Classification:

1. K nearest neighbor (K-NN)

Dimensionality Reduction techniques:

1. Principal component analysis (PCA)
2. Linear discriminative analysis (LDA)

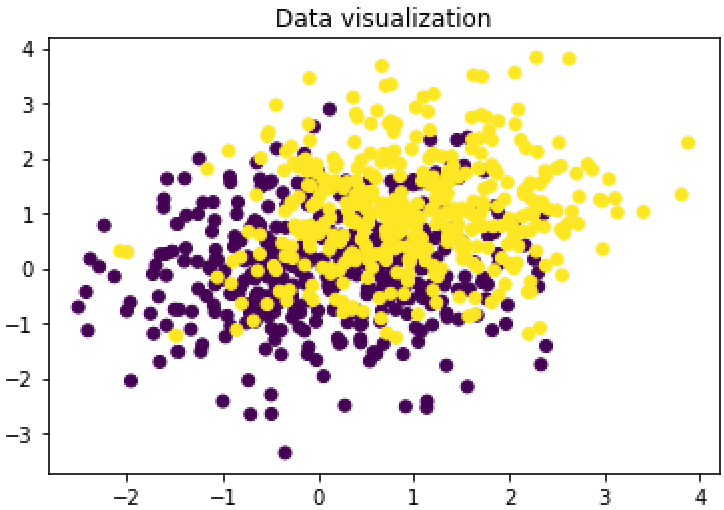
K-NN

In [ ]:

```
import numpy as np
import matplotlib.pyplot as plt

mean1=np.array([0,0])
mean2=np.array([1,1])
var=np.array([[1,0.1],[0.1,1]])
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,500)
data2=np.random.multivariate_normal(mean2,var,500)
data_train=np.concatenate((data1[:-100,],data2[:-100]))
label=np.concatenate((np.zeros(data1.shape[0]-100),np.ones(data2.shape[0]-100)))

plt.figure()
plt.scatter(data_train[:,0],data_train[:,1],c=label)
plt.title('Data visualization')
```

Out[ ]:

```
Text(0.5, 1.0, 'Data visualization')
```



In [ ]:

```
def euclidean_distance(row1, row2):
  return np.linalg.norm(row1-row2)
```

In [ ]:

```
def get_neighbors(train,label_train, test_row, num_neighbors):
  # insert your code here
  return neighbors
```

In [ ]:

```
def predict_classification(neigbors):
  # insert your code here
  return prediction
```

In [ ]:

```
# test data generation
data_test=np.concatenate((data1[-100:],data2[-100:]))
label_test=np.concatenate((np.zeros(100),np.ones(100)))
```

In [ ]:

```
K=2

pred_label=np.zeros(data_test.shape[0])
for i in range(data_test.shape[0]):
  neig=get_neighbors(data_train,label, data_test[i,:], K)
  pred_label[i]=predict_classification(neig)

accuracy=(len(np.where(pred_label==label_test)[0])/len(label_test))*100
print('Testing Accuracy=',accuracy,'%')
```

```
Testing Accuracy= 65.5 %
```

Principal component analysis (PCA)

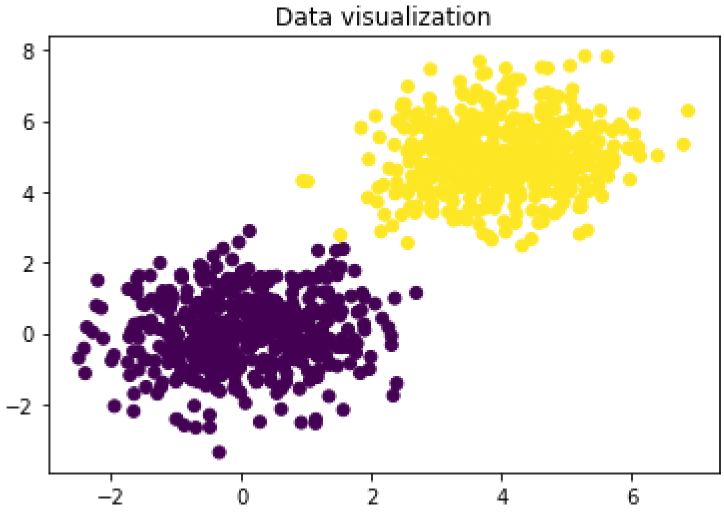
1. Generate 2D data of 1000 points
2.

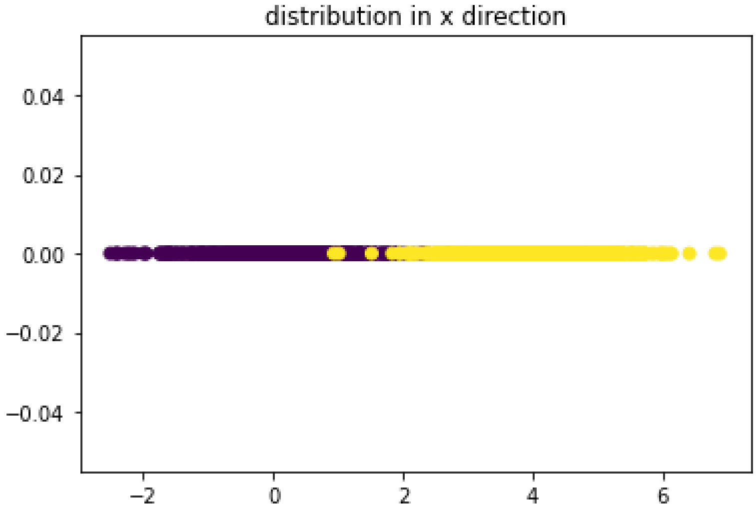
In [ ]:

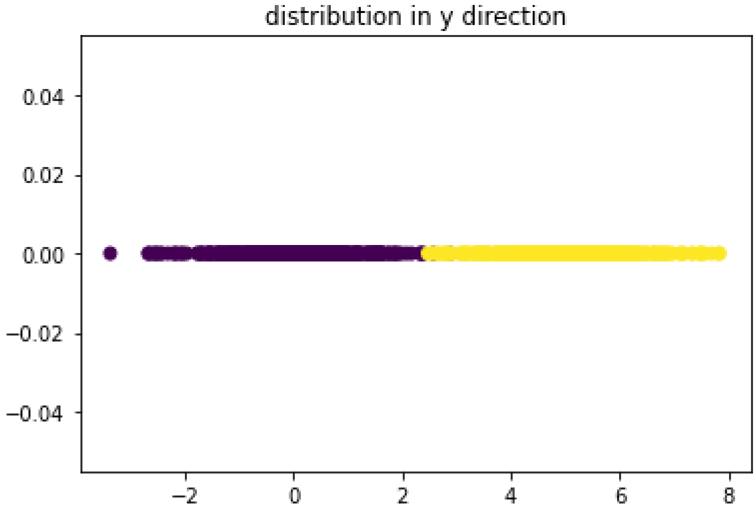
```
import numpy as np
import matplotlib.pyplot as plt

mean1=np.array([0,0])
mean2=np.array([4,5])
var=np.array([[1,0.1],[0.1,1]])
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,500)
data2=np.random.multivariate_normal(mean2,var,500)
data=np.concatenate((data1,data2))
label=np.concatenate((np.zeros(data1.shape[0]),np.ones(data2.shape[0])))

plt.figure()
plt.scatter(data[:,0],data[:,1],c=label)
plt.title('Data visualization')
plt.figure()
plt.scatter(data[:,0],np.zeros(data.shape[0]),c=label)
plt.title('distribution in x direction')
plt.figure()
plt.scatter(data[:,1],np.zeros(data.shape[0]),c=label)
plt.title('distribution in y direction')
```

Out[ ]:

```
Text(0.5, 1.0, 'distribution in y direction')
```





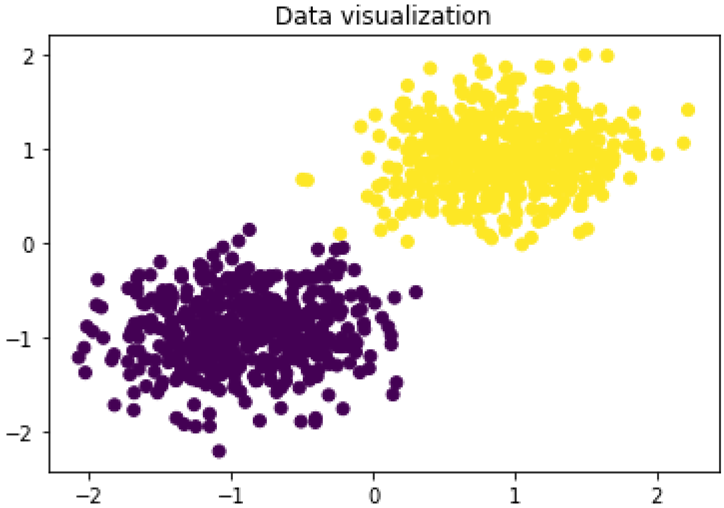


In [ ]:

```
#Data normalization

# perform data normalization here using mean substraction and std division
plt.figure()
plt.scatter(data[:,0],data[:,1],c=label)
plt.title('Data visualization')
```

Out[ ]:

```
Text(0.5, 1.0, 'Data visualization')
```



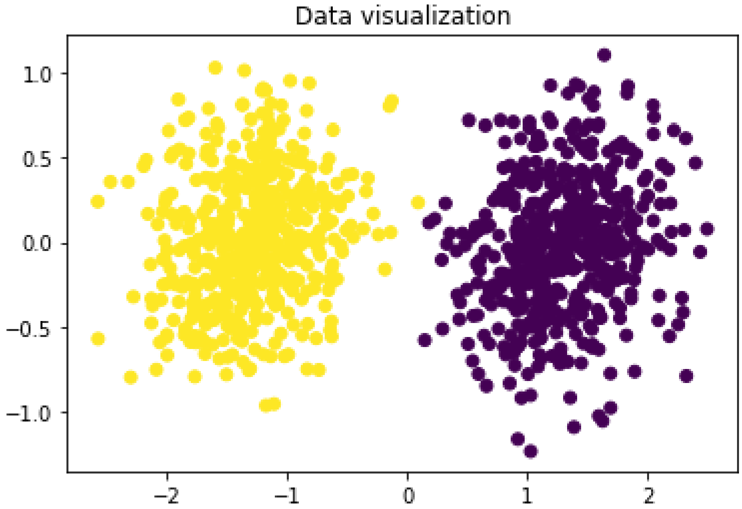
In [ ]:

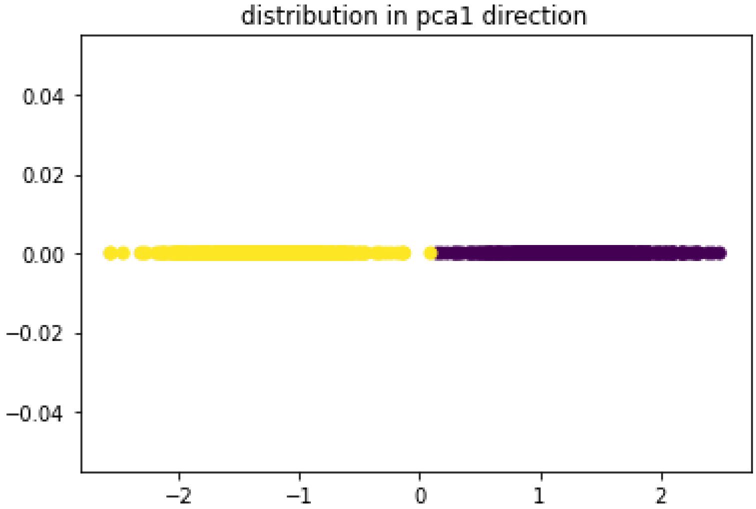
```
# PCA

# coverance matrix
cov=data.T @ data


# using sigular value decomposition
u,s,v=np.linalg.svd(cov)

trans_data=# insert your code here

var_pca1=np.var(trans_data[:,0])
var_pca2=np.var(trans_data[:,1])

print('variance along pca1 direction=',var_pca1)
print('variance along pca2 direction=',var_pca2)


plt.figure()
plt.scatter(trans_data[:,0],trans_data[:,1],c=label)
plt.title('Data visualization')
plt.figure()
plt.scatter(trans_data[:,0],np.zeros(data.shape[0]),c=label)
plt.title('distribution in pca1 direction')
plt.figure()
plt.scatter(trans_data[:,1],np.zeros(data.shape[0]),c=label)
plt.title('distribution in pca2 direction')
```

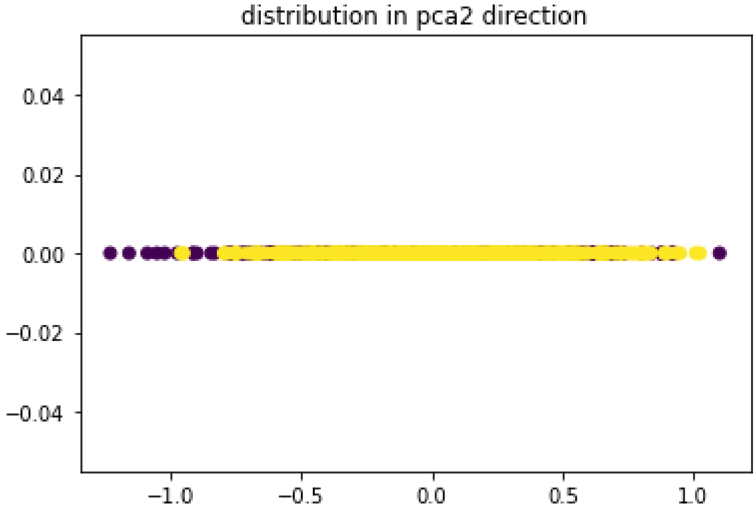
```
variance along pca1 direction= 1.8477663843459722
variance along pca2 direction= 0.15223361565402702
```

Out[ ]:

```
Text(0.5, 1.0, 'distribution in pca2 direction')
```







PCA 1 dimension is sufficient, we can droup PCA 2 dimension

In [ ]:

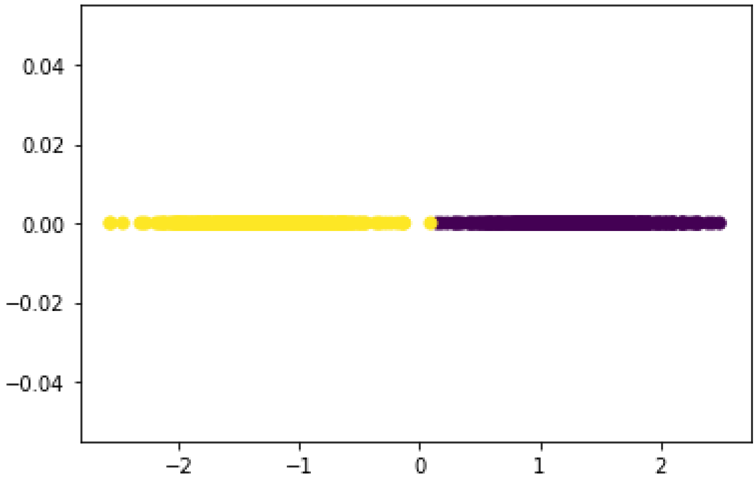
```
class pca:
  # Constructor
  def __init__(self, name='reg',data=None,retain_dim=None):
    self.name = name  # Create an instance variable
    self.data=data
    self.retain_dim=retain_dim if retain_dim is not None else self.ret_dim(self.
data)
    # compute pca transform value
  def pca_comp(self,data):
    data=self.pre_process(data)
    cov=# insert your code here
    u,_,_=np.linalg.svd(cov) # singular value decomposition
    u_req=# insert your code here
    trans_data=# insert your code here
    return trans_data,u_req
    # compute the required retain dimension
  def ret_dim(self,data):
    data=self.pre_process(data)
    cov=data.T @ data
    _,s,_=np.linalg.svd(cov)
    ind=# insert your code here # can also take 90%
    return ind+1
  def pre_process(self,data):
    data1=(data-np.mean(data,axis=0))

    data=data1/(np.std(data1,axis=0)+10**(-30)) # avoid divide by zero
    return data
```

In [ ]:

```
# pca transformation
PCA=pca(data=data)
trans_data,trans_mat=PCA.pca_comp(data)
plt.scatter(trans_data,np.zeros(trans_data.shape),c=label)
```

Out[ ]:

```
<matplotlib.collections.PathCollection at 0x7f1c3e7b1dd8>
```



In [ ]:

```
#classification using pca
#use k-nearest neighbour classifier after dimensionality reduction

from sklearn.neighbors import KNeighborsClassifier
k=5
knn = KNeighborsClassifier(n_neighbors=k)
knn.fit(trans_data, label)

print('KNN Training accuracy =',knn.score(trans_data,label)*100)

# test data
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,50)
data2=np.random.multivariate_normal(mean2,var,50)
data=np.concatenate((data1,data2))
tst_label=np.concatenate((np.zeros(data1.shape[0]),np.ones(data2.shape[0])))

print('KNN Testing accuracy =',knn.score(PCA.pre_process(data) @ trans_mat,tst_l
abel)*100)
```

```
KNN Training accuracy = 99.9
KNN Testing accuracy = 100.0
```

In [ ]:

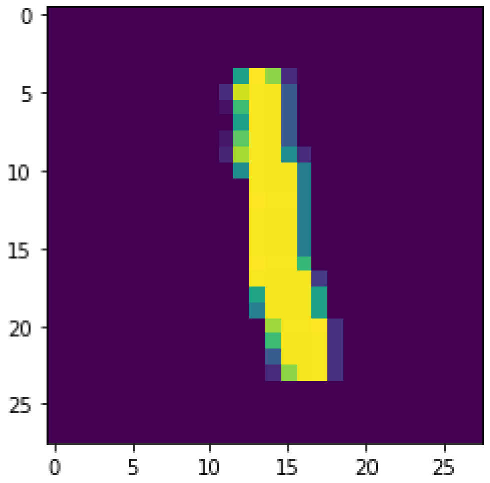
```
from google.colab import drive
drive.mount('/gdrive')
!pip install idx2numpy
```

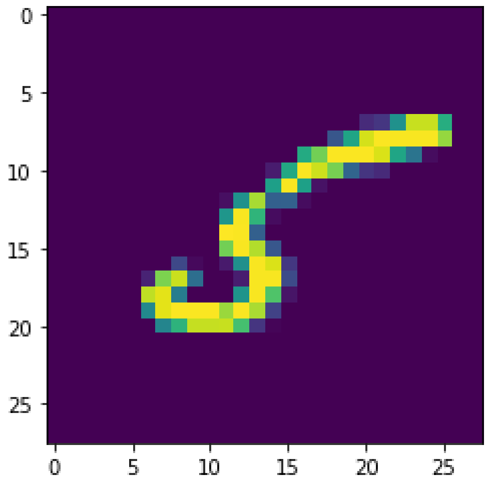
```
Drive already mounted at /gdrive; to attempt to forcibly remount, ca
ll drive.mount("/gdrive", force_remount=True).
Requirement already satisfied: idx2numpy in /usr/local/lib/python3.
6/dist-packages (1.2.2)
Requirement already satisfied: numpy in /usr/local/lib/python3.6/dis
t-packages (from idx2numpy) (1.18.5)
Requirement already satisfied: six in /usr/local/lib/python3.6/dist-
packages (from idx2numpy) (1.12.0)
```

In [ ]:

```
# MNIST data

import numpy as np
import matplotlib.pyplot as plt

file1='/gdrive/My Drive/Machine learning workshop blr/Colab_notebooks/train-imag
es.idx3-ubyte'
file2='/gdrive/My Drive/Machine learning workshop blr/Colab_notebooks/train-labe
ls.idx1-ubyte'

import idx2numpy

Images= idx2numpy.convert_from_file(file1)
labels= idx2numpy.convert_from_file(file2)

cl=[1,5]

# for class 1

id_1=np.where(labels==cl[0])
id1=id_1[0]
id1=id1[:50]
Im_1=Images[id1,:,:]
lab_1=labels[id1]

# for class 5
id_5=np.where(labels==cl[1])
id5=id_5[0]
id5=id5[:50]
Im_5=Images[id5,:,:]
lab_5=labels[id5]

plt.imshow(Im_1[1,:,:])
plt.figure()
plt.imshow(Im_5[1,:,:])

#print(Im_5.shape)

data=np.concatenate((Im_1,Im_5))
data=np.reshape(data,(data.shape[0],data.shape[1]*data.shape[2]))
print(data.shape)
G_lab=np.concatenate((lab_1,lab_5))
print(G_lab.shape)

data = data.astype('float32')

data /= 255
```

```
(100, 784)
(100,)
```

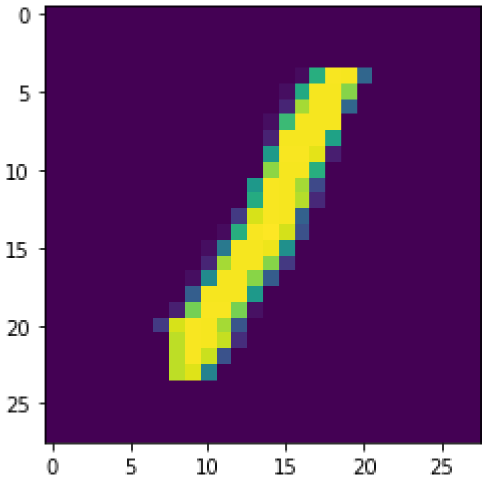


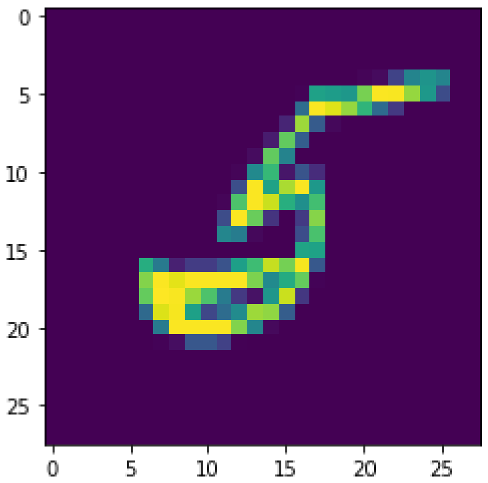


In [ ]:

```
print('Initial data dimension=',data.shape[1])
PCA=pca(data=data)

trans_data,trans_mat=PCA.pca_comp(data)
print('Retained dimesion after PCA=',trans_mat.shape[1])
k=5
knn = KNeighborsClassifier(n_neighbors=k)
knn.fit(trans_data, G_lab)

print('KNN Training accuracy =',knn.score(trans_data,G_lab)*100)


## testing
## data preparation
id_1=np.where(labels==cl[0])
id1=id_1[0]
id1=id1[100:150]
Im_1=Images[id1,:,:]
lab_1=labels[id1]

# for class 5
id_5=np.where(labels==cl[1])
id5=id_5[0]
id5=id5[100:150]
Im_5=Images[id5,:,:]
lab_5=labels[id5]

plt.imshow(Im_1[1,:,:])
plt.figure()
plt.imshow(Im_5[1,:,:])

print(Im_5.shape)

data_tst=np.concatenate((Im_1,Im_5))
data_tst=np.reshape(data_tst,(data_tst.shape[0],data_tst.shape[1]*data_tst.shape
[2]))

tst_lab=np.concatenate((lab_1,lab_5))


# final testing
print('KNN Testing accuracy =',knn.score(PCA.pre_process(data_tst) @ trans_mat,t
st_lab)*100)
```

```
Initial data dimension= 784
Retained dimesion after PCA= 36
KNN Training accuracy = 96.0
(50, 28, 28)
KNN Testing accuracy = 97.0
```





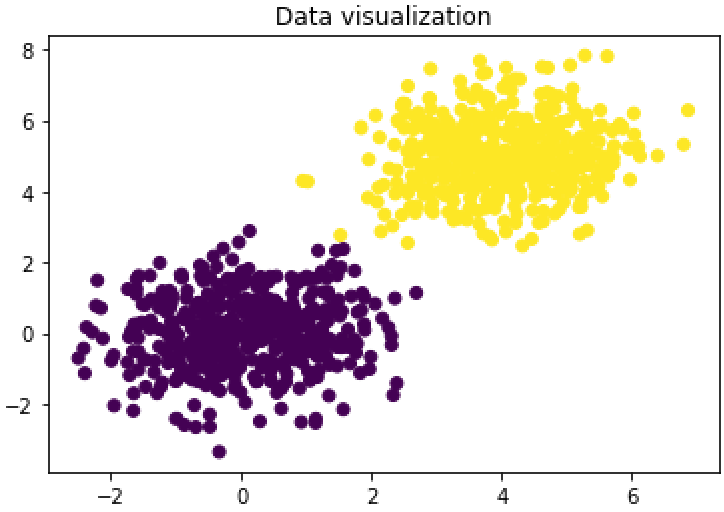
Linear Discriminate Analysis (LDA)

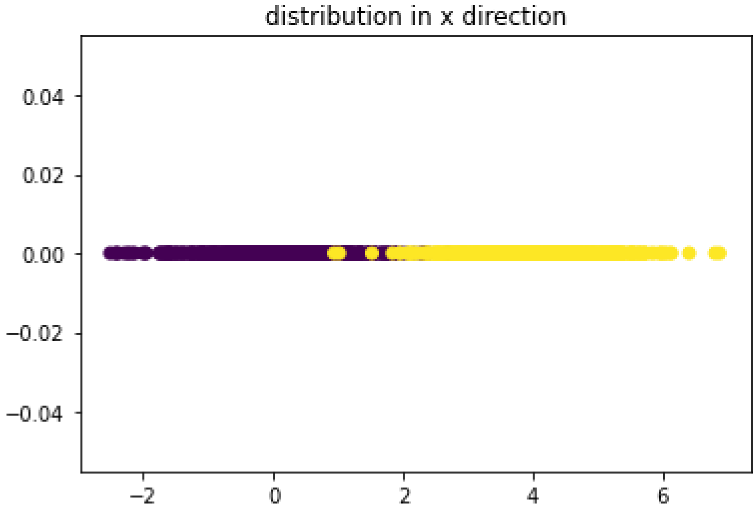
In [ ]:

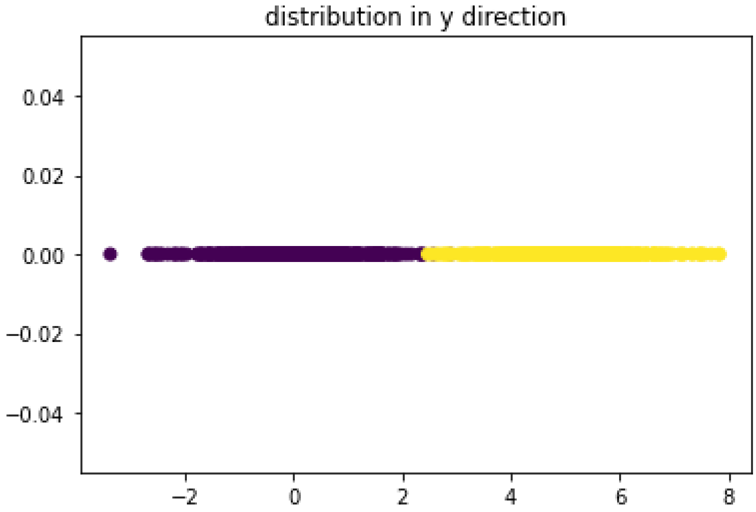
```
import numpy as np
import matplotlib.pyplot as plt

# data generation

mean1=np.array([0,0])
mean2=np.array([4,5])
var=np.array([[1,0.1],[0.1,1]])
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,500)
data2=np.random.multivariate_normal(mean2,var,500)
data=np.concatenate((data1,data2))
label=np.concatenate((np.zeros(data1.shape[0]),np.ones(data2.shape[0])))

plt.figure()
plt.scatter(data[:,0],data[:,1],c=label)
plt.title('Data visualization')
plt.figure()
plt.scatter(data[:,0],np.zeros(data.shape[0]),c=label)
plt.title('distribution in x direction')
plt.figure()
plt.scatter(data[:,1],np.zeros(data.shape[0]),c=label)
plt.title('distribution in y direction')
```

Out[ ]:

```
Text(0.5, 1.0, 'distribution in y direction')
```






distribution in y direction
0.04
0.02
0.00
−0.02
−0.04
−2
0
2
4
6
8

In [ ]:

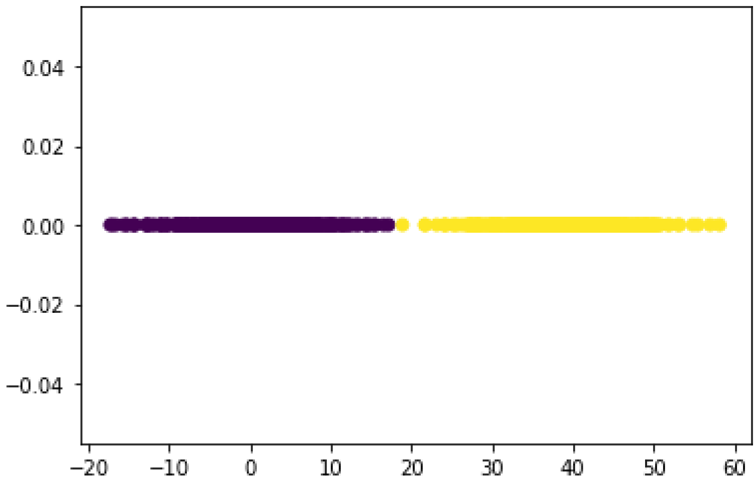
```
# perform 2-class and m-class LDA
def LDA(data,label):
  id={}
  data_l={}
  mean_l={}
  cov_l={}
  S_w=np.zeros((data.shape[1],data.shape[1]))


  cls=np.unique(label)
  for i in cls:
    id[i]=np.where(label==i)[0]
    data_l[i]=data[id[i],:]
    mean_l[i]=np.mean(data_l[i],axis=0)
    cov_l[i]=# insert your code here
    S_w=S_w+cov_l[i]


  S_w=S_w/len(data_l)

  if len(data_l)==2:
    S_b=# insert your code here
    w=# insert your code here

  else:
    S_t=np.cov(data,rowvar=False)
    S_b=# insert your code here
    u,_,_=# insert your code here
    w=u[:,:len(data_l)-1]

  return w
```

In [ ]:

```
# after LDA projection

w=LDA(data,label)
plt.figure()
plt.scatter(data @ w,np.zeros(data.shape[0]),c=label)
```

Out[ ]:

<matplotlib.collections.PathCollection at 0x7fdfa28c1d68>



In [ ]:

```
#classification using pca
#use k-nearest neighbour classifier after dimensionality reduction


from sklearn.neighbors import KNeighborsClassifier

LDA_data= data @ w[:,np.newaxis]
k=5
knn = KNeighborsClassifier(n_neighbors=k)
knn.fit(LDA_data, label)

print('KNN Training accuracy =',knn.score(LDA_data,label)*100)

# test data
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,50)
data2=np.random.multivariate_normal(mean2,var,50)
data_tst=np.concatenate((data1,data2))
tst_label=np.concatenate((np.zeros(data1.shape[0]),np.ones(data2.shape[0])))

print('KNN Testing accuracy =',knn.score(data_tst@ w[:,np.newaxis],tst_label)*10
0)
```

```
KNN Training accuracy = 100.0
KNN Testing accuracy = 100.0
```

LDA multiclass

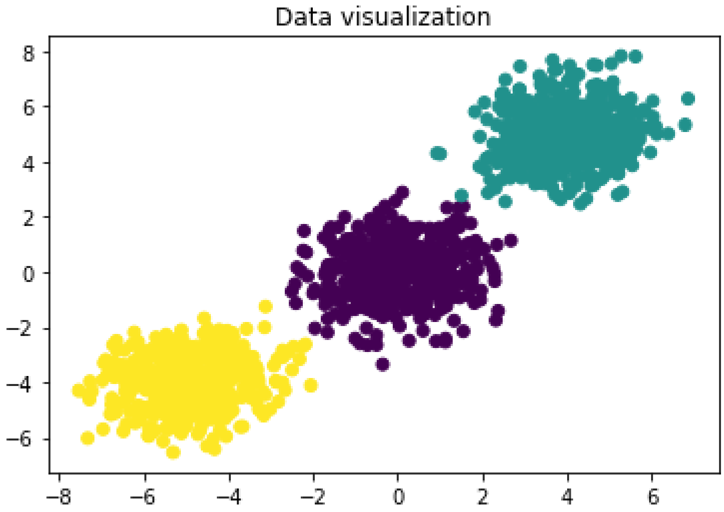
1. 3 class Sythetic data
2. Homework: Mnist 3 class and 10 class

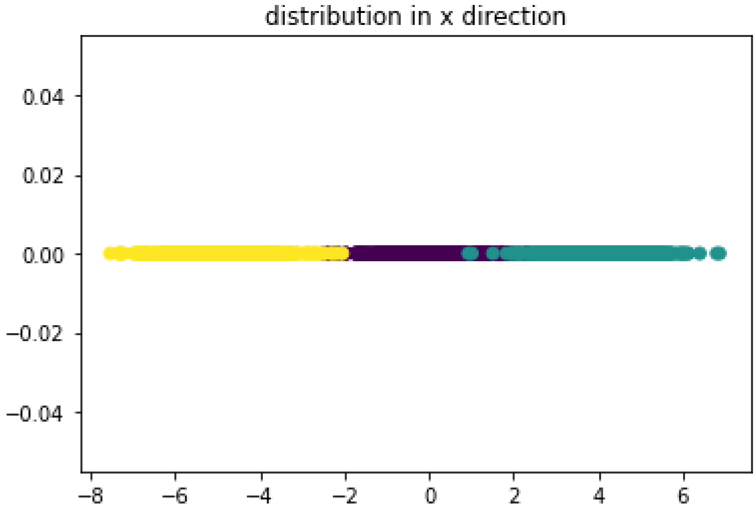
In [ ]:

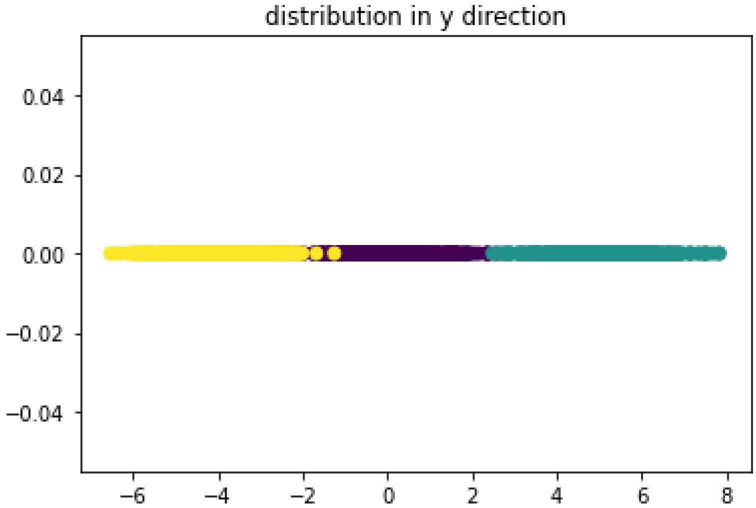
```
import numpy as np
import matplotlib.pyplot as plt

mean1=np.array([0,0])
mean2=np.array([4,5])
mean3=np.array([-5,-4])
var=np.array([[1,0.1],[0.1,1]])
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,500)
data2=np.random.multivariate_normal(mean2,var,500)
data3=np.random.multivariate_normal(mean3,var,500)
data=np.concatenate((data1,data2,data3))
label=np.concatenate((np.zeros(data1.shape[0]),np.ones(data2.shape[0]),np.ones(d
ata3.shape[0])+1))

plt.figure()
plt.scatter(data[:,0],data[:,1],c=label)
plt.title('Data visualization')
plt.figure()
plt.scatter(data[:,0],np.zeros(data.shape[0]),c=label)
plt.title('distribution in x direction')
plt.figure()
plt.scatter(data[:,1],np.zeros(data.shape[0]),c=label)
plt.title('distribution in y direction')
```

Out[ ]:

```
Text(0.5, 1.0, 'distribution in y direction')
```







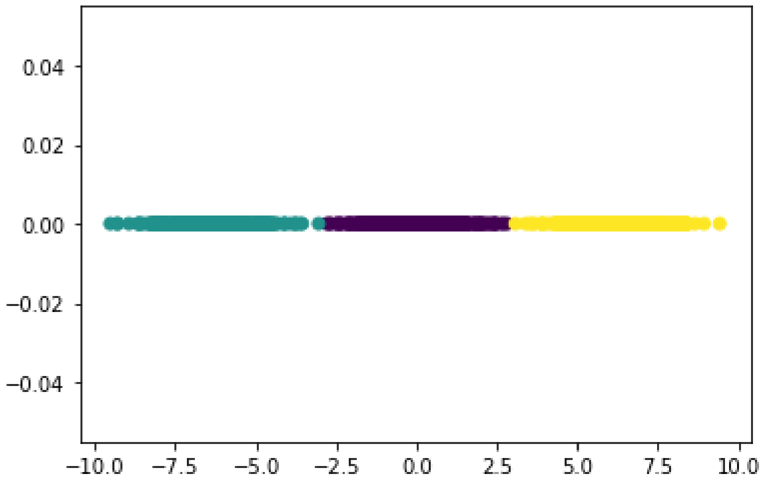
In [ ]:

```
# after projection
w=LDA(data,label)
print(w.shape)
plt.figure()
plt.scatter(data @ w[:,0],np.zeros(data.shape[0]),c=label) # by performing 1D pr
ojection
```

```
(2, 2)
```

Out[ ]:

```
<matplotlib.collections.PathCollection at 0x7fdfa23d6048>
```



In [ ]:

```
# testing (using KNN)

from sklearn.neighbors import KNeighborsClassifier

LDA_data= data @ w
k=5
knn = KNeighborsClassifier(n_neighbors=k)
knn.fit(LDA_data, label)

print('KNN Training accuracy =',knn.score(LDA_data,label)*100)

# test data
np.random.seed(0)
data1=np.random.multivariate_normal(mean1,var,50)
data2=np.random.multivariate_normal(mean2,var,50)
data3=np.random.multivariate_normal(mean3,var,50)
data_tst=np.concatenate((data1,data2,data3))
tst_label=np.concatenate((np.zeros(data1.shape[0]),np.ones(data2.shape[0]),np.on
es(data2.shape[0])+1))

print('KNN Testing accuracy =',knn.score(data_tst@ w,tst_label)*100)
```

```
KNN Training accuracy = 99.93333333333332
KNN Testing accuracy = 100.0
```