assignment-1

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0.0.1 Required libraries

[ ]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.spatial import distance
from matplotlib import style
from sklearn import preprocessing
from sklearn.manifold import TSNE
```

1 Question 1

In this exercise, you will work with Census Income Data Set that you can download from the following link: https://archive.ics.uci.edu/ml/datasets/Census+Income

Once you have downloaded the data, you will prepare a data visualization report along the lines of visualization done for the Boston Housing data. Feel free to provide any additional visualization that might help in better understanding of the data. Write a paragraph about what characteristics of the data you see via visualization.

[ ]:
```
headers = ["age", "workclass", "fnlwgt", "education", "education-num",␣
 ↪"marital-status",
    "occupation", "relationship", "race", "sex", "capital-gain", "capital-loss",
    "hours-per-week", "native-country", "prediction"]
data = pd.read_csv("adult.data", names=headers)
```

[ ]:
```
data.shape, data.columns
```

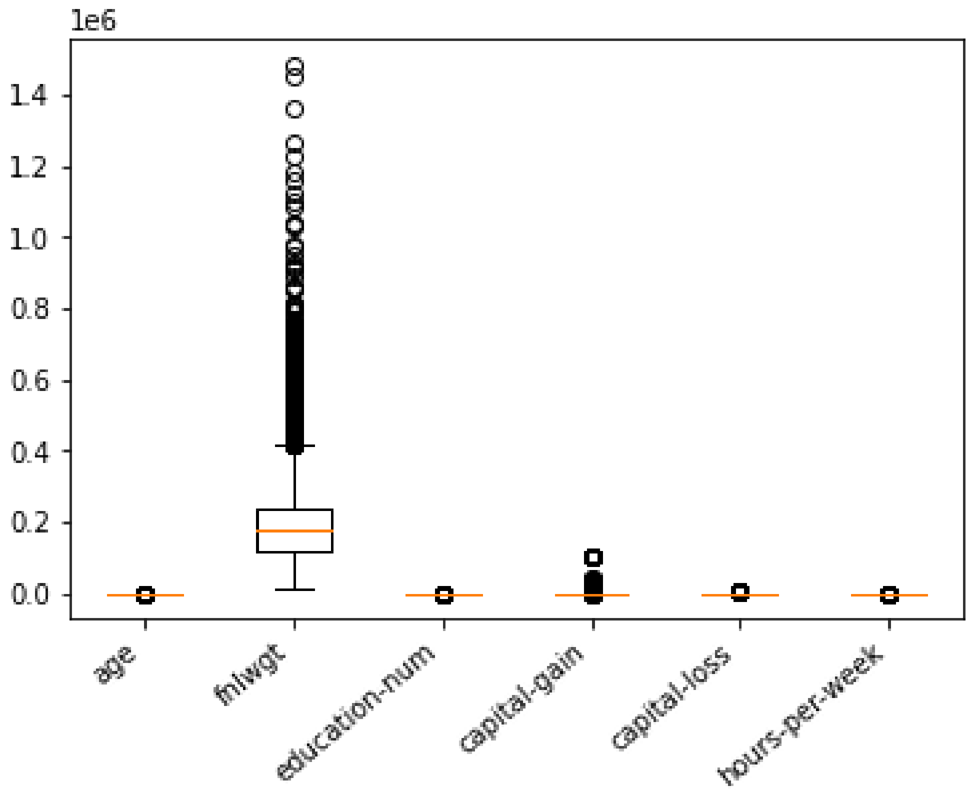
[ ]:
```
((32561, 15),
 Index(['age', 'workclass', 'fnlwgt', 'education', 'education-num',
        'marital-status', 'occupation', 'relationship', 'race', 'sex',
        'capital-gain', 'capital-loss', 'hours-per-week', 'native-country',
        'prediction'],
```

```
      dtype='object'))
```

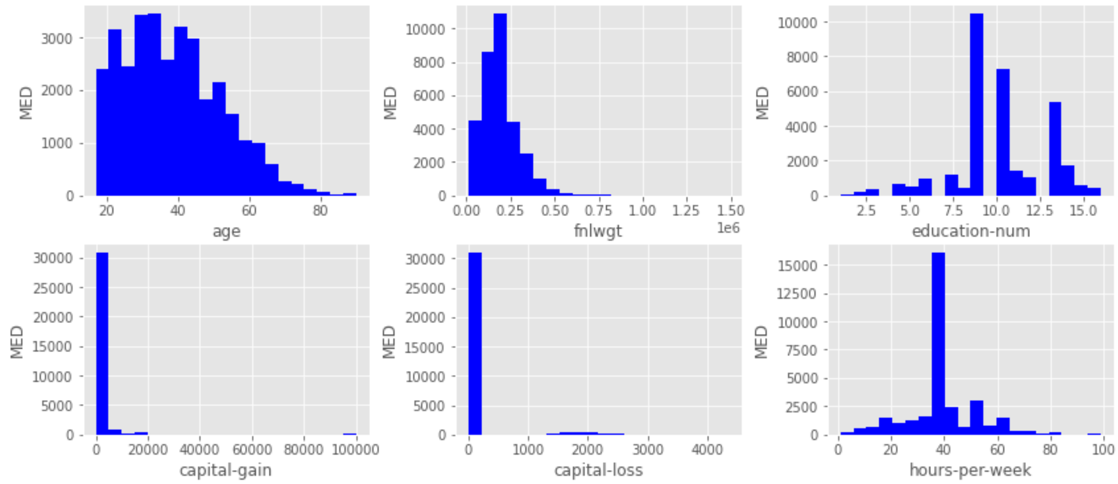
[ ]:
```
data.describe()
```

[ ]:
```
                age        fnlwgt  education-num  capital-gain  capital-loss  \
count  32561.000000  3.256100e+04   32561.000000  32561.000000  32561.000000
mean      38.581647  1.897784e+05      10.080679   1077.648844     87.303830
std       13.640433  1.055500e+05       2.572720   7385.292085    402.960219
min       17.000000  1.228500e+04       1.000000      0.000000      0.000000
25%       28.000000  1.178270e+05       9.000000      0.000000      0.000000
50%       37.000000  1.783560e+05      10.000000      0.000000      0.000000
75%       48.000000  2.370510e+05      12.000000      0.000000      0.000000
max       90.000000  1.484705e+06      16.000000  99999.000000   4356.000000

       hours-per-week
count    32561.000000
mean        40.437456
std         12.347429
min          1.000000
25%         40.000000
50%         40.000000
75%         45.000000
max         99.000000
```

[ ]:
```
continuousHeaders = ["age", "fnlwgt", "education-num", "capital-gain",␣
 ↪"capital-loss", "hours-per-week"]
continuousData = [data[header] for header in continuousHeaders]
plt.boxplot(continuousData)
plt.xticks(np.arange(1, len(continuousData) + 1), continuousHeaders,␣
 ↪rotation=40, ha="right")
plt.show()
```



[ ]:
```
plt.style.use("ggplot")
fig, axes = plt.subplots(2, 3, figsize=(14, 6))
for i in range(1, len(continuousHeaders) + 1):
    plt.subplot(2, 3, i)
    plt.hist(continuousData[i-1], bins=20, color='b')
    plt.xlabel(continuousHeaders[i-1])
    plt.ylabel("MED")
plt.subplots_adjust(wspace=0.30, hspace=0.25)
plt.show()
```

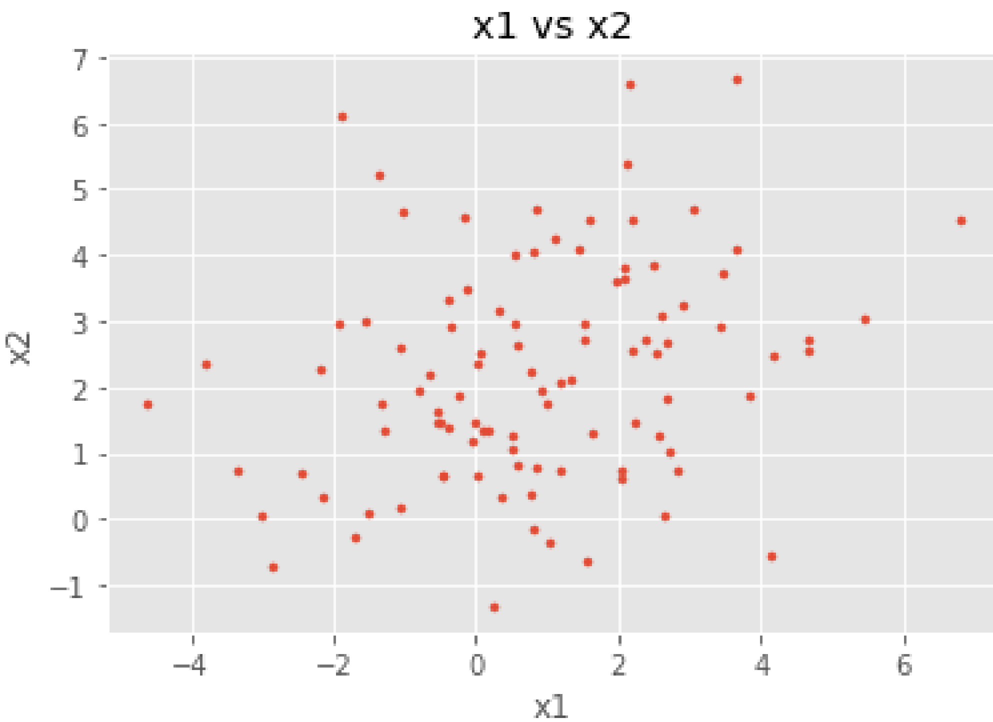


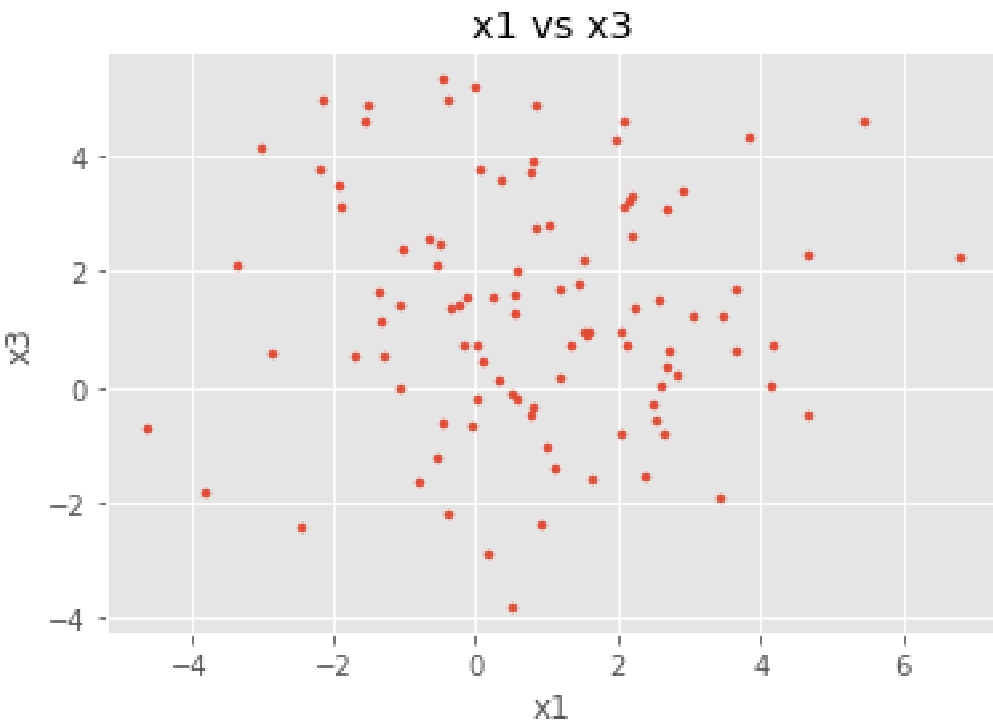
2 Question 2

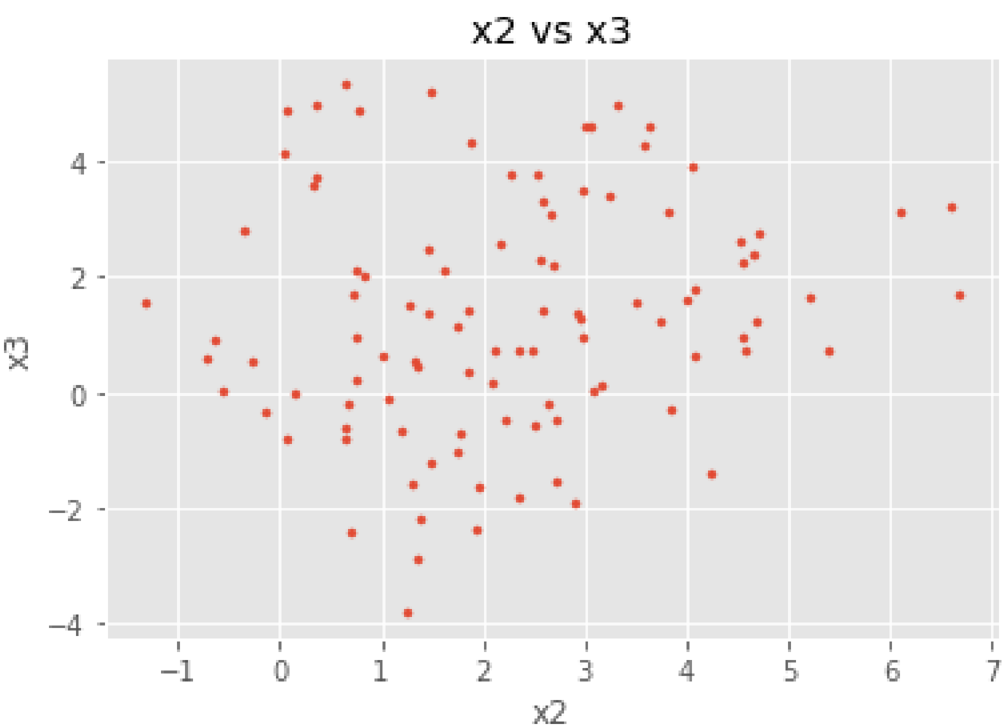
This exercise is designed to make you familiar with multivariate normal distribution generation and using the generated data. 1. Generate 100 3-dimensional vectors that come from a normal distribution with mean vector as [1 2 1]t and 3x3 covariance matrix as [5 0.8 -0.3; 0.8 3 0.6; -0.3 0.6 4] 2. Make scatter plots of x1 vs x2, x1 vs x3, and x2 vs x3. Explain whatever relationships you can gather from these plots. 3. Pick any 5 pairs of generated vectors and calculate the Euclidean and the Mahalanobis distances between those pairs

[ ]:
```
mean = [1, 2, 1]
cov = [
    [5, 0.8, -0.3],
    [0.8, 3, 0.6],
    [-0.3, 0.6, 4]
]

x = np.random.multivariate_normal(mean, cov, 100)
x1, x2, x3 = x.T

plt.scatter(x1, x2, marker=".")
plt.title("x1 vs x2")
plt.xlabel("x1")
plt.ylabel("x2")
plt.show()

plt.scatter(x1, x3, marker=".")
plt.title("x1 vs x3")
```

```
plt.xlabel("x1")
plt.ylabel("x3")
plt.show()

plt.scatter(x2, x3, marker=".")
plt.title("x2 vs x3")
plt.xlabel("x2")
plt.ylabel("x3")
plt.show()
```




x1 vs x3
x3
x1
4
2
0
−2
−4
−4
−2
0
2
4
6


x2 vs x3
x3
x2
4
2
0
−2
−4
−1
0
1
2
3
4
5
6
7

It does not appear that there is any strong correlation between any of x1, x2, and x3.

There does seem to be however a very small positive correlation between x1 and x2, and x2 and x3, while a very small negative correlation between x1 and x3 exists.

[ ]:
```
for i in range(5):
    index1, index2 = np.random.randint(1, 100), np.random.randint(1, 100)
    y1, y2 = x[index1], x[index2]

    euclidean = distance.euclidean(y1, y2)
    mahalanobis = distance.mahalanobis(y1, y2, np.linalg.inv(cov))
    print(str.format("Pair {}:\n\tEuclidean: {}\n\tMahalanobis: {}", i,␣
 ↪euclidean, mahalanobis))
```

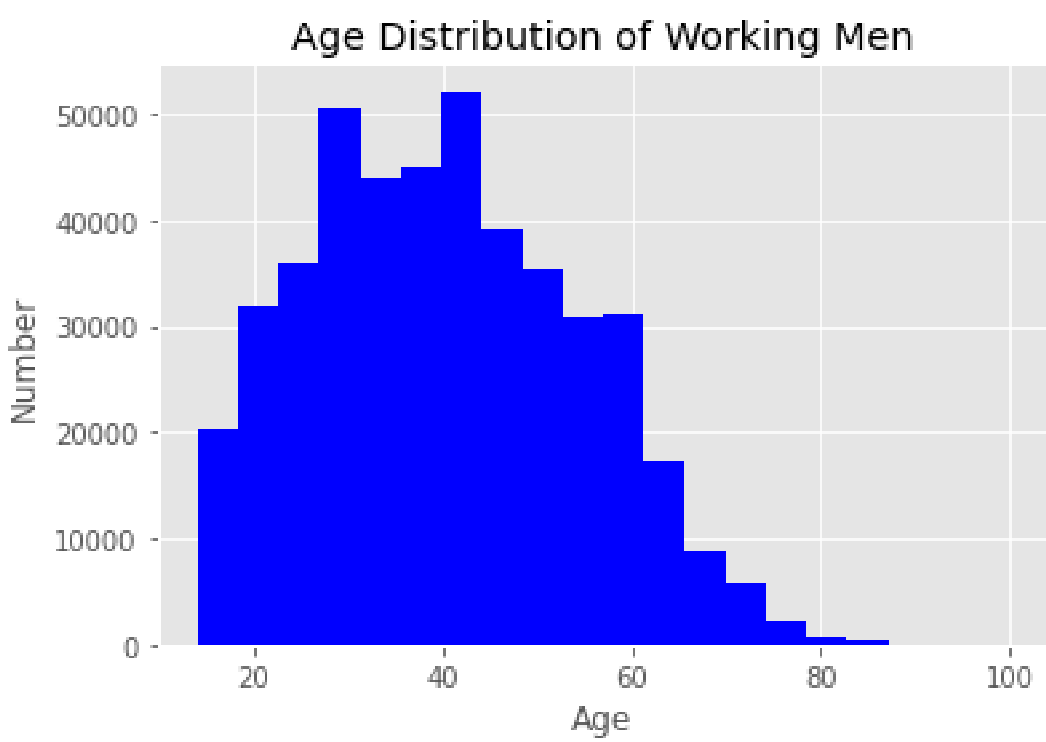
```
Pair 0:
        Euclidean: 1.754964403767681
        Mahalanobis: 0.7900904963638573
Pair 1:
        Euclidean: 7.8542785084105775
        Mahalanobis: 3.5406273912457555
Pair 2:
        Euclidean: 3.389640682047855
        Mahalanobis: 1.646362839639934
Pair 3:
        Euclidean: 5.063181930039343
        Mahalanobis: 2.4949026892368416
Pair 4:
        Euclidean: 7.097191162839146
        Mahalanobis: 3.679977692236872
```

3 Question 3

This exercise is designed to make you familiar with IPUMS USA data source. Go to http://usa.ipums.org, click on IPUMS Registration and Login and apply for access. You will need an account to get data. You will select 1960 1% sample
and use the following variables to prepare your data extract: Marital status, Sex, Relate, Age, and Employment status. You will specify the csv format for your extract. Once you have downloaded the data, you will read the data into
a data frame and visualize the age distribution of working men and the age distribution of working women. You will also calculate the % of household
headed by women.

[ ]:
```
data = pd.read_csv("usa_00001.csv")
```

```
plt.hist(data[(data["SEX"] == 1) & (data["EMPSTAT"] == 1)]["AGE"],bins = 20,␣
 ↪color="b")
plt.title("Age Distribution of Working Men")
plt.xlabel("Age")
plt.ylabel("Number")
plt.show()

plt.hist(data[(data["SEX"] == 2) & (data["EMPSTAT"] == 1)]["AGE"],bins = 20,␣
 ↪color="r")
plt.title("Age Distribution of Working Women")
plt.xlabel("Age")
plt.ylabel("Number")
plt.show()

print("Households headed by women: " + str(
    data[(data["SEX"] == 1) & (data["RELATE"] == 1)].size / data.size * 100
))
```




```
Households headed by women: 24.37512778572889
```

4 Question 4

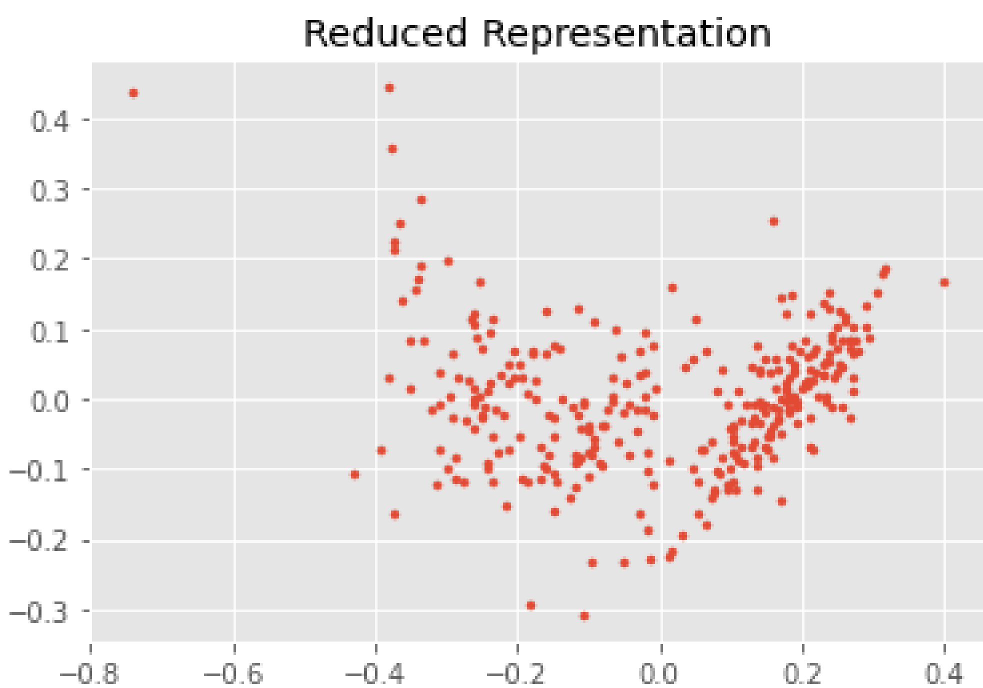
You will perform this exercise using the PCA-Exercise
data posted on the course page.

Suppose we are interested in reducing the six-dimensional records to two dimensions by means of principal component analysis. List the eigenvalues and eigenvectors obtained via PCA. Determine the reduced representation
for all of the records and plot the reduced representation in the form of a scatter plot. Reconstruct the original data and compute the reconstruction
error.

[ ]:
```
data = pd.read_csv("PCAExerciseData.csv").to_numpy()
X = data[:,:-1].astype(int)
X = preprocessing.normalize(X, norm="l2")

mean = np.mean(X, 0)
cov = np.cov(X.T)
w, v = np.linalg.eig(cov)
print("Eigenvalues:", w)
print("Eigenvectors:", v)
```

```
Eigenvalues: [4.12131748e-02 1.03626108e-02 3.78810737e-06 7.22517819e-04
 4.27420831e-03 3.41720000e-03]
Eigenvectors: [[-2.35386016e-01 -4.81243069e-01 -5.75357988e-01  3.77441118e-01
  -4.26531029e-01  2.39939996e-01]
 [-8.65121989e-02 -1.35808515e-02  5.81140380e-01  1.23573825e-01
  -7.56747382e-01 -2.58205284e-01]
 [-2.82166799e-01 -3.87816762e-01 -9.82250877e-04  2.08546930e-01
   3.39303909e-01 -7.81895215e-01]
 [-1.50317302e-01 -4.67366205e-01  5.75531652e-01  2.52493506e-01
   3.38346586e-01  4.99505229e-01]
 [ 5.29719889e-01  2.56503232e-01  6.68320154e-04  8.00833606e-01
   8.87401407e-02 -6.62812705e-02]
 [-7.44508233e-01  5.77575753e-01 -9.74726347e-04  3.06085698e-01
   8.90186170e-02  1.02469615e-01]]
```

[ ]:
```
A = np.array([v[:,0], v[:,1]])
Y = np.matmul(A, (X-mean).T)

plt.scatter(Y[0], Y[1], marker=".")
plt.title("Reduced Representation")
plt.show()
```



[ ]:
```
Xhat = np.matmul(A.T, Y).T + mean
err = np.sum((X-Xhat)**2) / len(X)
```

```
print("Error:"+str(err))
```

```
Error:0.008390560325741033
```

5 Question 5

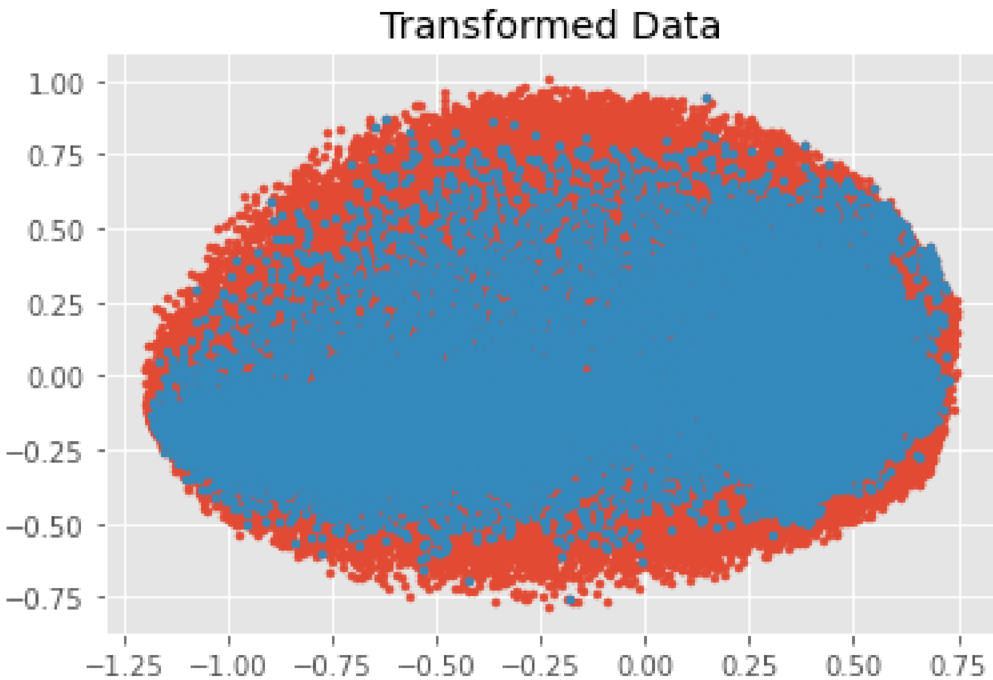
In this exercise, you will apply PCA to the Spoken Arabic Digit Dataset at the following link: https://archive.ics.uci.edu/ml/datasets/Spoken+Arabic+Digit and reduce the train data to two dimensions [The class labels are not used in PCA]. List all eigenvalues and make a scatter plot of the transformed data. Show transformed data points for any digit pair of your choice in different colors or shapes.

[ ]:
```
rawdata = pd.read_table("Train_Arabic_Digit.txt", delimiter=" ").astype(float)
categoryData = rawdata.notna().to_numpy().astype(bool)
digitIndices = {0: 0}
digit = 1
blocks = 0
for i in range(len(categoryData)):
    if False in categoryData[i]:
        blocks += 1

    if blocks >= 660:
        digitIndices[digit] = i
        digit += 1
        blocks = 0

data = rawdata.dropna().to_numpy()

X = preprocessing.normalize(data, norm="l2")

mean = np.mean(X, 0)
cov = np.cov(X.T)
w, v = np.linalg.eig(cov)
print("Eigenvalues: " + str(w))
print("Eigenvectors: " + str(v))
```

```
Eigenvalues: [0.25099642 0.09568619 0.05920114 0.03965005 0.02645368 0.02381982
 0.01347961 0.01453371 0.00433683 0.01082354 0.00823997 0.00764936
 0.00633945]
Eigenvectors: [[ 0.83232088  0.17761996 -0.33081102  0.34969484 -0.08739872
-0.08709557
  -0.15106037  0.00240085  0.03245863 -0.02357452  0.02466739  0.06083771
   0.00157466]
 [ 0.27109085  0.28639132  0.89456799  0.08185084  0.06254089  0.14371221
  -0.03273003 -0.05607395  0.01255042 -0.08554081  0.03292545  0.01203326
```

```
  0.00738775]
 [-0.31208742  0.70745339 -0.08132578  0.11789449 -0.26727193 -0.41394842
  -0.08311863  0.02600792  0.03647807 -0.28946285 -0.08717562 -0.19610738
   0.00695424]
 [-0.26218989  0.34701607 -0.1719523   0.5047973   0.13686404  0.58984866
   0.11502976 -0.21816343  0.00191102  0.25139886  0.03879772  0.15045552
   0.10780031]
 [-0.16417796 -0.24329104  0.06069082  0.47607122  0.33759503 -0.28389867
   0.00179326  0.21783548  0.06697094 -0.40937205  0.35911423  0.27791442
   0.25146267]
 [-0.08669891 -0.280102    0.11720681  0.41306815  0.16139217 -0.29592662
  -0.21997834 -0.4111831   0.2738996   0.22924985 -0.33667425 -0.37206314
  -0.13865211]
 [-0.06893657 -0.12643844  0.06735364  0.02378349 -0.43765661 -0.18177544
  -0.10397888 -0.60843837 -0.29323153 -0.02818379  0.11942703  0.51648776
  -0.02762149]
 [-0.00847326 -0.30465812  0.07235925  0.31567958 -0.64313856  0.25489583
   0.36290999  0.13298032  0.14648434 -0.29045881 -0.04003053 -0.25178906
  -0.05840804]
 [-0.05313928  0.06975833  0.11534242  0.15623474 -0.13380226 -0.29305773
   0.27055248  0.38580688  0.2058041   0.50912148 -0.0527695   0.41622135
  -0.38881938]
 [-0.08055929 -0.07471956  0.09335695  0.20483845 -0.21528095 -0.04469731
  -0.35506059  0.28824995 -0.51829413  0.40526     0.35555702 -0.32919332
   0.10999804]
 [-0.10992373 -0.01411977 -0.02044024 -0.10718935 -0.18802976  0.24397661
  -0.63305738  0.07375313  0.56856065 -0.04420252  0.31034564  0.11332444
  -0.20089098]
 [-0.07740948 -0.06300307 -0.01476174  0.16413515  0.11777936  0.19497423
  -0.31376439  0.22760978 -0.40966053 -0.32035539 -0.44142548  0.16633339
  -0.51746142]
 [-0.03042056 -0.06672185  0.06544009  0.00286126 -0.19904671  0.02968147
  -0.25803799  0.23450518  0.09186425  0.10868984 -0.55735846  0.2590687
   0.65592512]]
```

[ ]:
```python
A = np.array([v[:,0], v[:,1]])

Y = np.matmul(A, (X-mean).T)

plt.scatter(Y[0], Y[1], marker=".")
# The digit 0:
plt.scatter(Y[0,:digitIndices[1]], Y[1,:digitIndices[1]], marker=".")
plt.title("Transformed Data")
plt.show()
```

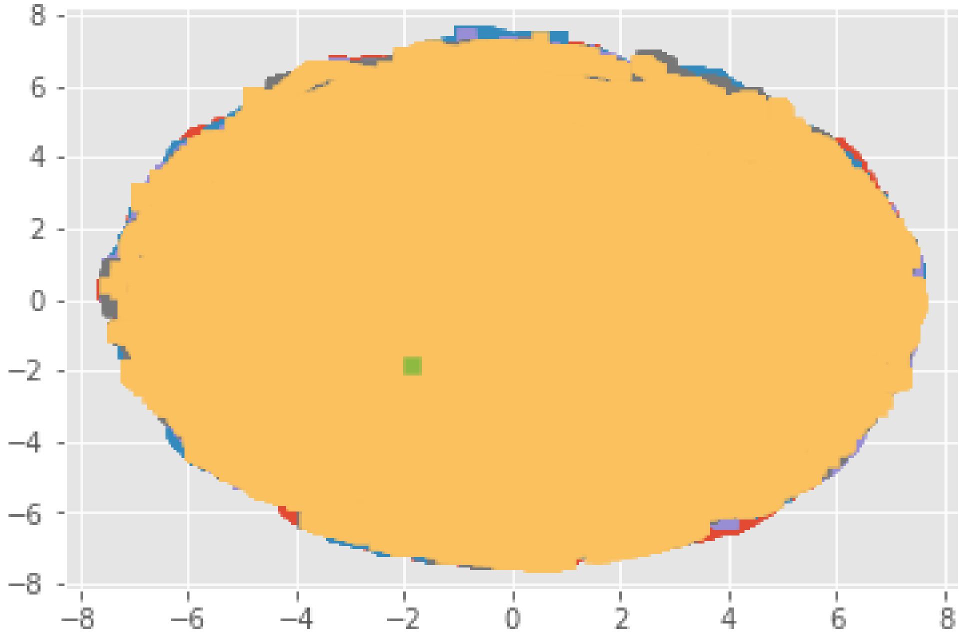


6 Question 6

Repeat Exercise #5 using t-SNE visualization method to visualize the entire train data set. Comment on the results obtained.

[ ]:
```
X_10 = TSNE(n_components=2, perplexity=10, n_iter=250,␣
 ↪n_iter_without_progress=50, n_jobs=-1).fit_transform(data)
```

[ ]:
```
size = X_10.size
block = size // 10
for i in range(10):
    plt.scatter(X_10[i*block:(i+1)*block,0], X_10[i*block:(i+1)*block,1],␣
 ↪marker=",")
plt.show()
```



It appears that this representation is just a blob without any clear distinction between digits. I had to adjust some of the arguments given to the `TSNE()` since it was taking too long to run without them. I believe some of these arguments may have caused the output to look like this.