Load MNIST Data

In [ ]:

```
# MNIST dataset downloaded from Kaggle :
#https://www.kaggle.com/c/digit-recognizer/data

# Functions to read and show images.

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt



d0 = pd.read_csv('mnist_train.csv')

print(d0.head(5)) # print first five rows of d0.

# save the labels into a variable l.
l = d0['label']

# Drop the label feature and store the pixel data in d.
d = d0.drop("label",axis=1)
```

```
   label  1x1  1x2  1x3  1x4  1x5  ...  28x23  28x24  28x25  28x26  28x27  28x28
0      5    0    0    0    0    0  ...      0      0      0      0      0      0
1      0    0    0    0    0    0  ...      0      0      0      0      0      0
2      4    0    0    0    0    0  ...      0      0      0      0      0      0
3      1    0    0    0    0    0  ...      0      0      0      0      0      0
4      9    0    0    0    0    0  ...      0      0      0      0      0      0

[5 rows x 785 columns]
```

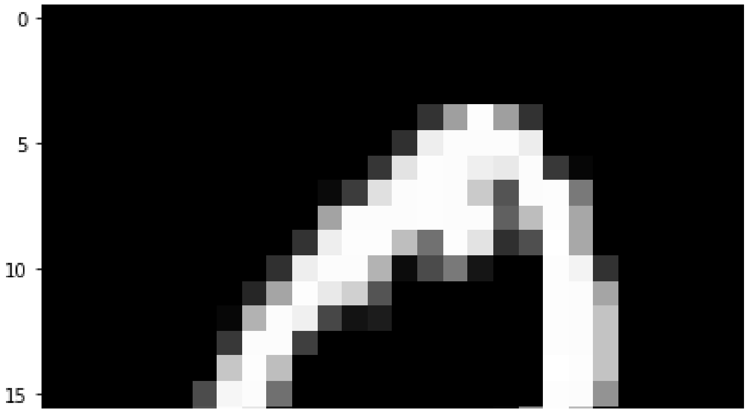
In [ ]:

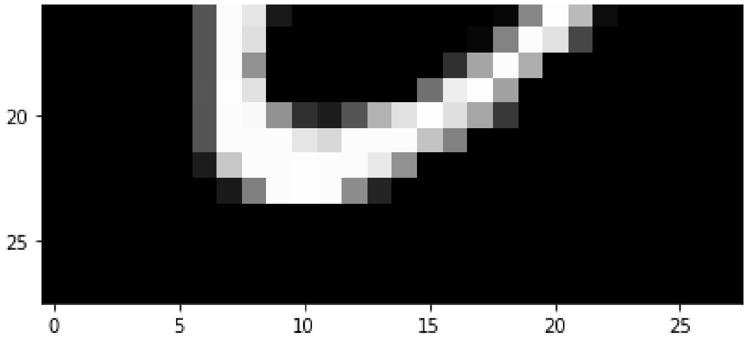
```
print(d.shape)
print(l.shape)
```

```
(60000, 784)
(60000,)
```

In [ ]:

```
# display or plot a number.
plt.figure(figsize=(7,7))
idx = 1

grid_data = d.iloc[idx].to_numpy().reshape(28,28)   # reshape from 1d to 2d pixel array
plt.imshow(grid_data, interpolation = "none", cmap = "gray")
plt.show()

print(l[idx])
```





```
0
```

2D Visualization using PCA

In [ ]:

```
# Pick first 15K data-points to work on for time-effeciency.
#Excercise: Perform the same analysis on all of 42K data-points.

labels = l.head(15000)
data = d.head(15000)

print("the shape of sample data = ", data.shape)
```

```
the shape of sample data =  (15000, 784)
```

In [ ]:

```
# Data-preprocessing: Standardizing the data

from sklearn.preprocessing import StandardScaler
standardized_data = StandardScaler().fit_transform(data)
print(standardized_data.shape)
```

```
(15000, 784)
```

In [ ]:

```
#find the co-variance matrix which is : A^T * A
sample_data = standardized_data

# matrix multiplication using numpy
covar_matrix = np.matmul(sample_data.T , sample_data)

print ( "The shape of variance matrix = ", covar_matrix.shape)
```

```
The shape of variance matrix =  (784, 784)
```

In [ ]:

```
# finding the top two eigen-values and corresponding eigen-vectors
# for projecting onto a 2-Dim space.

from scipy.linalg import eigh

# the parameter 'eigvals' is defined (low value to heigh value)
# eigh function will return the eigen values in asending order
# this code generates only the top 2 (782 and 783) eigenvalues.
values, vectors = eigh(covar_matrix, eigvals=(782,783))

print("Shape of eigen vectors = ",vectors.shape)
# converting the eigen vectors into (2,d) shape for easyness of further computations
vectors = vectors.T

print("Updated shape of eigen vectors = ",vectors.shape)
# here the vectors[1] represent the eigen vector corresponding 1st principal eigen vector
# here the vectors[0] represent the eigen vector corresponding 2nd principal eigen vector
```

```
Shape of eigen vectors =  (784, 2)
Shape of eigen vectors =  (784, 2)
Updated shape of eigen vectors =  (2, 784)
```

In [ ]:

```
# projecting the original data sample on the plane
#formed by two principal eigen vectors by vector-vector multiplication.

import matplotlib.pyplot as plt
new_coordinates = np.matmul(vectors, sample_data.T)

print (" resultanat new data points' shape ", vectors.shape, "X", sample_data.T.shape,"
= ", new_coordinates.shape)
```

```
 resultanat new data points' shape  (2, 784) X (784, 15000)  =  (2, 15000)
```

In [ ]:

```
import pandas as pd

# appending label to the 2d projected data
new_coordinates = np.vstack((new_coordinates, labels)).T

# creating a new data frame for ploting the labeled points.
dataframe = pd.DataFrame(data=new_coordinates, columns=("1st_principal", "2nd_principal"
, "label"))
print(dataframe.head())
```

```
   1st_principal  2nd_principal  label
0      -4.457050       0.960769    5.0
1      -7.397795      -8.658155    0.0
2       9.640690      -2.082854    4.0
3      -3.356074       7.187465    1.0
4       2.979880       4.933889    9.0
```

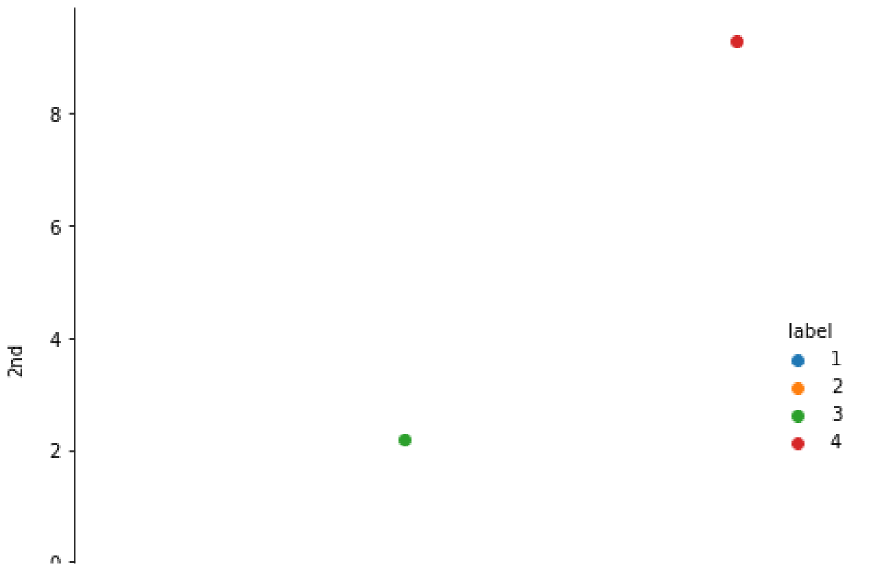
In [ ]:

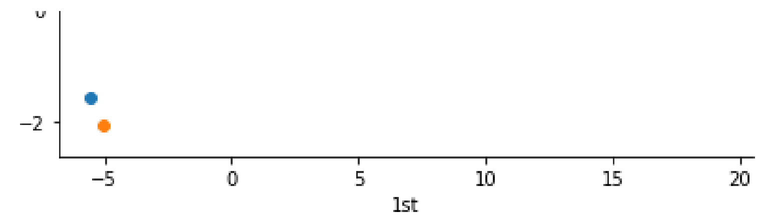
```
import pandas as pd
df=pd.DataFrame()
df['1st']=[-5.558661,-5.043558,6.193635 ,19.305278]
df['2nd']=[-1.558661,-2.043558,2.193635 ,9.305278]
df['label']=[1,2,3,4]
```

In [ ]:

```
import seaborn as sn
import matplotlib.pyplot as plt
sn.FacetGrid(df, hue="label", size=6).map(plt.scatter, '1st', '2nd').add_legend()
plt.show()
```

```
/usr/local/lib/python3.6/dist-packages/seaborn/axisgrid.py:243: UserWarning: The `size` p
arameter has been renamed to `height`; please update your code.
  warnings.warn(msg, UserWarning)
```



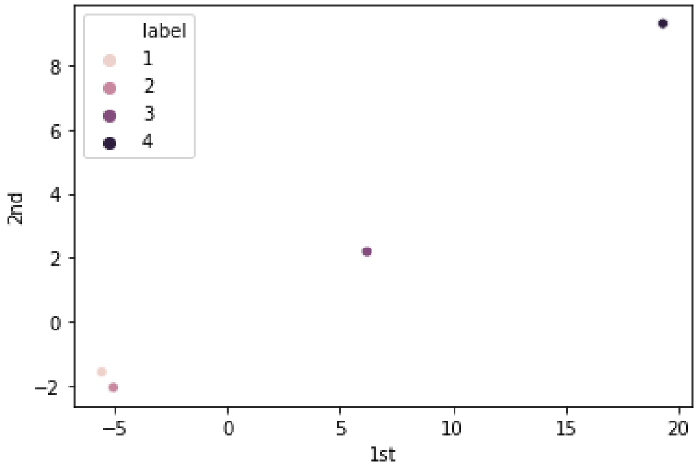


In [ ]:

```
sn.scatterplot(x="1st",y="2nd",hue="label",data=df)
```

Out[ ]:

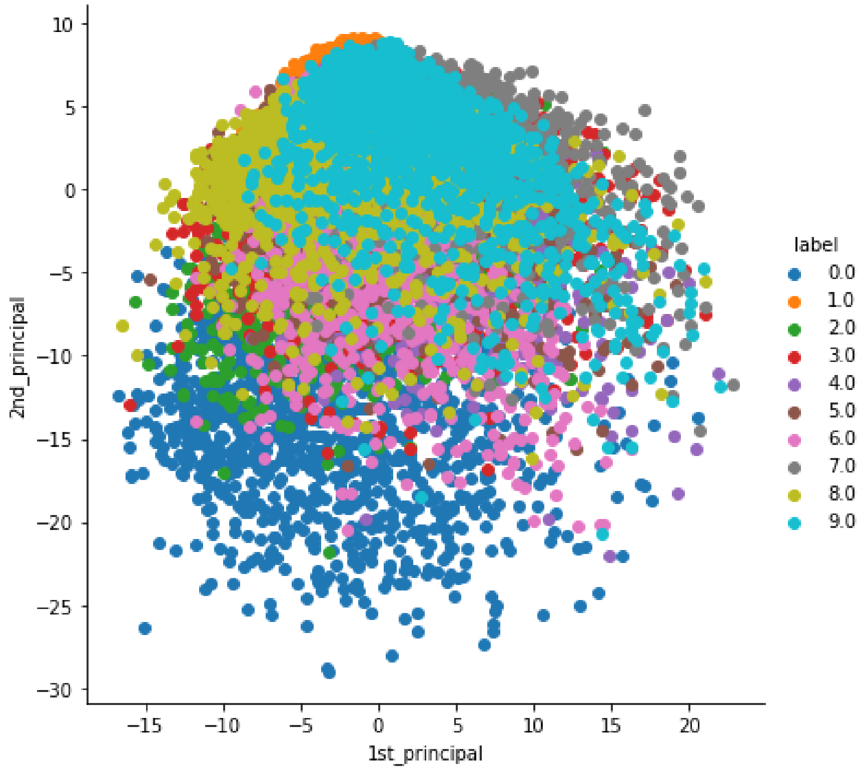
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fce7099de80>
```



In [ ]:

```
# ploting the 2d data points with seaborn
import seaborn as sn
sn.FacetGrid(dataframe, hue="label", size=6).map(plt.scatter, '1st_principal', '2nd_prin
cipal').add_legend()
plt.show()
```

```
/usr/local/lib/python3.6/dist-packages/seaborn/axisgrid.py:243: UserWarning: The `size` p
arameter has been renamed to `height`; please update your code.
  warnings.warn(msg, UserWarning)
```

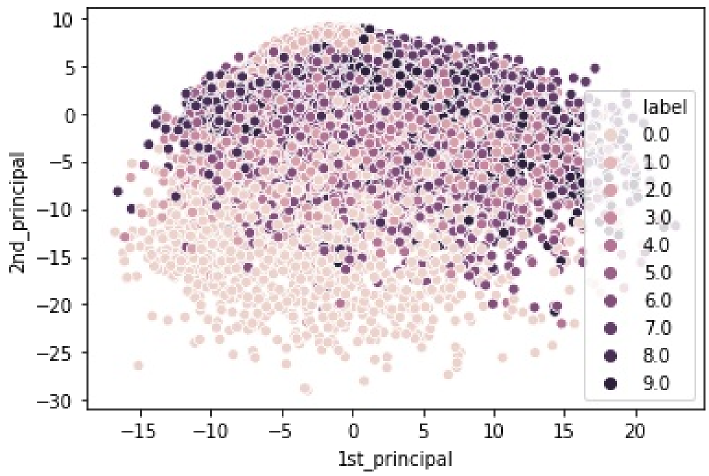


In [ ]:

```
sn.scatterplot(x="1st_principal",y="2nd_principal",legend="full",hue="label",data=datafr
ame)
```

Out[ ]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fce6dc885f8>
```



PCA using Scikit-Learn

In [ ]:

```
# initializing the pca
from sklearn import decomposition
pca = decomposition.PCA()
```

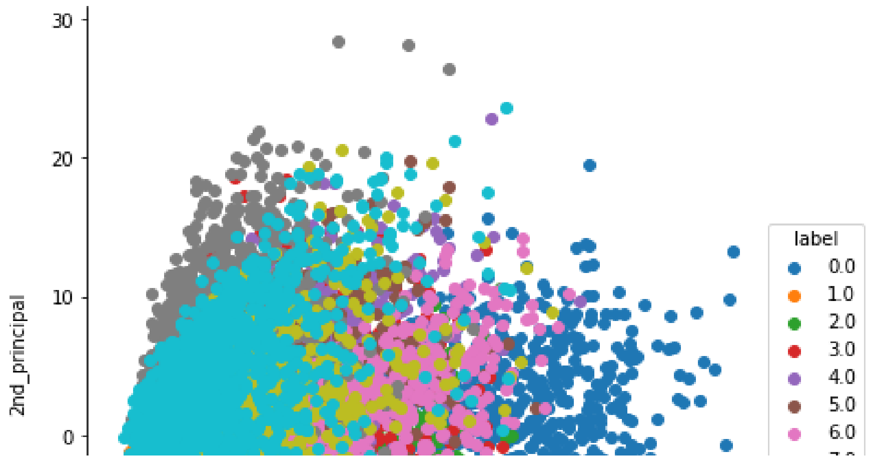
In [ ]:

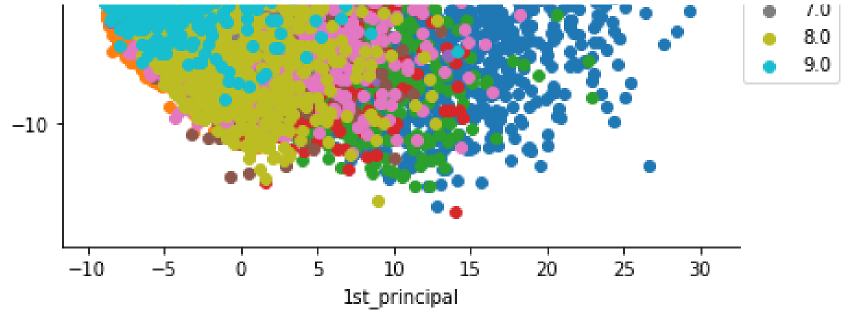
```
# configuring the parameteres
# the number of components = 2
pca.n_components = 2
pca_data = pca.fit_transform(sample_data)

# pca_reduced will contain the 2-d projects of simple data
print("shape of pca_reduced.shape = ", pca_data.shape)
```

```
shape of pca_reduced.shape =  (15000, 2)
```

In [ ]:

```
# attaching the label for each 2-d data point
pca_data = np.vstack((pca_data.T, labels)).T

# creating a new data fram which help us in ploting the result data
pca_df = pd.DataFrame(data=pca_data, columns=("1st_principal", "2nd_principal", "label")
)
sn.FacetGrid(pca_df, hue="label", size=6).map(plt.scatter, '1st_principal', '2nd_princip
al').add_legend()
plt.show()
```

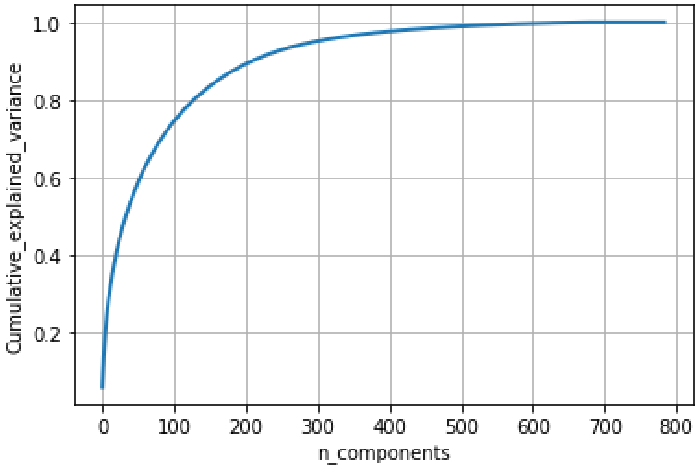




PCA for dimensionality redcution (not for visualization)

In [ ]:

```
# PCA for dimensionality redcution (non-visualization)

pca.n_components = 784
pca_data = pca.fit_transform(sample_data)

percentage_var_explained = pca.explained_variance_ / np.sum(pca.explained_variance_);

cum_var_explained = np.cumsum(percentage_var_explained)

# Plot the PCA spectrum
plt.figure(1, figsize=(6, 4))

plt.clf()
plt.plot(cum_var_explained, linewidth=2)
plt.axis('tight')
plt.grid()
plt.xlabel('n_components')
plt.ylabel('Cumulative_explained_variance')
plt.show()


# If we take 200-dimensions, approx. 90% of variance is expalined.
```

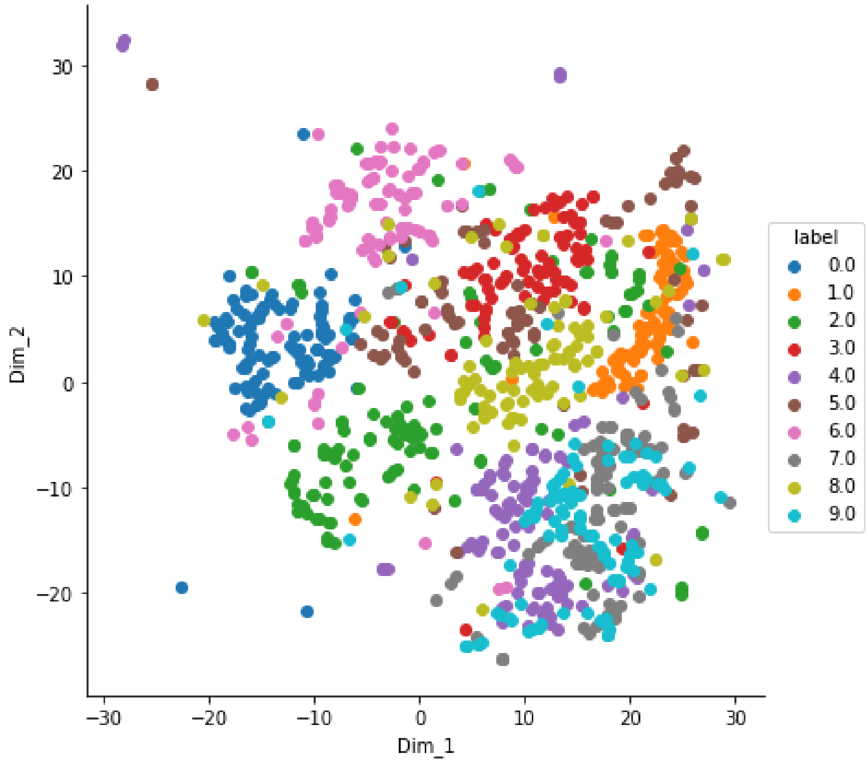


t-SNE using Scikit-Learn

In [ ]:

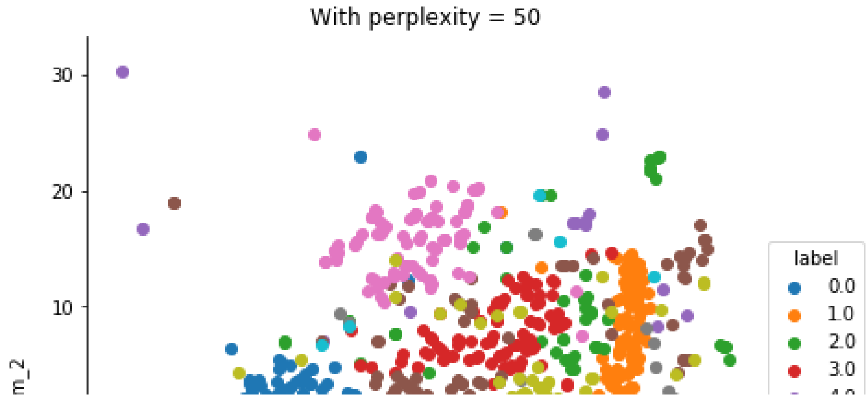
```
# TSNE

from sklearn.manifold import TSNE

# Picking the top 1000 points as TSNE takes a lot of time for 15K points
data_1000 = standardized_data[0:1000,:]
labels_1000 = labels[0:1000]

model = TSNE(n_components=2, random_state=0)
```

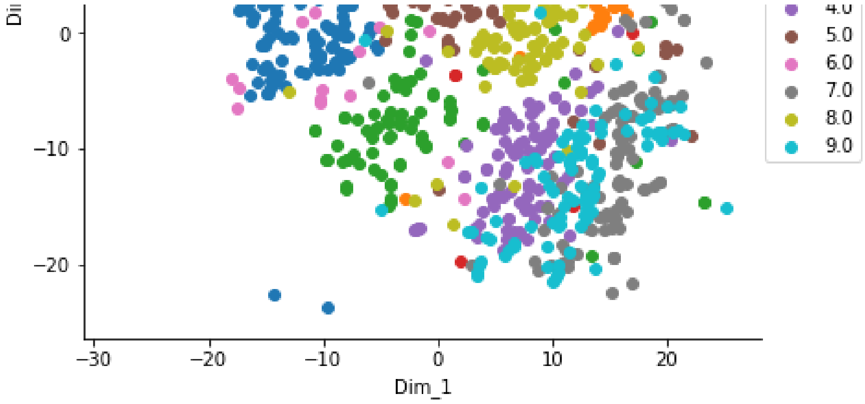
```
# configuring the parameteres
# the number of components = 2
# default perplexity = 30
# default learning rate = 200
# default Maximum number of iterations for the optimization = 1000

tsne_data = model.fit_transform(data_1000)


# creating a new data frame which help us in ploting the result data
tsne_data = np.vstack((tsne_data.T, labels_1000)).T
tsne_df = pd.DataFrame(data=tsne_data, columns=("Dim_1", "Dim_2", "label"))

# Ploting the result of tsne
sn.FacetGrid(tsne_df, hue="label", size=6).map(plt.scatter, 'Dim_1', 'Dim_2').add_legend
()
plt.show()
```



In [ ]:

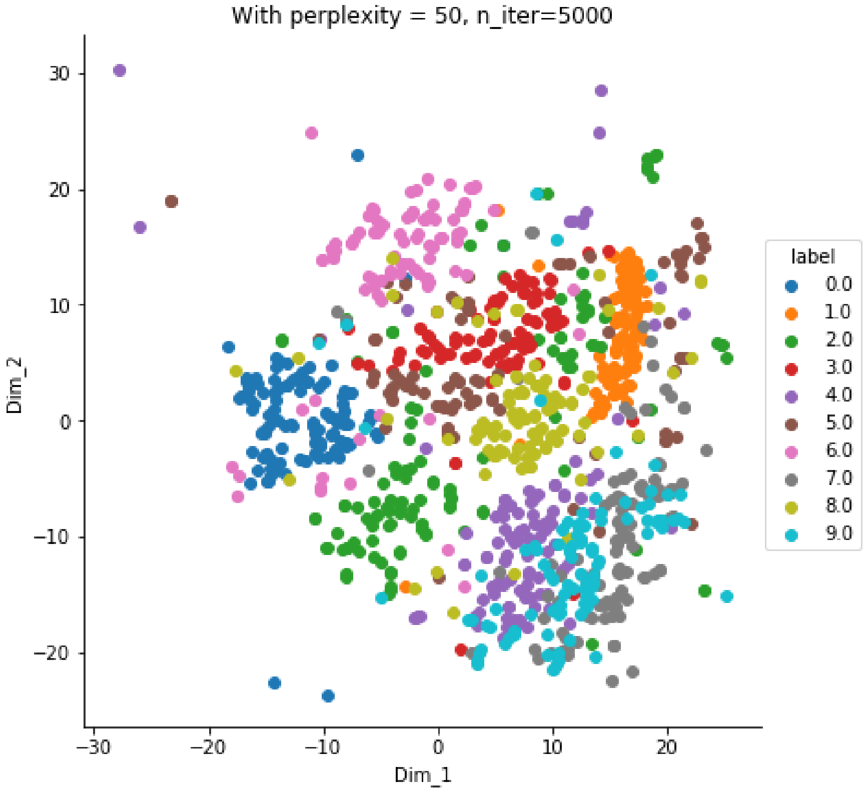
```
model = TSNE(n_components=2, random_state=0, perplexity=50)
tsne_data = model.fit_transform(data_1000)

# creating a new data fram which help us in ploting the result data
tsne_data = np.vstack((tsne_data.T, labels_1000)).T
tsne_df = pd.DataFrame(data=tsne_data, columns=("Dim_1", "Dim_2", "label"))

# Ploting the result of tsne
sn.FacetGrid(tsne_df, hue="label", size=6).map(plt.scatter, 'Dim_1', 'Dim_2').add_legend
()
plt.title('With perplexity = 50')
plt.show()
```





In [ ]:

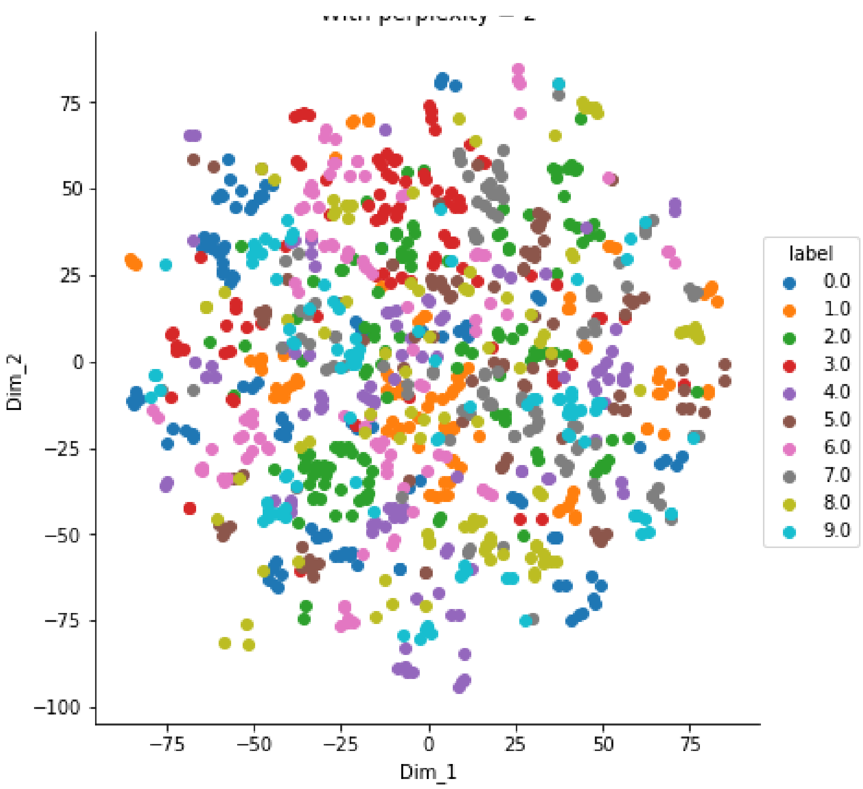
```
model = TSNE(n_components=2, random_state=0, perplexity=50,  n_iter=5000)
tsne_data = model.fit_transform(data_1000)

# creating a new data fram which help us in ploting the result data
tsne_data = np.vstack((tsne_data.T, labels_1000)).T
tsne_df = pd.DataFrame(data=tsne_data, columns=("Dim_1", "Dim_2", "label"))

# Ploting the result of tsne
sn.FacetGrid(tsne_df, hue="label", size=6).map(plt.scatter, 'Dim_1', 'Dim_2').add_legend
()
plt.title('With perplexity = 50, n_iter=5000')
plt.show()
```



In [ ]:

```
model = TSNE(n_components=2, random_state=0, perplexity=2)
tsne_data = model.fit_transform(data_1000)

# creating a new data fram which help us in ploting the result data
tsne_data = np.vstack((tsne_data.T, labels_1000)).T
tsne_df = pd.DataFrame(data=tsne_data, columns=("Dim_1", "Dim_2", "label"))

# Ploting the result of tsne
sn.FacetGrid(tsne_df, hue="label", size=6).map(plt.scatter, 'Dim_1', 'Dim_2').add_legend
()
plt.title('With perplexity = 2')
plt.show()
```

With perplexity = 2


with perplexity = 2
Dim_2
75
50
25
0
−25
−50
−75
−100
Dim_1
−75
−50
−25
0
25
50
75
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0