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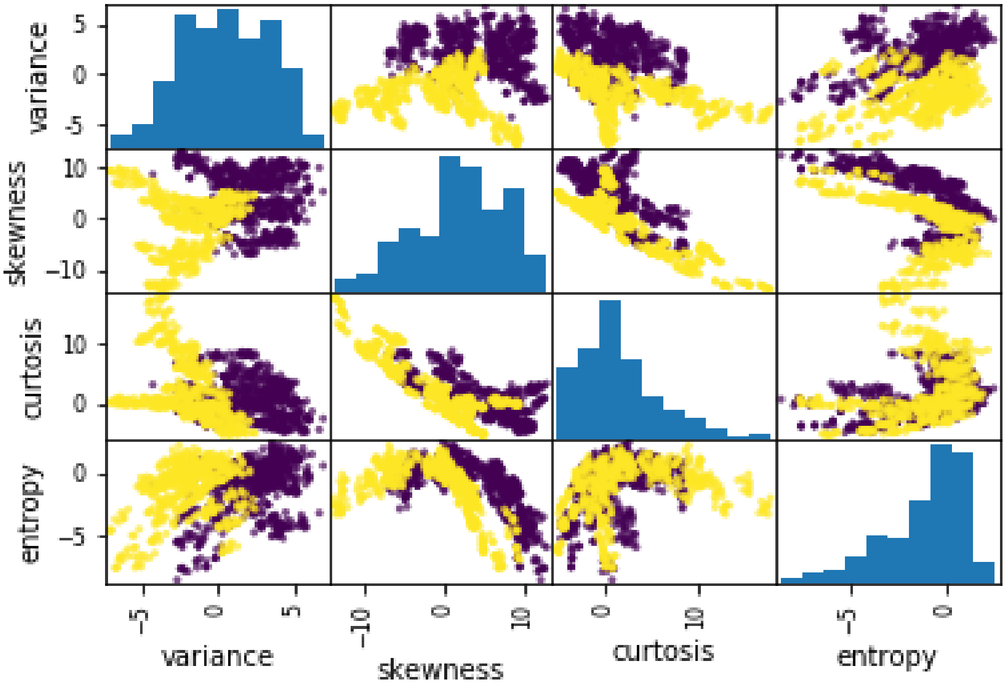
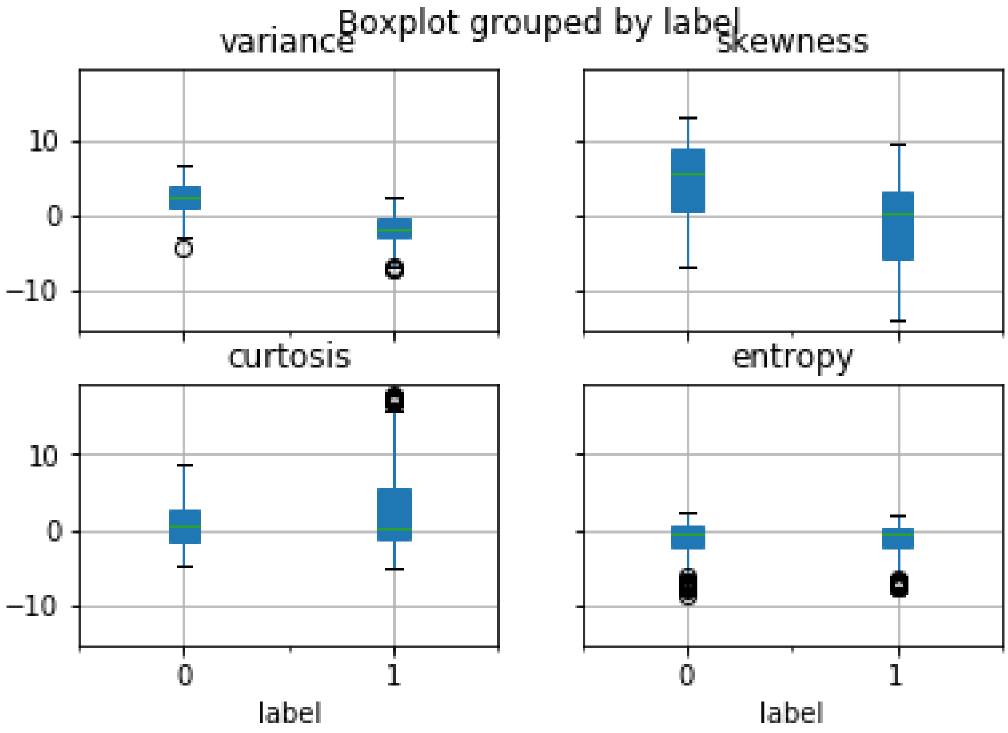
```
In [47]: import pandas as pd
         import matplotlib.pyplot as plt
         import numpy as np
         import seaborn as sns
```

```
In [4]: 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 = nameattribute)
        class0t_y = pd.DataFrame(class0t, columns = ['label'])


        class1 = data.loc[data.label==1, :]
        class1t = class1[0:200]
        class1t_x = pd.DataFrame(class1t, columns = nameattribute)
        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 = nameattribute)
```

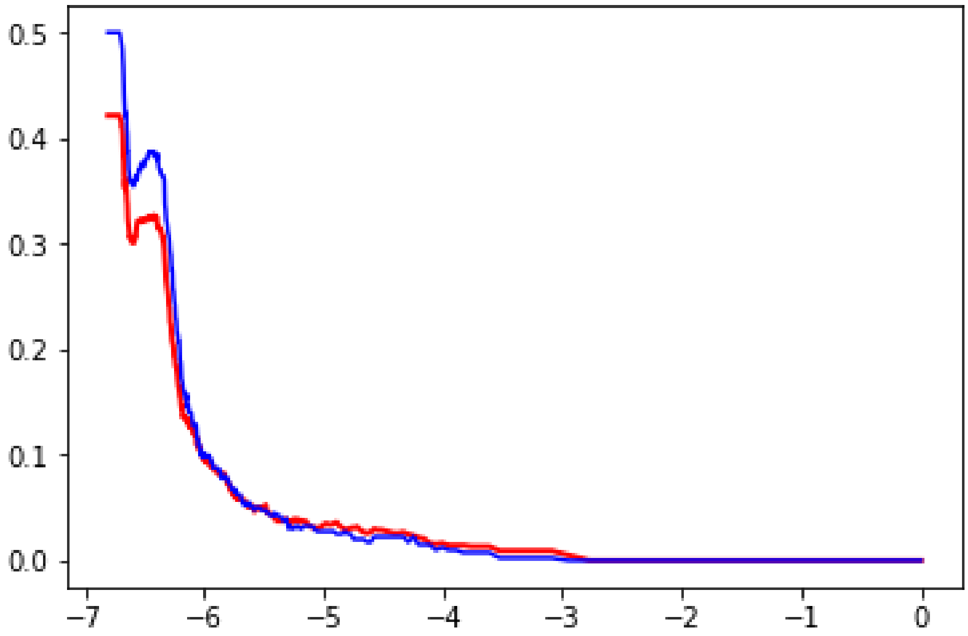
```
class0tr_y = pd.DataFrame(class0tr, columns = ['label'])

class1tr_x = pd.DataFrame(class1tr, columns = nameattribute)
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 [7]: 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(trainin
             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 =2
        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 is
```

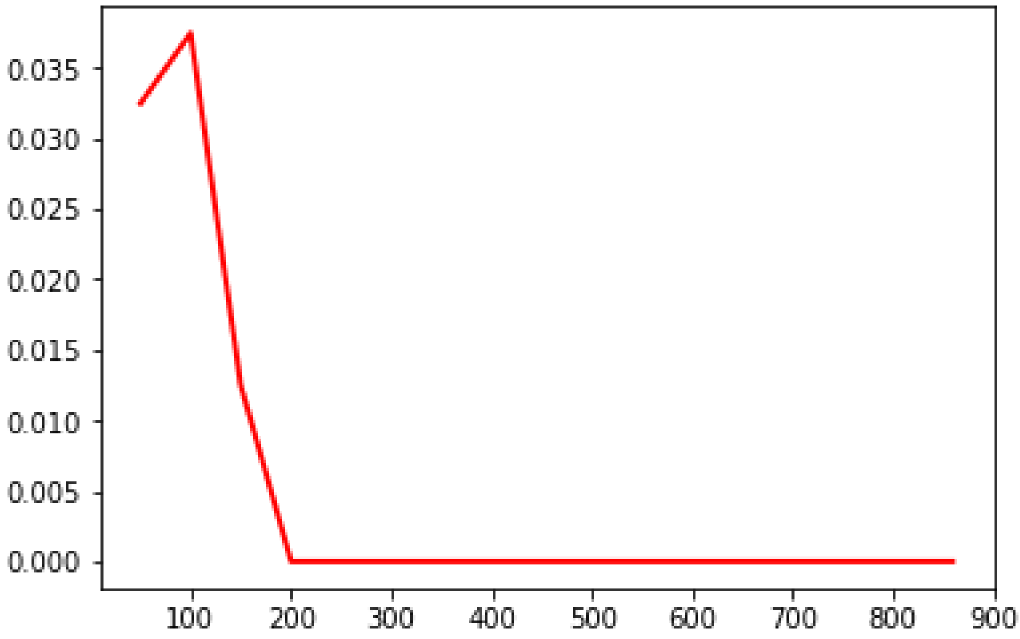
```
when k equal to  [ 1  4  7 10 13 16 19]
the test accuracy are all 100%
Owning to reduce the complexity of the model, i choose the largest k, which is  19
```



```
In [10]: 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 [11]: #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()
         ax.plot(size_sample, error_best,label=None, color = 'red',linewidth = 2)

Out[11]: [<matplotlib.lines.Line2D at 0x1041d49b0>]
```



```
In [12]: #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(trainin
             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 l
         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 [13]: 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 [14]: #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(trainin
             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 chebys
    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]
```

```
In [16]: #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(trainin
             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 b
         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 mahalan
    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 [17]: 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(trainin
             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 [18]: 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(trainin
             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
```

```
In [19]: 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='chebyshev
             knn.fit(trainingdata_x,trainingdata_y.ravel())
             train_acc = np.append(train_acc,accuracy_score(trainingdata_y, knn.predict(trainin
             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
```