Integrating PCA in Pipelines - Lab

Introduction

In a previous section, you learned about how to use pipelines in scikit-learn to combine several supervised learning algorithms in a manageable pipeline. In this lesson, you will integrate PCA along with classifiers in the pipeline.

Objectives

In this lab you will:

- Integrate PCA in scikit-learn pipelines

The Data Science Workflow

You will be following the data science workflow:

1. Initial data inspection, exploratory data analysis, and cleaning
2. Feature engineering and selection
3. Create a baseline model
4. Create a machine learning pipeline and compare results with the baseline model
5. Interpret the model and draw conclusions

Initial data inspection, exploratory data analysis, and cleaning

You'll use a dataset created by the Otto group, which was also used in a Kaggle competition. The description of the dataset is as follows:

The Otto Group is one of the world's biggest e-commerce companies, with subsidiaries in more than 20 countries, including Crate & Barrel (USA), Otto.de (Germany) and 3 Suisses (France). They are selling millions of products worldwide every day, with several thousand products being added to their product line.

A consistent analysis of the performance of their products is crucial. However, due to their global infrastructure, many identical products get classified differently. Therefore, the quality of product analysis depends heavily on the ability to accurately cluster similar products. The better the classification, the more insights the Otto Group can generate about their product range.

In this lab, you'll use a dataset containing:

- A column `id`, which is an anonymous id unique to a product
- 93 columns `feat_1`, `feat_2`, ..., `feat_93`, which are the various features of a product
- a column `target` - the class of a product

The dataset is stored in the `'otto_group.csv'` file. Import this file into a DataFrame called `data`, and then:

- Check for missing values
- Check the distribution of columns
- ... and any other things that come to your mind to explore the data

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

```
data = pd.read_csv("otto_group.csv")
```

```
data.head()
```

<style scoped> .dataframe tbody tr th:only-of-type { vertical-align: middle; }

```
.dataframe tbody tr th {
    vertical-align: top;
}

.dataframe thead th {
    text-align: right;
}
```

</style>

	id	feat_1	feat_2	feat_3	feat_4	feat_5	feat_6	feat_7	feat_8
0	1	1	0	0	0	0	0	0	0
1	2	0	0	0	0	0	0	0	1
2	3	0	0	0	0	0	0	0	1
3	4	1	0	0	1	6	1	5	0
4	5	0	0	0	0	0	0	0	0

5 rows × 95 columns

```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 61878 entries, 0 to 61877
Data columns (total 95 columns):
id         61878 non-null int64
feat_1     61878 non-null int64
feat_2     61878 non-null int64
feat_3     61878 non-null int64
feat_4     61878 non-null int64
feat_5     61878 non-null int64
feat_6     61878 non-null int64
feat_7     61878 non-null int64
```

```
 feat_8     61878 non-null int64
 feat_9     61878 non-null int64
 feat_10    61878 non-null int64
 feat_11    61878 non-null int64
 feat_12    61878 non-null int64
 feat_13    61878 non-null int64
 feat_14    61878 non-null int64
 feat_15    61878 non-null int64
 feat_16    61878 non-null int64
 feat_17    61878 non-null int64
 feat_18    61878 non-null int64
 feat_19    61878 non-null int64
 feat_20    61878 non-null int64
 feat_21    61878 non-null int64
 feat_22    61878 non-null int64
 feat_23    61878 non-null int64
 feat_24    61878 non-null int64
 feat_25    61878 non-null int64
 feat_26    61878 non-null int64
 feat_27    61878 non-null int64
 feat_28    61878 non-null int64
 feat_29    61878 non-null int64
 feat_30    61878 non-null int64
 feat_31    61878 non-null int64
 feat_32    61878 non-null int64
 feat_33    61878 non-null int64
 feat_34    61878 non-null int64
 feat_35    61878 non-null int64
 feat_36    61878 non-null int64
 feat_37    61878 non-null int64
 feat_38    61878 non-null int64
 feat_39    61878 non-null int64
 feat_40    61878 non-null int64
 feat_41    61878 non-null int64
 feat_42    61878 non-null int64
 feat_43    61878 non-null int64
 feat_44    61878 non-null int64
 feat_45    61878 non-null int64
 feat_46    61878 non-null int64
 feat_47    61878 non-null int64
 feat_48    61878 non-null int64
 feat_49    61878 non-null int64
 feat_50    61878 non-null int64
 feat_51    61878 non-null int64
 feat_52    61878 non-null int64
 feat_53    61878 non-null int64
 feat_54    61878 non-null int64
 feat_55    61878 non-null int64
 feat_56    61878 non-null int64
```

```
 feat_57    61878 non-null int64
 feat_58    61878 non-null int64
 feat_59    61878 non-null int64
 feat_60    61878 non-null int64
 feat_61    61878 non-null int64
 feat_62    61878 non-null int64
 feat_63    61878 non-null int64
 feat_64    61878 non-null int64
 feat_65    61878 non-null int64
 feat_66    61878 non-null int64
 feat_67    61878 non-null int64
 feat_68    61878 non-null int64
 feat_69    61878 non-null int64
 feat_70    61878 non-null int64
 feat_71    61878 non-null int64
 feat_72    61878 non-null int64
 feat_73    61878 non-null int64
 feat_74    61878 non-null int64
 feat_75    61878 non-null int64
 feat_76    61878 non-null int64
 feat_77    61878 non-null int64
 feat_78    61878 non-null int64
 feat_79    61878 non-null int64
 feat_80    61878 non-null int64
 feat_81    61878 non-null int64
 feat_82    61878 non-null int64
 feat_83    61878 non-null int64
 feat_84    61878 non-null int64
 feat_85    61878 non-null int64
 feat_86    61878 non-null int64
 feat_87    61878 non-null int64
 feat_88    61878 non-null int64
 feat_89    61878 non-null int64
 feat_90    61878 non-null int64
 feat_91    61878 non-null int64
 feat_92    61878 non-null int64
 feat_93    61878 non-null int64
 target     61878 non-null object
dtypes: int64(94), object(1)
memory usage: 44.8+ MB
```

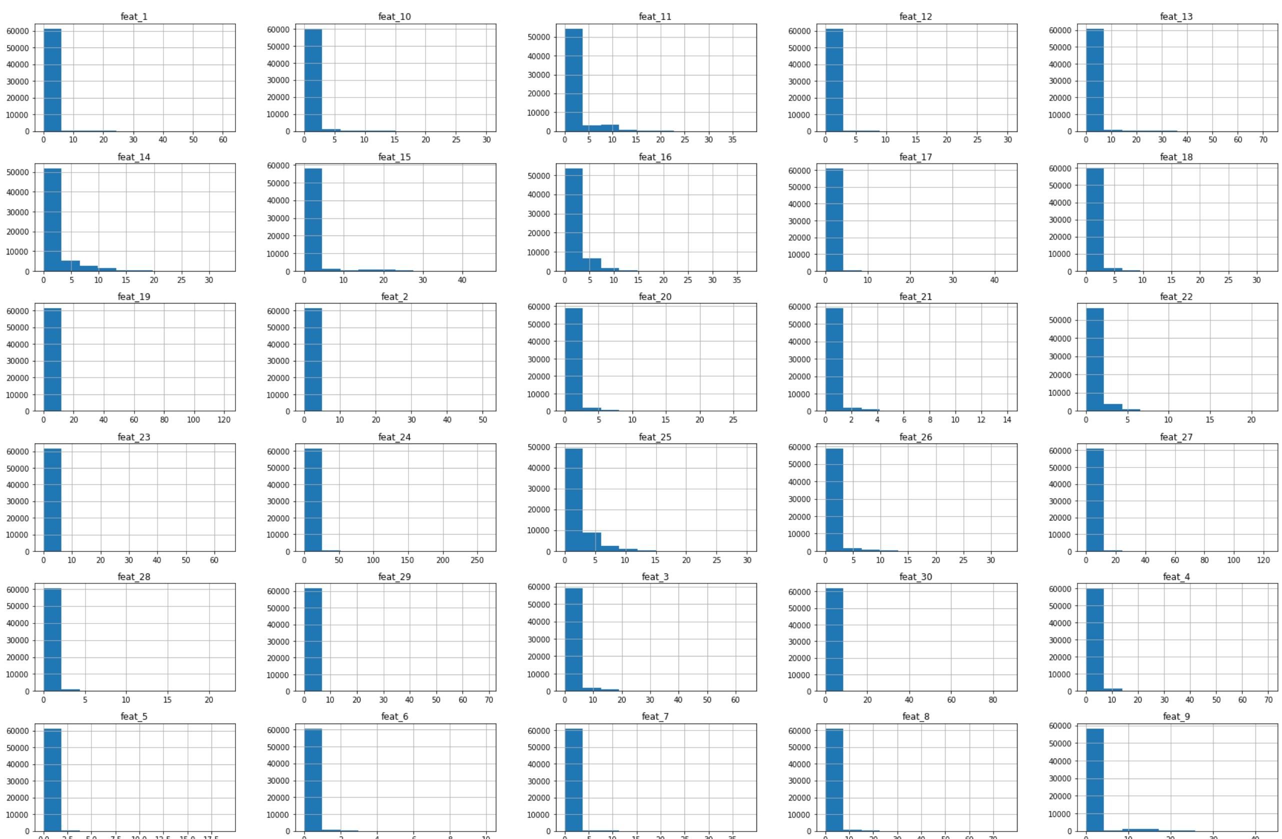
```python
data.isna().any()
```

```
id          False
feat_1      False
feat_2      False
```

```
feat_3      False
feat_4      False
feat_5      False
feat_6      False
feat_7      False
feat_8      False
feat_9      False
feat_10     False
feat_11     False
feat_12     False
feat_13     False
feat_14     False
feat_15     False
feat_16     False
feat_17     False
feat_18     False
feat_19     False
feat_20     False
feat_21     False
feat_22     False
feat_23     False
feat_24     False
feat_25     False
feat_26     False
feat_27     False
feat_28     False
feat_29     False
            ...
feat_65     False
feat_66     False
feat_67     False
feat_68     False
feat_69     False
feat_70     False
feat_71     False
feat_72     False
feat_73     False
feat_74     False
feat_75     False
feat_76     False
feat_77     False
feat_78     False
feat_79     False
feat_80     False
feat_81     False
feat_82     False
feat_83     False
feat_84     False
feat_85     False
```

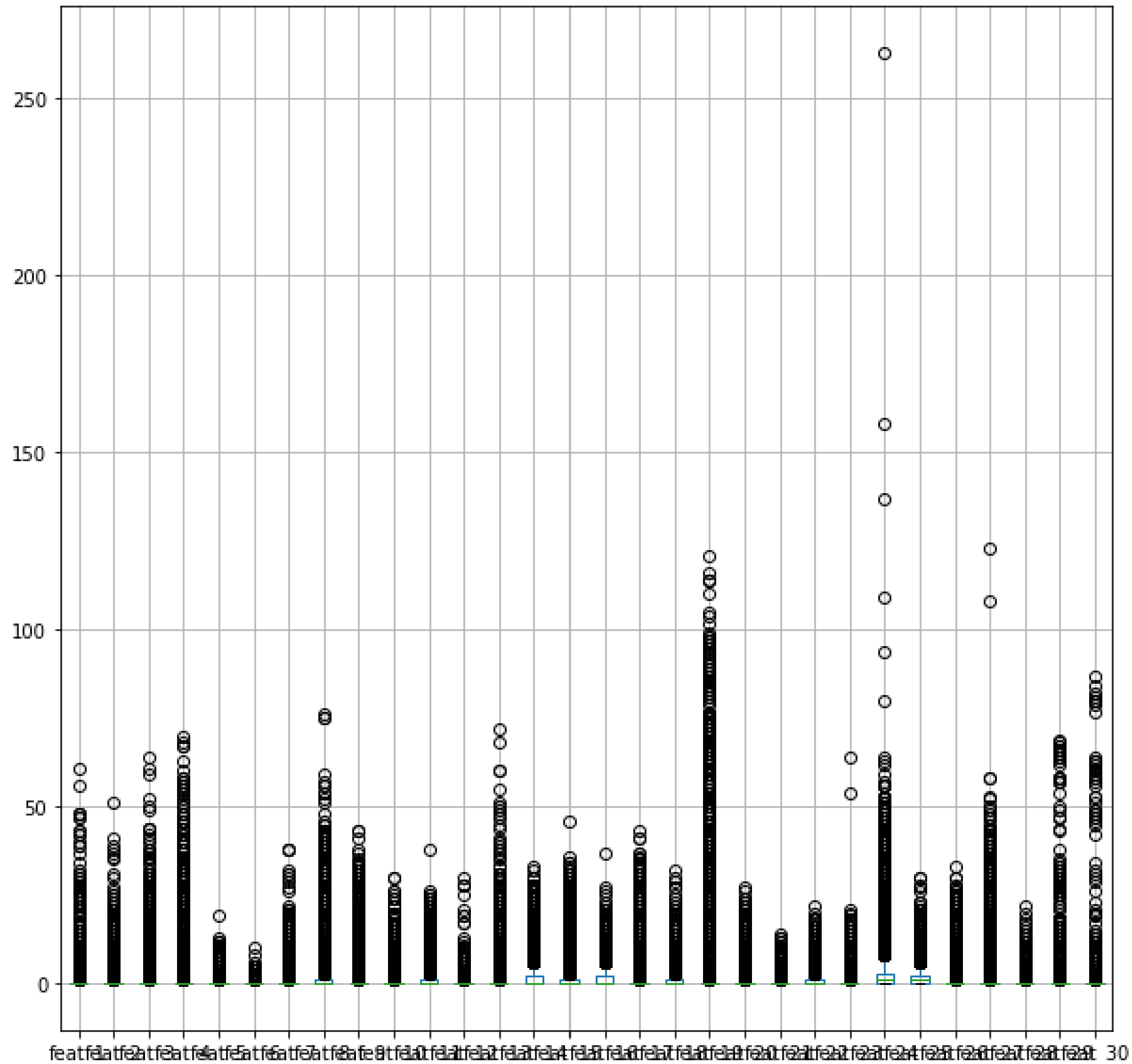
```
feat_86     False
feat_87     False
feat_88     False
feat_89     False
feat_90     False
feat_91     False
feat_92     False
feat_93     False
target      False
Length: 95, dtype: bool
```

```
# We only looked at some of the features here, make sure to do a quick check for all
feat = data.loc[:, 'feat_1':'feat_30']
feat.hist(figsize=(30,20));
```



If you look at all the histograms, you can tell that a lot of the data are zero-inflated, so most of the variables contain mostly zeros and then some higher values here and there. No normality, but for most machine learning techniques this is not an issue.

```
feat.boxplot(figsize=(10,10));
```



Because there are so many zeroes, most values above zero will seem to be outliers. The safe decision for this data is to not delete any outliers and see what happens. With many 0s, sparse data is available and high values may be super informative. Moreover, without having any intuitive meaning for each of the features, we don't know if a value of ~260 is actually an outlier.

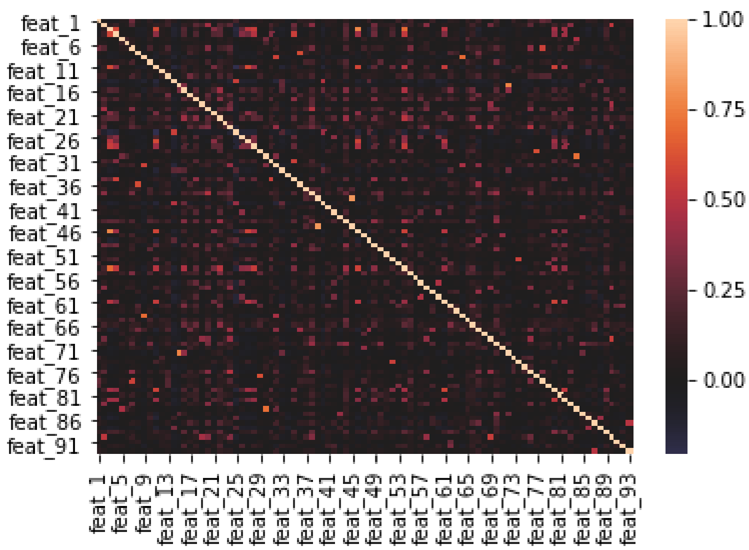
```
# Is there any missing data?

feat.isna().any().any()
```

```
False
```

Feature engineering and selection with PCA

Have a look at the correlation structure of your features using a heatmap.

```
feat = data.loc[:, 'feat_1':'feat_93']

import seaborn as sns
sns.heatmap(feat.corr(), center=0);
```

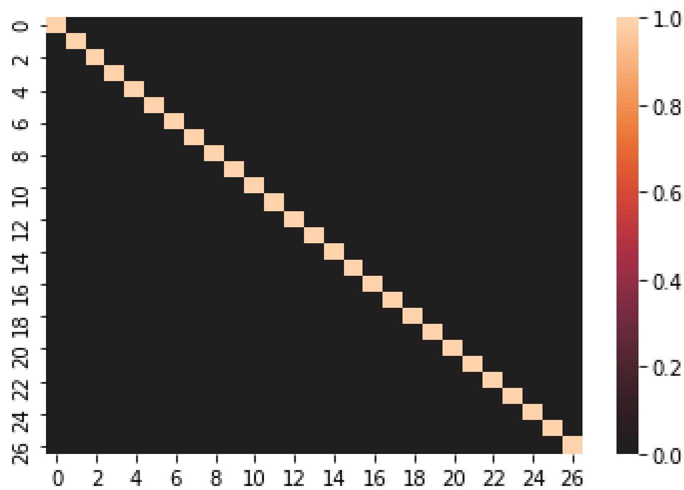


Use PCA to select a number of features in a way that you still keep 80% of your explained variance.

```
from sklearn.decomposition import PCA
pca_1 = PCA(n_components=20)
pca_2 = PCA(n_components=40)
pca_3 = PCA(n_components=60)

principalComponents = pca_1.fit_transform(feat)
principalComponents = pca_2.fit_transform(feat)
principalComponents = pca_3.fit_transform(feat)

print(np.sum(pca_1.explained_variance_ratio_))
print(np.sum(pca_2.explained_variance_ratio_))
print(np.sum(pca_3.explained_variance_ratio_))

pca = PCA(n_components=27)
principalComponents = pca.fit_transform(feat)
print(np.sum(pca.explained_variance_ratio_))
```

```
0.7275643792253975
0.8885505230944062
0.9598045557819248
0.8003287639023293
```

```
import seaborn as sns
sns.heatmap(pd.DataFrame(principalComponents).corr(), center=0);
```



Create a train-test split with a test size of 40%

This is a relatively big training set, so you can assign 40% to the test set. Set the `random_state` to 42.

```
y = data['target']
X = data.loc[:, 'feat_1':'feat_93']
```

```
# Load and split the data

from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.4, random_stat
```

Create a baseline model

Create your baseline model *in a pipeline setting*. In the pipeline:

- Your first step will be to scale your features down to the number of features that ensure you keep just 80% of your explained variance (which we saw before)
- Your second step will be to build a basic logistic regression model

Make sure to fit the model using the training set and test the result by obtaining the accuracy using the test set. Set the `random_state` to 123.

```
from sklearn.linear_model import LogisticRegression
from sklearn.pipeline import Pipeline



# Construct some pipelines
pipe_lr = Pipeline([('pca', PCA(n_components=27, random_state=123)),
                    ('clf', LogisticRegression(random_state=123))])

# Fit the pipelines
pipe_lr.fit(X_train, y_train)

print(pipe_lr.score(X_test, y_test))
```

```
0.7171541693600517
```

```
np.sum(pipe_lr.predict(X_test) == y_test)/len(y_test)
```

```
0.7171541693600517
```

Create a pipeline consisting of a linear SVM, a simple decision tree, and a simple random forest classifier

Repeat the above, but now create three different pipelines:

- One for a standard linear SVM
- One for a default decision tree
- One for a random forest classifier

```
# ⏰ This cell may take several minutes to run
from sklearn import svm
from sklearn.pipeline import Pipeline
```

```
from sklearn.ensemble import RandomForestClassifier
from sklearn import tree

## KEEP IT FOR NOW
# Construct some pipelines
pipe_svm = Pipeline([('pca', PCA(n_components=27)),
                     ('clf', svm.SVC(random_state=123))])

pipe_tree = Pipeline([('pca', PCA(n_components=27)),
                      ('clf', tree.DecisionTreeClassifier(random_state=123))])

pipe_rf = Pipeline([('pca', PCA(n_components=27)),
                    ('clf', RandomForestClassifier(random_state=123))])

# List of pipelines and pipeline names
pipelines = [pipe_svm, pipe_tree, pipe_rf]
pipeline_names = ['Support Vector Machine','Decision Tree','Random Forest']

# Loop to fit each of the three pipelines
for pipe in pipelines:
    print(pipe)
    pipe.fit(X_train, y_train)

# Compare accuracies
for index, val in enumerate(pipelines):
    print('%s pipeline test accuracy: %.3f' % (pipeline_names[index], val.score(X_te
```

```
Pipeline(memory=None,
     steps=[('pca', PCA(copy=True, iterated_power='auto', n_components=27,
random_state=None,
  svd_solver='auto', tol=0.0, whiten=False)), ('clf', SVC(C=1.0, cache_size=200,
class_weight=None, coef0=0.0,
  decision_function_shape='ovr', degree=3, gamma='auto', kernel='rbf',
  max_iter=-1, probability=False, random_state=123, shrinking=True,
  tol=0.001, verbose=False))])
Pipeline(memory=None,
     steps=[('pca', PCA(copy=True, iterated_power='auto', n_components=27,
random_state=None,
  svd_solver='auto', tol=0.0, whiten=False)), ('clf',
DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=None,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=123,
            splitter='best'))])
Pipeline(memory=None,
     steps=[('pca', PCA(copy=True, iterated_power='auto', n_components=27,
```

```
random_state=None,
  svd_solver='auto', tol=0.0, whiten=False)), ('clf',
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=None, max_features='auto', max_leaf_nodes=None,
           ...timators=10, n_jobs=1,
            oob_score=False, random_state=123, verbose=0, warm_start=False))])
Support Vector Machine pipeline test accuracy: 0.749
Decision Tree pipeline test accuracy: 0.666
Random Forest pipeline test accuracy: 0.745
```

Pipeline with grid search

Construct two pipelines with grid search:

- one for random forests - try to have around 40 different models
- one for the AdaBoost algorithm

Random Forest pipeline with grid search

```
# imports
from sklearn import svm
from sklearn.model_selection import GridSearchCV
from sklearn.pipeline import Pipeline
```

```
# ⏰ This cell may take a long time to run!
# Construct pipeline
pipe_rf = Pipeline([('pca', PCA(n_components=27)),
                    ('clf', RandomForestClassifier(random_state = 123))])

# Set grid search params
param_grid_forest = [
  {'clf__n_estimators': [120],
   'clf__criterion': ['entropy', 'gini'],
   'clf__max_depth': [4, 5, 6],
   'clf__min_samples_leaf':[0.05 ,0.1, 0.2],
   'clf__min_samples_split':[0.05 ,0.1, 0.2]
  }
]

# Construct grid search
gs_rf = GridSearchCV(estimator=pipe_rf,
                     param_grid=param_grid_forest,
                     scoring='accuracy',
```

```
                        cv=3, verbose=2, return_train_score = True)

# Fit using grid search
gs_rf.fit(X_train, y_train)

# Best accuracy
print('Best accuracy: %.3f' % gs_rf.best_score_)

# Best params
print('\nBest params:\n', gs_rf.best_params_)
```

```
Fitting 3 folds for each of 54 candidates, totalling 162 fits
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.2s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120


[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    7.4s remaining:    0.0s


[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.2s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.3s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.1s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.2s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.2s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.3s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
```

```
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
```

```
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.5s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.5s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.5s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.6s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.7s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.5s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
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clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.6s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.3s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.5s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
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[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.5s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.6s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.8s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.5s
[CV] clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   8.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   8.0s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
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clf__min_samples_split=0.05, clf__n_estimators=120, total=   7.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.5s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.7s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   7.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.5s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   6.5s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
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[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
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[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.8s
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[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.7s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
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[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   4.8s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
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[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
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clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
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[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=entropy, clf__max_depth=6, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.4s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
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clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.9s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.9s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.9s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.5s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.5s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.5s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
```

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[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   1.9s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   1.9s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
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[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
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clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=4, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   1.9s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.2s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.2s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.3s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.2s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.2s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.2s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.6s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.5s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.6s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.1s
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[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.05, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.1, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.1, clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.1s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.05, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2, clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
```

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clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   1.9s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=5, clf__min_samples_leaf=0.2,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   2.0s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.4s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.3s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.05, clf__n_estimators=120, total=   4.3s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.3s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.3s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.1, clf__n_estimators=120, total=   4.3s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.6s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
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[CV]  clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120, total=   3.5s
[CV] clf__criterion=gini, clf__max_depth=6, clf__min_samples_leaf=0.05,
clf__min_samples_split=0.2, clf__n_estimators=120
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[Parallel(n_jobs=1)]: Done 162 out of 162 | elapsed: 11.1min finished


Best accuracy: 0.623

Best params:
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Use your grid search object along with `.cv_results` to get the full result overview

```
gs_rf.cv_results_
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```

```
# ⏰ This cell may take several minutes to run
from sklearn.ensemble import AdaBoostClassifier
# Construct pipeline
pipe_ab = Pipeline([('pca', PCA(n_components=27)),
                    ('clf', AdaBoostClassifier(random_state = 123))])

# Set grid search params
adaboost_param_grid = {
    'clf__n_estimators': [30, 50, 70],
```

```
    'clf__learning_rate': [1.0, 0.5, 0.1]
}

# Construct grid search
gs_ab = GridSearchCV(estimator=pipe_ab,
            param_grid=adaboost_param_grid,
            scoring='accuracy',
            cv=3, verbose=2, return_train_score = True)

# Fit using grid search
gs_ab.fit(X_train, y_train)

# Best accuracy
print('Best accuracy: %.3f' % gs_ab.best_score_)

# Best params
print('\nBest params:\n', gs_ab.best_params_)
```

```
Fitting 3 folds for each of 9 candidates, totalling 27 fits
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[CV] ..... clf__learning_rate=1.0, clf__n_estimators=30, total=   3.6s
[CV] clf__learning_rate=1.0, clf__n_estimators=30 ....................


[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    3.8s remaining:    0.0s


[CV] ..... clf__learning_rate=1.0, clf__n_estimators=30, total=   3.6s
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```

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[CV] clf__learning_rate=0.1, clf__n_estimators=70 ...................
[CV] ..... clf__learning_rate=0.1, clf__n_estimators=70, total=   8.1s


[Parallel(n_jobs=1)]: Done  27 out of  27 | elapsed:  2.7min finished


Best accuracy: 0.665

Best params:
 {'clf__learning_rate': 0.5, 'clf__n_estimators': 70}
```

Use your grid search object along with `.cv_results` to get the full result overview:

```
gs_ab.cv_results_
```

Level-up (Optional): SVM pipeline with grid search

As extra level-up work, construct a pipeline with grid search for support vector machines.

- Make sure your grid isn't too big. You'll see it takes quite a while to fit SVMs with non-linear kernel functions!

```
# ⏰ This cell may take a very long time to run!
# Construct pipeline
pipe_svm = Pipeline([('pca', PCA(n_components=27)),
                     ('clf', svm.SVC(random_state=123))])

# Set grid search params
param_grid_svm = [
  {'clf__C': [0.1, 1, 10] , 'clf__kernel': ['linear']},
  {'clf__C': [1, 10], 'clf__gamma': [0.001, 0.01], 'clf__kernel': ['rbf']},
 ]

# Construct grid search
gs_svm = GridSearchCV(estimator=pipe_svm,
                      param_grid=param_grid_svm,
                      scoring='accuracy',
                      cv=3, verbose=2, return_train_score = True)

# Fit using grid search
gs_svm.fit(X_train, y_train)

# Best accuracy
print('Best accuracy: %.3f' % gs_svm.best_score_)

# Best params
print('\nBest params:\n', gs_svm.best_params_)
```

Use your grid search object along with `.cv_results` to get the full result overview:

```
gs_svm.cv_results_
```

Note

Note that this solution is only one of many options. The results in the Random Forest and AdaBoost models show that there is a lot of improvement possible by tuning the hyperparameters further, so make sure to explore this yourself!

Summary

Great! You've gotten a lot of practice in using PCA in pipelines. What algorithm would you choose and why?

Releases

No releases published

Packages

No packages published

Contributors 2


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Languages

- **Jupyter Notebook** 100.0%