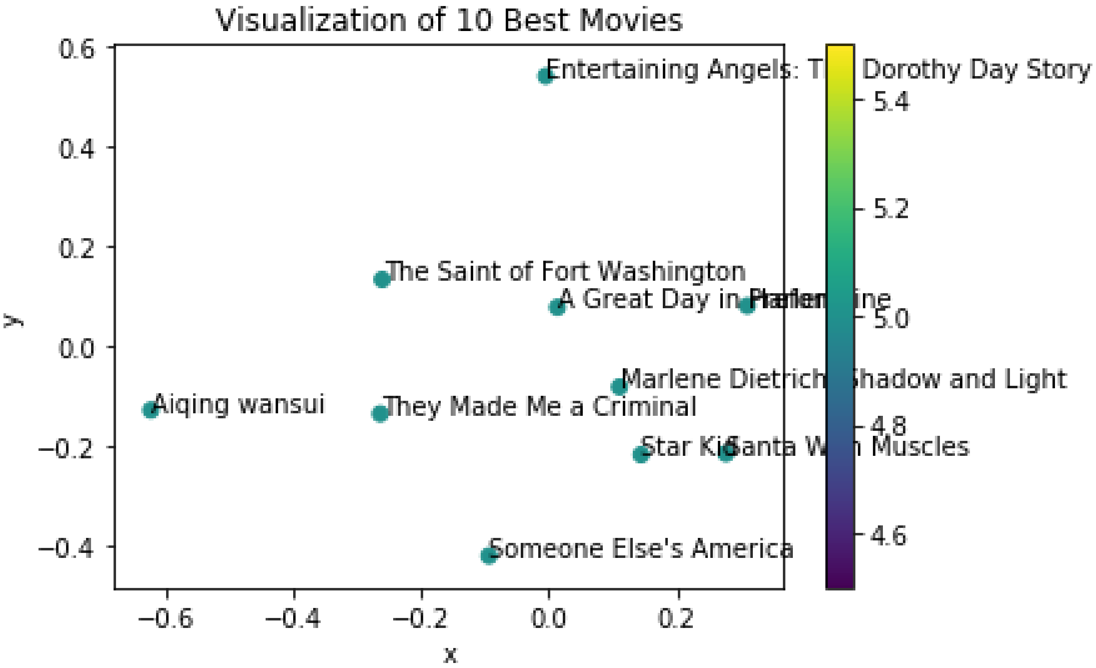
```
best = sorted_df.head(10)['ID']

for i in best:
    print(movies[movies['ID'] == i]['Title'])

titles = ["Someone Else's America", 'Prefontaine', 'Aiqing wansui', 'Star Kid', 'Ente

x = [0]*10
y = [0]*10
count = 0
for i in best:
    x[count] = V_tilde[0][i-1]
    y[count] = V_tilde[1][i-1]
    count += 1

# clustering
X = np.column_stack((x, y))
labels = KMeans(n_clusters=3, random_state=0).fit_predict(X)

# plot visualization
fig, ax = plt.subplots()
plt.scatter(x, y)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Best Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.savefig('matrix_2_c.png')

# plot clusters
fig, ax = plt.subplots()
plt.scatter(x, y, c=labels)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Best Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.savefig('matrix_2_c_clusters.png')

# visualize movies by their average ratings
ratings = []
for i in best:
    ratings.append(movies['avg_rating'][i-1])
```

```python
fig, ax = plt.subplots()
plt.scatter(x, y, c=ratings)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Best Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.colorbar()
plt.savefig('matrix_2_c_ratings.png')
```

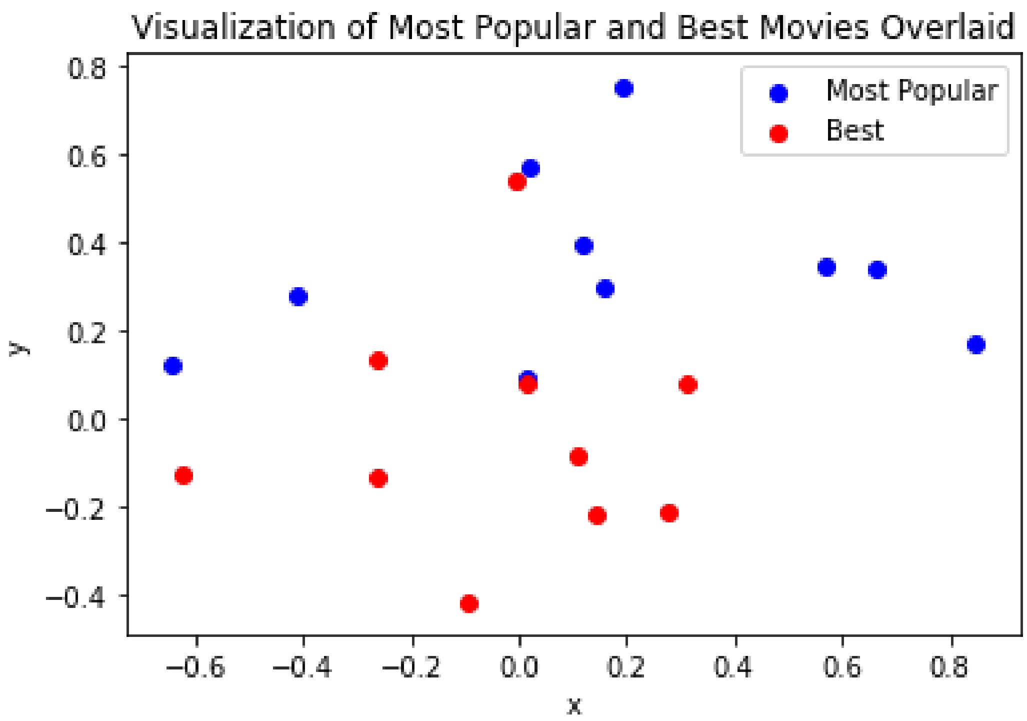
```
1588    Someone Else's America (1995)
Name: Title, dtype: object
1179    Prefontaine (1997)
Name: Title, dtype: object
1525    Aiqing wansui (1994)
Name: Title, dtype: object
1282    Star Kid (1997)
Name: Title, dtype: object
1637    Entertaining Angels: The Dorothy Day Story (1996)
Name: Title, dtype: object
1112    They Made Me a Criminal (1939)
Name: Title, dtype: object
1191    Marlene Dietrich: Shadow and Light (1996)
Name: Title, dtype: object
807    Great Day in Harlem, A (1994)
Name: Title, dtype: object
1456    Saint of Fort Washington, The (1993)
Name: Title, dtype: object
1489    Santa with Muscles (1996)
Name: Title, dtype: object
```


Visualization of 10 Best Movies
0.6
0.4
0.2
0.0
−0.2
−0.4
y
−0.6
−0.4
−0.2
0.0
0.2
x
Entertaining Angels: The Dorothy Day Story
The Saint of Fort Washington
A Great Day in Harlem
Prefontaine
Marlene Dietrich: Shadow and Light
Aiqing wansui
They Made Me a Criminal
Star Kid
Santa With Muscles
Someone Else's America


Visualization of 10 Best Movies
0.6
0.4
0.2
0.0
−0.2
−0.4
y
−0.6
−0.4
−0.2
0.0
0.2
x
Entertaining Angels: The Dorothy Day Story
The Saint of Fort Washington
A Great Day in Harlem
Prefontaine
Marlene Dietrich: Shadow and Light
Aiqing wansui
They Made Me a Criminal
Star Kid
Santa With Muscles
Someone Else's America



```
In [140]: # overlay best and most popular movies
          x = [0]*20
          y = [0]*20
          count = 0

          for i in pop:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1
          for i in best:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1

          fig, ax = plt.subplots()
          plt.scatter(x[:10], y[:10], c='b')
          plt.scatter(x[10:20], y[10:20], c='r')

          plt.title('Visualization of Most Popular and Best Movies Overlaid')
          plt.xlabel('x')
          plt.ylabel('y')
          plt.legend(['Most Popular', 'Best'])
          plt.savefig('matrix_2_pop_best.png')
```

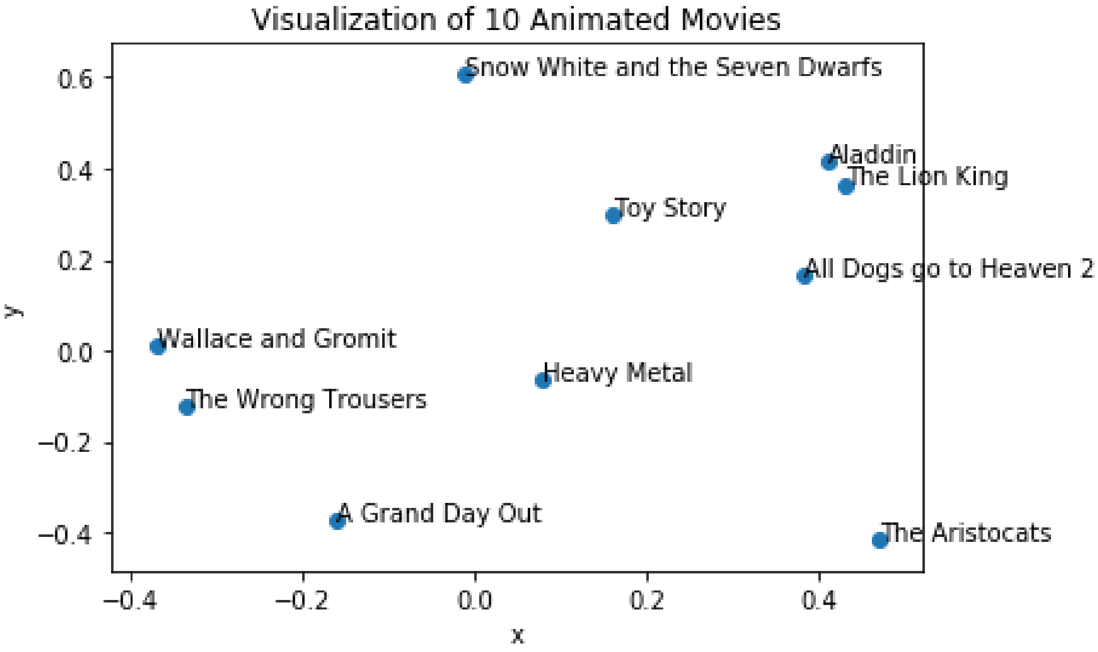


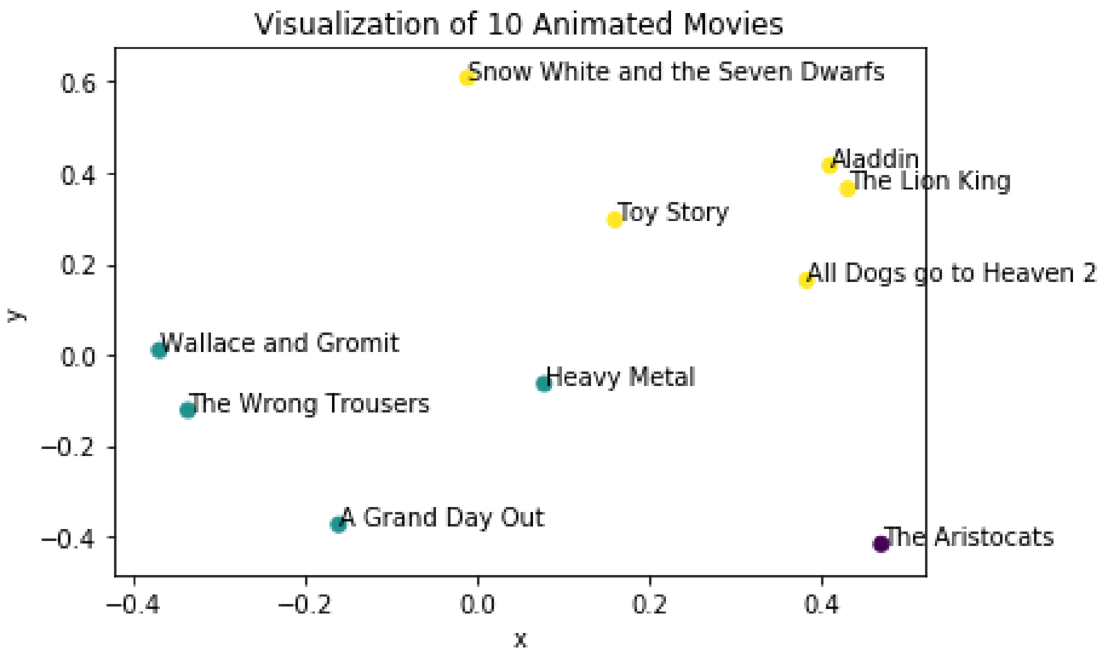
```
In [130]: # Visualize 10 animated movies
          # get all animated movies
          animated = movies[movies['Animation'] == 1]['ID'].head(10)

          for i in animated:
              print(movies[movies['ID'] == i]['Title'])

          titles = ['Toy Story', 'The Lion King', 'Aladdin', 'Snow White and the Seven Dwarfs'

          x = [0]*10
          y = [0]*10
          count = 0

          for i in animated:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1

          # clustering
          X = np.column_stack((x, y))
          labels = KMeans(n_clusters=3, random_state=0).fit_predict(X)

          # plot visualization
          fig, ax = plt.subplots()
```

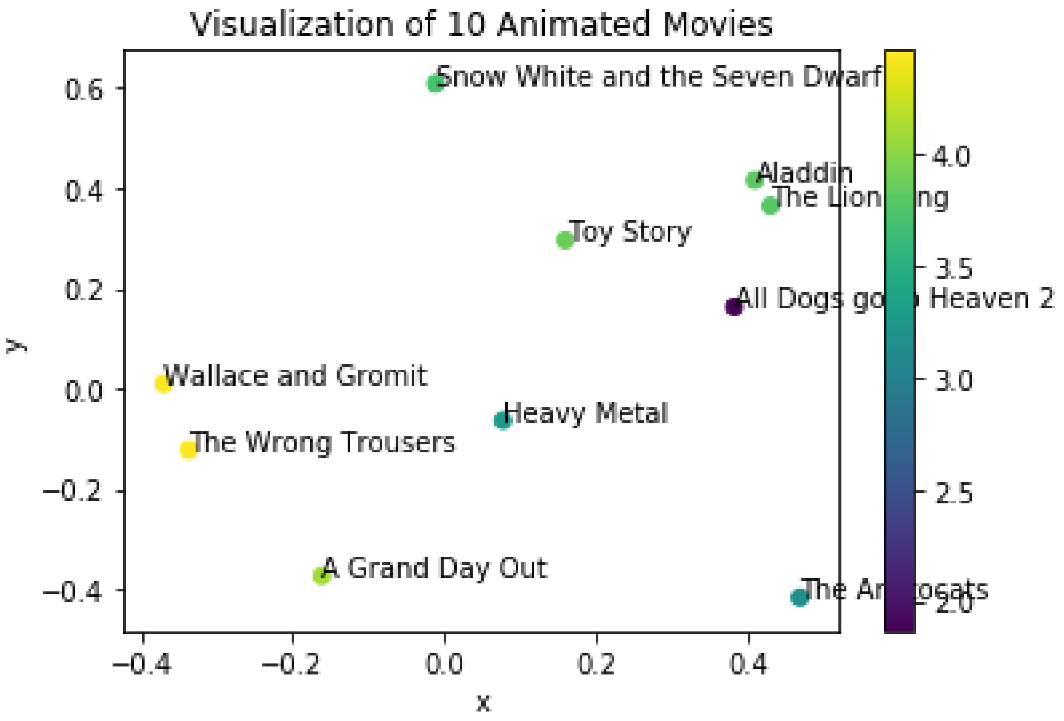
```
    plt.scatter(x, y)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Animated Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.savefig('matrix_2_d_1.png')

    # plot clusters
    fig, ax = plt.subplots()
    plt.scatter(x, y, c=labels)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Animated Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.savefig('matrix_2_d_1_clusters.png')

    # visualize movies by their average ratings
    ratings = []
    for i in animated:
        ratings.append(movies['avg_rating'][i-1])

    fig, ax = plt.subplots()
    plt.scatter(x, y, c=ratings)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Animated Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.colorbar()
    plt.savefig('matrix_2_d_1_ratings.png')
```

```
0    Toy Story (1995)
Name: Title, dtype: object
70    Lion King, The (1994)
Name: Title, dtype: object
94    Aladdin (1992)
Name: Title, dtype: object
98    Snow White and the Seven Dwarfs (1937)
Name: Title, dtype: object
100    Heavy Metal (1981)
```

```
Name: Title, dtype: object
101    Aristocats, The (1970)
Name: Title, dtype: object
102    All Dogs Go to Heaven 2 (1996)
Name: Title, dtype: object
113    Wallace & Gromit: The Best of Aardman Animatio...
Name: Title, dtype: object
168    Wrong Trousers, The (1993)
Name: Title, dtype: object
188    Grand Day Out, A (1992)
Name: Title, dtype: object
```





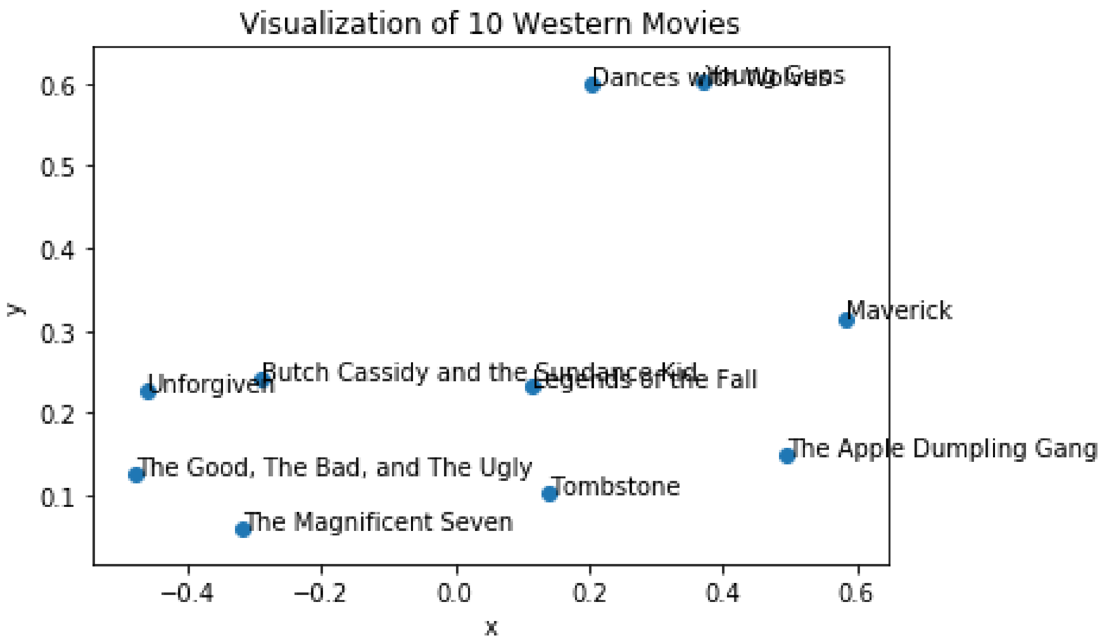


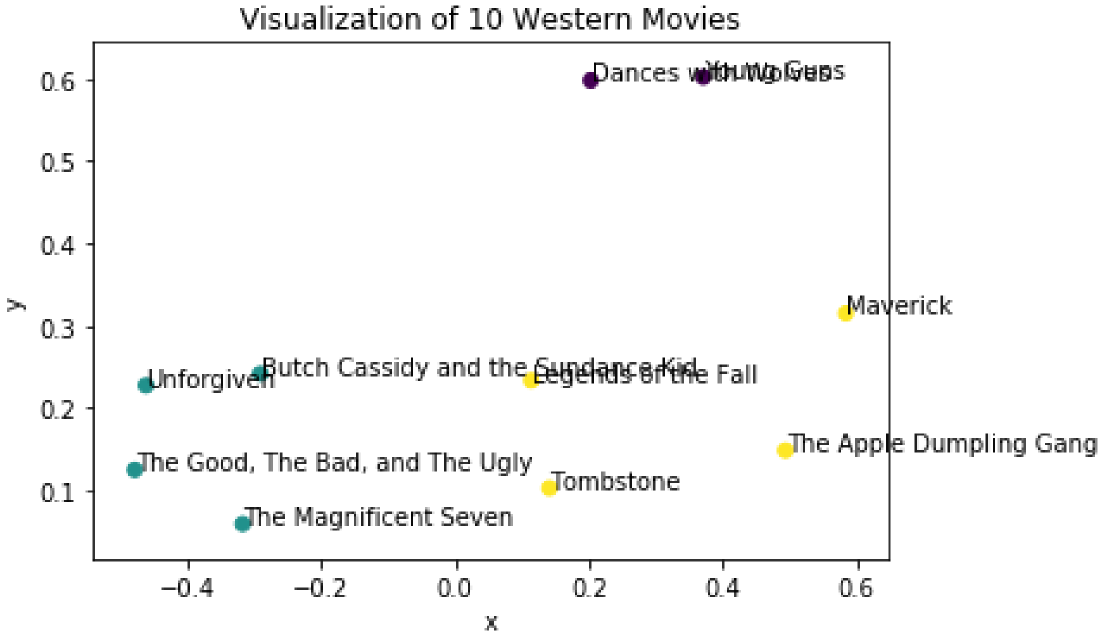
```
In [131]: # Visualize 10 Western movies
          # get all Western movies
```

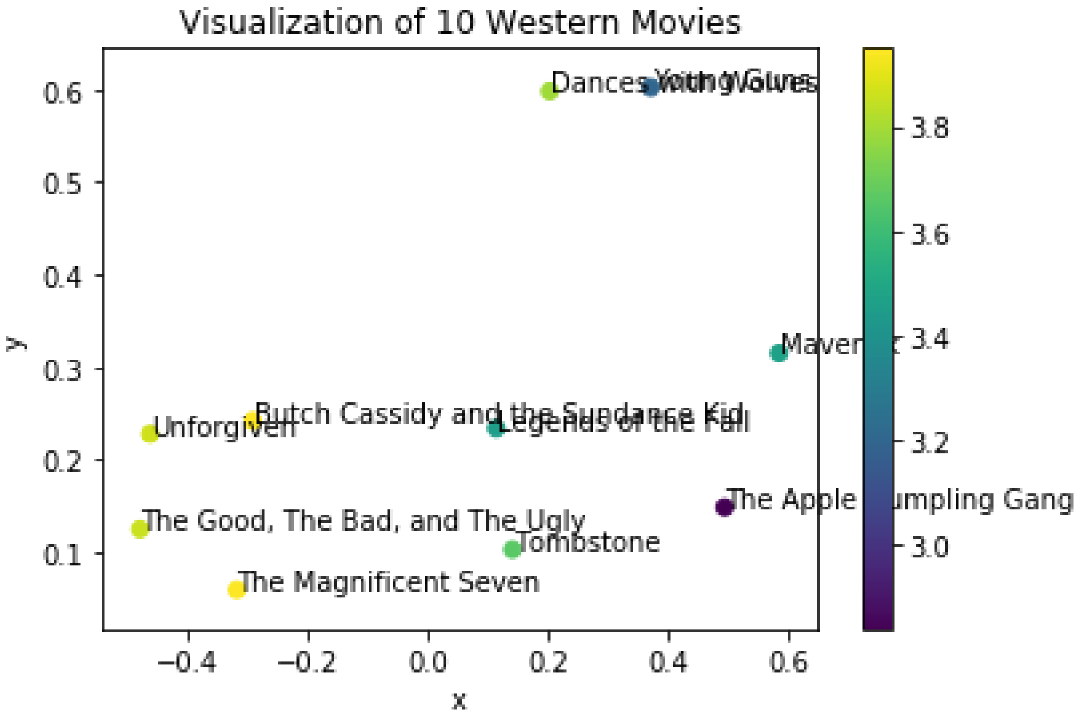
```
western = movies[movies['Western'] == 1]['ID'].head(10)

for i in western:
    print(movies[movies['ID'] == i]['Title'])

titles = ['Legends of the Fall', 'Maverick', 'Dances with Wolves', 'The Good, The Bac

x = [0]*10
y = [0]*10
count = 0

for i in western:
    x[count] = V_tilde[0][i-1]
    y[count] = V_tilde[1][i-1]
    count += 1

# clustering
X = np.column_stack((x, y))
labels = KMeans(n_clusters=3, random_state=0).fit_predict(X)

# plot visualization
fig, ax = plt.subplots()
plt.scatter(x, y)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Western Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.savefig('matrix_2_d_2.png')

# plot clusters
fig, ax = plt.subplots()
plt.scatter(x, y, c=labels)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Western Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.savefig('matrix_2_d_2_clusters.png')

# visualize movies by their average ratings
ratings = []
for i in western:
    ratings.append(movies['avg_rating'][i-1])
```

```
fig, ax = plt.subplots()
plt.scatter(x, y, c=ratings)

for i, txt in enumerate(titles):
    ax.annotate(txt, (x[i], y[i]))

plt.title('Visualization of 10 Western Movies')
plt.xlabel('x')
plt.ylabel('y')
plt.colorbar()
plt.savefig('matrix_2_d_2_ratings.png')
```

```
50    Legends of the Fall (1994)
Name: Title, dtype: object
72    Maverick (1994)
Name: Title, dtype: object
96    Dances with Wolves (1990)
Name: Title, dtype: object
176    Good, The Bad and The Ugly, The (1966)
Name: Title, dtype: object
202    Unforgiven (1992)
Name: Title, dtype: object
231    Young Guns (1988)
Name: Title, dtype: object
411    Apple Dumpling Gang, The (1975)
Name: Title, dtype: object
431    Butch Cassidy and the Sundance Kid (1969)
Name: Title, dtype: object
466    Tombstone (1993)
Name: Title, dtype: object
505    Magnificent Seven, The (1954)
Name: Title, dtype: object
```


Visualization of 10 Western Movies
Dances with Wolves
Young Guns
Maverick
Unforgiven
Butch Cassidy and the Sundance Kid
Legends of the Fall
The Apple Dumpling Gang
The Good, The Bad, and The Ugly
Tombstone
The Magnificent Seven
0.6
0.5
0.4
0.3
0.2
0.1
y
−0.4
−0.2
0.0
0.2
0.4
0.6
x


Visualization of 10 Western Movies
Dances with Wolves
Young Guns
Maverick
Unforgiven
Butch Cassidy and the Sundance Kid
Legends of the Fall
The Apple Dumpling Gang
The Good, The Bad, and The Ugly
Tombstone
The Magnificent Seven
0.6
0.5
0.4
0.3
0.2
0.1
y
−0.4
−0.2
0.0
0.2
0.4
0.6
x

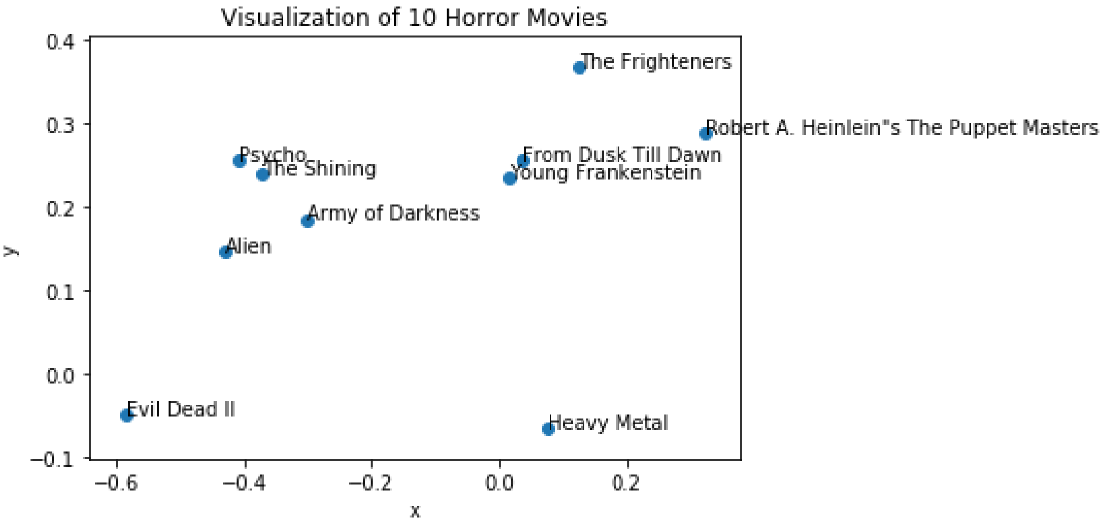


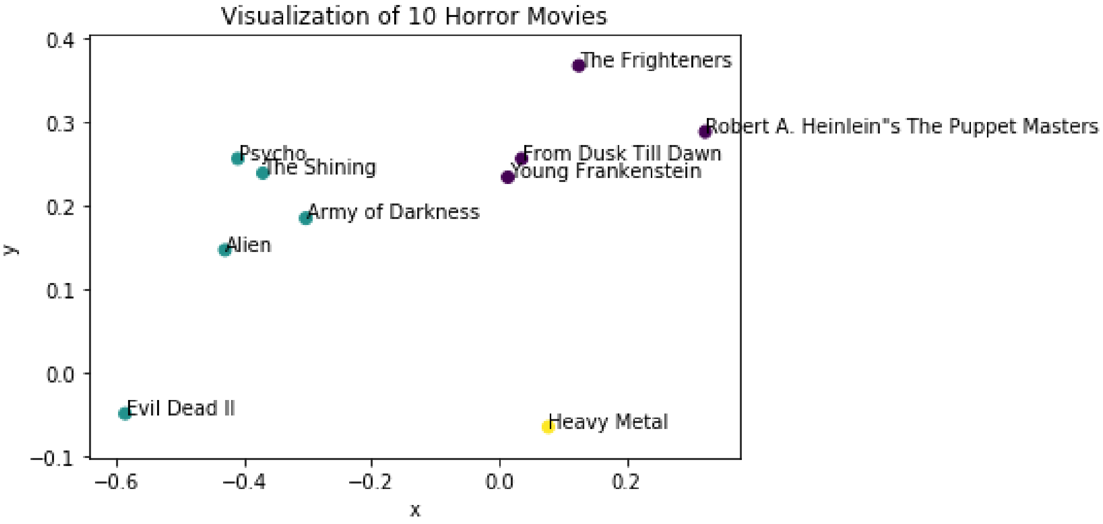
```
In [132]: # Visualize 10 horror movies
          horror = movies[movies['Horror'] == 1]['ID'].head(10)

          for i in horror:
              print(movies[movies['ID'] == i]['Title'])

          titles = ['From Dusk Till Dawn', 'Robert A. Heinlein"s The Puppet Masters', 'Heavy M

          x = [0]*10
          y = [0]*10
          count = 0

          for i in horror:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1

          # clustering
          X = np.column_stack((x, y))
          labels = KMeans(n_clusters=3, random_state=0).fit_predict(X)

          # plot visualization
          fig, ax = plt.subplots()
          plt.scatter(x, y)
```

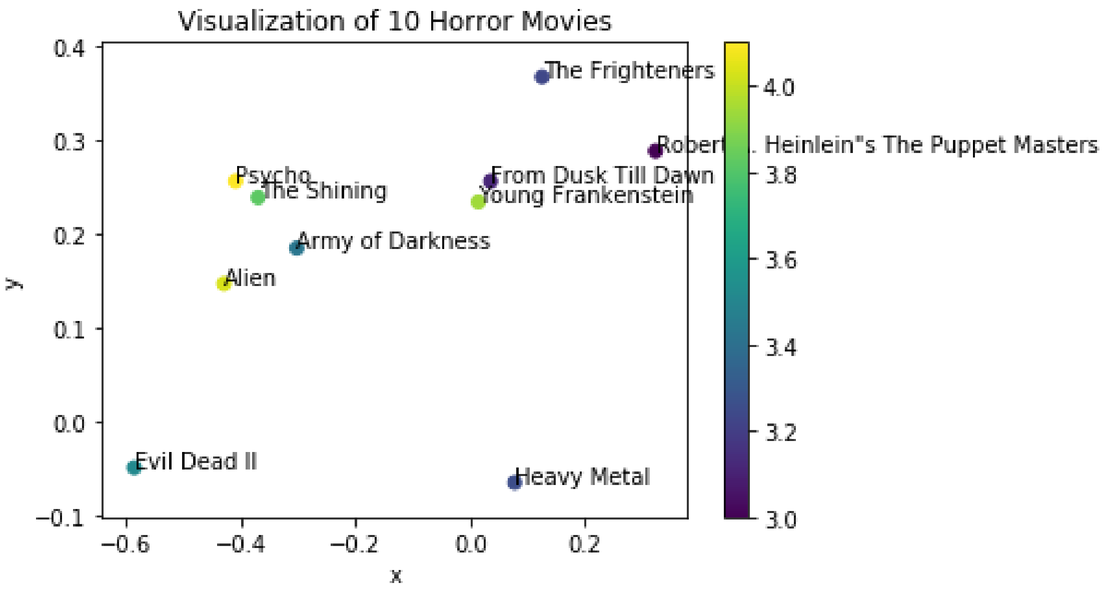
```
    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Horror Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.savefig('matrix_2_d_3_.png')

    # plot clusters
    fig, ax = plt.subplots()
    plt.scatter(x, y, c=labels)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Horror Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.savefig('matrix_2_d_3_clusters.png')

    # visualize movies by their average ratings
    ratings = []
    for i in horror:
        ratings.append(movies['avg_rating'][i-1])

    fig, ax = plt.subplots()
    plt.scatter(x, y, c=ratings)

    for i, txt in enumerate(titles):
        ax.annotate(txt, (x[i], y[i]))

    plt.title('Visualization of 10 Horror Movies')
    plt.xlabel('x')
    plt.ylabel('y')
    plt.colorbar()
    plt.savefig('matrix_2_d_3_ratings.png')
```

```
16    From Dusk Till Dawn (1996)
Name: Title, dtype: object
83    Robert A. Heinlein's The Puppet Masters (1994)
Name: Title, dtype: object
100    Heavy Metal (1981)
Name: Title, dtype: object
122    Frighteners, The (1996)
Name: Title, dtype: object
182    Alien (1979)
Name: Title, dtype: object
```

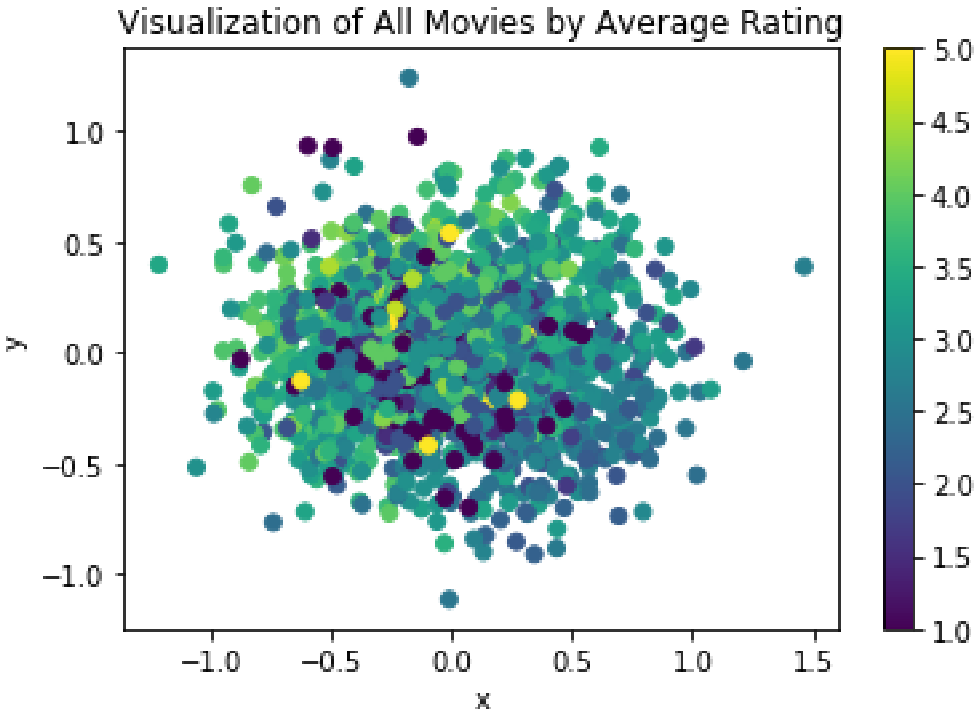
```
183    Army of Darkness (1993)
Name: Title, dtype: object
184    Psycho (1960)
Name: Title, dtype: object
199    Shining, The (1980)
Name: Title, dtype: object
200    Evil Dead II (1987)
Name: Title, dtype: object
207    Young Frankenstein (1974)
Name: Title, dtype: object
```



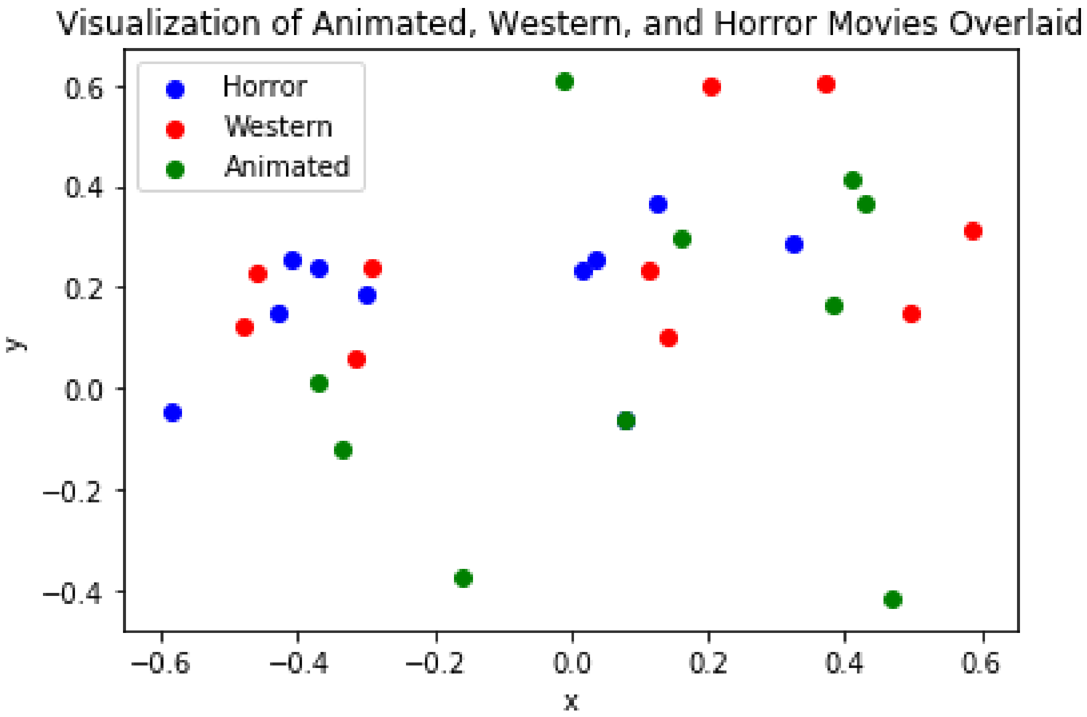




```
In [136]: # visualization of all movies by average rating
          ratings = []
          for i in range(len(movies)):
              ratings.append(movies['avg_rating'][i])

          fig, ax = plt.subplots()
          plt.scatter(V_tilde[0], V_tilde[1], c=ratings)

          plt.title('Visualization of All Movies by Average Rating')
          plt.xlabel('x')
          plt.ylabel('y')
          plt.colorbar()
          plt.savefig('matrix_2_avg_rating.png')
```



```
In [135]: x = [0]*30
          y = [0]*30
          count = 0

          for i in horror:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1
          for i in western:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1
          for i in animated:
              x[count] = V_tilde[0][i-1]
              y[count] = V_tilde[1][i-1]
              count += 1

          fig, ax = plt.subplots()
          plt.scatter(x[:10], y[:10], c='b')
          plt.scatter(x[10:20], y[10:20], c='r')
          plt.scatter(x[20:30], y[20:30], c='g')

          plt.title('Visualization of Animated, Western, and Horror Movies Overlaid')
          plt.xlabel('x')
          plt.ylabel('y')
          plt.legend(['Horror', 'Western', 'Animated'])
          plt.savefig('matrix_2_genres.png')
```


Visualization of Animated, Western, and Horror Movies Overlaid
● Horror
● Western
● Animated
y
x