CSE572-Lab10-key

November 4, 2022

1 CSE 572: Lab 10

In this lab, you will practice implementing techniques for model selection including cross validation and grid search.

To execute and make changes to this notebook, click File > Save a copy to save your own version in your Google Drive or Github. Read the step-by-step instructions below carefully. To execute the code, click on each cell below and press the SHIFT-ENTER keys simultaneously or by clicking the Play button.

When you finish executing all code/exercises, save your notebook then download a copy (.ipynb file). Submit the following **three** things: 1. a link to your Colab notebook, 2. the .ipynb file, and 3. a pdf of the executed notebook on Canvas.

To generate a pdf of the notebook, click File > Print > Save as PDF.

[1]:
```python
# Import libraries
import numpy as np
import pandas as pd

# Set the random seed for reproducibility
seed = 0
np.random.seed(0)
```

1.0.1 Load the iris dataset

[2]:
```python
data = pd.read_csv('http://archive.ics.uci.edu/ml/machine-learning-databases/
↪iris/iris.data', header=None)
data.columns = ['sepal length', 'sepal width', 'petal length', 'petal width',␣
↪'class']

data.sample(5, random_state=seed)
```

[2]:

	sepal length	sepal width	petal length	petal width	class
114	5.8	2.8	5.1	2.4	Iris-virginica
62	6.0	2.2	4.0	1.0	Iris-versicolor
33	5.5	4.2	1.4	0.2	Iris-setosa
107	7.3	2.9	6.3	1.8	Iris-virginica
7	5.0	3.4	1.5	0.2	Iris-setosa

[3]:
```
data.shape
```

[3]:
```
(150, 5)
```

Standardize the data by subtracting the feature-wise mean and dividing by the feature-wise standard deviation for each sample.

[4]:
```
# YOUR CODE HERE

data[data.columns[:-1]] = (data[data.columns[:-1]] - data[data.columns[:-1]].
↪mean(axis=0)) / data[data.columns[:-1]].std(axis=0)
```

[5]:
```
data.sample(5, random_state=seed)
```

[5]:

	sepal length	sepal width	petal length	petal width	class
114	-0.052331	-0.585801	0.760212	1.574155	Iris-virginica
62	0.189196	-1.969583	0.136778	-0.260321	Iris-versicolor
33	-0.414621	2.643024	-1.336794	-1.308593	Iris-setosa
107	1.759119	-0.355171	1.440322	0.787951	Iris-virginica
7	-1.018437	0.797981	-1.280118	-1.308593	Iris-setosa

1.0.2 k-fold Cross validation

We will use 5-fold cross validation to train and evaluate our classifier. We will not do any model selection/hyperparameter tuning in this step, so we need to split our data into a training and test set.

To split the data into 5 folds we will shuffle the rows and then split them into k equal groups.

[6]:
```
k = 5

# Note: np.split raises error if indices_or_sections is
# an integer and doesn't result in equal size splits
folds = np.split(data.sample(frac=1, random_state=seed), indices_or_sections=k)
```

Use a for loop to print the number of samples and number of samples from each class in each fold.

[7]:
```
# YOUR CODE HERE

for i, fold in enumerate(folds):
    print('Fold {} has {} instances ({} setosa, {} virginica, {} versicolor)'.
↪format(
        i+1,
        fold.shape[0],
        fold[fold['class'] == 'Iris-setosa'].shape[0],
        fold[fold['class'] == 'Iris-virginica'].shape[0],
        fold[fold['class'] == 'Iris-versicolor'].shape[0]))
```

```
Fold 1 has 30 instances (11 setosa, 6 virginica, 13 versicolor)
Fold 2 has 30 instances (5 setosa, 15 virginica, 10 versicolor)
Fold 3 has 30 instances (10 setosa, 10 virginica, 10 versicolor)
Fold 4 has 30 instances (14 setosa, 10 virginica, 6 versicolor)
Fold 5 has 30 instances (10 setosa, 9 virginica, 11 versicolor)
```

1.0.3 Train a k Nearest Neighbors classifier

We will use the KNeighborsClassifier in sklearn for our classification model. Use cross validation to train and evaluate the model. Set hyperparameters to `n_neighbors=5`, `metric='l2'`, and `weights='uniform'`.

Implement a for loop to iterate through each fold, training a new kNN model each iteration with one fold assigned to validation and the remaining folds assigned to training. Compute the validation accuracy for each iteration and append it to the `accuracies` list.

[8]:
```python
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score

accuracies = []

# YOUR CODE HERE

for i in range(len(folds)):
    # assign the folds to training and validation
    val = folds[i]
    train = pd.concat(folds[0:i] + folds[i+1:])
    # train the classifier
    knn = KNeighborsClassifier(n_neighbors=5, metric='l2', weights='uniform')
    knn.fit(train[train.columns[:-1]], train['class'])
    # predict test set
    pred_val = knn.predict(val[val.columns[:-1]])
    # append accuracy to list
    accuracies.append(accuracy_score(val['class'], pred_val))
```

```
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```

Print the mean and standard deviation of the accuracy from cross validation (across all k folds).

[9]:
```python
print('Mean accuracy: {:.2f}'.format(np.mean(accuracies)))
print('Standard deviation of accuracy: {:.2f}'.format(np.std(accuracies)))
```

```
Mean accuracy: 0.95
Standard deviation of accuracy: 0.06
```

Question 1: If you increased the number of folds, do you expect the standard deviation of the accuracy across k folds to increase or decrease? Why?

Answer:

YOUR ANSWER HERE

The standard deviation would be expected to increase because more folds means smaller datasets in each fold, which means there will be more variability from fold to fold and the model will be less likely to generalize to the held-out fold.

1.0.4 Hyperparameter selection using cross validation and grid search

In this exercise, we will use the KNeighborsClassifier again but this time we will perform hyperparameter selection using k-fold cross validation and Grid Search.

We have three model choices (hyperparameters) for our kNN model: - Number of neighbors (k or `n_neighbors`). We will consider all integer values $k \in [1, 10]$. - Whether to treat all neighbors equally when taking majority vote, or weight them according to their distance from the query point (`weights='uniform'` or `weights='distance'`). - The distance metric for computing distance between query point and neighbors (`metric` argument). We will consider three options for `metric`: `'l1'`, `'l2'`, and `'cosine'`.

Question 2: How many total combinations of the above hyperparameter choices are there?

Answer:

YOUR ANSWER HERE

10 values for neighbors * 2 values for weights * 3 values for distance metric = 60

Instead of implementing cross validation manually as we did in the previous example, we will use the GridSearchCV class in sklearn to perform grid search and cross validation simultaneously.

First, we will split the data into a training (70%) and test (30%) test.

[10]:
```
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(data[data.columns[:-1]],
                                                    data['class'],
                                                    test_size=0.3,
                                                    random_state=seed)
```

We will then use the training set for cross validation and grid search to select the optimal hyperparameter settings.

Next, we define the values for grid search using a dictionary in which the keys are the parameter names to be passed to the model function and each corresponding value is a list of possible values to try in grid search.

[11]:
```
param_grid = {'n_neighbors': list(range(1, 11)),
              'weights': ['uniform', 'distance'],
              'metric': ['l1', 'l2', 'cosine']
             }
```

Next, we instantiate a kNeighborsClassifier but do not specify the hyperparameter settings yet.

[12]:
```
knn = KNeighborsClassifier()
```

We can then pass this classifier and our parameter grid to a new GridSearchCV object and fit the GridSearchCV using our training data.

[13]:
```
from sklearn.model_selection import GridSearchCV

clf = GridSearchCV(knn, param_grid)

clf.fit(X_train, y_train)
```

```
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```
[13]: GridSearchCV(estimator=KNeighborsClassifier(),
                 param_grid={'metric': ['l1', 'l2', 'cosine'],
                             'n_neighbors': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10],
                             'weights': ['uniform', 'distance']})
```

The cross validation results are stored as an attribute of the GridSearchCV object as a dictionary with keys as column headers and values as columns, that can be imported into a pandas DataFrame.

```
[14]: cv_results = pd.DataFrame(clf.cv_results_)

      cv_results
```

```
[14]:     mean_fit_time  std_fit_time  mean_score_time  std_score_time param_metric  \
      0        0.001475      0.000152         0.002119        0.000167           l1
      1        0.001329      0.000067         0.001411        0.000067           l1
      2        0.001382      0.000052         0.001990        0.000085           l1
      3        0.001293      0.000062         0.001385        0.000037           l1
      4        0.001205      0.000079         0.001714        0.000062           l1
      5        0.001129      0.000026         0.001241        0.000037           l1
      6        0.001105      0.000016         0.001552        0.000013           l1
      7        0.001099      0.000007         0.001190        0.000025           l1
      8        0.001082      0.000005         0.001564        0.000045           l1
      9        0.001086      0.000006         0.001166        0.000004           l1
      10       0.001079      0.000009         0.001729        0.000347           l1
      11       0.001164      0.000119         0.001345        0.000185           l1
      12       0.001962      0.000652         0.002491        0.000484           l1
      13       0.001341      0.000048         0.001573        0.000206           l1
      14       0.001498      0.000091         0.002180        0.000205           l1
      15       0.001323      0.000082         0.001447        0.000068           l1
      16       0.001283      0.000040         0.001882        0.000074           l1
      17       0.001242      0.000048         0.001316        0.000036           l1
      18       0.001214      0.000075         0.001696        0.000082           l1
      19       0.001069      0.000005         0.001178        0.000029           l1
      20       0.001067      0.000004         0.001538        0.000075           l2
      21       0.001080      0.000020         0.001147        0.000031           l2
      22       0.001114      0.000096         0.001526        0.000017           l2
      23       0.001084      0.000045         0.001252        0.000215           l2
      24       0.001101      0.000014         0.001755        0.000099           l2
      25       0.001098      0.000044         0.001145        0.000024           l2
      26       0.001199      0.000159         0.001827        0.000263           l2
      27       0.001140      0.000123         0.001253        0.000177           l2
      28       0.001115      0.000094         0.001771        0.000281           l2
      29       0.001251      0.000270         0.001269        0.000131           l2
      30       0.001066      0.000042         0.001594        0.000214           l2
      31       0.001150      0.000135         0.001260        0.000179           l2
      32       0.001072      0.000037         0.001520        0.000020           l2
      33       0.001058      0.000008         0.001163        0.000049           l2
```

34	0.001038	0.000003	0.001492	0.000019	l2
35	0.001055	0.000037	0.001142	0.000028	l2
36	0.001034	0.000004	0.001487	0.000020	l2
37	0.001037	0.000003	0.001128	0.000007	l2
38	0.001045	0.000014	0.001485	0.000018	l2
39	0.001082	0.000103	0.001133	0.000011	l2
40	0.000926	0.000004	0.001511	0.000118	cosine
41	0.001093	0.000332	0.001112	0.000029	cosine
42	0.001187	0.000419	0.002051	0.000312	cosine
43	0.001062	0.000165	0.001276	0.000182	cosine
44	0.001048	0.000163	0.002111	0.000581	cosine
45	0.001007	0.000098	0.001164	0.000093	cosine
46	0.001006	0.000079	0.001578	0.000216	cosine
47	0.000952	0.000006	0.001207	0.000070	cosine
48	0.000959	0.000018	0.001557	0.000106	cosine
49	0.000945	0.000003	0.001140	0.000005	cosine
50	0.000946	0.000005	0.001507	0.000020	cosine
51	0.000958	0.000022	0.001144	0.000003	cosine
52	0.000961	0.000033	0.001536	0.000048	cosine
53	0.000945	0.000003	0.001146	0.000006	cosine
54	0.000944	0.000002	0.001504	0.000034	cosine
55	0.001002	0.000126	0.001855	0.001010	cosine
56	0.000906	0.000003	0.001507	0.000074	cosine
57	0.000967	0.000077	0.001283	0.000341	cosine
58	0.001165	0.000164	0.002034	0.000379	cosine
59	0.000952	0.000053	0.001193	0.000042	cosine

	param_n_neighbors	param_weights	\
0	1	uniform	
1	1	distance	
2	2	uniform	
3	2	distance	
4	3	uniform	
5	3	distance	
6	4	uniform	
7	4	distance	
8	5	uniform	
9	5	distance	
10	6	uniform	
11	6	distance	
12	7	uniform	
13	7	distance	
14	8	uniform	
15	8	distance	
16	9	uniform	
17	9	distance	
18	10	uniform	

```
19                10      distance
20                 1       uniform
21                 1      distance
22                 2       uniform
23                 2      distance
24                 3       uniform
25                 3      distance
26                 4       uniform
27                 4      distance
28                 5       uniform
29                 5      distance
30                 6       uniform
31                 6      distance
32                 7       uniform
33                 7      distance
34                 8       uniform
35                 8      distance
36                 9       uniform
37                 9      distance
38                10       uniform
39                10      distance
40                 1       uniform
41                 1      distance
42                 2       uniform
43                 2      distance
44                 3       uniform
45                 3      distance
46                 4       uniform
47                 4      distance
48                 5       uniform
49                 5      distance
50                 6       uniform
51                 6      distance
52                 7       uniform
53                 7      distance
54                 8       uniform
55                 8      distance
56                 9       uniform
57                 9      distance
58                10       uniform
59                10      distance

                                              params  split0_test_score  \
0   {'metric': 'l1', 'n_neighbors': 1, 'weights': …          0.857143
1   {'metric': 'l1', 'n_neighbors': 1, 'weights': …          0.857143
2   {'metric': 'l1', 'n_neighbors': 2, 'weights': …          0.857143
3   {'metric': 'l1', 'n_neighbors': 2, 'weights': …          0.857143
```

4	{'metric': 'l1', 'n_neighbors': 3, 'weights': …	0.904762
5	{'metric': 'l1', 'n_neighbors': 3, 'weights': …	0.904762
6	{'metric': 'l1', 'n_neighbors': 4, 'weights': …	0.857143
7	{'metric': 'l1', 'n_neighbors': 4, 'weights': …	0.857143
8	{'metric': 'l1', 'n_neighbors': 5, 'weights': …	0.809524
9	{'metric': 'l1', 'n_neighbors': 5, 'weights': …	0.809524
10	{'metric': 'l1', 'n_neighbors': 6, 'weights': …	0.857143
11	{'metric': 'l1', 'n_neighbors': 6, 'weights': …	0.857143
12	{'metric': 'l1', 'n_neighbors': 7, 'weights': …	0.809524
13	{'metric': 'l1', 'n_neighbors': 7, 'weights': …	0.809524
14	{'metric': 'l1', 'n_neighbors': 8, 'weights': …	0.857143
15	{'metric': 'l1', 'n_neighbors': 8, 'weights': …	0.857143
16	{'metric': 'l1', 'n_neighbors': 9, 'weights': …	0.857143
17	{'metric': 'l1', 'n_neighbors': 9, 'weights': …	0.857143
18	{'metric': 'l1', 'n_neighbors': 10, 'weights':…	0.857143
19	{'metric': 'l1', 'n_neighbors': 10, 'weights':…	0.857143
20	{'metric': 'l2', 'n_neighbors': 1, 'weights': …	0.904762
21	{'metric': 'l2', 'n_neighbors': 1, 'weights': …	0.904762
22	{'metric': 'l2', 'n_neighbors': 2, 'weights': …	0.857143
23	{'metric': 'l2', 'n_neighbors': 2, 'weights': …	0.904762
24	{'metric': 'l2', 'n_neighbors': 3, 'weights': …	0.857143
25	{'metric': 'l2', 'n_neighbors': 3, 'weights': …	0.857143
26	{'metric': 'l2', 'n_neighbors': 4, 'weights': …	0.857143
27	{'metric': 'l2', 'n_neighbors': 4, 'weights': …	0.904762
28	{'metric': 'l2', 'n_neighbors': 5, 'weights': …	0.809524
29	{'metric': 'l2', 'n_neighbors': 5, 'weights': …	0.809524
30	{'metric': 'l2', 'n_neighbors': 6, 'weights': …	0.809524
31	{'metric': 'l2', 'n_neighbors': 6, 'weights': …	0.809524
32	{'metric': 'l2', 'n_neighbors': 7, 'weights': …	0.809524
33	{'metric': 'l2', 'n_neighbors': 7, 'weights': …	0.809524
34	{'metric': 'l2', 'n_neighbors': 8, 'weights': …	0.857143
35	{'metric': 'l2', 'n_neighbors': 8, 'weights': …	0.857143
36	{'metric': 'l2', 'n_neighbors': 9, 'weights': …	0.857143
37	{'metric': 'l2', 'n_neighbors': 9, 'weights': …	0.857143
38	{'metric': 'l2', 'n_neighbors': 10, 'weights':…	0.857143
39	{'metric': 'l2', 'n_neighbors': 10, 'weights':…	0.857143
40	{'metric': 'cosine', 'n_neighbors': 1, 'weight…	0.714286
41	{'metric': 'cosine', 'n_neighbors': 1, 'weight…	0.714286
42	{'metric': 'cosine', 'n_neighbors': 2, 'weight…	0.714286
43	{'metric': 'cosine', 'n_neighbors': 2, 'weight…	0.714286
44	{'metric': 'cosine', 'n_neighbors': 3, 'weight…	0.809524
45	{'metric': 'cosine', 'n_neighbors': 3, 'weight…	0.761905
46	{'metric': 'cosine', 'n_neighbors': 4, 'weight…	0.809524
47	{'metric': 'cosine', 'n_neighbors': 4, 'weight…	0.761905
48	{'metric': 'cosine', 'n_neighbors': 5, 'weight…	0.809524
49	{'metric': 'cosine', 'n_neighbors': 5, 'weight…	0.761905
50	{'metric': 'cosine', 'n_neighbors': 6, 'weight…	0.809524

```
51  {'metric': 'cosine', 'n_neighbors': 6, 'weight…          0.809524
52  {'metric': 'cosine', 'n_neighbors': 7, 'weight…          0.761905
53  {'metric': 'cosine', 'n_neighbors': 7, 'weight…          0.809524
54  {'metric': 'cosine', 'n_neighbors': 8, 'weight…          0.761905
55  {'metric': 'cosine', 'n_neighbors': 8, 'weight…          0.809524
56  {'metric': 'cosine', 'n_neighbors': 9, 'weight…          0.761905
57  {'metric': 'cosine', 'n_neighbors': 9, 'weight…          0.809524
58  {'metric': 'cosine', 'n_neighbors': 10, 'weigh…          0.761905
59  {'metric': 'cosine', 'n_neighbors': 10, 'weigh…          0.809524

    split1_test_score  split2_test_score  split3_test_score  \
0            0.904762           1.000000           0.904762
1            0.904762           1.000000           0.904762
2            0.904762           1.000000           0.857143
3            0.904762           1.000000           0.904762
4            1.000000           1.000000           0.857143
5            1.000000           1.000000           0.904762
6            1.000000           1.000000           0.904762
7            1.000000           1.000000           0.904762
8            1.000000           1.000000           0.904762
9            1.000000           1.000000           0.904762
10           1.000000           1.000000           0.952381
11           1.000000           1.000000           0.904762
12           1.000000           1.000000           0.904762
13           1.000000           1.000000           0.904762
14           1.000000           1.000000           0.904762
15           1.000000           1.000000           0.904762
16           1.000000           1.000000           0.904762
17           1.000000           1.000000           0.904762
18           1.000000           1.000000           0.904762
19           1.000000           1.000000           0.904762
20           0.904762           1.000000           0.904762
21           0.904762           1.000000           0.904762
22           0.904762           1.000000           0.952381
23           0.904762           1.000000           0.904762
24           1.000000           1.000000           0.857143
25           1.000000           1.000000           0.904762
26           1.000000           1.000000           0.904762
27           1.000000           1.000000           0.904762
28           1.000000           1.000000           0.952381
29           1.000000           1.000000           0.952381
30           1.000000           1.000000           0.952381
31           1.000000           1.000000           0.904762
32           1.000000           1.000000           0.904762
33           1.000000           1.000000           0.904762
34           1.000000           1.000000           0.904762
35           1.000000           1.000000           0.904762
```

36	1.000000	1.000000	0.904762
37	1.000000	1.000000	0.904762
38	1.000000	1.000000	0.952381
39	1.000000	1.000000	0.904762
40	0.857143	0.952381	0.857143
41	0.857143	0.952381	0.857143
42	0.857143	0.904762	0.857143
43	0.857143	0.952381	0.857143
44	0.952381	0.952381	0.857143
45	0.952381	1.000000	0.857143
46	0.952381	0.952381	0.809524
47	0.952381	1.000000	0.857143
48	0.952381	0.952381	0.904762
49	0.952381	1.000000	0.904762
50	0.952381	0.952381	0.904762
51	0.904762	1.000000	0.904762
52	0.952381	0.809524	0.904762
53	0.952381	1.000000	0.904762
54	0.952381	0.952381	0.809524
55	0.952381	1.000000	0.904762
56	0.904762	0.904762	0.857143
57	0.952381	1.000000	0.904762
58	0.904762	0.952381	0.809524
59	0.952381	1.000000	0.904762

	split4_test_score	mean_test_score	std_test_score	rank_test_score
0	0.952381	0.923810	0.048562	37
1	0.952381	0.923810	0.048562	37
2	0.952381	0.914286	0.055533	44
3	0.952381	0.923810	0.048562	37
4	0.952381	0.942857	0.055533	10
5	0.952381	0.952381	0.042592	2
6	1.000000	0.952381	0.060234	2
7	0.952381	0.942857	0.055533	10
8	0.952381	0.933333	0.071270	27
9	0.952381	0.933333	0.071270	27
10	1.000000	0.961905	0.055533	1
11	0.952381	0.942857	0.055533	10
12	0.952381	0.933333	0.071270	27
13	0.952381	0.933333	0.071270	27
14	0.952381	0.942857	0.055533	10
15	0.952381	0.942857	0.055533	10
16	0.952381	0.942857	0.055533	10
17	0.952381	0.942857	0.055533	10
18	0.952381	0.942857	0.055533	10
19	0.952381	0.942857	0.055533	10
20	0.952381	0.933333	0.038095	27

21	0.952381	0.933333	0.038095	27
22	0.952381	0.933333	0.048562	25
23	0.952381	0.933333	0.038095	27
24	0.952381	0.933333	0.064594	25
25	0.952381	0.942857	0.055533	10
26	1.000000	0.952381	0.060234	2
27	0.952381	0.952381	0.042592	2
28	1.000000	0.952381	0.073771	2
29	1.000000	0.952381	0.073771	2
30	1.000000	0.952381	0.073771	2
31	0.952381	0.933333	0.071270	27
32	0.952381	0.933333	0.071270	27
33	0.952381	0.933333	0.071270	27
34	0.952381	0.942857	0.055533	10
35	0.952381	0.942857	0.055533	10
36	0.952381	0.942857	0.055533	10
37	0.952381	0.942857	0.055533	10
38	0.952381	0.952381	0.052164	2
39	0.952381	0.942857	0.055533	10
40	0.857143	0.847619	0.076190	57
41	0.857143	0.847619	0.076190	57
42	0.857143	0.838095	0.064594	60
43	0.857143	0.847619	0.076190	57
44	0.952381	0.904762	0.060234	48
45	0.952381	0.904762	0.085184	48
46	0.952381	0.895238	0.069985	52
47	0.952381	0.904762	0.085184	48
48	0.904762	0.904762	0.052164	48
49	0.952381	0.914286	0.081927	44
50	0.952381	0.914286	0.055533	44
51	0.952381	0.914286	0.063174	44
52	0.904762	0.866667	0.069985	56
53	0.952381	0.923810	0.064594	37
54	0.952381	0.885714	0.083027	53
55	0.952381	0.923810	0.064594	37
56	0.952381	0.876190	0.064594	54
57	0.952381	0.923810	0.064594	37
58	0.952381	0.876190	0.077372	54
59	0.952381	0.923810	0.064594	37

Look at the GridSearchCV documentation to read about the other attributes stored after fitting. Print the value of the attribute that gives the parameter settings for the best results on the hold out data.

[15]:
```
# YOUR CODE HERE

clf.best_params_
```

[15]: {'metric': 'l1', 'n_neighbors': 6, 'weights': 'uniform'}

Train a new kNN classifier using the hyperparameter settings that were found to give the best results on the hold out data from GridSearchCV (the values printed in the last cell). Train it on the full training set.

[16]:
```
# YOUR CODE HERE

knn_best = KNeighborsClassifier(n_neighbors=6, weights='uniform', metric='l1')

knn_best.fit(X_train, y_train)
```

[16]: KNeighborsClassifier(metric='l1', n_neighbors=6)

Apply the trained classifier to the test dataset and print the test accuracy.

[17]:
```
# YOUR CODE HERE

print(accuracy_score(y_test, knn_best.predict(X_test)))
```

```
0.9777777777777777
```

```
/Users/hkerner/anaconda3/envs/cse572/lib/python3.9/site-
packages/sklearn/neighbors/_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)
```