HW1

May 29, 2019

In [56]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from seaborn import scatterplot
from sklearn import neighbors
from sklearn import datasets
from sklearn.metrics import confusion_matrix
import sklearn.metrics as metr
from sklearn import preprocessing
import math
from sklearn.metrics import accuracy_score
from sklearn.metrics import zero_one_loss
from sklearn.neighbors import KNeighborsClassifier
from prettytable import PrettyTable
```

In [57]:
```
path1= 'C:\\Users\\HP\\Desktop\\EE559\\HW1\\vertebral_column_data'
path=path1+'/column_2C.dat'                                                          # c
data = pd.read_table(path,header=None,sep='\s+')
data.columns = ['PI','PT','LLA','SS','PR','GOS','class']                             # cha
n = range(10,220,10)
```

In [58]:
```
def train_test_sample(num):
    num_AB = (int)(2*num/3)
    num_NO = (int)(num/3)
#   print(num_AB,num_NO)
    train_AB = data.loc[data['class'] == 'AB'].head(num_AB)
    train_NO = data.loc[data['class'] == 'NO'].head(num_NO)
    train = train_NO.append(train_AB)
    # print (train.shape)
    test_AB = data.loc[data['class'] == 'AB'][num_AB:]
    test_NO = data.loc[data['class'] == 'NO'][num_NO:]
    test = test_NO.append(test_AB)
    # print (test.shape)
    return train,test
```

In [59]:
```
def knn( X_train,X):
    num_test = X.shape[0]
```

```
            num_train = X_train.shape[0]
            dists = np.zeros((num_test, num_train))
            dists = np.multiply(np.dot(X, X_train.T), -2)
            sq1 = np.sum(np.square(X), axis=1, keepdims=True)
            sq2 = np.sum(np.square(X_train), axis=1)
            dists = np.add(dists, sq1)
            dists = np.add(dists, sq2)
            dists = dists.astype('float32')
            dists = np.sqrt(dists)
            return dists
```

```
In [60]: def predict_labels(dists, y_train,k=1):
             num_test = dists.shape[0]
             y_pred = np.zeros(num_test)
             for i in range(num_test):
                 closest_y = np.array(y_train)[np.argsort(dists[i])[:k]]
                 y_pred[i] = np.argmax(np.bincount(closest_y))
             return y_pred
```

```
In [61]: def data_preprocessing(train,test): # make train and test sample
             train1 = train.values
             train_1 = np.delete(train1,6,axis =1)
             y_train = []
             y_test  = []

             for i in range(train1.shape[0]):
                 if train1[i][6] == 'AB':
                     y_train.append(1)
                 elif train1[i][6] == 'NO':
                     y_train.append(0)
                 else:
                     break

             test1 = test.values
             test_1 = np.delete(test1,6,axis =1)
             for i in range(test1.shape[0]):
                 if test1[i][6] == 'AB':
                     y_test.append(1)
                 elif test1[i][6] == 'NO':
                     y_test.append(0)
                 else:
                     break
             return y_train,y_test,train_1,test_1
```

```
In [62]: def result_deduction(y_test,y_pred_best):
             C2 = confusion_matrix(y_test, y_pred_best, labels=None, sample_weight=None)
             print ('The confusion matrix is')
             print (C2)
```

```
        TP = C2[0][0]
        TN=  C2[1][1]
        FP=  C2[1][0]
        FN=  C2[0][1]
        TPR = TP /(TP + FN)
        TNR = TN /(TN + FP)
        precision = TP/(TP+FP)
        recall=TP/(TP+FN)
        f1_score = 2*precision * recall/(precision + recall )
        print ('The Ture positive rate is %f'%(TPR))
        print ('The Ture negative rate is %f'%(TNR))
        print ('precision is %f'%(precision))
        print ('The f1 score is %f'%(f1_score))
        plt.figure()
        sns.heatmap(C2, annot=True)
```

```
In [63]: def find_error(train,test,k_ = range(1,211,3)):
             y_train,y_test,train_1,test_1  = data_preprocessing(train,test)
             dists = knn(train_1 ,test_1 )
             final_result = []
             a = b =0
             a_1 = b_1 = 0
             for i in range(len(k_)):
                 a = b = 0
                 y_pred = predict_labels(dists,y_train,k = k_[i])
                 for j in range(len(y_pred)):
                     if y_pred[j] == y_test[j]:
                         a = a + 1
                     elif y_pred[j] != y_test[j]:
                         b = b + 1
                     else:
                         break
                 accuracy = a/(a+b)
                 error    = b/(a+b)
                 # print('Got %d / %d error rate: %f, when k is %d' % (a, len(y_pred), error,k
                 final_result.append(error)
             # plt.errorbar(k_, final_result)
             # plt.title('test of K')
             # plt.xlabel('K')
             # plt.ylabel('Accuracy')
             best_k = k_[final_result.index(min(final_result ))]
             y_pred_best = predict_labels(dists,y_train,k = best_k)  # predict value [.......]

             for j in range(len(y_pred_best)):
                 if y_pred_best[j] == y_test[j]:
                     a_1 = a_1 + 1
                 elif y_pred_best[j] != y_test[j]:
                     b_1 = b_1 + 1
```

```
            else:
                break
        error_lowest = b_1 / (a_1 + b_1)
        # print ('The best k is %d and the lowest error is %f' %(best_k,error_lowest))
        return error_lowest,best_k,y_pred_best
```

```
In [64]: def b_2():
             plt.figure()
             sns.pairplot(data, hue="class",diag_kind="kde")
         print ('The answer of the (b-1) is ')
         b_2()
```

```
The answer of the (b-1) is
```

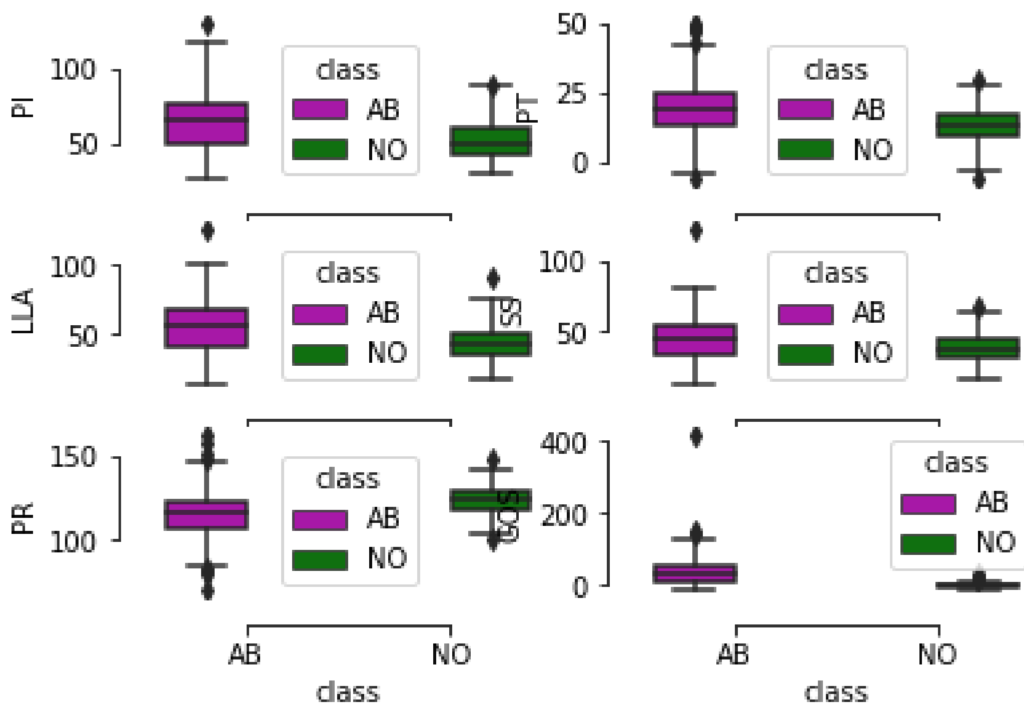
```
<matplotlib.figure.Figure at 0x2683f1c8400>
```

```
In [65]: def b_3():
             plt.figure()
             plt.subplot(321)
             sns.boxplot(x='class', y='PI', hue="class", palette=["m", "g"],
                         data=data)
             sns.despine(offset=10, trim=True)
             plt.subplot(322)
             sns.boxplot(x='class', y='PT', hue="class", palette=["m", "g"],
                         data=data)
             sns.despine(offset=10, trim=True)
             plt.subplot(323)
             sns.boxplot(x='class', y='LLA', hue="class", palette=["m", "g"],
                         data=data)
             sns.despine(offset=10, trim=True)
             plt.subplot(324)
             sns.boxplot(x='class', y='SS', hue="class", palette=["m", "g"],
                         data=data)
             sns.despine(offset=10, trim=True)
             plt.subplot(325)
             sns.boxplot(x='class', y='PR', hue="class", palette=["m", "g"],
                         data=data)
             sns.despine(offset=10, trim=True)

             plt.subplot(326)
             sns.boxplot(x='class', y='GOS', hue="class", palette=["m", "g"],
                         data=data)
             sns.despine(offset=10, trim=True)

             train, test = train_test_sample(210)
             y_train, y_test, train_1, test_1= data_preprocessing(train, test)
             print('The shape of training set is ')
             print(train.shape)
             print('The shape of test set is ')
             print(test.shape)
             print('The train data set look like this ')
             print(train)
         print ('The answer of the (b-2 and b-3) is ')
         b_3()
```

```
The answer of the (b-2 and b-3) is
The shape of training set is
(210, 7)
The shape of test set is
(100, 7)
The train data set look like this
```

	PI	PT	LLA	SS	PR	GOS	class
210	38.51	16.96	35.11	21.54	127.63	7.99	NO
211	54.92	18.97	51.60	35.95	125.85	2.00	NO
212	44.36	8.95	46.90	35.42	129.22	4.99	NO
213	48.32	17.45	48.00	30.87	128.98	-0.91	NO
214	45.70	10.66	42.58	35.04	130.18	-3.39	NO
215	30.74	13.35	35.90	17.39	142.41	-2.01	NO
216	50.91	6.68	30.90	44.24	118.15	-1.06	NO
217	38.13	6.56	50.45	31.57	132.11	6.34	NO
218	51.62	15.97	35.00	35.66	129.39	1.01	NO
219	64.31	26.33	50.96	37.98	106.18	3.12	NO
220	44.49	21.79	31.47	22.70	113.78	-0.28	NO
221	54.95	5.87	53.00	49.09	126.97	-0.63	NO
222	56.10	13.11	62.64	43.00	116.23	31.17	NO
223	69.40	18.90	75.97	50.50	103.58	-0.44	NO
224	89.83	22.64	90.56	67.20	100.50	3.04	NO
225	59.73	7.72	55.34	52.00	125.17	3.24	NO
226	63.96	16.06	63.12	47.90	142.36	6.30	NO
227	61.54	19.68	52.89	41.86	118.69	4.82	NO
228	38.05	8.30	26.24	29.74	123.80	3.89	NO
229	43.44	10.10	36.03	33.34	137.44	-3.11	NO
230	65.61	23.14	62.58	42.47	124.13	-4.08	NO
231	53.91	12.94	39.00	40.97	118.19	5.07	NO
232	43.12	13.82	40.35	29.30	128.52	0.97	NO
233	40.68	9.15	31.02	31.53	139.12	-2.51	NO
234	37.73	9.39	42.00	28.35	135.74	13.68	NO
235	63.93	19.97	40.18	43.96	113.07	-11.06	NO
236	61.82	13.60	64.00	48.22	121.78	1.30	NO
237	62.14	13.96	58.00	48.18	133.28	4.96	NO
238	69.00	13.29	55.57	55.71	126.61	10.83	NO
239	56.45	19.44	43.58	37.00	139.19	-1.86	NO
..	...	...	...	...	...	...	...
110	63.90	13.71	62.12	50.19	114.13	41.42	AB
111	85.00	29.61	83.35	55.39	126.91	71.32	AB
112	42.02	-6.55	67.90	48.58	111.59	27.34	AB
113	69.76	19.28	48.50	50.48	96.49	51.17	AB
114	80.99	36.84	86.96	44.14	141.09	85.87	AB
115	129.83	8.40	48.38	121.43	107.69	418.54	AB
116	70.48	12.49	62.42	57.99	114.19	56.90	AB
117	86.04	38.75	47.87	47.29	122.09	61.99	AB
118	65.54	24.16	45.78	41.38	136.44	16.38	AB
119	60.75	15.75	43.20	45.00	113.05	31.69	AB
120	54.74	12.10	41.00	42.65	117.64	40.38	AB
121	83.88	23.08	87.14	60.80	124.65	80.56	AB
122	80.07	48.07	52.40	32.01	110.71	67.73	AB
123	65.67	10.54	56.49	55.12	109.16	53.93	AB
124	74.72	14.32	32.50	60.40	107.18	37.02	AB
125	48.06	5.69	57.06	42.37	95.44	32.84	AB

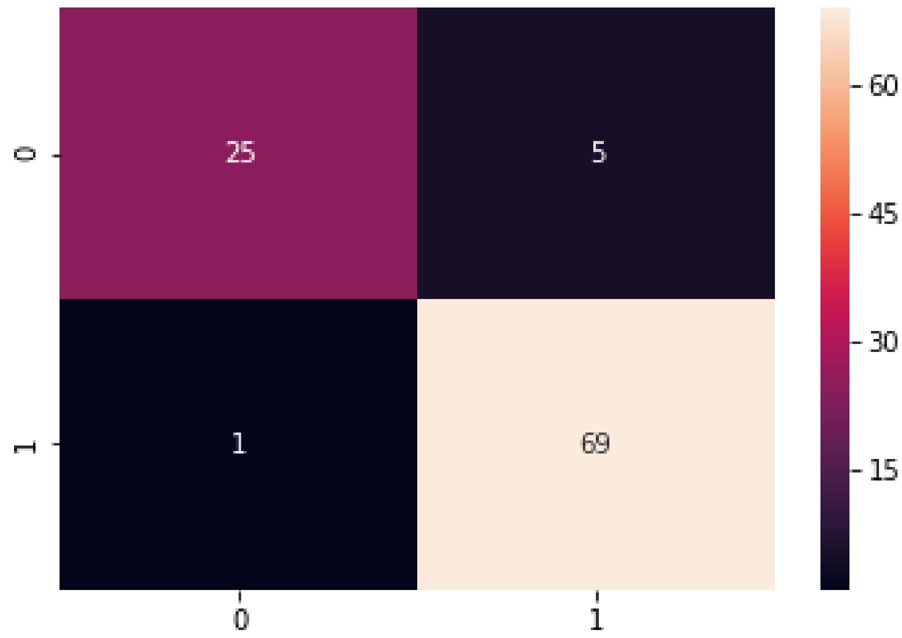
```
126    70.68  21.70  59.18   48.97  103.01   27.81    AB
127    80.43  17.00  66.54   63.43  116.44   57.78    AB
128    90.51  28.27  69.81   62.24  100.89   58.82    AB
129    77.24  16.74  49.78   60.50  110.69   39.79    AB
130    50.07   9.12  32.17   40.95   99.71   26.77    AB
131    69.78  13.78  58.00   56.00  118.93   17.91    AB
132    69.63  21.12  52.77   48.50  116.80   54.82    AB
133    81.75  20.12  70.56   61.63  119.43   55.51    AB
134    52.20  17.21  78.09   34.99  136.97   54.94    AB
135    77.12  30.35  77.48   46.77  110.61   82.09    AB
136    88.02  39.84  81.77   48.18  116.60   56.77    AB
137    83.40  34.31  78.42   49.09  110.47   49.67    AB
138    72.05  24.70  79.87   47.35  107.17   56.43    AB
139    85.10  21.07  91.73   64.03  109.06   38.03    AB

[210 rows x 7 columns]
```

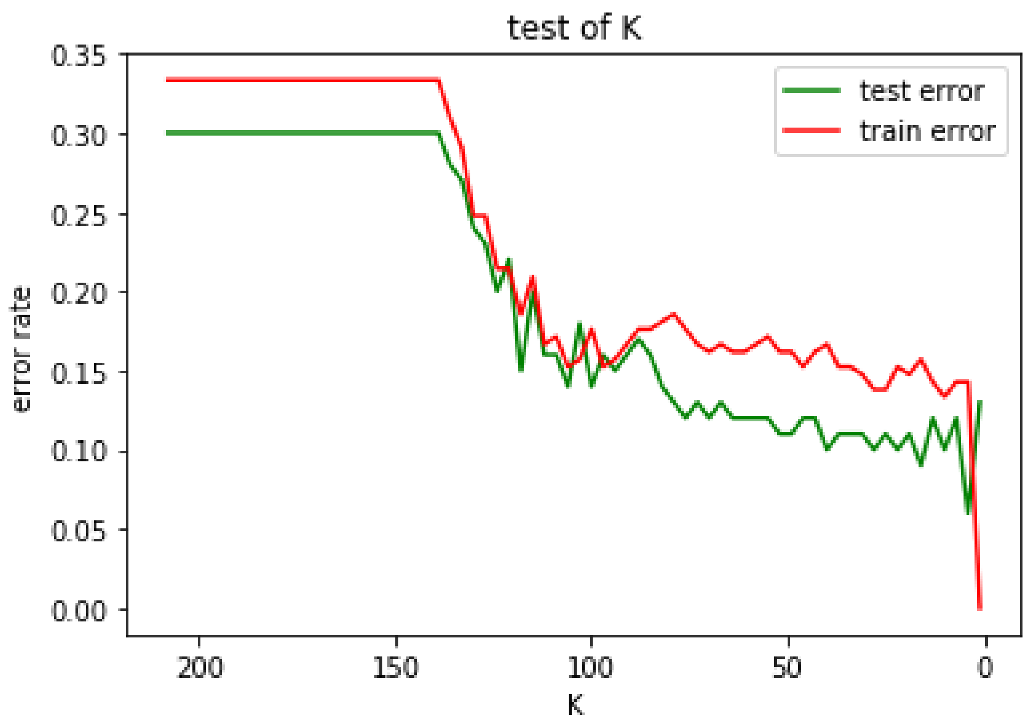



```
In [66]: def c_2_1():
             k_ = range(1, 211,3)
             train, test = train_test_sample(210)
             y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
             error_c_2_1  =[]
             error_c_2_1_train = []
```

```
            for i in range(len(k_)):
                knn = KNeighborsClassifier(n_neighbors=k_[i], metric='euclidean')
                knn.fit(train_1, y_train)
                y_pred = knn.predict(test_1)
                # print('TEST : The k is %d, and the error rate is %.2f' % (k_[i],zero_one_lo
                error_c_2_1.append(zero_one_loss(y_test, y_pred))

            best_k = k_[error_c_2_1.index(min(error_c_2_1))]
            knn = KNeighborsClassifier(n_neighbors=best_k, metric='euclidean')
            knn.fit(train_1, y_train)
            y_pred = knn.predict(test_1)
            print('The best k is %d and the lowest error is %f' % (best_k, zero_one_loss(y_te
            result_deduction(y_test,y_pred)
            for i in range(len(k_)):
                knn = KNeighborsClassifier(n_neighbors=k_[i], metric='euclidean')
                knn.fit(train_1, y_train)
                y_pred_train = knn.predict(train_1)
                # print('TRAIN: The k is %d, and the error rate is %.2f' % (k_[i],zero_one_lo
                error_c_2_1_train.append(zero_one_loss(y_train, y_pred_train))

            print('The lowest train error is %f' % (min(error_c_2_1_train)))
            plt.figure()
            plt.plot(k_, error_c_2_1,color='green',label='test error')
            plt.plot(k_, error_c_2_1_train,color='red', label='train error')
            plt.gca().invert_xaxis()
            plt.title('test of K')
            plt.xlabel('K')
            plt.ylabel('error rate')
            plt.legend()
        print ('The answer of the (c-2) is ')
        c_2_1()
```

```
The answer of the (c-2) is
The best k is 4 and the lowest error is 0.060000
The confusion matrix is
[[25  5]
 [ 1 69]]
The Ture positive rate is 0.833333
The Ture negative rate is 0.985714
precision is 0.961538
The f1 score is 0.892857
The lowest train error is 0.000000
```

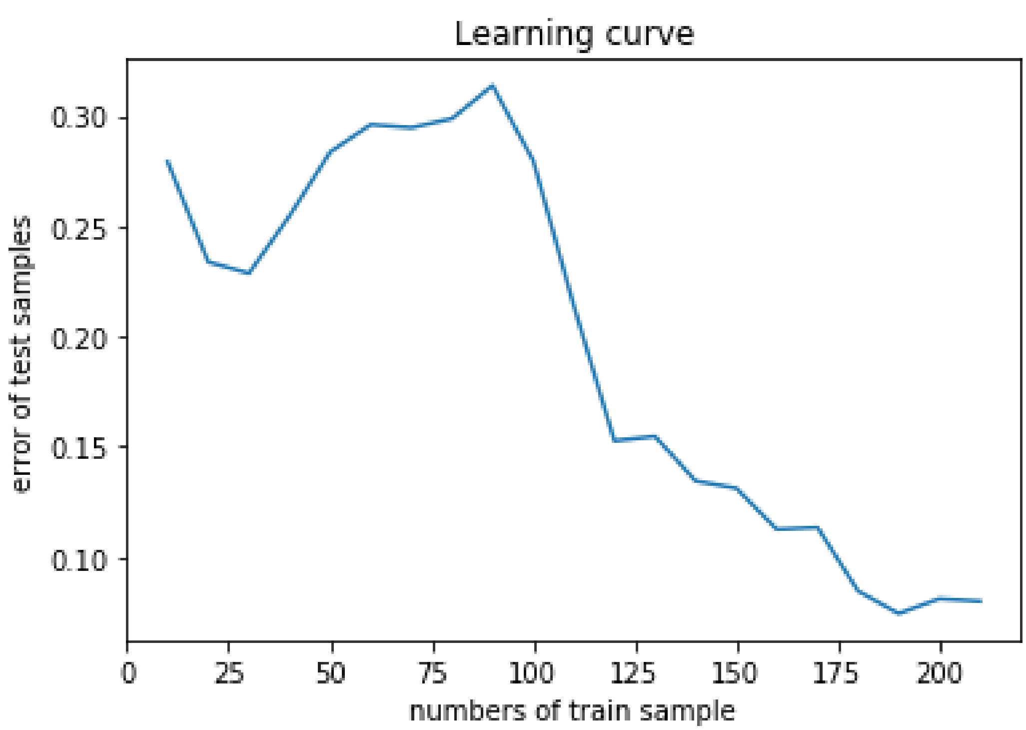





```
In [67]: def c_3_1():
             c_3_rate = []
```

```
    c_3_rate_lowest = []

    for i in range(len(n)):
#         print('n is %d' % (n[i]))
        train, test = train_test_sample(n[i])
        y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
        c_3_rate = []
        k_ = range(1, len(train_1), 5)
#         print (max(k_))
        for j in range(len(k_)):
            knn = KNeighborsClassifier(n_neighbors=k_[j], metric='euclidean')
            knn.fit(train_1, y_train)
            y_pred = knn.predict(test_1)
            c_3_rate.append(zero_one_loss(y_test, y_pred))
        c_3_rate_lowest.append(min(c_3_rate))

    plt.figure()
    plt.title('Learning curve')
    plt.xlabel('numbers of train sample')
    plt.ylabel('error of test samples')
    plt.plot(n, c_3_rate_lowest)
print ('The answer of the (c-3) is ')
c_3_1()
```

```
The answer of the (c-3) is
```



```
In [68]: def d_1():
             p = []
             log_p_1 = []
             log_p = range(1, 11, 1)
             for i in range(len(log_p)):
                 log_p_1.append(log_p[i] / 10)
                 p.append(math.pow(10, log_p_1[i]))
             k_d = range(1,211,5)
             x = PrettyTable(["matrix", "k*", "error rate"])

             error_d_1 = []
             for i in range(len(k_d)):

                 knn = KNeighborsClassifier(n_neighbors=k_d[i], metric='manhattan')
                 train, test = train_test_sample(210)
                 y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
                 knn.fit(train_1, y_train)
         #         print (train_1)
                 y_pred = knn.predict(test_1)
                 # print('The k is %d, and the error rate (zero one loss) is %.2f' % (k_d[i],z
                 error_d_1.append(1-accuracy_score(y_test, y_pred) )
             best_k_d = k_d[error_d_1.index(min(error_d_1))]

             x.add_row(["manhattan", best_k_d, min(error_d_1)])
         #     print(error_d_1)

             error_d_1 = []   # find the p and error rate log
             for j in range(len(p)):
                 knn = KNeighborsClassifier(n_neighbors=best_k_d, p=p[j], metric='minkowski')
                 train, test = train_test_sample(210)
                 y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
                 knn.fit(train_1, y_train)
                 y_pred = knn.predict(test_1)
                 error_d_1.append(zero_one_loss(y_test, y_pred))
                 # print (log_p_1[j],error_d_1[j])  #for check
             best_log10_p = log_p_1[error_d_1.index(min(error_d_1))]
             print ('The best log10(p) is %f with the lowest error rate %.5f'%(best_log10_p,mi

             error_d_1 = []
             for i in range(len(k_d)):
                 knn = KNeighborsClassifier(n_neighbors=k_d[i], metric='chebyshev')
                 train, test = train_test_sample(210)
                 y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
                 knn.fit(train_1, y_train)
                 y_pred = knn.predict(test_1)
```

```python
            # print('The k is %d, and the error rate (zero one loss) is %.2f' % (k_d[i],z
            error_d_1.append(zero_one_loss(y_test, y_pred))
        best_k_d = k_d[error_d_1.index(min(error_d_1))]
        x.add_row(["chebyshev", best_k_d, min(error_d_1)])
#     print(error_d_1)

        error_d_1 = []
        for i in range(len(k_d)):
            train, test = train_test_sample(210)
            y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
            V = np.cov(train_1.astype(float).T)
            knn = KNeighborsClassifier(n_neighbors=k_d[i],metric='mahalanobis',metric_para
            y_pred = knn.predict(test_1)
            # print('The k is %d, and the error rate (zero one loss) is %.2f' % (k_d[i],z
            error_d_1.append(zero_one_loss(y_test, y_pred))
        best_k_d = k_d[error_d_1.index(min(error_d_1))]
        # print ('The best k is %d with the lowest error is %f when we want Mahalanobis d
        x.add_row(["mahalanobis", best_k_d, min(error_d_1)])
        print (x)
#     print(error_d_1)

    print ('The answer of the (d) is ')
    d_1()
```

```
The answer of the (d) is
The best log10(p) is 0.600000 with the lowest error rate 0.06000
+-------------+----+---------------------+
|    matrix   | k* |      error rate     |
+-------------+----+---------------------+
|  manhattan  | 6  | 0.10999999999999999 |
|  chebyshev  | 16 | 0.07999999999999996 |
| mahalanobis | 1  | 0.17000000000000004 |
+-------------+----+---------------------+
```

```python
In [69]: def e():
             k_d = range(1,211,5)
             x = PrettyTable(["matrix", "k* wighted by distance", "error rate"])

             error_d_1 = []
             for i in range(len(k_d)):
                 train, test = train_test_sample(210)
                 y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
                 knn = KNeighborsClassifier(n_neighbors=k_d[i], metric='euclidean', weights='di
                 y_pred = knn.predict(test_1)
                 # print('The k is %d, and the error rate (zero one loss) is %.2f' % (k_d[i],z
                 error_d_1.append(zero_one_loss(y_test, y_pred))
             best_k_d = k_d[error_d_1.index(min(error_d_1))]
```

```python
        # print ('The best k is %d with the lowest error is %f when we want Mahalanobis d
        x.add_row(["euclidean", best_k_d, min(error_d_1)])

        error_d_1 = []
        for i in range(len(k_d)):
            knn = KNeighborsClassifier(n_neighbors=k_d[i],weights='distance',metric='manha
            train, test = train_test_sample(210)
            y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
            knn.fit(train_1, y_train)
            y_pred = knn.predict(test_1)
            # print('The k is %d, and the error rate (zero one loss) is %.2f' % (k_d[i],z
            error_d_1.append(zero_one_loss(y_test, y_pred))
#           print (error_d_1)
        best_k_d = k_d[error_d_1.index(min(error_d_1))]
        # print ('The best k is %d with the lowest error is %f when we want Manhattan dis
        x.add_row(["manhattan", best_k_d, min(error_d_1)])

        error_d_1 = []
        for i in range(len(k_d)):
            knn = KNeighborsClassifier(n_neighbors=k_d[i], weights='distance',metric='cheb
            train, test = train_test_sample(210)
            y_train, y_test, train_1, test_1 = data_preprocessing(train, test)
            knn.fit(train_1, y_train)
            y_pred = knn.predict(test_1)
            # print('The k is %d, and the error rate (zero one loss) is %.2f' % (k_d[i],z
            error_d_1.append(zero_one_loss(y_test, y_pred))
        best_k_d = k_d[error_d_1.index(min(error_d_1))]
        # print ('The best k is %d with the lowest error is %f when we want Chebyshev dis
        x.add_row(["chebyshev", best_k_d, min(error_d_1)])
        print ('The answer of the (e) is ')
        print (x)
    e()
```

```
The answer of the (e) is
+-----------+------------------------+---------------------+
|   matrix  | k* wighted by distance |      error rate     |
+-----------+------------------------+---------------------+
| euclidean |           6            | 0.09999999999999998 |
| manhattan |           26           | 0.09999999999999998 |
| chebyshev |           16           | 0.10999999999999999 |
+-----------+------------------------+---------------------+
```

The lowest training error rate I achieved in this exercise is 0, shown in the function c_3_1()