Data Science in Practice 2020

Problem Set 2

Descriptive report

Authors :

- Rayan Chaouche
- Yann Martinson
- Christopher Padovani
- Jules Triomphe

1. Initialization

Loading modules :

In [1]:

```python
import pandas as pd
import numpy as np
import seaborn as sns

from operator import itemgetter, attrgetter
from scipy.stats import randint as sp_randint

from sklearn.model_selection import train_test_split, GridSearchCV, RandomizedSearchCV, cross_val_score
from sklearn.metrics import log_loss, classification_report, confusion_matrix, roc_curve, accuracy_score, roc_auc_score, precision_recall_fscore_support, precision_recall_curve, auc
from sklearn.ensemble import RandomForestClassifier
from sklearn.neighbors import KNeighborsClassifier, NeighborhoodComponentsAnalysis
from sklearn.preprocessing import StandardScaler

# import time

from matplotlib import pyplot as plt
```

Defining functions :

In [2]:

```python
def df_pp() :

    df_raw = pd.read_csv('customers.csv')

    # clean up lines

    total_length = len(df_raw)
    df_raw = df_raw[df_raw['TotalCharges'] != ' ']
    df_raw.TotalCharges = df_raw.TotalCharges.astype('float')
    cleanup_length = len(df_raw)
    print('%s lines were deleted.' %(total_length - cleanup_length))

    # output into dummies

    churn_dummy_dict = {'Yes': 1, 'No': 0}
    df_raw.Churn.replace(churn_dummy_dict, inplace = True)

    # X y splitting

    y = df_raw.Churn.copy()
    X_raw = df_raw.drop(columns ='Churn').copy()

    # input into dummies

    X_raw_types = dict(X_raw.dtypes)
    features = list(X_raw.columns)
    categorical_features = [feat for feat in features if X_raw_types[feat] == 'O']
    categorical_features.remove('customerID')

    X = pd.get_dummies(X_raw, columns = categorical_features,prefix_sep=':')
    X = X.drop(columns = 'customerID').copy()

    return df_raw,categorical_features, X, y, cleanup_length
```

In [3]:

```python
def df_preprocessing_knn() :

    df_raw,categorical_features, X, y, _ = df_pp()

    # train val splitting

    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.20)

    y_train = y_train.tolist()
    y_test = y_test.tolist()

    return df_raw,categorical_features, X, X_train, X_test, y, y_train, y_test
```

In [4]:

```python
def df_preprocessing_rf(test_size) :

    df_raw,categorical_features, X, y, cleanup_length = df_pp()

    # train val splitting

    train = np.random.rand(cleanup_length)> test_size

    X_train = X[train]
    X_test = X[~train]

    y_train = y[train].tolist()
    y_test = y[~train].tolist()

    return df_raw,categorical_features, X, X_train, X_test, y, y_train, y_test
```

In [5]:

```python
def plot_importance(feature_importance_sorted, n, type_of_search):

    plt.figure(figsize=(15,5))
    x = np.arange(n)
    y = [feature_importance_sorted[i][1] for i in range(n)]
    labels = [feature_importance_sorted[i][0] for i in range(n)]
    ax = sns.barplot(y,x,orient="h");
    plt.xlabel("Importance fraction", fontsize = 12)
    ax.set_xticklabels(['{:,.0%}'.format(x) for x in ax.get_xticks()])
    plt.yticks(x,labels, fontsize = 15)
    plt.title('Most important feature: {}'.format(type_of_search), fontsize = 15)
    plt.show()
```

2. K-Nearest Neighbors Classifier

We start by scaling the data.

In [6]:

```python
df_raw,categorical_features, X, X_train, X_test, y, y_train, y_test = df_preprocessing_
knn()
```

11 lines were deleted.

In [7]:

```python
scaler = StandardScaler()
scaler.fit(X_train)

X_train = scaler.transform(X_train)
X_test = scaler.transform(X_test)
```

We run simulations for k-values between 1 and 100 to find the best fit parameters.

```python
error_uni = np.array([0])
error_dist = np.array([0])

for i in range(1, 100):
    knn_uni = KNeighborsClassifier(n_neighbors=i, weights='uniform')
    knn_uni.fit(X_train, y_train)
    pred_i_uni = knn_uni.predict(X_test)
    error_uni = np.append(error_uni, np.array(np.mean(pred_i_uni != y_test)))

    knn_dist = KNeighborsClassifier(n_neighbors=i, weights='distance')
    knn_dist.fit(X_train, y_train)
    pred_i_dist = knn_dist.predict(X_test)
    error_dist = np.append(error_dist, np.array(np.mean(pred_i_dist != y_test)))


plt.figure(figsize=(12, 6))
plt.plot(error_uni[1:], color='red', linestyle='dashed', marker='o', markerfacecolor='b
lue', markersize=10, label='Uniform weights')
plt.plot(error_dist[1:], color='black', linestyle='dashed', marker='o', markerfacecolor
='green', markersize=10, label='Distance weights')
plt.title('Error Rate K Value')
plt.xlabel('K Value')
plt.ylabel('Mean Error')
plt.legend(loc='best')
plt.show()

print('Minimum error rate with uniform weights: {:.2%} for k = {}'.format(min(error_uni
[1:]), np.argmin(error_uni[1:]) + 1))
print('Minimum error rate with distance weights: {:.2%} for k = {}'.format(min(error_di
st[1:]), np.argmin(error_dist[1:]) + 1))
```


Error Rate K Value
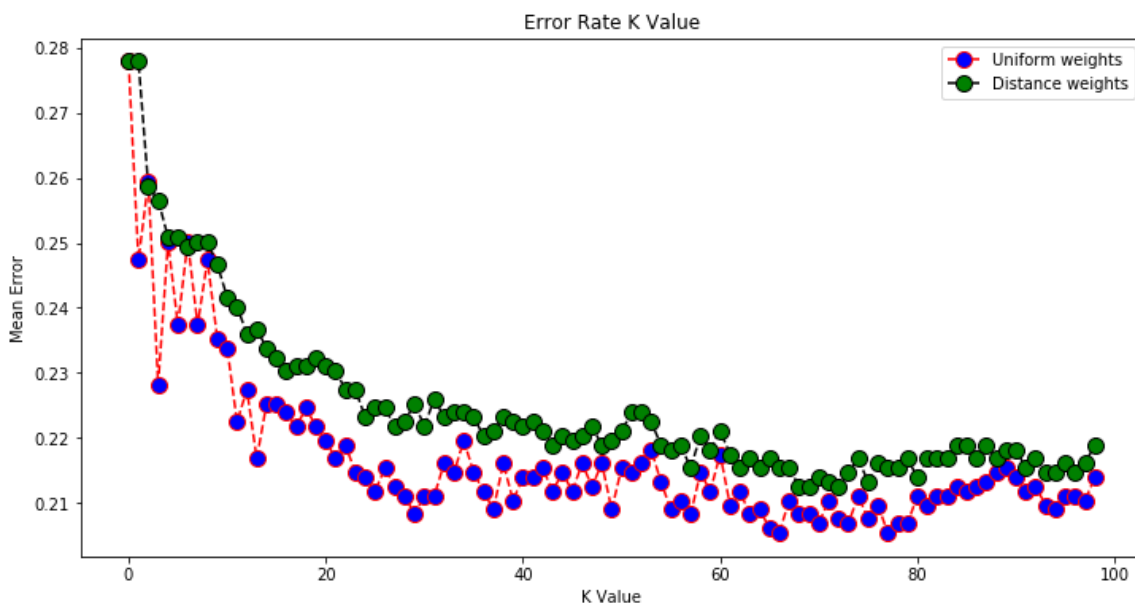
```
Minimum error rate with uniform weights: 20.54% for k = 67
Minimum error rate with distance weights: 21.25% for k = 69
```

```
classifier_uni = KNeighborsClassifier(n_neighbors = (np.argmin(error_uni[1:]) + 1), wei
ghts='uniform')
classifier_uni.fit(X_train, y_train)
classifier_dist = KNeighborsClassifier(n_neighbors = (np.argmin(error_dist[1:]) + 1), w
eights='distance')
classifier_dist.fit(X_train, y_train)

y_pred_uni = classifier_uni.predict(X_test)
y_pred_dist = classifier_dist.predict(X_test)
```

```python
plt.figure(figsize=(8,8))
sns.heatmap(confusion_matrix(y_test, y_pred_uni), annot=True, fmt="d", cmap="nipy_spect
ral")
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion matrix for the uniform weights KNN method (k = {})'.format(np.argm
in(error_uni[1:]) + 1), fontsize = 15);
print("UNIFORM WEIGHTS")
print("Accuracy: {:.2%}".format(accuracy_score(y_test, y_pred_uni)))
print(classification_report(y_test, y_pred_uni))
```

```
UNIFORM WEIGHTS
Accuracy: 79.46%
              precision    recall  f1-score   support

           0       0.87      0.86      0.86      1058
           1       0.58      0.59      0.59       349

    accuracy                           0.79      1407
   macro avg       0.72      0.73      0.73      1407
weighted avg       0.80      0.79      0.80      1407
```

Confusion matrix for the uniform weights KNN method (k = 67)
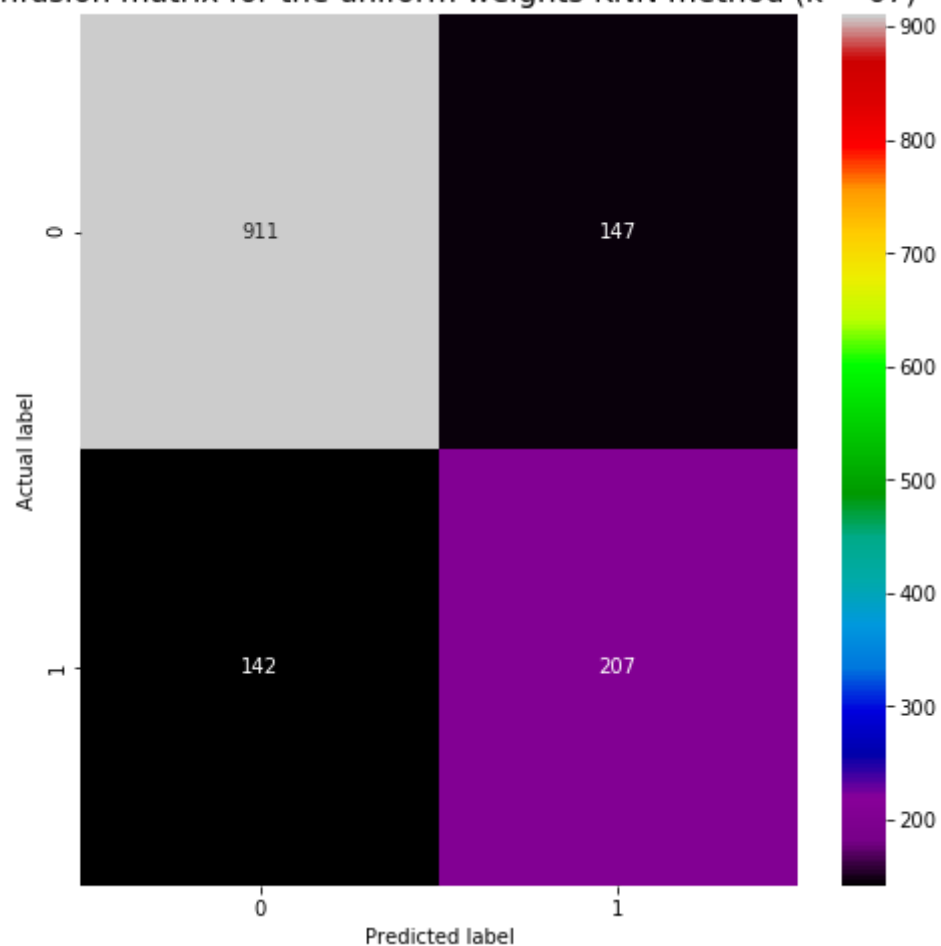
```python
plt.figure(figsize=(8,8))
sns.heatmap(confusion_matrix(y_test, y_pred_dist), annot=True, fmt="d", cmap="nipy_spec
tral")
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion matrix for the distance weights KNN method (k = {})'.format(np.arg
min(error_dist[1:]) + 1), fontsize = 15);
print("DISTANCE WEIGHTS")
print("Accuracy: {:.2%}".format(accuracy_score(y_test, y_pred_dist)))
print(classification_report(y_test, y_pred_dist))
```

```
DISTANCE WEIGHTS
Accuracy: 78.75%
              precision    recall  f1-score   support

           0       0.86      0.86      0.86      1058
           1       0.57      0.57      0.57       349

    accuracy                           0.79      1407
   macro avg       0.72      0.72      0.72      1407
weighted avg       0.79      0.79      0.79      1407
```
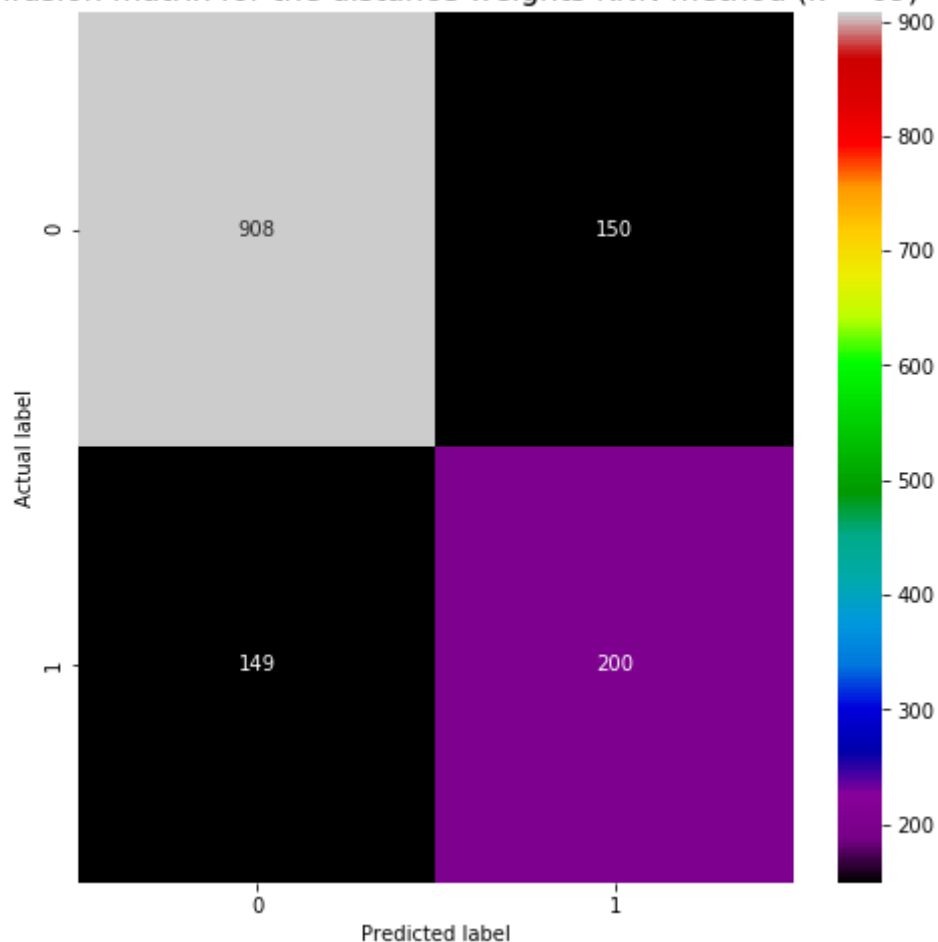

3. Random Forest Classifier

We will compare two methods, which are grid search and random search.

In [12]:

```
df_raw,categorical_features, X, X_train, X_test, y, y_train, y_test = df_preprocessing_
rf(0.3)
```

11 lines were deleted.

In [13]:

```
clf = RandomForestClassifier(n_jobs=-1)
```

3.1 Grid search

To avoid having too high a computational time, we will focus on 2 of the mot important parameters that are max depth and the number of estimators.

Max Depth

This parameter is the depth of the trees, which is one of the most important. We range it between 4 (anything lower seems too low and imcreases computational time without much results) and 15.

Number of estimators

This parameter is the number of trees that are going to be generated. Here the choice of the number of trees will mostly affect the computational time. Let's set the values between 10 and 500 and see the effects.

In [14]:

```
max_depth = list(range(4,16))
```

In [15]:

```
n_estimators = [10, 15, 20, 50, 100, 200, 500]
```

Let's use the default 5 folds of cross validation.

In [16]:

```
grid_parameters = {'max_depth' : max_depth, 'n_estimators' : n_estimators }
```

In [17]:

```
grid_clf = GridSearchCV(clf, param_grid = grid_parameters, verbose = 3)
```

```
grid_clf.fit(X_train, y_train);
```

```
Fitting 5 folds for each of 84 candidates, totalling 420 fits
[CV] max_depth=4, n_estimators=10 ...................................

[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent wo
rkers.

[CV] ........ max_depth=4, n_estimators=10, score=0.796, total=   7.7s
[CV] max_depth=4, n_estimators=10 ...................................

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    7.6s remaining:
0.0s

[CV] ........ max_depth=4, n_estimators=10, score=0.786, total=   0.2s
[CV] max_depth=4, n_estimators=10 ...................................

[Parallel(n_jobs=1)]: Done   2 out of   2 | elapsed:    7.9s remaining:
0.0s
```

```
[CV] ........ max_depth=4, n_estimators=10, score=0.765, total=   0.3s
[CV] max_depth=4, n_estimators=10 .....................................
[CV] ........ max_depth=4, n_estimators=10, score=0.781, total=   0.2s
[CV] max_depth=4, n_estimators=10 .....................................
[CV] ........ max_depth=4, n_estimators=10, score=0.795, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.799, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.780, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.769, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.790, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.794, total=   0.3s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.801, total=   0.3s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.785, total=   0.4s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.769, total=   0.4s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.789, total=   0.3s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.792, total=   0.4s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.795, total=   0.7s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.782, total=   0.7s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.768, total=   0.7s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.791, total=   0.7s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.799, total=   0.6s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.793, total=   1.0s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.786, total=   0.9s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.766, total=   1.0s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.793, total=   1.1s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.793, total=   1.1s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.795, total=   1.7s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.786, total=   1.7s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.770, total=   1.8s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.792, total=   1.6s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.795, total=   1.9s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.795, total=   4.0s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.784, total=   3.8s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.771, total=   3.7s
```

```
[CV] max_depth=4, n_estimators=500 .....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.791, total=    4.2s
[CV] max_depth=4, n_estimators=500 .....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.793, total=    3.5s
[CV] max_depth=5, n_estimators=10 ......................................
[CV] ........ max_depth=5, n_estimators=10, score=0.801, total=    0.3s
[CV] max_depth=5, n_estimators=10 ......................................
[CV] ........ max_depth=5, n_estimators=10, score=0.794, total=    0.3s
[CV] max_depth=5, n_estimators=10 ......................................
[CV] ........ max_depth=5, n_estimators=10, score=0.775, total=    0.3s
[CV] max_depth=5, n_estimators=10 ......................................
[CV] ........ max_depth=5, n_estimators=10, score=0.785, total=    0.2s
[CV] max_depth=5, n_estimators=10 ......................................
[CV] ........ max_depth=5, n_estimators=10, score=0.794, total=    0.3s
[CV] max_depth=5, n_estimators=15 ......................................
[CV] ........ max_depth=5, n_estimators=15, score=0.798, total=    0.3s
[CV] max_depth=5, n_estimators=15 ......................................
[CV] ........ max_depth=5, n_estimators=15, score=0.792, total=    0.4s
[CV] max_depth=5, n_estimators=15 ......................................
[CV] ........ max_depth=5, n_estimators=15, score=0.771, total=    0.4s
[CV] max_depth=5, n_estimators=15 ......................................
[CV] ........ max_depth=5, n_estimators=15, score=0.788, total=    0.3s
[CV] max_depth=5, n_estimators=15 ......................................
[CV] ........ max_depth=5, n_estimators=15, score=0.798, total=    0.3s
[CV] max_depth=5, n_estimators=20 ......................................
[CV] ........ max_depth=5, n_estimators=20, score=0.797, total=    0.4s
[CV] max_depth=5, n_estimators=20 ......................................
[CV] ........ max_depth=5, n_estimators=20, score=0.798, total=    0.4s
[CV] max_depth=5, n_estimators=20 ......................................
[CV] ........ max_depth=5, n_estimators=20, score=0.761, total=    0.4s
[CV] max_depth=5, n_estimators=20 ......................................
[CV] ........ max_depth=5, n_estimators=20, score=0.793, total=    0.4s
[CV] max_depth=5, n_estimators=20 ......................................
[CV] ........ max_depth=5, n_estimators=20, score=0.804, total=    0.3s
[CV] max_depth=5, n_estimators=50 ......................................
[CV] ........ max_depth=5, n_estimators=50, score=0.808, total=    0.7s
[CV] max_depth=5, n_estimators=50 ......................................
[CV] ........ max_depth=5, n_estimators=50, score=0.793, total=    0.6s
[CV] max_depth=5, n_estimators=50 ......................................
[CV] ........ max_depth=5, n_estimators=50, score=0.772, total=    0.7s
[CV] max_depth=5, n_estimators=50 ......................................
[CV] ........ max_depth=5, n_estimators=50, score=0.793, total=    0.6s
[CV] max_depth=5, n_estimators=50 ......................................
[CV] ........ max_depth=5, n_estimators=50, score=0.791, total=    0.6s
[CV] max_depth=5, n_estimators=100 .....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.805, total=    1.0s
[CV] max_depth=5, n_estimators=100 .....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.799, total=    0.9s
[CV] max_depth=5, n_estimators=100 .....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.772, total=    1.0s
[CV] max_depth=5, n_estimators=100 .....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.797, total=    0.9s
[CV] max_depth=5, n_estimators=100 .....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.799, total=    1.2s
[CV] max_depth=5, n_estimators=200 .....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.800, total=    1.8s
[CV] max_depth=5, n_estimators=200 .....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.789, total=    1.9s
[CV] max_depth=5, n_estimators=200 .....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.767, total=    1.7s
[CV] max_depth=5, n_estimators=200 .....................................
```

```
[CV] ....... max_depth=5, n_estimators=200, score=0.796, total=   1.8s
[CV] max_depth=5, n_estimators=200 ....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.795, total=   1.8s
[CV] max_depth=5, n_estimators=500 ....................................
[CV] ....... max_depth=5, n_estimators=500, score=0.804, total=   3.9s
[CV] max_depth=5, n_estimators=500 ....................................
[CV] ....... max_depth=5, n_estimators=500, score=0.791, total=   5.2s
[CV] max_depth=5, n_estimators=500 ....................................
[CV] ....... max_depth=5, n_estimators=500, score=0.771, total=   5.9s
[CV] max_depth=5, n_estimators=500 ....................................
[CV] ....... max_depth=5, n_estimators=500, score=0.794, total=   5.2s
[CV] max_depth=5, n_estimators=500 ....................................
[CV] ....... max_depth=5, n_estimators=500, score=0.798, total=   5.7s
[CV] max_depth=6, n_estimators=10 .....................................
[CV] ........ max_depth=6, n_estimators=10, score=0.805, total=   0.4s
[CV] max_depth=6, n_estimators=10 .....................................
[CV] ........ max_depth=6, n_estimators=10, score=0.799, total=   0.3s
[CV] max_depth=6, n_estimators=10 .....................................
[CV] ........ max_depth=6, n_estimators=10, score=0.774, total=   0.4s
[CV] max_depth=6, n_estimators=10 .....................................
[CV] ........ max_depth=6, n_estimators=10, score=0.783, total=   0.3s
[CV] max_depth=6, n_estimators=10 .....................................
[CV] ........ max_depth=6, n_estimators=10, score=0.795, total=   0.3s
[CV] max_depth=6, n_estimators=15 .....................................
[CV] ........ max_depth=6, n_estimators=15, score=0.801, total=   0.4s
[CV] max_depth=6, n_estimators=15 .....................................
[CV] ........ max_depth=6, n_estimators=15, score=0.799, total=   0.4s
[CV] max_depth=6, n_estimators=15 .....................................
[CV] ........ max_depth=6, n_estimators=15, score=0.782, total=   0.4s
[CV] max_depth=6, n_estimators=15 .....................................
[CV] ........ max_depth=6, n_estimators=15, score=0.793, total=   0.4s
[CV] max_depth=6, n_estimators=15 .....................................
[CV] ........ max_depth=6, n_estimators=15, score=0.799, total=   0.5s
[CV] max_depth=6, n_estimators=20 .....................................
[CV] ........ max_depth=6, n_estimators=20, score=0.806, total=   0.4s
[CV] max_depth=6, n_estimators=20 .....................................
[CV] ........ max_depth=6, n_estimators=20, score=0.798, total=   0.5s
[CV] max_depth=6, n_estimators=20 .....................................
[CV] ........ max_depth=6, n_estimators=20, score=0.768, total=   0.5s
[CV] max_depth=6, n_estimators=20 .....................................
[CV] ........ max_depth=6, n_estimators=20, score=0.795, total=   0.4s
[CV] max_depth=6, n_estimators=20 .....................................
[CV] ........ max_depth=6, n_estimators=20, score=0.791, total=   0.4s
[CV] max_depth=6, n_estimators=50 .....................................
[CV] ........ max_depth=6, n_estimators=50, score=0.808, total=   0.7s
[CV] max_depth=6, n_estimators=50 .....................................
[CV] ........ max_depth=6, n_estimators=50, score=0.791, total=   0.9s
[CV] max_depth=6, n_estimators=50 .....................................
[CV] ........ max_depth=6, n_estimators=50, score=0.771, total=   0.7s
[CV] max_depth=6, n_estimators=50 .....................................
[CV] ........ max_depth=6, n_estimators=50, score=0.797, total=   0.7s
[CV] max_depth=6, n_estimators=50 .....................................
[CV] ........ max_depth=6, n_estimators=50, score=0.792, total=   0.7s
[CV] max_depth=6, n_estimators=100 ....................................
[CV] ....... max_depth=6, n_estimators=100, score=0.805, total=   1.4s
[CV] max_depth=6, n_estimators=100 ....................................
[CV] ....... max_depth=6, n_estimators=100, score=0.797, total=   1.2s
[CV] max_depth=6, n_estimators=100 ....................................
[CV] ....... max_depth=6, n_estimators=100, score=0.770, total=   1.3s
[CV] max_depth=6, n_estimators=100 ....................................
[CV] ....... max_depth=6, n_estimators=100, score=0.798, total=   1.1s
```

```
[CV] max_depth=6, n_estimators=100 ....................................
[CV] ....... max_depth=6, n_estimators=100, score=0.797, total=   1.2s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.804, total=   2.4s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.799, total=   2.4s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ...... max_depth=6, n_estimators=200, score=0.768, total=   2.3s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.797, total=   2.3s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ...... max_depth=6, n_estimators=200, score=0.799, total=   2.3s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ....... max_depth=6, n_estimators=500, score=0.809, total=   5.9s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ...... max_depth=6, n_estimators=500, score=0.793, total=   5.6s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ...... max_depth=6, n_estimators=500, score=0.772, total=   5.6s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ...... max_depth=6, n_estimators=500, score=0.800, total=   5.1s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ...... max_depth=6, n_estimators=500, score=0.794, total=   4.8s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.810, total=   0.3s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.803, total=   0.3s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.780, total=   0.2s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.796, total=   0.2s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.809, total=   0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.811, total=   0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.800, total=   0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.770, total=   0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.791, total=   0.4s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.799, total=   0.3s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.810, total=   0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.802, total=   0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.780, total=   0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.797, total=   0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.807, total=   0.5s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.809, total=   0.7s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.803, total=   0.8s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.772, total=   0.7s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.809, total=   0.7s
[CV] max_depth=7, n_estimators=50 ....................................
```

```
[CV] ........ max_depth=7, n_estimators=50, score=0.804, total=    0.8s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.813, total=    1.3s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.801, total=    1.3s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.770, total=    1.3s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.807, total=    1.3s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.797, total=    1.7s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.809, total=    3.3s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.794, total=    3.7s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.772, total=    4.1s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.801, total=    4.1s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.795, total=    4.2s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.809, total=    6.3s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.803, total=    7.6s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.772, total=    7.4s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.799, total=    6.7s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.796, total=    6.2s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.805, total=    0.5s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.802, total=    0.5s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.770, total=    0.4s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.794, total=    0.5s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.806, total=    0.4s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.807, total=    0.4s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.797, total=    0.5s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.771, total=    0.6s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.804, total=    0.4s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.802, total=    0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.812, total=    0.5s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.804, total=    0.5s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.770, total=    0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.804, total=    0.6s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.806, total=    0.4s
```

```
[CV] max_depth=8, n_estimators=50 ...................................
[CV] ........ max_depth=8, n_estimators=50, score=0.814, total=   1.1s
[CV] max_depth=8, n_estimators=50 ...................................
[CV] ........ max_depth=8, n_estimators=50, score=0.798, total=   0.8s
[CV] max_depth=8, n_estimators=50 ...................................
[CV] ........ max_depth=8, n_estimators=50, score=0.780, total=   0.7s
[CV] max_depth=8, n_estimators=50 ...................................
[CV] ........ max_depth=8, n_estimators=50, score=0.800, total=   0.9s
[CV] max_depth=8, n_estimators=50 ...................................
[CV] ........ max_depth=8, n_estimators=50, score=0.797, total=   0.8s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.806, total=   1.5s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.801, total=   1.5s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.774, total=   1.3s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.799, total=   1.1s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.801, total=   1.2s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.808, total=   2.5s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.800, total=   2.7s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.773, total=   2.6s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.803, total=   2.5s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.797, total=   2.7s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.808, total=   6.1s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.806, total=   5.8s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.771, total=   6.1s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.804, total=   5.6s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.798, total=   5.9s
[CV] max_depth=9, n_estimators=10 ...................................
[CV] ........ max_depth=9, n_estimators=10, score=0.806, total=   0.3s
[CV] max_depth=9, n_estimators=10 ...................................
[CV] ........ max_depth=9, n_estimators=10, score=0.791, total=   0.3s
[CV] max_depth=9, n_estimators=10 ...................................
[CV] ........ max_depth=9, n_estimators=10, score=0.773, total=   0.3s
[CV] max_depth=9, n_estimators=10 ...................................
[CV] ........ max_depth=9, n_estimators=10, score=0.782, total=   0.3s
[CV] max_depth=9, n_estimators=10 ...................................
[CV] ........ max_depth=9, n_estimators=10, score=0.794, total=   0.3s
[CV] max_depth=9, n_estimators=15 ...................................
[CV] ........ max_depth=9, n_estimators=15, score=0.802, total=   0.4s
[CV] max_depth=9, n_estimators=15 ...................................
[CV] ........ max_depth=9, n_estimators=15, score=0.793, total=   0.4s
[CV] max_depth=9, n_estimators=15 ...................................
[CV] ........ max_depth=9, n_estimators=15, score=0.779, total=   0.4s
[CV] max_depth=9, n_estimators=15 ...................................
[CV] ........ max_depth=9, n_estimators=15, score=0.788, total=   0.5s
[CV] max_depth=9, n_estimators=15 ...................................
[CV] ........ max_depth=9, n_estimators=15, score=0.793, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
```

```
[CV] ........ max_depth=9, n_estimators=20, score=0.808, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.794, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.780, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.802, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.808, total=   0.4s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.807, total=   0.7s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.796, total=   0.8s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.776, total=   0.8s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.799, total=   0.7s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.800, total=   0.8s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.812, total=   1.2s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.803, total=   1.3s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.777, total=   1.3s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.803, total=   1.3s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.801, total=   1.3s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.812, total=   2.5s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.801, total=   2.4s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.778, total=   2.5s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.800, total=   2.5s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.801, total=   2.5s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.815, total=   6.2s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.800, total=   6.0s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.773, total=   6.0s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.804, total=   5.7s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.804, total=   5.9s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.804, total=   0.4s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.800, total=   0.3s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.785, total=   0.3s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.782, total=   0.3s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.798, total=   0.3s
[CV] max_depth=10, n_estimators=15 ..................................
[CV] ....... max_depth=10, n_estimators=15, score=0.814, total=   0.4s
```

```
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.789, total=   0.4s
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.780, total=   0.4s
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.794, total=   0.4s
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.793, total=   0.4s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.803, total=   0.5s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.789, total=   0.5s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.768, total=   0.6s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.789, total=   0.4s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.784, total=   0.4s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.811, total=   0.7s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.790, total=   0.8s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.779, total=   0.8s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.793, total=   0.7s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.808, total=   0.8s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.804, total=   1.4s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.795, total=   1.3s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.774, total=   1.4s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.803, total=   1.3s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.800, total=   1.4s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.810, total=   2.6s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.799, total=   2.6s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.777, total=   2.5s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.803, total=   2.5s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.802, total=   2.7s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.811, total=   6.2s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.796, total=   5.7s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.782, total=   6.0s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ....... max_depth=10, n_estimators=500, score=0.803, total=   6.0s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ....... max_depth=10, n_estimators=500, score=0.800, total=   6.0s
[CV] max_depth=11, n_estimators=10 ....................................
[CV] ....... max_depth=11, n_estimators=10, score=0.799, total=   0.3s
[CV] max_depth=11, n_estimators=10 ....................................
```

```
[CV] ....... max_depth=11, n_estimators=10, score=0.794, total=   0.3s
[CV] max_depth=11, n_estimators=10 ...................................
[CV] ....... max_depth=11, n_estimators=10, score=0.779, total=   0.3s
[CV] max_depth=11, n_estimators=10 ...................................
[CV] ....... max_depth=11, n_estimators=10, score=0.777, total=   0.3s
[CV] max_depth=11, n_estimators=10 ...................................
[CV] ....... max_depth=11, n_estimators=10, score=0.791, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.803, total=   0.4s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.789, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.764, total=   0.4s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.792, total=   0.4s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.781, total=   0.3s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.800, total=   0.4s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.791, total=   0.4s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.772, total=   0.4s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.789, total=   0.6s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.803, total=   0.5s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.800, total=   0.8s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.796, total=   0.8s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.768, total=   0.7s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.795, total=   0.8s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.796, total=   0.7s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.804, total=   1.4s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.795, total=   1.4s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.772, total=   1.4s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.793, total=   1.4s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.796, total=   1.4s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.804, total=   2.7s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.792, total=   2.7s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.774, total=   2.6s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.796, total=   2.8s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.804, total=   2.6s
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.806, total=   6.5s
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.794, total=   6.1s
```

```
[CV] max_depth=11, n_estimators=500 ....................................
[CV] ...... max_depth=11, n_estimators=500, score=0.773, total=    6.5s
[CV] max_depth=11, n_estimators=500 ....................................
[CV] ...... max_depth=11, n_estimators=500, score=0.796, total=    5.9s
[CV] max_depth=11, n_estimators=500 ....................................
[CV] ...... max_depth=11, n_estimators=500, score=0.798, total=    6.3s
[CV] max_depth=12, n_estimators=10 .....................................
[CV] ....... max_depth=12, n_estimators=10, score=0.792, total=    0.4s
[CV] max_depth=12, n_estimators=10 .....................................
[CV] ....... max_depth=12, n_estimators=10, score=0.790, total=    0.3s
[CV] max_depth=12, n_estimators=10 .....................................
[CV] ....... max_depth=12, n_estimators=10, score=0.773, total=    0.4s
[CV] max_depth=12, n_estimators=10 .....................................
[CV] ....... max_depth=12, n_estimators=10, score=0.785, total=    0.4s
[CV] max_depth=12, n_estimators=10 .....................................
[CV] ....... max_depth=12, n_estimators=10, score=0.796, total=    0.3s
[CV] max_depth=12, n_estimators=15 .....................................
[CV] ....... max_depth=12, n_estimators=15, score=0.790, total=    0.3s
[CV] max_depth=12, n_estimators=15 .....................................
[CV] ....... max_depth=12, n_estimators=15, score=0.779, total=    0.4s
[CV] max_depth=12, n_estimators=15 .....................................
[CV] ....... max_depth=12, n_estimators=15, score=0.770, total=    0.3s
[CV] max_depth=12, n_estimators=15 .....................................
[CV] ....... max_depth=12, n_estimators=15, score=0.790, total=    0.4s
[CV] max_depth=12, n_estimators=15 .....................................
[CV] ....... max_depth=12, n_estimators=15, score=0.791, total=    0.3s
[CV] max_depth=12, n_estimators=20 .....................................
[CV] ....... max_depth=12, n_estimators=20, score=0.804, total=    0.6s
[CV] max_depth=12, n_estimators=20 .....................................
[CV] ....... max_depth=12, n_estimators=20, score=0.785, total=    0.4s
[CV] max_depth=12, n_estimators=20 .....................................
[CV] ....... max_depth=12, n_estimators=20, score=0.758, total=    0.4s
[CV] max_depth=12, n_estimators=20 .....................................
[CV] ....... max_depth=12, n_estimators=20, score=0.794, total=    0.4s
[CV] max_depth=12, n_estimators=20 .....................................
[CV] ....... max_depth=12, n_estimators=20, score=0.790, total=    0.4s
[CV] max_depth=12, n_estimators=50 .....................................
[CV] ....... max_depth=12, n_estimators=50, score=0.796, total=    0.8s
[CV] max_depth=12, n_estimators=50 .....................................
[CV] ....... max_depth=12, n_estimators=50, score=0.800, total=    0.8s
[CV] max_depth=12, n_estimators=50 .....................................
[CV] ....... max_depth=12, n_estimators=50, score=0.777, total=    0.7s
[CV] max_depth=12, n_estimators=50 .....................................
[CV] ....... max_depth=12, n_estimators=50, score=0.790, total=    0.7s
[CV] max_depth=12, n_estimators=50 .....................................
[CV] ....... max_depth=12, n_estimators=50, score=0.791, total=    0.8s
[CV] max_depth=12, n_estimators=100 ....................................
[CV] ...... max_depth=12, n_estimators=100, score=0.800, total=    1.4s
[CV] max_depth=12, n_estimators=100 ....................................
[CV] ...... max_depth=12, n_estimators=100, score=0.789, total=    1.4s
[CV] max_depth=12, n_estimators=100 ....................................
[CV] ...... max_depth=12, n_estimators=100, score=0.774, total=    1.4s
[CV] max_depth=12, n_estimators=100 ....................................
[CV] ...... max_depth=12, n_estimators=100, score=0.797, total=    1.4s
[CV] max_depth=12, n_estimators=100 ....................................
[CV] ...... max_depth=12, n_estimators=100, score=0.796, total=    1.3s
[CV] max_depth=12, n_estimators=200 ....................................
[CV] ...... max_depth=12, n_estimators=200, score=0.799, total=    2.8s
[CV] max_depth=12, n_estimators=200 ....................................
[CV] ...... max_depth=12, n_estimators=200, score=0.786, total=    2.6s
[CV] max_depth=12, n_estimators=200 ....................................
```

```
[CV] ...... max_depth=12, n_estimators=200, score=0.775, total=   2.8s
[CV] max_depth=12, n_estimators=200 ..................................
[CV] ...... max_depth=12, n_estimators=200, score=0.795, total=   2.6s
[CV] max_depth=12, n_estimators=200 ..................................
[CV] ...... max_depth=12, n_estimators=200, score=0.797, total=   3.8s
[CV] max_depth=12, n_estimators=500 ..................................
[CV] ...... max_depth=12, n_estimators=500, score=0.803, total=  10.2s
[CV] max_depth=12, n_estimators=500 ..................................
[CV] ...... max_depth=12, n_estimators=500, score=0.788, total=   8.2s
[CV] max_depth=12, n_estimators=500 ..................................
[CV] ...... max_depth=12, n_estimators=500, score=0.777, total=   7.0s
[CV] max_depth=12, n_estimators=500 ..................................
[CV] ...... max_depth=12, n_estimators=500, score=0.791, total=   7.1s
[CV] max_depth=12, n_estimators=500 ..................................
[CV] ...... max_depth=12, n_estimators=500, score=0.795, total=   6.9s
[CV] max_depth=13, n_estimators=10 ...................................
[CV] ....... max_depth=13, n_estimators=10, score=0.787, total=   0.3s
[CV] max_depth=13, n_estimators=10 ...................................
[CV] ....... max_depth=13, n_estimators=10, score=0.770, total=   0.3s
[CV] max_depth=13, n_estimators=10 ...................................
[CV] ....... max_depth=13, n_estimators=10, score=0.762, total=   0.2s
[CV] max_depth=13, n_estimators=10 ...................................
[CV] ....... max_depth=13, n_estimators=10, score=0.773, total=   0.3s
[CV] max_depth=13, n_estimators=10 ...................................
[CV] ....... max_depth=13, n_estimators=10, score=0.784, total=   0.3s
[CV] max_depth=13, n_estimators=15 ...................................
[CV] ....... max_depth=13, n_estimators=15, score=0.788, total=   0.4s
[CV] max_depth=13, n_estimators=15 ...................................
[CV] ....... max_depth=13, n_estimators=15, score=0.781, total=   0.4s
[CV] max_depth=13, n_estimators=15 ...................................
[CV] ....... max_depth=13, n_estimators=15, score=0.764, total=   0.4s
[CV] max_depth=13, n_estimators=15 ...................................
[CV] ....... max_depth=13, n_estimators=15, score=0.780, total=   0.4s
[CV] max_depth=13, n_estimators=15 ...................................
[CV] ....... max_depth=13, n_estimators=15, score=0.799, total=   0.4s
[CV] max_depth=13, n_estimators=20 ...................................
[CV] ....... max_depth=13, n_estimators=20, score=0.801, total=   0.4s
[CV] max_depth=13, n_estimators=20 ...................................
[CV] ....... max_depth=13, n_estimators=20, score=0.780, total=   0.5s
[CV] max_depth=13, n_estimators=20 ...................................
[CV] ....... max_depth=13, n_estimators=20, score=0.769, total=   0.5s
[CV] max_depth=13, n_estimators=20 ...................................
[CV] ....... max_depth=13, n_estimators=20, score=0.782, total=   0.4s
[CV] max_depth=13, n_estimators=20 ...................................
[CV] ....... max_depth=13, n_estimators=20, score=0.791, total=   0.4s
[CV] max_depth=13, n_estimators=50 ...................................
[CV] ....... max_depth=13, n_estimators=50, score=0.799, total=   0.8s
[CV] max_depth=13, n_estimators=50 ...................................
[CV] ....... max_depth=13, n_estimators=50, score=0.784, total=   0.7s
[CV] max_depth=13, n_estimators=50 ...................................
[CV] ....... max_depth=13, n_estimators=50, score=0.773, total=   0.8s
[CV] max_depth=13, n_estimators=50 ...................................
[CV] ....... max_depth=13, n_estimators=50, score=0.789, total=   0.8s
[CV] max_depth=13, n_estimators=50 ...................................
[CV] ....... max_depth=13, n_estimators=50, score=0.797, total=   0.7s
[CV] max_depth=13, n_estimators=100 ..................................
[CV] ...... max_depth=13, n_estimators=100, score=0.796, total=   1.4s
[CV] max_depth=13, n_estimators=100 ..................................
[CV] ...... max_depth=13, n_estimators=100, score=0.787, total=   1.4s
[CV] max_depth=13, n_estimators=100 ..................................
[CV] ...... max_depth=13, n_estimators=100, score=0.768, total=   1.3s
```

```
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.790, total=   1.4s
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.798, total=   1.4s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.794, total=   2.8s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.789, total=   2.9s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.771, total=   2.7s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.791, total=   2.7s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.794, total=   2.9s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.798, total=   6.8s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.783, total=   7.2s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.775, total=   7.0s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.787, total=   6.9s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.800, total=   6.9s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.793, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.792, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.769, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.783, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.796, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.793, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.786, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.771, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.782, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.778, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.789, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.777, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.772, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.785, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.787, total=   0.4s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.801, total=   0.8s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.786, total=   0.8s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.765, total=   0.7s
[CV] max_depth=14, n_estimators=50 ....................................
```

```
[CV] ....... max_depth=14, n_estimators=50, score=0.787, total=   0.7s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.803, total=   0.8s
[CV] max_depth=14, n_estimators=100 ...................................
[CV] ...... max_depth=14, n_estimators=100, score=0.795, total=   1.5s
[CV] max_depth=14, n_estimators=100 ...................................
[CV] ...... max_depth=14, n_estimators=100, score=0.790, total=   1.5s
[CV] max_depth=14, n_estimators=100 ...................................
[CV] ...... max_depth=14, n_estimators=100, score=0.774, total=   1.5s
[CV] max_depth=14, n_estimators=100 ...................................
[CV] ...... max_depth=14, n_estimators=100, score=0.792, total=   1.7s
[CV] max_depth=14, n_estimators=100 ...................................
[CV] ...... max_depth=14, n_estimators=100, score=0.795, total=   1.5s
[CV] max_depth=14, n_estimators=200 ...................................
[CV] ...... max_depth=14, n_estimators=200, score=0.792, total=   2.9s
[CV] max_depth=14, n_estimators=200 ...................................
[CV] ...... max_depth=14, n_estimators=200, score=0.788, total=   2.7s
[CV] max_depth=14, n_estimators=200 ...................................
[CV] ...... max_depth=14, n_estimators=200, score=0.776, total=   2.9s
[CV] max_depth=14, n_estimators=200 ...................................
[CV] ...... max_depth=14, n_estimators=200, score=0.788, total=   2.8s
[CV] max_depth=14, n_estimators=200 ...................................
[CV] ...... max_depth=14, n_estimators=200, score=0.791, total=   2.6s
[CV] max_depth=14, n_estimators=500 ...................................
[CV] ...... max_depth=14, n_estimators=500, score=0.799, total=   6.8s
[CV] max_depth=14, n_estimators=500 ...................................
[CV] ...... max_depth=14, n_estimators=500, score=0.779, total=   6.7s
[CV] max_depth=14, n_estimators=500 ...................................
[CV] ...... max_depth=14, n_estimators=500, score=0.774, total=   7.2s
[CV] max_depth=14, n_estimators=500 ...................................
[CV] ...... max_depth=14, n_estimators=500, score=0.793, total=   6.9s
[CV] max_depth=14, n_estimators=500 ...................................
[CV] ...... max_depth=14, n_estimators=500, score=0.801, total=   6.7s
[CV] max_depth=15, n_estimators=10 ....................................
[CV] ....... max_depth=15, n_estimators=10, score=0.775, total=   0.4s
[CV] max_depth=15, n_estimators=10 ....................................
[CV] ....... max_depth=15, n_estimators=10, score=0.784, total=   0.3s
[CV] max_depth=15, n_estimators=10 ....................................
[CV] ....... max_depth=15, n_estimators=10, score=0.764, total=   0.3s
[CV] max_depth=15, n_estimators=10 ....................................
[CV] ....... max_depth=15, n_estimators=10, score=0.772, total=   0.4s
[CV] max_depth=15, n_estimators=10 ....................................
[CV] ....... max_depth=15, n_estimators=10, score=0.774, total=   0.3s
[CV] max_depth=15, n_estimators=15 ....................................
[CV] ....... max_depth=15, n_estimators=15, score=0.797, total=   0.3s
[CV] max_depth=15, n_estimators=15 ....................................
[CV] ....... max_depth=15, n_estimators=15, score=0.787, total=   0.4s
[CV] max_depth=15, n_estimators=15 ....................................
[CV] ....... max_depth=15, n_estimators=15, score=0.762, total=   0.4s
[CV] max_depth=15, n_estimators=15 ....................................
[CV] ....... max_depth=15, n_estimators=15, score=0.776, total=   0.4s
[CV] max_depth=15, n_estimators=15 ....................................
[CV] ....... max_depth=15, n_estimators=15, score=0.790, total=   0.4s
[CV] max_depth=15, n_estimators=20 ....................................
[CV] ....... max_depth=15, n_estimators=20, score=0.789, total=   0.4s
[CV] max_depth=15, n_estimators=20 ....................................
[CV] ....... max_depth=15, n_estimators=20, score=0.785, total=   0.4s
[CV] max_depth=15, n_estimators=20 ....................................
[CV] ....... max_depth=15, n_estimators=20, score=0.764, total=   0.4s
[CV] max_depth=15, n_estimators=20 ....................................
[CV] ....... max_depth=15, n_estimators=20, score=0.775, total=   0.4s
```

```
[CV] max_depth=15, n_estimators=20 ...................................
[CV] ....... max_depth=15, n_estimators=20, score=0.776, total=   0.5s
[CV] max_depth=15, n_estimators=50 ...................................
[CV] ....... max_depth=15, n_estimators=50, score=0.802, total=   0.8s
[CV] max_depth=15, n_estimators=50 ...................................
[CV] ....... max_depth=15, n_estimators=50, score=0.782, total=   0.8s
[CV] max_depth=15, n_estimators=50 ...................................
[CV] ....... max_depth=15, n_estimators=50, score=0.766, total=   0.8s
[CV] max_depth=15, n_estimators=50 ...................................
[CV] ....... max_depth=15, n_estimators=50, score=0.781, total=   0.8s
[CV] max_depth=15, n_estimators=50 ...................................
[CV] ....... max_depth=15, n_estimators=50, score=0.795, total=   0.9s
[CV] max_depth=15, n_estimators=100 ...................................
[CV] ...... max_depth=15, n_estimators=100, score=0.796, total=   1.4s
[CV] max_depth=15, n_estimators=100 ...................................
[CV] ...... max_depth=15, n_estimators=100, score=0.785, total=   1.4s
[CV] max_depth=15, n_estimators=100 ...................................
[CV] ...... max_depth=15, n_estimators=100, score=0.768, total=   1.4s
[CV] max_depth=15, n_estimators=100 ...................................
[CV] ...... max_depth=15, n_estimators=100, score=0.785, total=   1.3s
[CV] max_depth=15, n_estimators=100 ...................................
[CV] ...... max_depth=15, n_estimators=100, score=0.795, total=   1.2s
[CV] max_depth=15, n_estimators=200 ...................................
[CV] ...... max_depth=15, n_estimators=200, score=0.793, total=   2.9s
[CV] max_depth=15, n_estimators=200 ...................................
[CV] ...... max_depth=15, n_estimators=200, score=0.778, total=   2.7s
[CV] max_depth=15, n_estimators=200 ...................................
[CV] ...... max_depth=15, n_estimators=200, score=0.772, total=   3.2s
[CV] max_depth=15, n_estimators=200 ...................................
[CV] ...... max_depth=15, n_estimators=200, score=0.784, total=   2.7s
[CV] max_depth=15, n_estimators=200 ...................................
[CV] ...... max_depth=15, n_estimators=200, score=0.796, total=   3.1s
[CV] max_depth=15, n_estimators=500 ...................................
[CV] ...... max_depth=15, n_estimators=500, score=0.796, total=   7.1s
[CV] max_depth=15, n_estimators=500 ...................................
[CV] ...... max_depth=15, n_estimators=500, score=0.778, total=   7.2s
[CV] max_depth=15, n_estimators=500 ...................................
[CV] ...... max_depth=15, n_estimators=500, score=0.771, total=   7.0s
[CV] max_depth=15, n_estimators=500 ...................................
[CV] ...... max_depth=15, n_estimators=500, score=0.790, total=   6.9s
[CV] max_depth=15, n_estimators=500 ...................................
[CV] ...... max_depth=15, n_estimators=500, score=0.796, total=   6.9s

[Parallel(n_jobs=1)]: Done 420 out of 420 | elapsed: 12.1min finished
```

```
GridSearchCV(cv=None, error_score=nan,
             estimator=RandomForestClassifier(bootstrap=True, ccp_alpha=0.
0,
                                              class_weight=None,
                                              criterion='gini', max_depth=
None,
                                              max_features='auto',
                                              max_leaf_nodes=None,
                                              max_samples=None,
                                              min_impurity_decrease=0.0,
                                              min_impurity_split=None,
                                              min_samples_leaf=1,
                                              min_samples_split=2,
                                              min_weight_fraction_leaf=0.
0,
                                              n_estimators=100, n_jobs=-1,
                                              oob_score=False,
                                              random_state=None, verbose=
0,
                                              warm_start=False),
             iid='deprecated', n_jobs=None,
             param_grid={'max_depth': [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 1
4,
                                       15],
                         'n_estimators': [10, 15, 20, 50, 100, 200, 500]},
             pre_dispatch='2*n_jobs', refit=True, return_train_score=Fals
e,
             scoring=None, verbose=3)
```

Let's check which model is the best.

In [19]:

```
grid_best_score = grid_clf.best_score_
grid_best_parameters = grid_clf.best_params_
grid_best_max_depth = grid_best_parameters.get('max_depth')
grid_best_n_estimators = grid_best_parameters.get('n_estimators')

print('Grid search best_score: {:.5}'.format(grid_best_score))
print('best_max_depth: {}'.format(grid_best_max_depth))
print('best_n_estimators: {}'.format(grid_best_n_estimators))
```

```
Grid search best_score: 0.79992
best_max_depth: 7
best_n_estimators: 10
```

In [20]:

```
grid_clf_best = RandomForestClassifier(n_jobs = -1,max_depth = grid_best_max_depth, n_e
stimators = grid_best_n_estimators )
```

In [21]:

```
grid_clf_best.fit(X_train, y_train);
```

Let's apply it to our validation set.

In [22]:

```
grid_y_pred = grid_clf_best.predict(X_test)
```

In [23]:

```
print("Accuracy: {:.2%}".format(accuracy_score(y_test, grid_y_pred)))
```

Accuracy: 81.21%

Given this accuracy, we can take a deeper look into the results.

In [24]:

```
grid_cm = confusion_matrix(y_test, grid_y_pred)
index = ['Negative','Positive']
columns = ['Negative','Positive']
cm_df = pd.DataFrame(grid_cm,columns,index)


plt.figure(figsize=(8,8))
sns.heatmap(cm_df, annot=True, fmt="d", cmap="nipy_spectral")
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion matrix for the grid search', fontsize = 15);
```
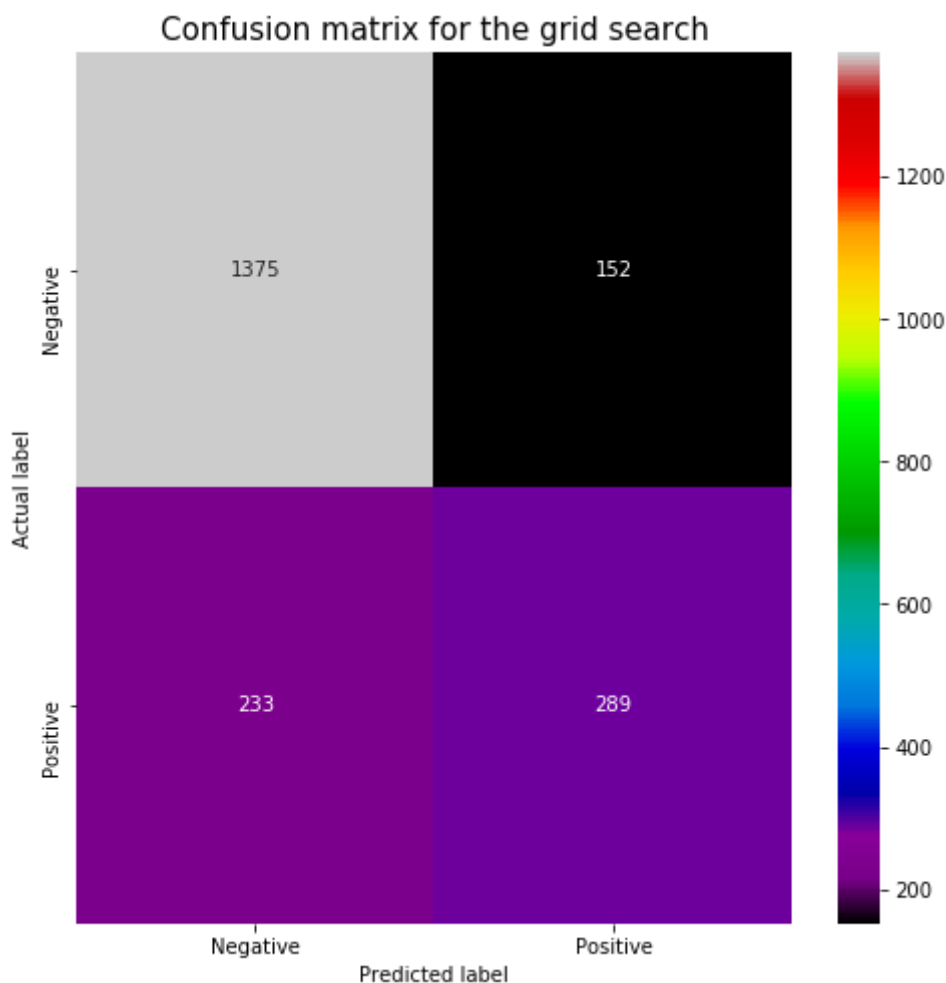

Feature importance

```
grid_feature_importances = [(list(X.columns)[i], grid_clf_best.feature_importances_[i])
for i in range(len(list(X.columns)))]
grid_feature_importances.sort(key=itemgetter(1), reverse = True)
plot_importance(grid_feature_importances, 10, 'Grid search')
```
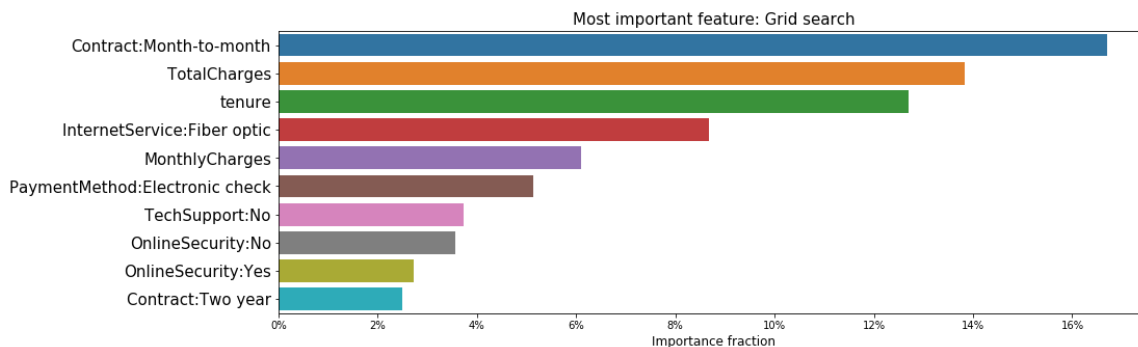

In [26]:

```
print(classification_report(y_test,grid_y_pred))
```

```
              precision    recall  f1-score   support

           0       0.86      0.90      0.88      1527
           1       0.66      0.55      0.60       522

    accuracy                           0.81      2049
   macro avg       0.76      0.73      0.74      2049
weighted avg       0.80      0.81      0.81      2049
```

Feature selection

Let's try to run the model again, but this time selecting only the most impacting features to save us some work and let's compare the results.

In [27]:

```
grid_selected_features = [grid_feature_importances[i][0] for i in range(15)]
grid_X_train_sel = X_train[grid_selected_features]
grid_X_test_sel = X_test[grid_selected_features]
```

```
grid_clf.fit(grid_X_train_sel, y_train);
```

```
Fitting 5 folds for each of 84 candidates, totalling 420 fits
[CV] max_depth=4, n_estimators=10 ...................................

[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent wo
rkers.

[CV] ........ max_depth=4, n_estimators=10, score=0.797, total=   0.4s
[CV] max_depth=4, n_estimators=10 ...................................

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.3s remaining:
0.0s

[CV] ........ max_depth=4, n_estimators=10, score=0.780, total=   0.2s
[CV] max_depth=4, n_estimators=10 ...................................

[Parallel(n_jobs=1)]: Done   2 out of   2 | elapsed:    0.5s remaining:
0.0s
```

```
[CV] ........ max_depth=4, n_estimators=10, score=0.773, total=   0.3s
[CV] max_depth=4, n_estimators=10 .....................................
[CV] ........ max_depth=4, n_estimators=10, score=0.792, total=   0.2s
[CV] max_depth=4, n_estimators=10 .....................................
[CV] ........ max_depth=4, n_estimators=10, score=0.801, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.799, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.791, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.767, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.791, total=   0.3s
[CV] max_depth=4, n_estimators=15 .....................................
[CV] ........ max_depth=4, n_estimators=15, score=0.799, total=   0.3s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.798, total=   0.4s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.786, total=   0.4s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.768, total=   0.4s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.788, total=   0.4s
[CV] max_depth=4, n_estimators=20 .....................................
[CV] ........ max_depth=4, n_estimators=20, score=0.793, total=   0.4s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.805, total=   0.6s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.790, total=   0.6s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.767, total=   0.7s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.791, total=   0.7s
[CV] max_depth=4, n_estimators=50 .....................................
[CV] ........ max_depth=4, n_estimators=50, score=0.792, total=   0.6s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.801, total=   1.1s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.790, total=   0.9s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.763, total=   1.1s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.794, total=   1.1s
[CV] max_depth=4, n_estimators=100 ....................................
[CV] ....... max_depth=4, n_estimators=100, score=0.800, total=   1.0s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.798, total=   1.7s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.789, total=   1.7s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.764, total=   1.9s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.791, total=   1.9s
[CV] max_depth=4, n_estimators=200 ....................................
[CV] ....... max_depth=4, n_estimators=200, score=0.796, total=   1.8s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.798, total=   4.4s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.787, total=   4.6s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.767, total=   4.5s
```

```
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.791, total=   4.4s
[CV] max_depth=4, n_estimators=500 ....................................
[CV] ....... max_depth=4, n_estimators=500, score=0.795, total=   4.4s
[CV] max_depth=5, n_estimators=10 .....................................
[CV] ........ max_depth=5, n_estimators=10, score=0.804, total=   0.2s
[CV] max_depth=5, n_estimators=10 .....................................
[CV] ........ max_depth=5, n_estimators=10, score=0.783, total=   0.2s
[CV] max_depth=5, n_estimators=10 .....................................
[CV] ........ max_depth=5, n_estimators=10, score=0.771, total=   0.3s
[CV] max_depth=5, n_estimators=10 .....................................
[CV] ........ max_depth=5, n_estimators=10, score=0.783, total=   0.2s
[CV] max_depth=5, n_estimators=10 .....................................
[CV] ........ max_depth=5, n_estimators=10, score=0.801, total=   0.3s
[CV] max_depth=5, n_estimators=15 .....................................
[CV] ........ max_depth=5, n_estimators=15, score=0.812, total=   0.3s
[CV] max_depth=5, n_estimators=15 .....................................
[CV] ........ max_depth=5, n_estimators=15, score=0.791, total=   0.3s
[CV] max_depth=5, n_estimators=15 .....................................
[CV] ........ max_depth=5, n_estimators=15, score=0.773, total=   0.3s
[CV] max_depth=5, n_estimators=15 .....................................
[CV] ........ max_depth=5, n_estimators=15, score=0.785, total=   0.3s
[CV] max_depth=5, n_estimators=15 .....................................
[CV] ........ max_depth=5, n_estimators=15, score=0.802, total=   0.3s
[CV] max_depth=5, n_estimators=20 .....................................
[CV] ........ max_depth=5, n_estimators=20, score=0.802, total=   0.4s
[CV] max_depth=5, n_estimators=20 .....................................
[CV] ........ max_depth=5, n_estimators=20, score=0.789, total=   0.4s
[CV] max_depth=5, n_estimators=20 .....................................
[CV] ........ max_depth=5, n_estimators=20, score=0.767, total=   0.4s
[CV] max_depth=5, n_estimators=20 .....................................
[CV] ........ max_depth=5, n_estimators=20, score=0.788, total=   0.4s
[CV] max_depth=5, n_estimators=20 .....................................
[CV] ........ max_depth=5, n_estimators=20, score=0.798, total=   0.4s
[CV] max_depth=5, n_estimators=50 .....................................
[CV] ........ max_depth=5, n_estimators=50, score=0.805, total=   0.6s
[CV] max_depth=5, n_estimators=50 .....................................
[CV] ........ max_depth=5, n_estimators=50, score=0.789, total=   0.5s
[CV] max_depth=5, n_estimators=50 .....................................
[CV] ........ max_depth=5, n_estimators=50, score=0.773, total=   0.6s
[CV] max_depth=5, n_estimators=50 .....................................
[CV] ........ max_depth=5, n_estimators=50, score=0.794, total=   0.6s
[CV] max_depth=5, n_estimators=50 .....................................
[CV] ........ max_depth=5, n_estimators=50, score=0.805, total=   0.6s
[CV] max_depth=5, n_estimators=100 ....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.804, total=   1.0s
[CV] max_depth=5, n_estimators=100 ....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.793, total=   1.0s
[CV] max_depth=5, n_estimators=100 ....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.770, total=   1.0s
[CV] max_depth=5, n_estimators=100 ....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.795, total=   1.0s
[CV] max_depth=5, n_estimators=100 ....................................
[CV] ....... max_depth=5, n_estimators=100, score=0.798, total=   0.9s
[CV] max_depth=5, n_estimators=200 ....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.802, total=   1.8s
[CV] max_depth=5, n_estimators=200 ....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.790, total=   1.8s
[CV] max_depth=5, n_estimators=200 ....................................
[CV] ....... max_depth=5, n_estimators=200, score=0.771, total=   1.9s
[CV] max_depth=5, n_estimators=200 ....................................
```

```
[CV] ....... max_depth=5, n_estimators=200, score=0.802, total=   1.7s
[CV] max_depth=5, n_estimators=200 ..................................
[CV] ....... max_depth=5, n_estimators=200, score=0.797, total=   1.8s
[CV] max_depth=5, n_estimators=500 ..................................
[CV] ....... max_depth=5, n_estimators=500, score=0.805, total=   4.5s
[CV] max_depth=5, n_estimators=500 ..................................
[CV] ....... max_depth=5, n_estimators=500, score=0.792, total=   6.5s
[CV] max_depth=5, n_estimators=500 ..................................
[CV] ....... max_depth=5, n_estimators=500, score=0.771, total=   6.6s
[CV] max_depth=5, n_estimators=500 ..................................
[CV] ....... max_depth=5, n_estimators=500, score=0.796, total=   5.6s
[CV] max_depth=5, n_estimators=500 ..................................
[CV] ....... max_depth=5, n_estimators=500, score=0.796, total=   5.0s
[CV] max_depth=6, n_estimators=10 ...................................
[CV] ........ max_depth=6, n_estimators=10, score=0.801, total=   0.3s
[CV] max_depth=6, n_estimators=10 ...................................
[CV] ........ max_depth=6, n_estimators=10, score=0.791, total=   0.2s
[CV] max_depth=6, n_estimators=10 ...................................
[CV] ........ max_depth=6, n_estimators=10, score=0.780, total=   0.2s
[CV] max_depth=6, n_estimators=10 ...................................
[CV] ........ max_depth=6, n_estimators=10, score=0.792, total=   0.3s
[CV] max_depth=6, n_estimators=10 ...................................
[CV] ........ max_depth=6, n_estimators=10, score=0.796, total=   0.3s
[CV] max_depth=6, n_estimators=15 ...................................
[CV] ........ max_depth=6, n_estimators=15, score=0.801, total=   0.4s
[CV] max_depth=6, n_estimators=15 ...................................
[CV] ........ max_depth=6, n_estimators=15, score=0.794, total=   0.3s
[CV] max_depth=6, n_estimators=15 ...................................
[CV] ........ max_depth=6, n_estimators=15, score=0.779, total=   0.3s
[CV] max_depth=6, n_estimators=15 ...................................
[CV] ........ max_depth=6, n_estimators=15, score=0.787, total=   0.3s
[CV] max_depth=6, n_estimators=15 ...................................
[CV] ........ max_depth=6, n_estimators=15, score=0.794, total=   0.3s
[CV] max_depth=6, n_estimators=20 ...................................
[CV] ........ max_depth=6, n_estimators=20, score=0.814, total=   0.3s
[CV] max_depth=6, n_estimators=20 ...................................
[CV] ........ max_depth=6, n_estimators=20, score=0.796, total=   0.3s
[CV] max_depth=6, n_estimators=20 ...................................
[CV] ........ max_depth=6, n_estimators=20, score=0.774, total=   0.4s
[CV] max_depth=6, n_estimators=20 ...................................
[CV] ........ max_depth=6, n_estimators=20, score=0.799, total=   0.3s
[CV] max_depth=6, n_estimators=20 ...................................
[CV] ........ max_depth=6, n_estimators=20, score=0.803, total=   0.4s
[CV] max_depth=6, n_estimators=50 ...................................
[CV] ........ max_depth=6, n_estimators=50, score=0.804, total=   0.6s
[CV] max_depth=6, n_estimators=50 ...................................
[CV] ........ max_depth=6, n_estimators=50, score=0.792, total=   0.5s
[CV] max_depth=6, n_estimators=50 ...................................
[CV] ........ max_depth=6, n_estimators=50, score=0.779, total=   0.6s
[CV] max_depth=6, n_estimators=50 ...................................
[CV] ........ max_depth=6, n_estimators=50, score=0.794, total=   0.5s
[CV] max_depth=6, n_estimators=50 ...................................
[CV] ........ max_depth=6, n_estimators=50, score=0.790, total=   0.6s
[CV] max_depth=6, n_estimators=100 ..................................
[CV] ....... max_depth=6, n_estimators=100, score=0.802, total=   0.9s
[CV] max_depth=6, n_estimators=100 ..................................
[CV] ....... max_depth=6, n_estimators=100, score=0.794, total=   0.9s
[CV] max_depth=6, n_estimators=100 ..................................
[CV] ....... max_depth=6, n_estimators=100, score=0.773, total=   1.0s
[CV] max_depth=6, n_estimators=100 ..................................
[CV] ....... max_depth=6, n_estimators=100, score=0.796, total=   0.9s
```

```
[CV] max_depth=6, n_estimators=100 ....................................
[CV] ....... max_depth=6, n_estimators=100, score=0.793, total=    0.9s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.803, total=    1.6s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.793, total=    1.9s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.775, total=    2.0s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.788, total=    1.9s
[CV] max_depth=6, n_estimators=200 ....................................
[CV] ....... max_depth=6, n_estimators=200, score=0.796, total=    2.0s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ....... max_depth=6, n_estimators=500, score=0.804, total=    4.4s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ....... max_depth=6, n_estimators=500, score=0.795, total=    4.4s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ....... max_depth=6, n_estimators=500, score=0.775, total=    4.6s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ....... max_depth=6, n_estimators=500, score=0.793, total=    4.7s
[CV] max_depth=6, n_estimators=500 ....................................
[CV] ....... max_depth=6, n_estimators=500, score=0.796, total=    4.3s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.812, total=    0.2s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.790, total=    0.2s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.774, total=    0.3s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.797, total=    0.2s
[CV] max_depth=7, n_estimators=10 ....................................
[CV] ........ max_depth=7, n_estimators=10, score=0.789, total=    0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.813, total=    0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.801, total=    0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.779, total=    0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.789, total=    0.3s
[CV] max_depth=7, n_estimators=15 ....................................
[CV] ........ max_depth=7, n_estimators=15, score=0.795, total=    0.3s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.807, total=    0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.797, total=    0.3s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.772, total=    0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.784, total=    0.4s
[CV] max_depth=7, n_estimators=20 ....................................
[CV] ........ max_depth=7, n_estimators=20, score=0.800, total=    0.3s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.810, total=    0.5s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.794, total=    0.6s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.780, total=    0.6s
[CV] max_depth=7, n_estimators=50 ....................................
[CV] ........ max_depth=7, n_estimators=50, score=0.792, total=    0.6s
[CV] max_depth=7, n_estimators=50 ....................................
```

```
[CV] ........ max_depth=7, n_estimators=50, score=0.791, total=   0.6s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.812, total=   1.0s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.796, total=   1.2s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.776, total=   1.0s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.787, total=   1.0s
[CV] max_depth=7, n_estimators=100 ....................................
[CV] ....... max_depth=7, n_estimators=100, score=0.790, total=   1.1s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.802, total=   2.0s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.801, total=   2.0s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ...... max_depth=7, n_estimators=200, score=0.778, total=   2.0s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.785, total=   2.0s
[CV] max_depth=7, n_estimators=200 ....................................
[CV] ....... max_depth=7, n_estimators=200, score=0.793, total=   2.1s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.805, total=   4.7s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.798, total=   4.7s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.777, total=   4.8s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.788, total=   4.4s
[CV] max_depth=7, n_estimators=500 ....................................
[CV] ....... max_depth=7, n_estimators=500, score=0.796, total=   4.6s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.803, total=   0.2s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.785, total=   0.3s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.775, total=   0.3s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.785, total=   0.3s
[CV] max_depth=8, n_estimators=10 .....................................
[CV] ........ max_depth=8, n_estimators=10, score=0.796, total=   0.3s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.809, total=   0.3s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.796, total=   0.3s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.776, total=   0.3s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.785, total=   0.3s
[CV] max_depth=8, n_estimators=15 .....................................
[CV] ........ max_depth=8, n_estimators=15, score=0.799, total=   0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.814, total=   0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.790, total=   0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.787, total=   0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.781, total=   0.4s
[CV] max_depth=8, n_estimators=20 .....................................
[CV] ........ max_depth=8, n_estimators=20, score=0.798, total=   0.3s
```

```
[CV] max_depth=8, n_estimators=50 ....................................
[CV] ........ max_depth=8, n_estimators=50, score=0.807, total=   0.7s
[CV] max_depth=8, n_estimators=50 ....................................
[CV] ........ max_depth=8, n_estimators=50, score=0.792, total=   0.6s
[CV] max_depth=8, n_estimators=50 ....................................
[CV] ........ max_depth=8, n_estimators=50, score=0.781, total=   0.6s
[CV] max_depth=8, n_estimators=50 ....................................
[CV] ........ max_depth=8, n_estimators=50, score=0.793, total=   0.6s
[CV] max_depth=8, n_estimators=50 ....................................
[CV] ........ max_depth=8, n_estimators=50, score=0.795, total=   0.6s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.810, total=   1.2s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.794, total=   1.1s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.779, total=   1.2s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.784, total=   1.0s
[CV] max_depth=8, n_estimators=100 ...................................
[CV] ....... max_depth=8, n_estimators=100, score=0.792, total=   1.1s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.808, total=   2.1s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.797, total=   2.1s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.783, total=   2.0s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.783, total=   2.0s
[CV] max_depth=8, n_estimators=200 ...................................
[CV] ....... max_depth=8, n_estimators=200, score=0.795, total=   2.1s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.809, total=   4.7s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.794, total=   5.0s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.778, total=   4.9s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.782, total=   4.9s
[CV] max_depth=8, n_estimators=500 ...................................
[CV] ....... max_depth=8, n_estimators=500, score=0.794, total=   4.9s
[CV] max_depth=9, n_estimators=10 ....................................
[CV] ........ max_depth=9, n_estimators=10, score=0.803, total=   0.3s
[CV] max_depth=9, n_estimators=10 ....................................
[CV] ........ max_depth=9, n_estimators=10, score=0.794, total=   0.3s
[CV] max_depth=9, n_estimators=10 ....................................
[CV] ........ max_depth=9, n_estimators=10, score=0.778, total=   0.3s
[CV] max_depth=9, n_estimators=10 ....................................
[CV] ........ max_depth=9, n_estimators=10, score=0.780, total=   0.2s
[CV] max_depth=9, n_estimators=10 ....................................
[CV] ........ max_depth=9, n_estimators=10, score=0.790, total=   0.3s
[CV] max_depth=9, n_estimators=15 ....................................
[CV] ........ max_depth=9, n_estimators=15, score=0.803, total=   0.3s
[CV] max_depth=9, n_estimators=15 ....................................
[CV] ........ max_depth=9, n_estimators=15, score=0.792, total=   0.3s
[CV] max_depth=9, n_estimators=15 ....................................
[CV] ........ max_depth=9, n_estimators=15, score=0.777, total=   0.3s
[CV] max_depth=9, n_estimators=15 ....................................
[CV] ........ max_depth=9, n_estimators=15, score=0.787, total=   0.3s
[CV] max_depth=9, n_estimators=15 ....................................
[CV] ........ max_depth=9, n_estimators=15, score=0.790, total=   0.3s
[CV] max_depth=9, n_estimators=20 ....................................
```

```
[CV] ........ max_depth=9, n_estimators=20, score=0.781, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.803, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.779, total=   0.3s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.781, total=   0.4s
[CV] max_depth=9, n_estimators=20 ...................................
[CV] ........ max_depth=9, n_estimators=20, score=0.801, total=   0.4s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.807, total=   0.6s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.789, total=   0.7s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.773, total=   0.6s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.789, total=   0.6s
[CV] max_depth=9, n_estimators=50 ...................................
[CV] ........ max_depth=9, n_estimators=50, score=0.794, total=   0.6s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.806, total=   1.1s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.801, total=   1.1s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.783, total=   1.1s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.784, total=   1.0s
[CV] max_depth=9, n_estimators=100 ..................................
[CV] ....... max_depth=9, n_estimators=100, score=0.795, total=   1.1s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.810, total=   2.2s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.794, total=   2.2s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.778, total=   2.2s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.788, total=   2.2s
[CV] max_depth=9, n_estimators=200 ..................................
[CV] ....... max_depth=9, n_estimators=200, score=0.795, total=   2.1s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.812, total=   5.2s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.793, total=   5.1s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.781, total=   5.3s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.786, total=   5.1s
[CV] max_depth=9, n_estimators=500 ..................................
[CV] ....... max_depth=9, n_estimators=500, score=0.796, total=   5.3s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.793, total=   0.3s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.794, total=   0.2s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.770, total=   0.3s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.776, total=   0.4s
[CV] max_depth=10, n_estimators=10 ..................................
[CV] ....... max_depth=10, n_estimators=10, score=0.799, total=   0.3s
[CV] max_depth=10, n_estimators=15 ..................................
[CV] ....... max_depth=10, n_estimators=15, score=0.795, total=   0.4s
```

```
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.787, total=   0.3s
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.774, total=   0.4s
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.784, total=   0.4s
[CV] max_depth=10, n_estimators=15 ....................................
[CV] ....... max_depth=10, n_estimators=15, score=0.796, total=   0.3s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.803, total=   0.4s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.781, total=   0.4s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.777, total=   0.4s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.783, total=   0.4s
[CV] max_depth=10, n_estimators=20 ....................................
[CV] ....... max_depth=10, n_estimators=20, score=0.790, total=   0.3s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.802, total=   0.6s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.794, total=   0.6s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.772, total=   0.7s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.787, total=   0.7s
[CV] max_depth=10, n_estimators=50 ....................................
[CV] ....... max_depth=10, n_estimators=50, score=0.795, total=   0.6s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.799, total=   1.0s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.786, total=   1.1s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.784, total=   1.1s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.783, total=   1.1s
[CV] max_depth=10, n_estimators=100 ....................................
[CV] ...... max_depth=10, n_estimators=100, score=0.794, total=   1.1s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.803, total=   2.0s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.789, total=   2.2s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.781, total=   2.2s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.783, total=   2.1s
[CV] max_depth=10, n_estimators=200 ....................................
[CV] ...... max_depth=10, n_estimators=200, score=0.798, total=   2.3s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.798, total=   5.2s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.788, total=   5.3s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.780, total=   5.2s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ....... max_depth=10, n_estimators=500, score=0.785, total=   5.2s
[CV] max_depth=10, n_estimators=500 ....................................
[CV] ...... max_depth=10, n_estimators=500, score=0.795, total=   5.4s
[CV] max_depth=11, n_estimators=10 ....................................
[CV] ....... max_depth=11, n_estimators=10, score=0.790, total=   0.3s
[CV] max_depth=11, n_estimators=10 ....................................
```

```
[CV] ....... max_depth=11, n_estimators=10, score=0.771, total=   0.2s
[CV] max_depth=11, n_estimators=10 ...................................
[CV] ....... max_depth=11, n_estimators=10, score=0.774, total=   0.3s
[CV] max_depth=11, n_estimators=10 ...................................
[CV] ....... max_depth=11, n_estimators=10, score=0.774, total=   0.2s
[CV] max_depth=11, n_estimators=10 ...................................
[CV] ....... max_depth=11, n_estimators=10, score=0.789, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.790, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.776, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.769, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.786, total=   0.3s
[CV] max_depth=11, n_estimators=15 ...................................
[CV] ....... max_depth=11, n_estimators=15, score=0.787, total=   0.3s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.797, total=   0.4s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.786, total=   0.4s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.774, total=   0.3s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.780, total=   0.4s
[CV] max_depth=11, n_estimators=20 ...................................
[CV] ....... max_depth=11, n_estimators=20, score=0.798, total=   0.4s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.791, total=   0.7s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.780, total=   0.7s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.779, total=   0.6s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.783, total=   0.7s
[CV] max_depth=11, n_estimators=50 ...................................
[CV] ....... max_depth=11, n_estimators=50, score=0.796, total=   0.7s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.797, total=   1.1s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.786, total=   1.2s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.770, total=   1.1s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.780, total=   1.0s
[CV] max_depth=11, n_estimators=100 ..................................
[CV] ...... max_depth=11, n_estimators=100, score=0.798, total=   1.1s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.796, total=   2.4s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.791, total=   2.1s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.773, total=   2.1s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.782, total=   2.2s
[CV] max_depth=11, n_estimators=200 ..................................
[CV] ...... max_depth=11, n_estimators=200, score=0.797, total=   2.2s
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.796, total=   5.3s
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.786, total=   5.3s
```

```
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.770, total=   5.3s
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.782, total=   5.2s
[CV] max_depth=11, n_estimators=500 ..................................
[CV] ...... max_depth=11, n_estimators=500, score=0.795, total=   5.4s
[CV] max_depth=12, n_estimators=10 ...................................
[CV] ....... max_depth=12, n_estimators=10, score=0.783, total=   0.2s
[CV] max_depth=12, n_estimators=10 ...................................
[CV] ....... max_depth=12, n_estimators=10, score=0.787, total=   0.3s
[CV] max_depth=12, n_estimators=10 ...................................
[CV] ....... max_depth=12, n_estimators=10, score=0.761, total=   0.3s
[CV] max_depth=12, n_estimators=10 ...................................
[CV] ....... max_depth=12, n_estimators=10, score=0.764, total=   0.2s
[CV] max_depth=12, n_estimators=10 ...................................
[CV] ....... max_depth=12, n_estimators=10, score=0.786, total=   0.3s
[CV] max_depth=12, n_estimators=15 ...................................
[CV] ....... max_depth=12, n_estimators=15, score=0.789, total=   0.3s
[CV] max_depth=12, n_estimators=15 ...................................
[CV] ....... max_depth=12, n_estimators=15, score=0.777, total=   0.3s
[CV] max_depth=12, n_estimators=15 ...................................
[CV] ....... max_depth=12, n_estimators=15, score=0.773, total=   0.4s
[CV] max_depth=12, n_estimators=15 ...................................
[CV] ....... max_depth=12, n_estimators=15, score=0.775, total=   0.5s
[CV] max_depth=12, n_estimators=15 ...................................
[CV] ....... max_depth=12, n_estimators=15, score=0.785, total=   0.4s
[CV] max_depth=12, n_estimators=20 ...................................
[CV] ....... max_depth=12, n_estimators=20, score=0.784, total=   0.4s
[CV] max_depth=12, n_estimators=20 ...................................
[CV] ....... max_depth=12, n_estimators=20, score=0.786, total=   0.4s
[CV] max_depth=12, n_estimators=20 ...................................
[CV] ....... max_depth=12, n_estimators=20, score=0.772, total=   0.4s
[CV] max_depth=12, n_estimators=20 ...................................
[CV] ....... max_depth=12, n_estimators=20, score=0.781, total=   0.4s
[CV] max_depth=12, n_estimators=20 ...................................
[CV] ....... max_depth=12, n_estimators=20, score=0.786, total=   0.4s
[CV] max_depth=12, n_estimators=50 ...................................
[CV] ....... max_depth=12, n_estimators=50, score=0.794, total=   0.8s
[CV] max_depth=12, n_estimators=50 ...................................
[CV] ....... max_depth=12, n_estimators=50, score=0.782, total=   1.0s
[CV] max_depth=12, n_estimators=50 ...................................
[CV] ....... max_depth=12, n_estimators=50, score=0.774, total=   1.2s
[CV] max_depth=12, n_estimators=50 ...................................
[CV] ....... max_depth=12, n_estimators=50, score=0.775, total=   0.9s
[CV] max_depth=12, n_estimators=50 ...................................
[CV] ....... max_depth=12, n_estimators=50, score=0.793, total=   1.0s
[CV] max_depth=12, n_estimators=100 ..................................
[CV] ...... max_depth=12, n_estimators=100, score=0.800, total=   1.7s
[CV] max_depth=12, n_estimators=100 ..................................
[CV] ...... max_depth=12, n_estimators=100, score=0.786, total=   1.7s
[CV] max_depth=12, n_estimators=100 ..................................
[CV] ...... max_depth=12, n_estimators=100, score=0.770, total=   1.7s
[CV] max_depth=12, n_estimators=100 ..................................
[CV] ...... max_depth=12, n_estimators=100, score=0.788, total=   1.4s
[CV] max_depth=12, n_estimators=100 ..................................
[CV] ...... max_depth=12, n_estimators=100, score=0.791, total=   1.6s
[CV] max_depth=12, n_estimators=200 ..................................
[CV] ...... max_depth=12, n_estimators=200, score=0.791, total=   3.3s
[CV] max_depth=12, n_estimators=200 ..................................
[CV] ...... max_depth=12, n_estimators=200, score=0.789, total=   3.4s
[CV] max_depth=12, n_estimators=200 ..................................
```

```
[CV] ...... max_depth=12, n_estimators=200, score=0.767, total=   2.9s
[CV] max_depth=12, n_estimators=200 ...................................
[CV] ...... max_depth=12, n_estimators=200, score=0.780, total=   2.2s
[CV] max_depth=12, n_estimators=200 ...................................
[CV] ...... max_depth=12, n_estimators=200, score=0.789, total=   2.4s
[CV] max_depth=12, n_estimators=500 ...................................
[CV] ...... max_depth=12, n_estimators=500, score=0.793, total=   5.4s
[CV] max_depth=12, n_estimators=500 ...................................
[CV] ...... max_depth=12, n_estimators=500, score=0.788, total=   5.6s
[CV] max_depth=12, n_estimators=500 ...................................
[CV] ...... max_depth=12, n_estimators=500, score=0.769, total=   6.4s
[CV] max_depth=12, n_estimators=500 ...................................
[CV] ...... max_depth=12, n_estimators=500, score=0.789, total=   6.9s
[CV] max_depth=12, n_estimators=500 ...................................
[CV] ...... max_depth=12, n_estimators=500, score=0.792, total=   6.3s
[CV] max_depth=13, n_estimators=10 ....................................
[CV] ....... max_depth=13, n_estimators=10, score=0.785, total=   0.5s
[CV] max_depth=13, n_estimators=10 ....................................
[CV] ....... max_depth=13, n_estimators=10, score=0.778, total=   0.3s
[CV] max_depth=13, n_estimators=10 ....................................
[CV] ....... max_depth=13, n_estimators=10, score=0.772, total=   0.2s
[CV] max_depth=13, n_estimators=10 ....................................
[CV] ....... max_depth=13, n_estimators=10, score=0.784, total=   0.3s
[CV] max_depth=13, n_estimators=10 ....................................
[CV] ....... max_depth=13, n_estimators=10, score=0.787, total=   0.4s
[CV] max_depth=13, n_estimators=15 ....................................
[CV] ....... max_depth=13, n_estimators=15, score=0.772, total=   0.4s
[CV] max_depth=13, n_estimators=15 ....................................
[CV] ....... max_depth=13, n_estimators=15, score=0.791, total=   0.4s
[CV] max_depth=13, n_estimators=15 ....................................
[CV] ....... max_depth=13, n_estimators=15, score=0.766, total=   0.3s
[CV] max_depth=13, n_estimators=15 ....................................
[CV] ....... max_depth=13, n_estimators=15, score=0.775, total=   0.4s
[CV] max_depth=13, n_estimators=15 ....................................
[CV] ....... max_depth=13, n_estimators=15, score=0.789, total=   0.4s
[CV] max_depth=13, n_estimators=20 ....................................
[CV] ....... max_depth=13, n_estimators=20, score=0.777, total=   0.4s
[CV] max_depth=13, n_estimators=20 ....................................
[CV] ....... max_depth=13, n_estimators=20, score=0.787, total=   0.5s
[CV] max_depth=13, n_estimators=20 ....................................
[CV] ....... max_depth=13, n_estimators=20, score=0.769, total=   0.3s
[CV] max_depth=13, n_estimators=20 ....................................
[CV] ....... max_depth=13, n_estimators=20, score=0.772, total=   0.4s
[CV] max_depth=13, n_estimators=20 ....................................
[CV] ....... max_depth=13, n_estimators=20, score=0.798, total=   0.4s
[CV] max_depth=13, n_estimators=50 ....................................
[CV] ....... max_depth=13, n_estimators=50, score=0.777, total=   0.7s
[CV] max_depth=13, n_estimators=50 ....................................
[CV] ....... max_depth=13, n_estimators=50, score=0.786, total=   0.7s
[CV] max_depth=13, n_estimators=50 ....................................
[CV] ....... max_depth=13, n_estimators=50, score=0.769, total=   0.6s
[CV] max_depth=13, n_estimators=50 ....................................
[CV] ....... max_depth=13, n_estimators=50, score=0.777, total=   0.7s
[CV] max_depth=13, n_estimators=50 ....................................
[CV] ....... max_depth=13, n_estimators=50, score=0.800, total=   0.8s
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.783, total=   1.5s
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.789, total=   1.4s
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.773, total=   1.5s
```

```
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.776, total=   1.5s
[CV] max_depth=13, n_estimators=100 ...................................
[CV] ...... max_depth=13, n_estimators=100, score=0.790, total=   1.3s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.782, total=   2.9s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.781, total=   2.7s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.770, total=   2.3s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.782, total=   2.4s
[CV] max_depth=13, n_estimators=200 ...................................
[CV] ...... max_depth=13, n_estimators=200, score=0.792, total=   2.4s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.791, total=   5.7s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.782, total=   5.6s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.771, total=   5.7s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.782, total=   5.6s
[CV] max_depth=13, n_estimators=500 ...................................
[CV] ...... max_depth=13, n_estimators=500, score=0.793, total=   5.8s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.762, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.792, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.755, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.763, total=   0.3s
[CV] max_depth=14, n_estimators=10 ....................................
[CV] ....... max_depth=14, n_estimators=10, score=0.781, total=   0.2s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.778, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.779, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.773, total=   0.4s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.777, total=   0.3s
[CV] max_depth=14, n_estimators=15 ....................................
[CV] ....... max_depth=14, n_estimators=15, score=0.777, total=   0.3s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.778, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.786, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.762, total=   0.4s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.776, total=   0.3s
[CV] max_depth=14, n_estimators=20 ....................................
[CV] ....... max_depth=14, n_estimators=20, score=0.799, total=   0.4s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.781, total=   0.7s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.778, total=   0.7s
[CV] max_depth=14, n_estimators=50 ....................................
[CV] ....... max_depth=14, n_estimators=50, score=0.777, total=   0.7s
[CV] max_depth=14, n_estimators=50 ....................................
```

```
[CV] ....... max_depth=14, n_estimators=50, score=0.781, total=   0.7s
[CV] max_depth=14, n_estimators=50 ...................................
[CV] ....... max_depth=14, n_estimators=50, score=0.790, total=   0.7s
[CV] max_depth=14, n_estimators=100 ..................................
[CV] ...... max_depth=14, n_estimators=100, score=0.783, total=   1.2s
[CV] max_depth=14, n_estimators=100 ..................................
[CV] ...... max_depth=14, n_estimators=100, score=0.786, total=   1.3s
[CV] max_depth=14, n_estimators=100 ..................................
[CV] ...... max_depth=14, n_estimators=100, score=0.764, total=   1.4s
[CV] max_depth=14, n_estimators=100 ..................................
[CV] ...... max_depth=14, n_estimators=100, score=0.777, total=   1.5s
[CV] max_depth=14, n_estimators=100 ..................................
[CV] ...... max_depth=14, n_estimators=100, score=0.798, total=   1.2s
[CV] max_depth=14, n_estimators=200 ..................................
[CV] ...... max_depth=14, n_estimators=200, score=0.780, total=   2.2s
[CV] max_depth=14, n_estimators=200 ..................................
[CV] ...... max_depth=14, n_estimators=200, score=0.785, total=   2.4s
[CV] max_depth=14, n_estimators=200 ..................................
[CV] ...... max_depth=14, n_estimators=200, score=0.766, total=   2.5s
[CV] max_depth=14, n_estimators=200 ..................................
[CV] ...... max_depth=14, n_estimators=200, score=0.779, total=   2.3s
[CV] max_depth=14, n_estimators=200 ..................................
[CV] ...... max_depth=14, n_estimators=200, score=0.789, total=   2.1s
[CV] max_depth=14, n_estimators=500 ..................................
[CV] ...... max_depth=14, n_estimators=500, score=0.784, total=   6.1s
[CV] max_depth=14, n_estimators=500 ..................................
[CV] ...... max_depth=14, n_estimators=500, score=0.787, total=   6.1s
[CV] max_depth=14, n_estimators=500 ..................................
[CV] ...... max_depth=14, n_estimators=500, score=0.760, total=   6.7s
[CV] max_depth=14, n_estimators=500 ..................................
[CV] ...... max_depth=14, n_estimators=500, score=0.779, total=   5.9s
[CV] max_depth=14, n_estimators=500 ..................................
[CV] ...... max_depth=14, n_estimators=500, score=0.797, total=   6.0s
[CV] max_depth=15, n_estimators=10 ...................................
[CV] ....... max_depth=15, n_estimators=10, score=0.764, total=   0.2s
[CV] max_depth=15, n_estimators=10 ...................................
[CV] ....... max_depth=15, n_estimators=10, score=0.780, total=   0.3s
[CV] max_depth=15, n_estimators=10 ...................................
[CV] ....... max_depth=15, n_estimators=10, score=0.760, total=   0.3s
[CV] max_depth=15, n_estimators=10 ...................................
[CV] ....... max_depth=15, n_estimators=10, score=0.764, total=   0.3s
[CV] max_depth=15, n_estimators=10 ...................................
[CV] ....... max_depth=15, n_estimators=10, score=0.792, total=   0.3s
[CV] max_depth=15, n_estimators=15 ...................................
[CV] ....... max_depth=15, n_estimators=15, score=0.783, total=   0.3s
[CV] max_depth=15, n_estimators=15 ...................................
[CV] ....... max_depth=15, n_estimators=15, score=0.780, total=   0.4s
[CV] max_depth=15, n_estimators=15 ...................................
[CV] ....... max_depth=15, n_estimators=15, score=0.739, total=   0.3s
[CV] max_depth=15, n_estimators=15 ...................................
[CV] ....... max_depth=15, n_estimators=15, score=0.769, total=   0.3s
[CV] max_depth=15, n_estimators=15 ...................................
[CV] ....... max_depth=15, n_estimators=15, score=0.783, total=   0.3s
[CV] max_depth=15, n_estimators=20 ...................................
[CV] ....... max_depth=15, n_estimators=20, score=0.773, total=   0.4s
[CV] max_depth=15, n_estimators=20 ...................................
[CV] ....... max_depth=15, n_estimators=20, score=0.775, total=   0.4s
[CV] max_depth=15, n_estimators=20 ...................................
[CV] ....... max_depth=15, n_estimators=20, score=0.772, total=   0.4s
[CV] max_depth=15, n_estimators=20 ...................................
[CV] ....... max_depth=15, n_estimators=20, score=0.762, total=   0.4s
```

```
[CV] max_depth=15, n_estimators=20 ....................................
[CV] ....... max_depth=15, n_estimators=20, score=0.795, total=   0.5s
[CV] max_depth=15, n_estimators=50 ....................................
[CV] ....... max_depth=15, n_estimators=50, score=0.781, total=   0.6s
[CV] max_depth=15, n_estimators=50 ....................................
[CV] ....... max_depth=15, n_estimators=50, score=0.779, total=   0.6s
[CV] max_depth=15, n_estimators=50 ....................................
[CV] ....... max_depth=15, n_estimators=50, score=0.764, total=   0.5s
[CV] max_depth=15, n_estimators=50 ....................................
[CV] ....... max_depth=15, n_estimators=50, score=0.767, total=   0.6s
[CV] max_depth=15, n_estimators=50 ....................................
[CV] ....... max_depth=15, n_estimators=50, score=0.792, total=   0.5s
[CV] max_depth=15, n_estimators=100 ....................................
[CV] ...... max_depth=15, n_estimators=100, score=0.781, total=   1.0s
[CV] max_depth=15, n_estimators=100 ....................................
[CV] ...... max_depth=15, n_estimators=100, score=0.784, total=   1.2s
[CV] max_depth=15, n_estimators=100 ....................................
[CV] ...... max_depth=15, n_estimators=100, score=0.766, total=   1.3s
[CV] max_depth=15, n_estimators=100 ....................................
[CV] ...... max_depth=15, n_estimators=100, score=0.779, total=   1.2s
[CV] max_depth=15, n_estimators=100 ....................................
[CV] ...... max_depth=15, n_estimators=100, score=0.799, total=   1.3s
[CV] max_depth=15, n_estimators=200 ....................................
[CV] ...... max_depth=15, n_estimators=200, score=0.782, total=   2.5s
[CV] max_depth=15, n_estimators=200 ....................................
[CV] ...... max_depth=15, n_estimators=200, score=0.783, total=   2.4s
[CV] max_depth=15, n_estimators=200 ....................................
[CV] ...... max_depth=15, n_estimators=200, score=0.764, total=   2.3s
[CV] max_depth=15, n_estimators=200 ....................................
[CV] ...... max_depth=15, n_estimators=200, score=0.774, total=   2.1s
[CV] max_depth=15, n_estimators=200 ....................................
[CV] ...... max_depth=15, n_estimators=200, score=0.797, total=   2.6s
[CV] max_depth=15, n_estimators=500 ....................................
[CV] ...... max_depth=15, n_estimators=500, score=0.778, total=   5.7s
[CV] max_depth=15, n_estimators=500 ....................................
[CV] ...... max_depth=15, n_estimators=500, score=0.783, total=   5.8s
[CV] max_depth=15, n_estimators=500 ....................................
[CV] ...... max_depth=15, n_estimators=500, score=0.762, total=   5.9s
[CV] max_depth=15, n_estimators=500 ....................................
[CV] ...... max_depth=15, n_estimators=500, score=0.772, total=   5.8s
[CV] max_depth=15, n_estimators=500 ....................................
[CV] ...... max_depth=15, n_estimators=500, score=0.799, total=   5.8s

[Parallel(n_jobs=1)]: Done 420 out of 420 | elapsed: 10.3min finished
```

Out[28]:

```
GridSearchCV(cv=None, error_score=nan,
             estimator=RandomForestClassifier(bootstrap=True, ccp_alpha=0.
0,
                                              class_weight=None,
                                              criterion='gini', max_depth=
None,
                                              max_features='auto',
                                              max_leaf_nodes=None,
                                              max_samples=None,
                                              min_impurity_decrease=0.0,
                                              min_impurity_split=None,
                                              min_samples_leaf=1,
                                              min_samples_split=2,
                                              min_weight_fraction_leaf=0.
0,
                                              n_estimators=100, n_jobs=-1,
                                              oob_score=False,
                                              random_state=None, verbose=
0,
                                              warm_start=False),
             iid='deprecated', n_jobs=None,
             param_grid={'max_depth': [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 1
4,
                                       15],
                         'n_estimators': [10, 15, 20, 50, 100, 200, 500]},
             pre_dispatch='2*n_jobs', refit=True, return_train_score=Fals
e,
             scoring=None, verbose=3)
```

In [29]:

```
grid_best_score_sel = grid_clf.best_score_
grid_best_parameters_sel = grid_clf.best_params_
grid_best_max_depth_sel = grid_best_parameters.get('max_depth')
grid_best_n_estimators_sel = grid_best_parameters.get('n_estimators')
print('Grid search best_score with selected features: {:.5}'.format(grid_best_score_sel
))
print('Grid search best_max_depth with selected features: {}'.format(grid_best_max_dept
h_sel))
print('Grid search best_n_estimators with selected features: {}'.format(grid_best_n_est
imators_sel))
```

```
Grid search best_score with selected features: 0.79751
Grid search best_max_depth with selected features: 7
Grid search best_n_estimators with selected features: 10
```

In [30]:

```
grid_clf_best_sel = RandomForestClassifier(n_jobs = -1,max_depth = grid_best_max_depth_
sel, n_estimators = grid_best_n_estimators_sel )
```

In [31]:

```
grid_clf_best_sel.fit(grid_X_train_sel, y_train);
```

In [32]:

```
grid_y_pred_sel = grid_clf_best_sel.predict(grid_X_test_sel)
```

In [33]:

```
print("Accuracy: {:.2%}".format(accuracy_score(y_test, grid_y_pred_sel)))
```

Accuracy: 80.38%

3.2 Random Search

After having explored a grid search, we can adopt another approach. Instead of searching for each value, let's give our model more parameters input, but instead let it choose randomly at each iteration one value for each parameter. It will then be evaluated again.

In [34]:

```
n_estimators = range(10,1000,50)
criterion = ['gini', 'entropy']
max_features = ['sqrt', 'log2', None]
bootstrap = [True,False]
max_depth = range(5,50,10)
min_samples_leaf = range(2,100, 2)
min_samples_split = range(2,100,2)

random_parameters = {'n_estimators':n_estimators, 'max_features':max_features, 'max_dep
th':max_depth, 'min_samples_leaf':
                min_samples_leaf}
```

In [35]:

```
random_clf = RandomizedSearchCV(clf, param_distributions = random_parameters, n_iter =
20, verbose = 3)
```

```python
random_clf.fit(X_train, y_train);
```

```
Fitting 5 folds for each of 20 candidates, totalling 100 fits
[CV] n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=5
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent wo
rkers.
```

```
[CV]  n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=
5, score=0.803, total=   3.9s
[CV] n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=5
```

```
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    3.9s remaining:
0.0s
```

```
[CV]  n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=
5, score=0.789, total=   4.1s
[CV] n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=5
```

```
[Parallel(n_jobs=1)]: Done   2 out of   2 | elapsed:    8.0s remaining:
0.0s
```

```
[CV]  n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=
5, score=0.771, total=   4.3s
[CV] n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=5
[CV]  n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=
5, score=0.795, total=   4.9s
[CV] n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=5
[CV]  n_estimators=410, min_samples_leaf=18, max_features=sqrt, max_depth=
5, score=0.799, total=   4.2s
[CV] n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=45
[CV]  n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=4
5, score=0.805, total=   0.3s
[CV] n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=45
[CV]  n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=4
5, score=0.801, total=   0.3s
[CV] n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=45
[CV]  n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=4
5, score=0.768, total=   0.3s
[CV] n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=45
[CV]  n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=4
5, score=0.796, total=   0.3s
[CV] n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=45
[CV]  n_estimators=10, min_samples_leaf=72, max_features=log2, max_depth=4
5, score=0.804, total=   0.3s
[CV] n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=5
[CV]  n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=
5, score=0.824, total=  10.2s
[CV] n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=5
[CV]  n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=
5, score=0.792, total=  10.4s
[CV] n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=5
[CV]  n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=
5, score=0.775, total=  10.3s
[CV] n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=5
[CV]  n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=
5, score=0.789, total=  10.3s
[CV] n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=5
[CV]  n_estimators=560, min_samples_leaf=98, max_features=None, max_depth=
5, score=0.800, total=   9.7s
[CV] n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=5
[CV]  n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=
5, score=0.820, total=   1.4s
[CV] n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=5
[CV]  n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=
5, score=0.788, total=   1.3s
[CV] n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=5
[CV]  n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=
5, score=0.773, total=   1.3s
[CV] n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=5
[CV]  n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=
5, score=0.794, total=   1.1s
[CV] n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=5
[CV]  n_estimators=60, min_samples_leaf=60, max_features=None, max_depth=
5, score=0.799, total=   1.3s
[CV] n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=3
5
[CV]  n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=
35, score=0.800, total=   1.6s
[CV] n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=3
5
[CV]  n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=
35, score=0.783, total=   1.7s
```

```
[CV] n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=3
5
[CV]  n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=
35, score=0.771, total=   1.7s
[CV] n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=3
5
[CV]  n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=
35, score=0.789, total=   1.7s
[CV] n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=3
5
[CV]  n_estimators=160, min_samples_leaf=86, max_features=log2, max_depth=
35, score=0.801, total=   1.7s
[CV] n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=5
[CV]  n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=
5, score=0.799, total=   1.4s
[CV] n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=5
[CV]  n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=
5, score=0.783, total=   1.7s
[CV] n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=5
[CV]  n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=
5, score=0.767, total=   1.9s
[CV] n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=5
[CV]  n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=
5, score=0.793, total=   2.7s
[CV] n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=5
[CV]  n_estimators=160, min_samples_leaf=78, max_features=sqrt, max_depth=
5, score=0.796, total=   2.1s
[CV] n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=
25, score=0.824, total=  16.8s
[CV] n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=
25, score=0.795, total=  12.8s
[CV] n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=
25, score=0.772, total=  12.6s
[CV] n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=
25, score=0.794, total=  11.7s
[CV] n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=26, max_features=None, max_depth=
25, score=0.797, total=  11.8s
[CV] n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=4
5
[CV]  n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=
45, score=0.798, total=   2.1s
[CV] n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=4
5
[CV]  n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=
45, score=0.786, total=   1.8s
[CV] n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=4
5
[CV]  n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=
45, score=0.772, total=   1.9s
[CV] n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=4
5
```

```
[CV]  n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=
45, score=0.789, total=   2.0s
[CV] n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=4
5
[CV]  n_estimators=210, min_samples_leaf=90, max_features=log2, max_depth=
45, score=0.798, total=   2.1s
[CV] n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=
45, score=0.815, total=   2.9s
[CV] n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=
45, score=0.800, total=   2.7s
[CV] n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=
45, score=0.777, total=   2.4s
[CV] n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=
45, score=0.803, total=   2.6s
[CV] n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=16, max_features=sqrt, max_depth=
45, score=0.800, total=   2.7s
[CV] n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=2
5
[CV]  n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=
25, score=0.796, total=   6.7s
[CV] n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=2
5
[CV]  n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=
25, score=0.784, total=   6.2s
[CV] n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=2
5
[CV]  n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=
25, score=0.769, total=   6.4s
[CV] n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=2
5
[CV]  n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=
25, score=0.790, total=   6.0s
[CV] n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=2
5
[CV]  n_estimators=660, min_samples_leaf=78, max_features=log2, max_depth=
25, score=0.801, total=   5.8s
[CV] n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=2
5
[CV]  n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=
25, score=0.828, total=   6.3s
[CV] n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=2
5
[CV]  n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=
25, score=0.786, total=   6.7s
[CV] n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=2
5
[CV]  n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=
25, score=0.773, total=   6.5s
[CV] n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=2
5
[CV]  n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=
```

```
25, score=0.790, total=   5.9s
[CV] n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=2
5
[CV]  n_estimators=310, min_samples_leaf=66, max_features=None, max_depth=
25, score=0.798, total=   6.2s
[CV] n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=
15, score=0.816, total=   5.9s
[CV] n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=
15, score=0.801, total=   5.7s
[CV] n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=
15, score=0.775, total=   5.9s
[CV] n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=
15, score=0.805, total=   5.7s
[CV] n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=18, max_features=sqrt, max_depth=
15, score=0.801, total=   5.4s
[CV] n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=
15, score=0.813, total=   5.8s
[CV] n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=
15, score=0.798, total=   5.5s
[CV] n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=
15, score=0.771, total=   5.5s
[CV] n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=
15, score=0.803, total=   4.6s
[CV] n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=1
5
[CV]  n_estimators=560, min_samples_leaf=30, max_features=sqrt, max_depth=
15, score=0.802, total=   4.4s
[CV] n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=
25, score=0.796, total=   4.3s
[CV] n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=
25, score=0.788, total=   4.8s
[CV] n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=
25, score=0.767, total=   4.7s
[CV] n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=
25, score=0.789, total=   4.2s
```

```
[CV] n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=2
5
[CV]  n_estimators=510, min_samples_leaf=98, max_features=sqrt, max_depth=
25, score=0.796, total=   3.5s
[CV] n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=5
[CV]  n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=
5, score=0.804, total=   4.3s
[CV] n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=5
[CV]  n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=
5, score=0.788, total=   4.9s
[CV] n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=5
[CV]  n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=
5, score=0.767, total=   4.5s
[CV] n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=5
[CV]  n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=
5, score=0.795, total=   4.6s
[CV] n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=5
[CV]  n_estimators=510, min_samples_leaf=24, max_features=sqrt, max_depth=
5, score=0.795, total=   4.4s
[CV] n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=
45, score=0.808, total=   2.8s
[CV] n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=
45, score=0.790, total=   2.9s
[CV] n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=
45, score=0.768, total=   2.8s
[CV] n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=
45, score=0.794, total=   3.0s
[CV] n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=360, min_samples_leaf=62, max_features=sqrt, max_depth=
45, score=0.797, total=   2.9s
[CV] n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.809, total=   5.6s
[CV] n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.789, total=   6.2s
[CV] n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.769, total=   5.3s
[CV] n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.800, total=   6.2s
[CV] n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=610, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.799, total=   5.1s
[CV] n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=1
5
```

```
[CV]  n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=
15, score=0.811, total=   3.1s
[CV] n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=1
5
[CV]  n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=
15, score=0.797, total=   3.3s
[CV] n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=1
5
[CV]  n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=
15, score=0.774, total=   3.3s
[CV] n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=1
5
[CV]  n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=
15, score=0.803, total=   3.0s
[CV] n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=1
5
[CV]  n_estimators=360, min_samples_leaf=24, max_features=log2, max_depth=
15, score=0.800, total=   3.1s
[CV] n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.808, total=   2.4s
[CV] n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.795, total=   2.2s
[CV] n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.772, total=   3.6s
[CV] n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.798, total=   3.1s
[CV] n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=4
5
[CV]  n_estimators=260, min_samples_leaf=46, max_features=sqrt, max_depth=
45, score=0.796, total=   3.1s
[CV] n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=1
5
[CV]  n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=
15, score=0.812, total=   9.0s
[CV] n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=1
5
[CV]  n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=
15, score=0.795, total=   5.8s
[CV] n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=1
5
[CV]  n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=
15, score=0.776, total=   5.1s
[CV] n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=1
5
[CV]  n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=
15, score=0.793, total=   6.5s
[CV] n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=1
5
[CV]  n_estimators=260, min_samples_leaf=14, max_features=None, max_depth=
15, score=0.805, total=   5.3s
```

```
[Parallel(n_jobs=1)]: Done 100 out of 100 | elapsed:  7.6min finished
```

Out[36]:

```
RandomizedSearchCV(cv=None, error_score=nan,
                   estimator=RandomForestClassifier(bootstrap=True,
                                                    ccp_alpha=0.0,
                                                    class_weight=None,
                                                    criterion='gini',
                                                    max_depth=None,
                                                    max_features='auto',
                                                    max_leaf_nodes=None,
                                                    max_samples=None,
                                                    min_impurity_decrease=
0.0,
                                                    min_impurity_split=Non
e,
                                                    min_samples_leaf=1,
                                                    min_samples_split=2,
                                                    min_weight_fraction_le
af=0.0,
                                                    n_estimators=100, n_
j...
                                                    oob_score=False,
                                                    random_state=None,
                                                    verbose=0,
                                                    warm_start=False),
                   iid='deprecated', n_iter=20, n_jobs=None,
                   param_distributions={'max_depth': range(5, 50, 10),
                                        'max_features': ['sqrt', 'log2', N
one],
                                        'min_samples_leaf': range(2, 100,
2),
                                        'n_estimators': range(10, 1000, 5
0)},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=3)
```

In [37]:

```
random_best_score = random_clf.best_score_
print('Random search best_score: {:.4}'.format(random_best_score))
random_best_parameters = random_clf.best_params_
```

Random search best_score: 0.7999

In [38]:

```
random_best_parameters
```

Out[38]:

```
{'n_estimators': 560,
 'min_samples_leaf': 18,
 'max_features': 'sqrt',
 'max_depth': 15}
```

In [39]:

```
random_clf_best = RandomForestClassifier(max_depth = 35, max_features = 'sqrt', min_sam
ples_leaf = 9, n_estimators = 250)
```

```
random_clf_best.fit(X_train, y_train);
```

```
random_y_pred = random_clf_best.predict(X_test)
```

```
random_cm = confusion_matrix(y_test, random_y_pred)
annot_kws = {"ha": 'center',"va": 'center'}


plt.figure(figsize=(8,8))
sns.heatmap(cm_df, annot=True, fmt="d", cmap="nipy_spectral")
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
```
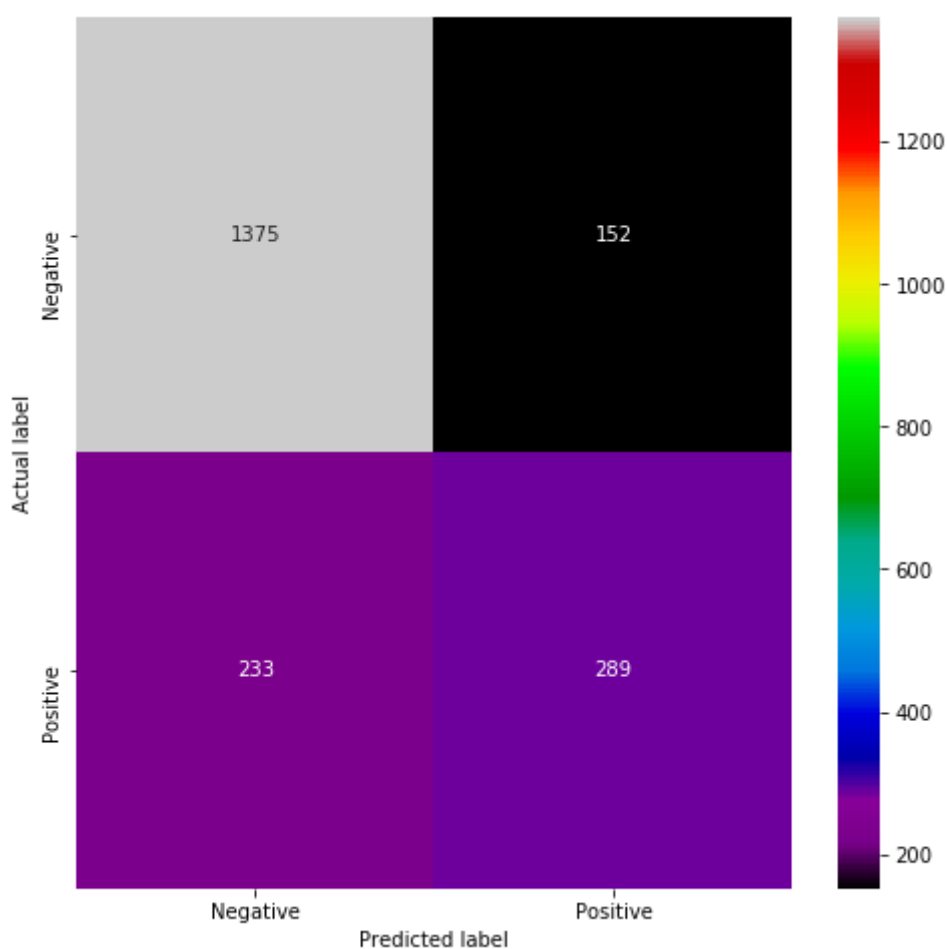
In [43]:

```python
random_feature_importances = [(list(X.columns)[i], random_clf_best.feature_importances_
[i]) for i in range(len(list(X.columns)))]
random_feature_importances.sort(key=itemgetter(1), reverse = True)
plot_importance(random_feature_importances, 10, 'Ransom search')
```

Most important feature: Ransom search

tenure
Contract:Month-to-month
TotalCharges
MonthlyCharges
OnlineSecurity:No
TechSupport:No
InternetService:Fiber optic
PaymentMethod:Electronic check
Contract:Two year
OnlineBackup:No

0%   2%   4%   6%   8%   10%   12%   14%
Importance fraction
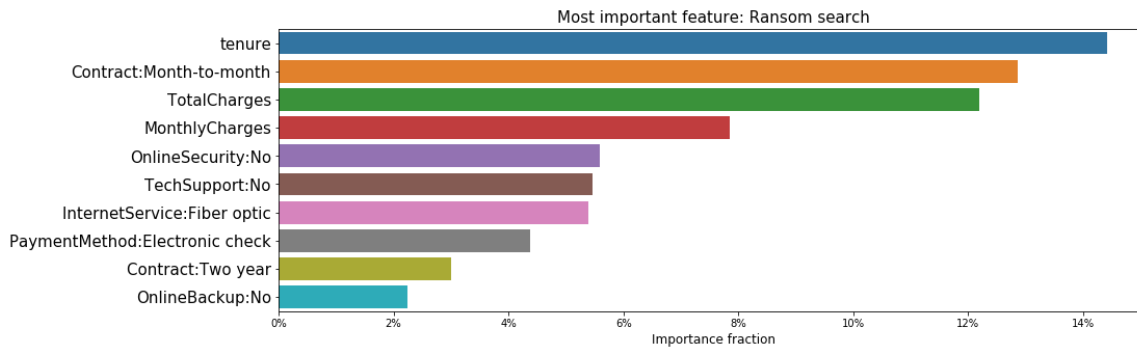
In [44]:

```python
print(classification_report(y_test,random_y_pred))
```

```
              precision    recall  f1-score   support

           0       0.85      0.91      0.88      1527
           1       0.67      0.51      0.58       522

    accuracy                           0.81      2049
   macro avg       0.76      0.71      0.73      2049
weighted avg       0.80      0.81      0.80      2049
```

In [45]:

```python
print("Accuracy: {:.2%}".format(accuracy_score(y_test, random_y_pred)))
```

Accuracy: 81.02%

3.3 Comparison

ROC Curve

In [46]:

```python
fpr_grid, tpr_grid, _ = roc_curve(y_test, grid_y_pred)
fpr_grid_sel, tpr_grid_sel, _ = roc_curve(y_test, grid_y_pred_sel)
fpr_random, tpr_random, _ = roc_curve(y_test, random_y_pred)
```

```python
plt.figure(figsize=(12, 6))
plt.plot([0, 1], [0, 1], 'k--')
plt.plot(fpr_grid, tpr_grid, label='Grid Search')
plt.plot(fpr_grid_sel, tpr_grid_sel, label='Grid Search with Selected Predictors')
plt.plot(fpr_random, tpr_random, label='Random Search')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')
plt.title('ROC curve')
plt.legend(loc='best')
plt.show()

roc_auc_grid = roc_auc_score(y_test, grid_y_pred)
print('ROC AUC for Grid Search: %.5f' % roc_auc_grid)
roc_auc_grid_sel = roc_auc_score(y_test, grid_y_pred_sel)
print('ROC AUC for Grid Search with selected predictors: %.5f' % roc_auc_grid_sel)
roc_auc_random = roc_auc_score(y_test, random_y_pred)
print('ROC AUC for Random Search: %.5f' % roc_auc_random)
```
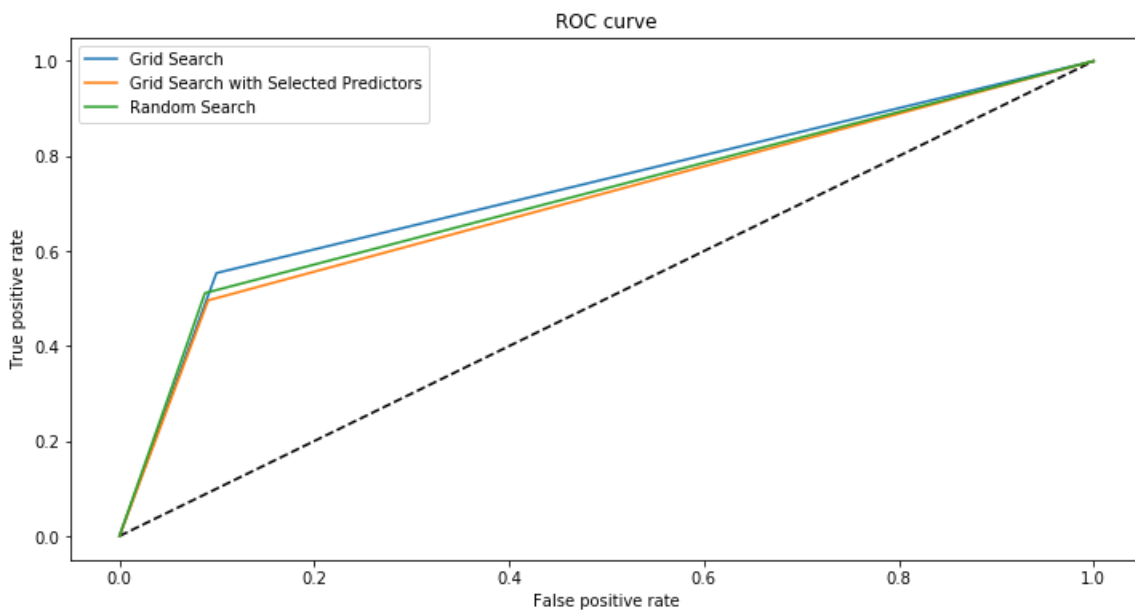


```
ROC AUC for Grid Search: 0.72705
ROC AUC for Grid Search with selected predictors: 0.70257
ROC AUC for Random Search: 0.71187
```

We observe that all three methods are better than a random prediction. The Grid Search with Selected Predictors has slightly better prediction than the Random Search, which has in turn slightly better prediction than the basic Grid Search.

```
plt.figure(figsize=(12, 6))
plt.xlim(0.05, 0.15)
plt.ylim(0.45, 0.6)
plt.plot([0, 1], [0, 1], 'k--')
plt.plot(fpr_grid, tpr_grid, label='Grid Search')
plt.plot(fpr_grid_sel, tpr_grid_sel, label='Grid Search with Selected Predictors')
plt.plot(fpr_random, tpr_random, label='Random Search')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')
plt.title('ROC curve')
plt.legend(loc='best')
plt.show()
```
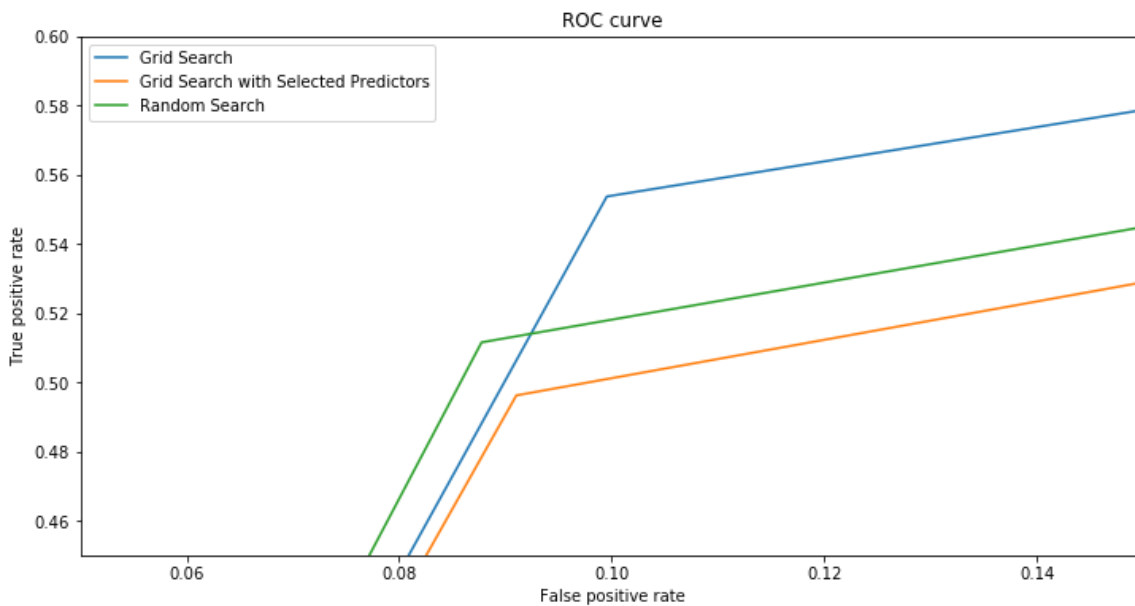

Precision - Recall Curve

```
grid_precision, grid_recall, _ = precision_recall_curve(y_test, grid_y_pred)
grid_precision_sel, grid_recall_sel, _ = precision_recall_curve(y_test, grid_y_pred_sel
)
random_precision, random_recall, _ = precision_recall_curve(y_test, random_y_pred)
```

```python
y_test = np.array(y_test)
no_skill = len(y_test[y_test == 1]) / len(y_test)

plt.figure(figsize=(12, 6))
plt.plot([0, 1], [no_skill, no_skill], linestyle='--', label='No Skill')
plt.plot(grid_recall, grid_precision, marker='.', label='Grid Search')
plt.plot(grid_recall_sel, grid_precision_sel, marker='.', label='Grid Search')
plt.plot(random_recall, random_precision, marker='.', label='Random Search')
plt.xlabel('Recall')
plt.ylabel('Precision')
plt.legend(loc='best')
plt.show()

pr_auc_grid = auc(grid_recall, grid_precision)
print('Precision-Recall AUC for Grid Search: %.5f' % pr_auc_grid)
pr_auc_grid_sel = auc(grid_recall_sel, grid_precision_sel)
print('Precision-Recall AUC for Grid Search with selected predictors: %.5f' % pr_auc_gr
id_sel)
pr_auc_random = auc(random_recall, random_precision)
print('Precision-Recall AUC for Random Search: %.5f' % pr_auc_random)
```
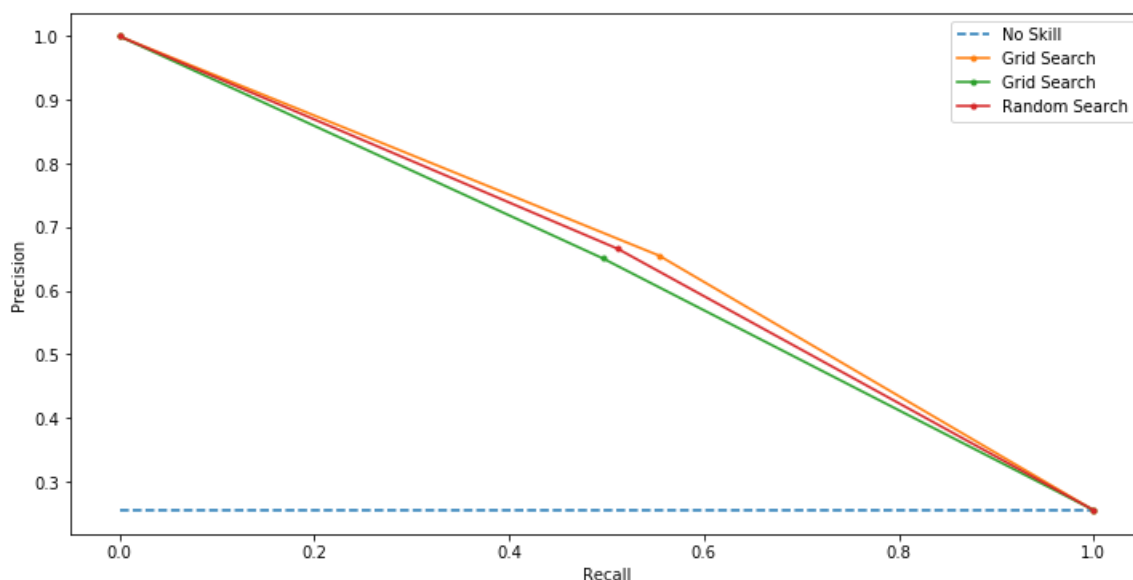


```
Precision-Recall AUC for Grid Search: 0.66134
Precision-Recall AUC for Grid Search with selected predictors: 0.63764
Precision-Recall AUC for Random Search: 0.65089
```

4. Conclusion

We illustrated two main methods which are K Nearest Neighbors and Random Forest. Each of these methods can be used differently, given the different inputs we give them or the approach we want to have. In the long run, we see that all of them approach a 80% accuracy, with small differences among them.

Analyzing the feature importance can give the company some insights into what is affecting the rate of churn and how it could help them retain a higher number of customers.