```
import numpy as np
import pandas as pd
import math as mt
import matplotlib.pyplot as plt
from google.colab import drive
from scipy.stats import multivariate_normal as mvn
import seaborn as sns
```

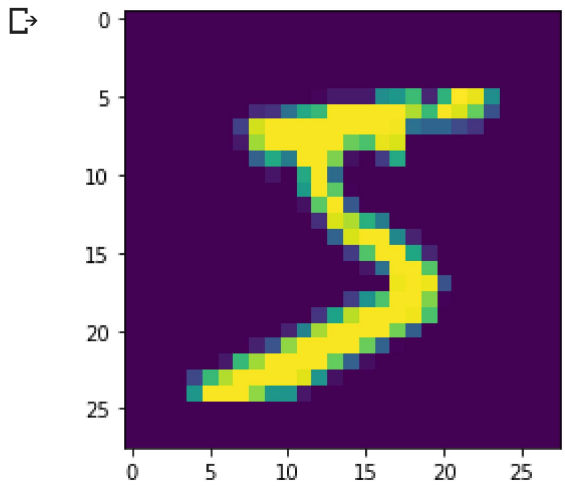
```
data = pd.read_csv('/content/drive/MyDrive/Colab Notebooks/DigitRecognition/MNIST_train.csv')
data_test = pd.read_csv('/content/drive/MyDrive/Colab Notebooks/DigitRecognition/MNIST_test.c
```

```
X_vi = data.iloc[:,3:]
type(X_vi)
```

```
pandas.core.frame.DataFrame
```

```
X_vi = X_vi.values.reshape(-1,28,28,1)
```

```
g = plt.imshow(X_vi[0][:,:,0])
```




```
data.head()
```

```
Unnamed: 0  index  labels  0  1  2  3  4  5  6  ...  774  775  776  777  778  779  78
```

```
data_test
```

	Unnamed: 0	index	labels	0	1	2	3	4	5	6	...	774	775	776	777	778	7
0	0	0	7	0	0	0	0	0	0	0	...	0	0	0	0	0	
1	1	1	2	0	0	0	0	0	0	0	...	0	0	0	0	0	
2	2	2	1	0	0	0	0	0	0	0	...	0	0	0	0	0	
3	3	3	0	0	0	0	0	0	0	0	...	0	0	0	0	0	
4	4	4	4	0	0	0	0	0	0	0	...	0	0	0	0	0	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9995	9995	9995	2	0	0	0	0	0	0	0	...	0	0	0	0	0	
9996	9996	9996	3	0	0	0	0	0	0	0	...	0	0	0	0	0	
9997	9997	9997	4	0	0	0	0	0	0	0	...	0	0	0	0	0	
9998	9998	9998	5	0	0	0	0	0	0	0	...	0	0	0	0	0	
9999	9999	9999	6	0	0	0	0	0	0	0	...	0	0	0	0	0	

10000 rows × 787 columns

```
df = data.iloc[:,1:]
df.shape
```

```
(60000, 786)
```

```
g = sns.countplot(y)
```

```
data.iloc[:,2].value_counts()
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning: Pass th
  FutureWarning
1    6742
7    6265
3    6131
2    5958
9    5949
0    5923
6    5918
8    5851
4    5842
5    5421
Name: labels, dtype: int64
```

```
class GaussBayes():

  def fit(self,X,y,epsilon=1e-3):

    self.likelihoods=dict()
    self.priors=dict()
    self.k = set(y.astype(int))

    for k in self.k:
      X_k = X[y==k,:]
      N_k, D = X_k.shape
      mu_k = X_k.mean(axis=0)
      self.likelihoods[k] = {"mean":X.mean(axis=0),"cov":(1/(N_k-1))*np.matmul((X_k-mu_k).T,X
      self.priors[k] = len(X_k) / len(X)
  def predict(self,X):
    N,D = X.shape
    P_hat = np.zeros((N,len(self.k)))
    for k, l in self.likelihoods.items():
      P_hat[:,k] = mvn.logpdf(X,l["mean"],l["cov"])+np.log(self.priors[k])

    return P_hat.argmax(axis=1)


data.iloc[:,3:].isnull().any().describe()
```

```
count       784
unique        1
top       False
freq        784
dtype: object
```

```
X = data.to_numpy()
X
```

```
array([[    0,     0,     5, ...,     0,     0,     0],
       [    1,     1,     0, ...,     0,     0,     0],
       [    2,     2,     4, ...,     0,     0,     0],
       ...,
```

```
            [59997, 59997,     5, ...,     0,     0,     0],
            [59998, 59998,     6, ...,     0,     0,     0],
            [59999, 59999,     8, ...,     0,     0,     0]])
```

```
Xt = data_test.to_numpy()
```

```
def min_max_scaling(column):
    return (column - column.min())/(column.max() - column.min())
```

```
xtest = Xt[:,3:]
xtest = min_max_scaling(xtest)
xtest.shape
```

```
(10000, 784)
```

```
ytest = Xt[:,2]
ytest
```

```
array([7, 2, 1, ..., 4, 5, 6])
```

```
x = X[:,3:]
x = min_max_scaling(x)
x.shape
```

```
(60000, 784)
```

```
y = X[:,2]
y
```

```
array([5, 0, 4, ..., 5, 6, 8])
```

```
modelGB = GaussBayes()
```

```
modelGB.fit(x,y)
```

```
y_hatGBtrain = modelGB.predict(x)
y_hatGBtest = modelGB.predict(xtest)
```

```
def accuracy(y, y_hat):
  return np.mean(y==y_hat)
```

```
accuracy(y,y_hatGBtrain)
```

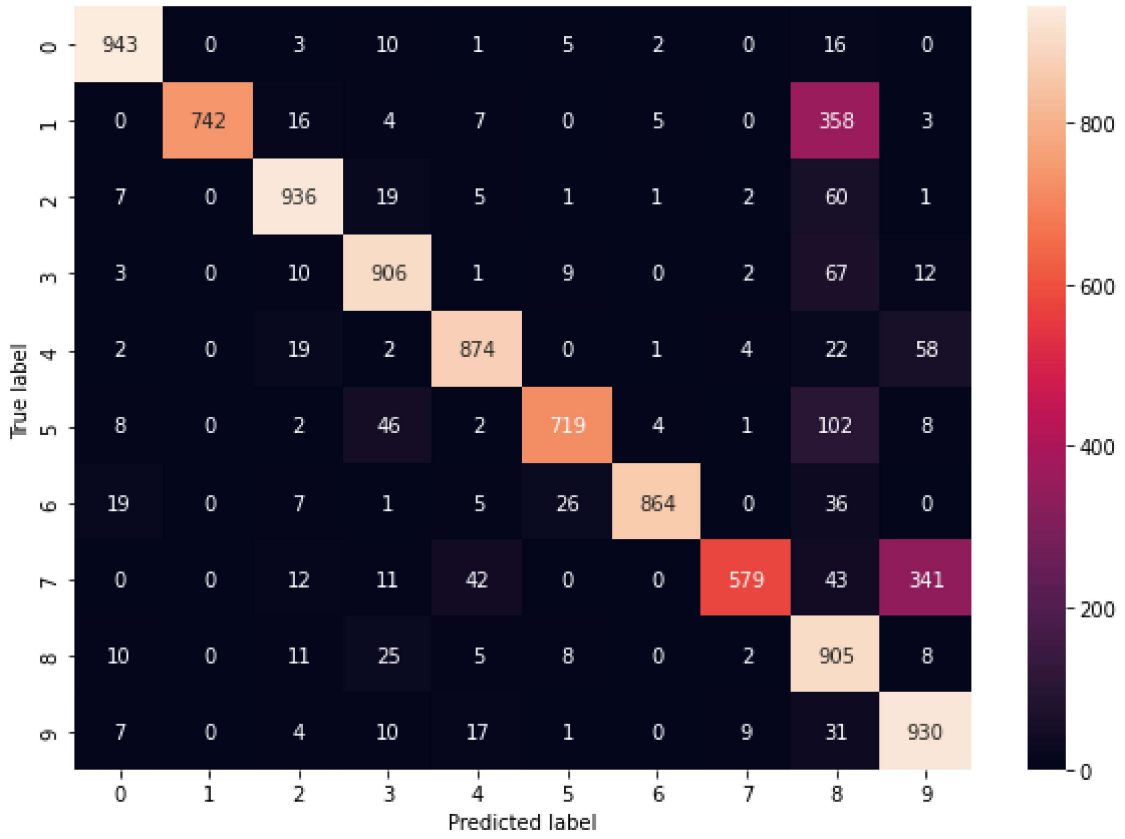
```
0.86575
```

```
accuracy(ytest,y_hatGBtest)
```

```
0.8398
```

```
plt.figure(figsize=(10,7))
y_actu = pd.Series(ytest, name='Actual')
y_pred = pd.Series(y_hatGBtest, name='Predicted')
cm = pd.crosstab(y_actu, y_pred)
ax = sns.heatmap(cm, annot=True, fmt="d")
plt.ylabel('True label')
plt.xlabel('Predicted label')
```

```
Text(0.5, 42.0, 'Predicted label')
```



KNN

```
class KNNClassifier():
  def fit(self, X, y):
    self.X = X
    self.y =y.astype(int)
  def predict(self,X, k, epsilon=1e-3):
    N = len(X)
    y_hat = np.zeros(N)
```

```
        for i in range(N):
          dist2 = np.sum((self.X-X[i])**2,axis=1)
          idxt = np.argsort(dist2)[:k]
          gamma_k = 1/(np.sqrt(dist2[idxt]+epsilon))
          y_hat[i] = np.bincount(self.y[idxt], weights =gamma_k).argmax()
        return y_hat


modelknn = KNNClassifier()


x = X[:,3:]
y = X[:,2]


xtest = Xt[:,3:]
ytest = Xt[:,2]


modelknn.fit(x,y)


y_hatM1train = modelknn.predict(x,12)


accuracy(y,y_hatM1train)
```

```
     1.0
```

```
y_hatM1 = modelknn.predict(xtest,12)


accuracy(ytest,y_hatM1)
```

```
     0.9678
```

```
import seaborn as sns
plt.figure(figsize=(10,7))
y_actu = pd.Series(ytest, name='Actual')
y_pred = pd.Series(y_hatM1, name='Predicted')
cm = pd.crosstab(y_actu, y_pred)
ax = sns.heatmap(cm, annot=True, fmt="d")
plt.ylabel('True label')
plt.xlabel('Predicted label')
```

```
Text(0.5, 42.0, 'Predicted label')
```

Naive Bayes


```
class GaussNB():

  def fit(self,X,y, epsilon=1e-3):

    self.likelihoods = dict()
    self.priors = dict()

    self.K = set(y.astype(int))

    for k in self.K:

      X_k = X[y==k, : ]

      self.likelihoods[k]= {"mean": X_k.mean(axis=0), "cov": X_k.var(axis=0) +epsilon}
      self.priors[k] = len(X-k)/len(X)


  def predict(self, X):

    N , D = X.shape

    P_hat =np.zeros((N, len(self.K)))

    for k, l in self.likelihoods.items():
    #Bayes Theorem application:
      P_hat[:,k] = mvn.logpdf(X, l["mean"],l["cov"])+ np.log(self.priors[k])

    return P_hat.argmax(axis=1)
```

```
model2d = GaussNB()

model2d.fit(x,y)


y_hatNB = model2d.predict(xtest)


accuracy(ytest,y_hatNB)
```

```
0.7746
```

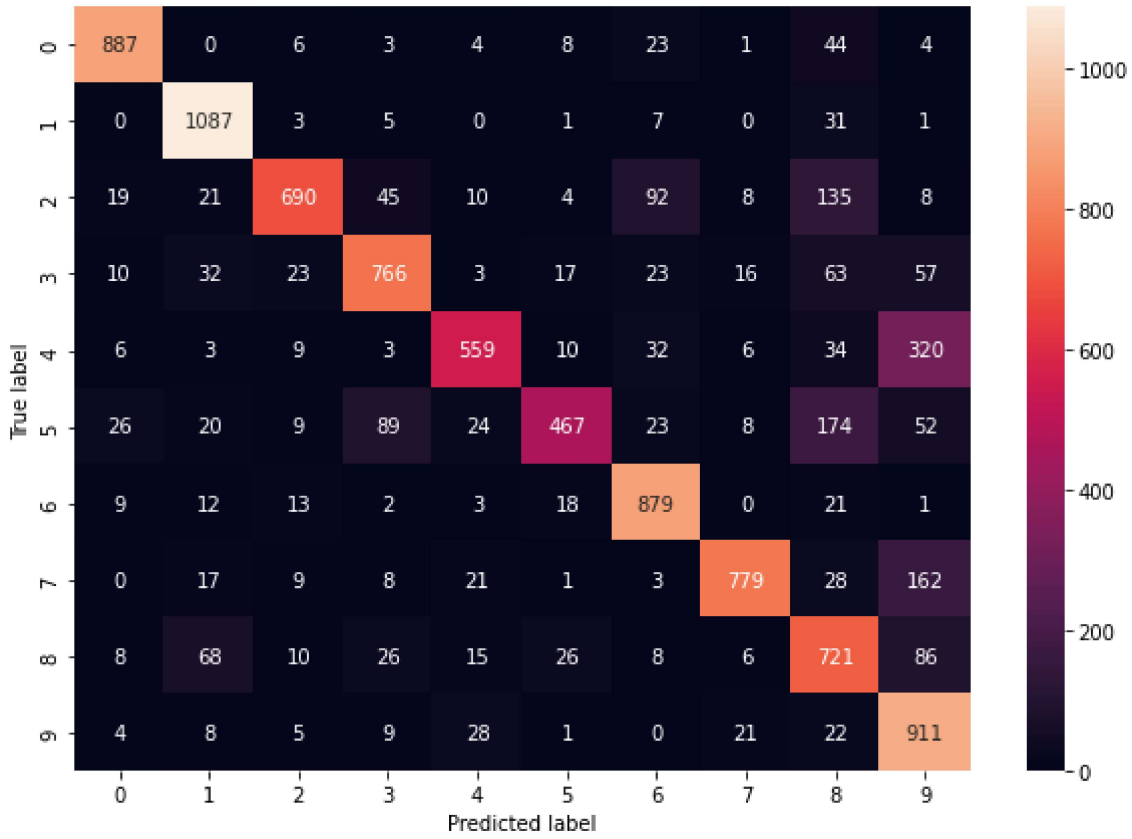
```
y_hatNBtrain = model2d.predict(x)


accuracy(y,y_hatNBtrain)
```

```
0.7683
```

```
plt.figure(figsize=(10,7))
y_actu = pd.Series(ytest, name='Actual')
y_pred = pd.Series(y_hatNB, name='Predicted')
cm = pd.crosstab(y_actu, y_pred)
ax = sns.heatmap(cm, annot=True, fmt="d")
plt.ylabel('True label')
plt.xlabel('Predicted label')
```

```
Text(0.5, 42.0, 'Predicted label')
```



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