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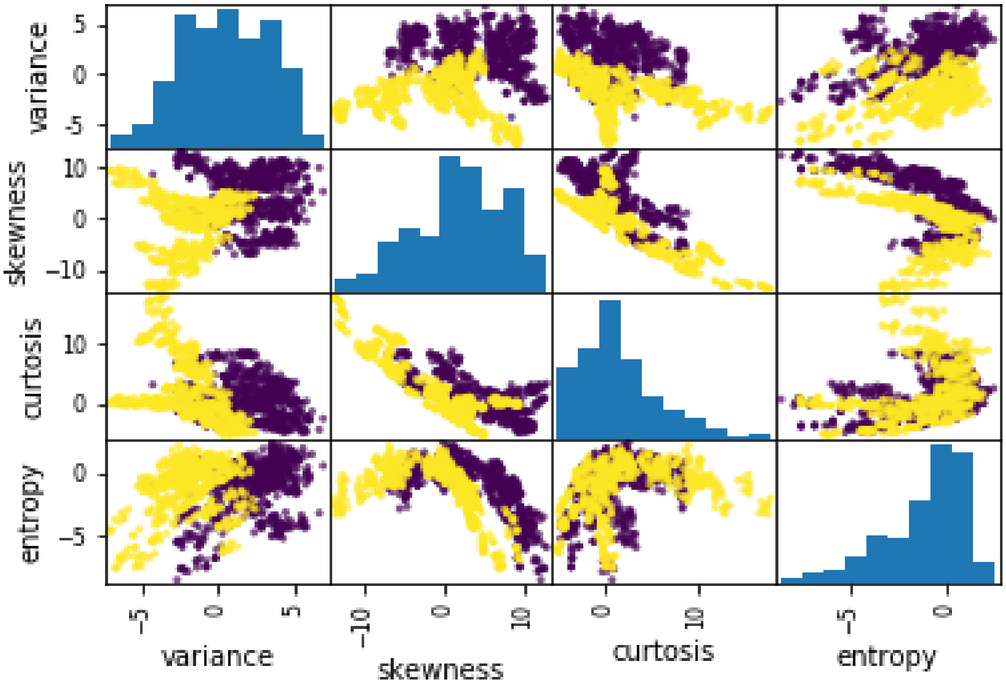
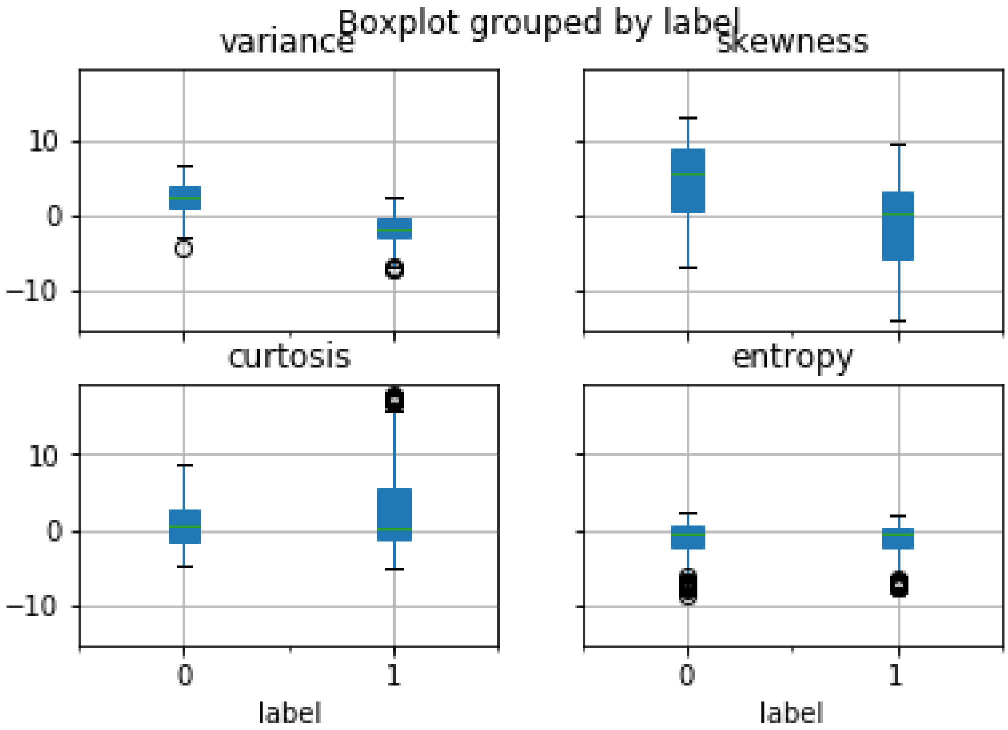
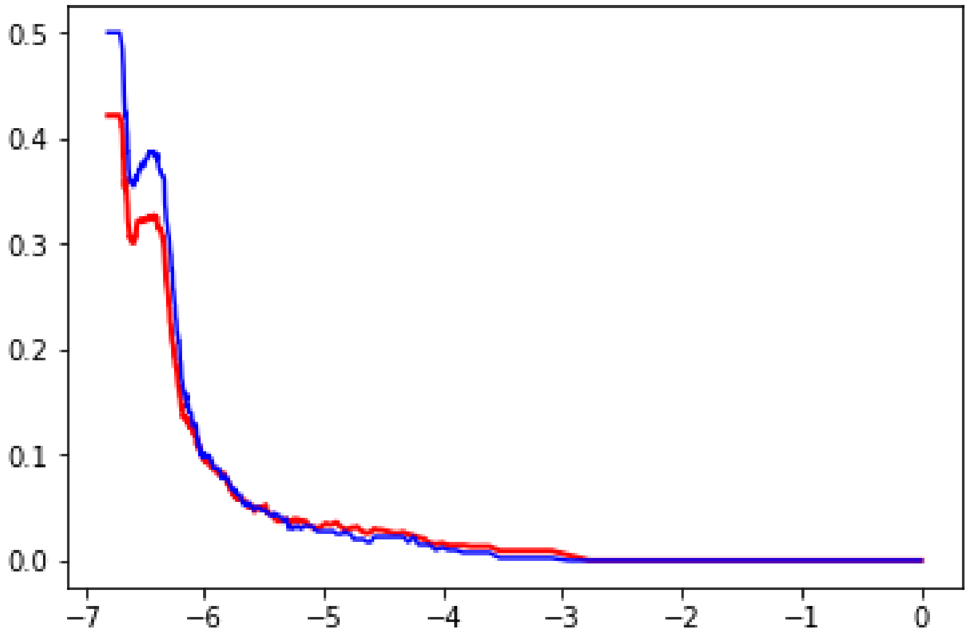
```
In [47]: import pandas as pd
         import matplotlib.pyplot as plt
         import numpy as np
         import seaborn as sns

In [140]: nameattribute = ["variance","skewness","curtosis","entropy"]
          #import data with attribute
          data = pd.read_csv("5591.txt" , names = nameattribute+ ['label'])
          #split data as attribute and label
          attribute = pd.DataFrame(data, columns = nameattribute)
          label = pd.DataFrame(data, columns = ['label'])
          #plot data
          pd.plotting.scatter_matrix(attribute, alpha = 0.7, c = data['label'])
          #boxplot data
          data.boxplot(column = nameattribute, by = 'label',  patch_artist = True, boxprops = 

          #split into test set and training set
          class0 = data.loc[data.label==0, :]
          class0t = class0[0:200]
          class0t_x = pd.DataFrame(class0t, columns = nameattribute1+ nameattribute2+nameattrib
          class0t_y = pd.DataFrame(class0t, columns = ['label'])


          class1 = data.loc[data.label==1, :]
          class1t = class1[0:200]
          class1t_x = pd.DataFrame(class1t, columns = nameattribute1+ nameattribute2+nameattrib
          class1t_y = pd.DataFrame(class1t, columns = ['label'])

          [r0,c0] = class0.shape
          [r1,c1] = class1.shape
          #test data
          testdata_x=np.array(class0t_x.append(class1t_x))
          testdata_y=np.array(class0t_y.append(class1t_y))

          class0tr = class0[201:r0]
          class1tr = class1[201:r0]
          class0tr_x = pd.DataFrame(class0tr, columns = nameattribute1+ nameattribute2+nameatt
          class0tr_y = pd.DataFrame(class0tr, columns = ['label'])

          class1tr_x = pd.DataFrame(class1tr, columns = nameattribute1+ nameattribute2+nameatt
          class1tr_y = pd.DataFrame(class1tr, columns = ['label'])

          #training data
          trainingdata_x=np.array(class0tr_x.append(class1tr_x))
          trainingdata_y=np.array(class0tr_y.append(class1tr_y))
```





```
In [150]: from sklearn.neighbors import KNeighborsClassifier
          from sklearn.metrics import accuracy_score
          min_error = np.empty([1,0])
          #built a array of k from 1 to 901, step is 3 as K
          train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          K = np.arange(1, 904, 3)
          for k in K :
               knn = KNeighborsClassifier(n_neighbors = k)
               knn.fit(trainingdata_x,trainingdata_y.ravel())
               train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(trai
               y_predict = knn.predict(testdata_x)
               test_acc = np.append(test_acc,accuracy_score(testdata_y, y_predict))
          K.astype(float)
          K_inv = 1.0/K
          f, ax = plt.subplots()
          ax.plot(np.log(K_inv), 1-train_acc, label = 'train error', color = 'red', linewidth
          ax.plot(np.log(K_inv), 1-test_acc, label = 'test error', color = 'blue')
          #legend = ax.legend('train accuracy','test accuracy')
          ta = np.max(test_acc)
          index = np.where(test_acc == ta)
          print ('when k equal to ', K[index])
          print ('the test accuracy are all 100%')
          min_error = np.append(min_error,1-ta)
          max_index = np.max(index)
          k_best = 1.0/K_inv[max_index]
          k_best = int(k_best)
          print ('Owning to reduce the complexity of the model, i choose the largest k, which
```

```
when k equal to  [ 1  4  7 10 13 16 19]
the test accuracy are all 100%
Owning to reduce the complexity of the model, i choose the largest k, which is  19
```

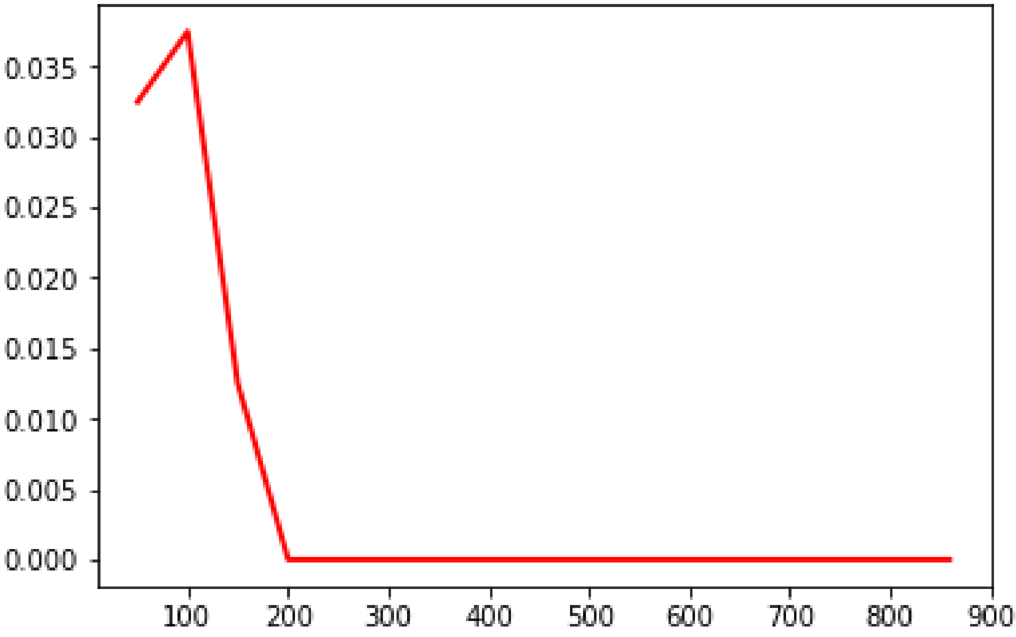


```
In [151]: from sklearn.metrics import confusion_matrix
          from sklearn.metrics import classification_report
          knn = KNeighborsClassifier(n_neighbors = k_best)
          knn.fit(trainingdata_x,trainingdata_y.ravel())
          y_predict = knn.predict(testdata_x)
          cf_matrix = confusion_matrix(testdata_y, y_predict)
          print (cf_matrix)

          TP = cf_matrix[0,0]
          TN = cf_matrix[1,1]
          FP = cf_matrix[0,1]
          FN = cf_matrix[1,0]
          TPR = TP/(TP+FN)
          TNR = TN/(TN+FP)
          print('TPR',TPR)
          print('TNR',TNR)
          #precision, and F-score

          answer = knn.predict_proba(testdata_x)[:,1]
          report = answer>0.5
          print(classification_report(testdata_y.ravel(), report))
```

```
[[200   0]
 [  0 200]]
TPR 1.0
TNR 1.0
             precision    recall  f1-score   support

          0       1.00      1.00      1.00       200
          1       1.00      1.00      1.00       200

avg / total       1.00      1.00      1.00       400
```

```
In [20]: #downsize sample,Plot the best error rate, which is obtained by some value of k, agai
         N = np.arange(50,950,50)
         size_sample = np.empty([1,0])
         error_best = np.empty([1,0])
         for n in N:
             X_train = np.array(class0tr_x[0:int(n/2)].append(class1tr_x[0:int(n/2)]))
             Y_train = np.array(class0tr_y[0:int(n/2)].append(class1tr_y[0:int(n/2)]))
             n_sample = Y_train.shape[0]
             size_sample=np.append(size_sample,n_sample)
             train_acc = np.empty([1,0])
             test_acc = np.empty([1,0])
             k= 1
             while(k<n_sample):
                 knn = KNeighborsClassifier(n_neighbors = k)
                 knn.fit(X_train,Y_train.ravel())
                 train_acc = np.append(train_acc,accuracy_score( Y_train, knn.predict( X_train
                 y_predict = knn.predict(testdata_x)
                 test_acc = np.append(test_acc,accuracy_score(testdata_y, y_predict))
                 k=k+40
             index = np.where(test_acc == np.max(test_acc))
             max_index = np.max(index)
             error_best = np.append(error_best,1-test_acc[max_index])
             min_error = np.append(min_error,np.min(error_best))
         fig, ax = plt.subplots()
         #label
         ax.plot(size_sample, error_best,label=None, color = 'red',linewidth = 2)
```

```
Out[20]: [<matplotlib.lines.Line2D at 0x118828208>]
```



```
In [155]: #other matrics  Summarizethe test errors (i.e., when k = k
          # in a table. Use all of your training data and select the best k when k  {1, 11, 21
          train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          error_test = np.empty([1,0])
          K = np.arange(1, 911, 10)
          for k in K :
              knn = KNeighborsClassifier(n_neighbors=k, metric='minkowski', p=1)
              knn.fit(trainingdata_x,trainingdata_y.ravel())
              train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(train
              y_predict = knn.predict(testdata_x)
              ta = accuracy_score(testdata_y, y_predict)
              test_acc = np.append(test_acc,ta)
              error_test = np.append(error_test,1-ta)
          index = np.where(test_acc == np.max(test_acc))
          max_index = np.max(index)
          k_best = K[max_index]
          min_error = np.append(min_error,np.min(error_best))

          print ('when k equal to ', K[index])
          print ('the test accuracy are all 100%')
          print ('Owning to reduce the complexity of the model, i choose the largest k, so the
          x=np.vstack((K,error_test))
          x=pd.DataFrame(x)
          print(x)
```

```
when k equal to  [ 1 11]
the test accuracy are all 100%
Owning to reduce the complexity of the model, i choose the largest k, so the best k for minkows
     0     1        2        3        4        5      6        7        8   \
0  1.0  11.0  21.0000  31.0000  41.0000  51.0000  61.00  71.0000  81.0000
1  0.0   0.0   0.0025   0.0075   0.0025   0.0025   0.01   0.0125   0.0225

       9   ...       81     82     83     84     85     86     87     88  \
0  91.00   ...  811.000  821.0  831.0  841.0  851.0  861.0  871.0  881.0
1   0.02   ...    0.495    0.5    0.5    0.5    0.5    0.5    0.5    0.5

      89     90
0  891.0  901.0
1    0.5    0.5

[2 rows x 91 columns]
```

```
In [159]: train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          error_test = np.empty([1,0])
          Q = np.arange(0.1, 1.1, 0.1)
          #np.exp10(log_p)
          for q in Q :
              knn = KNeighborsClassifier(n_neighbors=k_best, metric='minkowski', p=np.power(10
              knn.fit(trainingdata_x,trainingdata_y.ravel())
              train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(traini
              y_predict = knn.predict(testdata_x)
              ta = accuracy_score(testdata_y, y_predict)
              test_acc = np.append(test_acc,ta)
              error_test = np.append(error_test,1-ta)
          index = np.where(test_acc == np.max(test_acc))
          min_error = np.append(min_error,np.min(error_best))
          max_index = np.max(index)
          q_best = Q[max_index]
          print ('when log10(p) equal to ', Q[index])
          print ('the test accuracy are all 100%')
          print ('Owning to reduce the time complexity of the model, i choose the log10(p)=1')
```

```
when log10(p) equal to  [0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1. ]
the test accuracy are all 100%
Owning to reduce the time complexity of the model, i choose the log10(p)=1
```

```
In [163]: #cheb
          train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          error_test = np.empty([1,0])
          K = np.arange(1, 911, 10)
          for k in K :
              knn = KNeighborsClassifier(n_neighbors=k, metric='chebyshev')
              knn.fit(trainingdata_x,trainingdata_y.ravel())
              train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(traini
              y_predict = knn.predict(testdata_x)
              ta = accuracy_score(testdata_y, y_predict)
              test_acc = np.append(test_acc,ta)
              error_test = np.append(error_test,1-ta)
          index = np.where(test_acc == np.max(test_acc))
          max_index = np.max(index)
          k_best = K[max_index]
          print ('when k equal to ', K[index])
          print ('the test accuracy are all 100%')
          print ('Owning to reduce the complexity of the model, i choose the largest k, so the
          min_error = np.append(min_error,np.min(error_best))
          x=np.vstack((K,error_test))
          x=pd.DataFrame(x)
          print(x)
```

```
when k equal to  [ 1 11]
the test accuracy are all 100%
Owning to reduce the complexity of the model, i choose the largest k, so the best k for chebysh
     0     1        2      3        4       5      6       7       8       9  \
0  1.0  11.0  21.0000  31.00  41.0000  51.000  61.00  71.000  81.000  91.000
1  0.0   0.0   0.0025   0.01   0.0125   0.015   0.02   0.025   0.025   0.025

   ...       81     82     83     84     85     86     87     88     89     90
0  ...    811.0  821.0  831.0  841.0  851.0  861.0  871.0  881.0  891.0  901.0
1  ...      0.5    0.5    0.5    0.5    0.5    0.5    0.5    0.5    0.5    0.5

[2 rows x 91 columns]
0.0
```

```
In [165]: #mahalanobis
          train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          error_test = np.empty([1,0])
          K = np.arange(1, 911, 10)
          X=trainingdata_x
          for k in K :
              knn = KNeighborsClassifier(n_neighbors=k, algorithm="brute" ,metric='mahalanobis
              knn.fit(trainingdata_x,trainingdata_y.ravel())
              train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(traini
              y_predict = knn.predict(testdata_x)
              ta = accuracy_score(testdata_y, y_predict)
              test_acc = np.append(test_acc,ta)
              error_test = np.append(error_test,1-ta)
          index = np.where(test_acc == np.max(test_acc))
          max_index = np.max(index)
          k_best = K[max_index]
          print ('when k equal to ', K[index])
          print ('the test accuracy are all 100%')
          print ('Owning to reduce the complexity of the model, i choose the largest k, so the
          min_error = np.append(min_error,np.min(error_best))
          x=np.vstack((K,error_test))
          x=pd.DataFrame(x)
          print(x)
```

```
when k equal to  [ 1 11]
the test accuracy are all 100%
Owning to reduce the complexity of the model, i choose the largest k, so the best k for mahalar
    0     1       2       3       4        5      6       7       8       9   \
0  1.0  11.0  21.000  31.000  41.000  51.0000  61.00  71.000  81.000  91.000
1  0.0   0.0   0.005   0.005   0.005   0.0075   0.01   0.005   0.005   0.005

   ...     81     82     83     84     85     86     87     88     89     90
0  ...  811.0  821.0  831.0  841.0  851.0  861.0  871.0  881.0  891.0  901.0
1  ...    0.5    0.5    0.5    0.5    0.5    0.5    0.5    0.5    0.5    0.5

[2 rows x 91 columns]
```

```
In [167]: train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          error_test = np.empty([1,0])
          K = np.arange(1, 911, 10)
          for k in K :
              knn = KNeighborsClassifier(n_neighbors=k, weights = 'distance')
              knn.fit(trainingdata_x,trainingdata_y.ravel())
              train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(traini
              y_predict = knn.predict(testdata_x)
              ta = accuracy_score(testdata_y, y_predict)
              test_acc = np.append(test_acc,ta)
              error_test = np.append(error_test,1-ta)
          index = np.where(test_acc == np.max(test_acc))
          max_index = np.max(index)
          k_best = K[max_index]
          print ('when k equal to ', K[index])
          print ('the test accuracy are all 100%')
          print ('The best error for Euclidean is ', np.min(error_test))
          min_error = np.append(min_error,np.min(error_best))
          #x=np.vstack((K,error_test))
          #x=pd.DataFrame(x)
          #print(x)
```

```
when k equal to  [ 1 11 21 31 41 51]
the test accuracy are all 100%
The best error for Euclidean is  0.0
```

```
In [168]: train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
          error_test = np.empty([1,0])
          K = np.arange(1, 911, 10)
          for k in K :
              knn = KNeighborsClassifier(n_neighbors=k, weights = 'distance', metric='minkowski
              knn.fit(trainingdata_x,trainingdata_y.ravel())
              train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(traini
              y_predict = knn.predict(testdata_x)
              ta = accuracy_score(testdata_y, y_predict)
              test_acc = np.append(test_acc,ta)
              error_test = np.append(error_test,1-ta)
          index = np.where(test_acc == np.max(test_acc))
          max_index = np.max(index)
          k_best = K[max_index]
          print ('when k equal to ', K[index])
          print ('the test accuracy are all 100%')
          print ('The best error for minkowski when p=1 is ', np.min(error_test))
          min_error = np.append(min_error,np.min(error_best))
          #x=np.vstack((K,error_test))
          #x=pd.DataFrame(x)
          #print(x)
```

```
when k equal to  [ 1 11 21 31 41 51 61 71 81]
the test accuracy are all 100%
The best error for minkowski when p=1 is  0.0
    0     1     2     3     4     5     6     7     8        9     ...     \
0  1.0  11.0  21.0  31.0  41.0  51.0  61.0  71.0  81.0  91.0000    ...
1  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0025    ...

         81        82        83      84      85        86      87        88  \
0  811.0000  821.0000  831.0000  841.00  851.00  861.0000  871.00  881.0000
1    0.0625    0.0625    0.0625    0.07    0.07    0.0675    0.07    0.0725

         89        90
0  891.0000  901.0000
1    0.0725    0.0725

[2 rows x 91 columns]
```

```
In [170]: train_acc = np.empty([1,0])
          test_acc = np.empty([1,0])
```

```
error_test = np.empty([1,0])
K = np.arange(1, 911, 10)
for k in K :
    knn = KNeighborsClassifier(n_neighbors=k, weights = 'distance', metric='chebyshe
    knn.fit(trainingdata_x,trainingdata_y.ravel())
    train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(traini
    y_predict = knn.predict(testdata_x)
    ta = accuracy_score(testdata_y, y_predict)
    test_acc = np.append(test_acc,ta)
    error_test = np.append(error_test,1-ta)
index = np.where(test_acc == np.max(test_acc))
max_index = np.max(index)
k_best = K[max_index]
print ('when k equal to ', K[index])
print ('the test accuracy are all 100%')
print ('The best error for chebyshev is ', np.min(error_test))
min_error = np.append(min_error,np.min(error_best))
#x=np.vstack((K,error_test))
#x=pd.DataFrame(x)
#print(x)
```

```
when k equal to  [  1  11  21  31 271 281 291 301 311 321 331 341 351 361 371 381 391 401
 411 421 431 441 451 461 471 481]
the test accuracy are all 100%
The best error for chebyshev is  0.0
```

```
In [173]: print('the min error in this exercise is ',np.min(min_error))
```

```
the min error in this exercise is  0.0
```