Heart_disease

January 31, 2024

[1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score, precision_score
from sklearn.model_selection import GridSearchCV, RandomizedSearchCV
```

[2]:
```
data = pd.read_csv('heart.csv')
data.info
```

[2]:
```
<bound method DataFrame.info of       age  sex  cp  trestbps  chol  fbs  restecg
thalach  exang  oldpeak  \
0      52    1   0       125   212    0        1      168      0      1.0
1      53    1   0       140   203    1        0      155      1      3.1
2      70    1   0       145   174    0        1      125      1      2.6
3      61    1   0       148   203    0        1      161      0      0.0
4      62    0   0       138   294    1        1      106      0      1.9
…    …   …   ..       …    …  …       …      …    …       …
1020   59    1   1       140   221    0        1      164      1      0.0
1021   60    1   0       125   258    0        0      141      1      2.8
1022   47    1   0       110   275    0        0      118      1      1.0
1023   50    0   0       110   254    0        0      159      0      0.0
1024   54    1   0       120   188    0        1      113      0      1.4

      slope  ca  thal  target
0         2   2     3       0
1         0   0     3       0
2         0   0     3       0
3         2   1     3       0
4         1   3     2       0
…     …  ..   …     …
1020      2   0     2       1
1021      1   1     3       0
1022      1   1     2       0
1023      2   0     2       1
```

```
1024      1   1     3       0

[1025 rows x 14 columns]>
```

[3]:
```
# Has 14 different features
data.head()
```

[3]:

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target
0	52	1	0	125	212	0	1	168	0	1.0	2	2	3	0
1	53	1	0	140	203	1	0	155	1	3.1	0	0	3	0
2	70	1	0	145	174	0	1	125	1	2.6	0	0	3	0
3	61	1	0	148	203	0	1	161	0	0.0	2	1	3	0
4	62	0	0	138	294	1	1	106	0	1.9	1	3	2	0

[4]:
```
# In order:
# age
# sex
# chest pain type (4 values)
# resting blood pressure
# serum cholestoral in mg/dl
# fasting blood sugar > 120 mg/dl
# resting electrocardiographic results (values 0,1,2)
# maximum heart rate achieved
# exercise induced angina
# oldpeak = ST depression induced by exercise relative to rest
# the slope of the peak exercise ST segment
# number of major vessels (0-3) colored by flourosopy
# thal: 0 = normal; 1 = fixed defect; 2 = reversable defect
```

[5]:
```
# Check for duplicates
data.duplicated().sum()
```

[5]:
```
723
```

[6]:
```
# Drop them
data = data.drop_duplicates()
```

[7]:
```
data.shape
```

[7]:
```
(302, 14)
```

[8]:
```
count = data['target'].value_counts()
healthy = count[0]
diseased = count[1]

print("Count of healthy people:", healthy)
print("Count of sick people:", diseased)
```

```
Count of healthy people: 138
Count of sick people: 164
```

[9]:
```
# Let's look some leading risk factors when it comes to heart diseases

plt.figure(figsize=(10, 4))
sns.countplot(x="age", data=data, linewidth=2, hue = "target")
plt.xticks(rotation=45, ha="right")
plt.tight_layout()
plt.title("Diseased vs. healthy (age)")
plt.show()

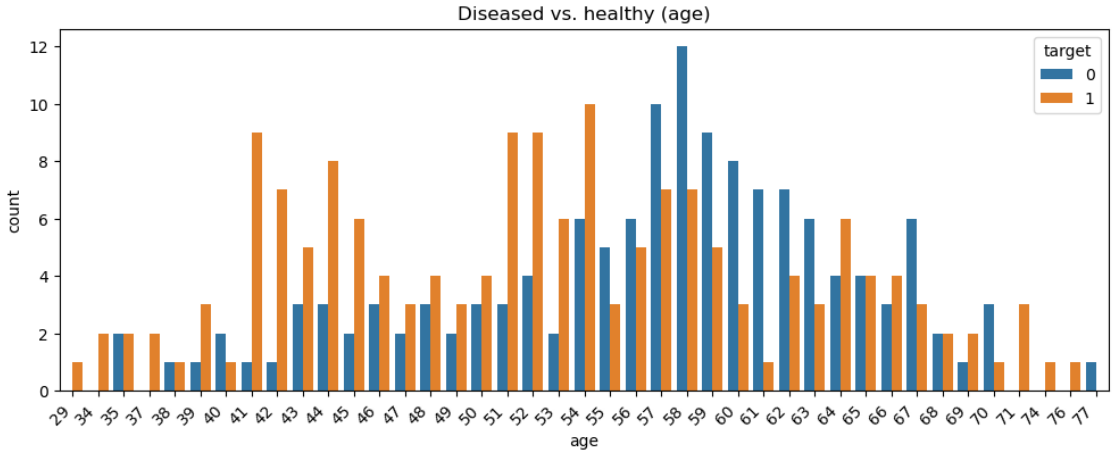
plt.figure(figsize=(10, 4))
sns.countplot(x="sex", data=data, linewidth=2, hue = "target")
plt.tight_layout()
plt.title("Diseased vs. healthy (sex)")
plt.show()

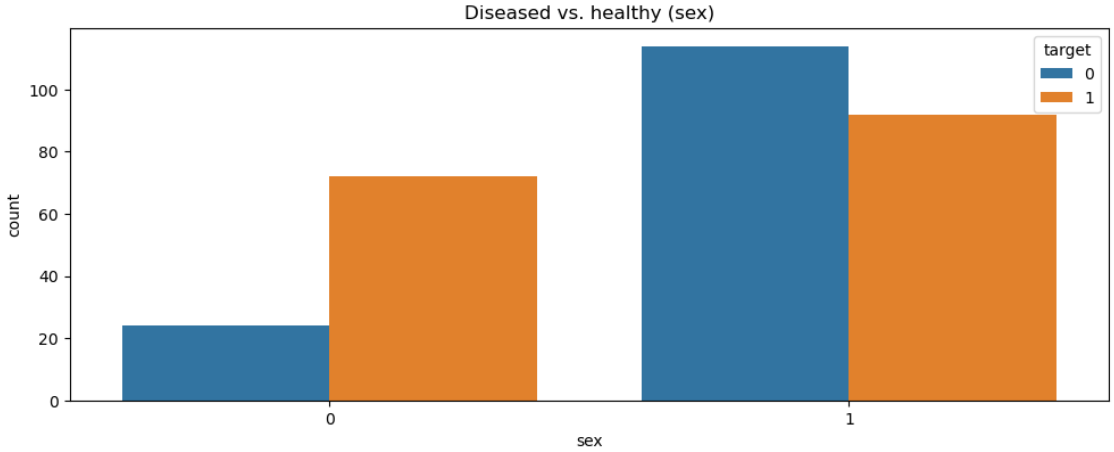
plt.figure(figsize=(10, 4))
sns.countplot(x="trestbps", data=data, linewidth=2, hue = "target")
plt.xticks(rotation=45, ha="right")
plt.tight_layout()
plt.title("Diseased vs. healthy (resting blood pressure)")
plt.show()

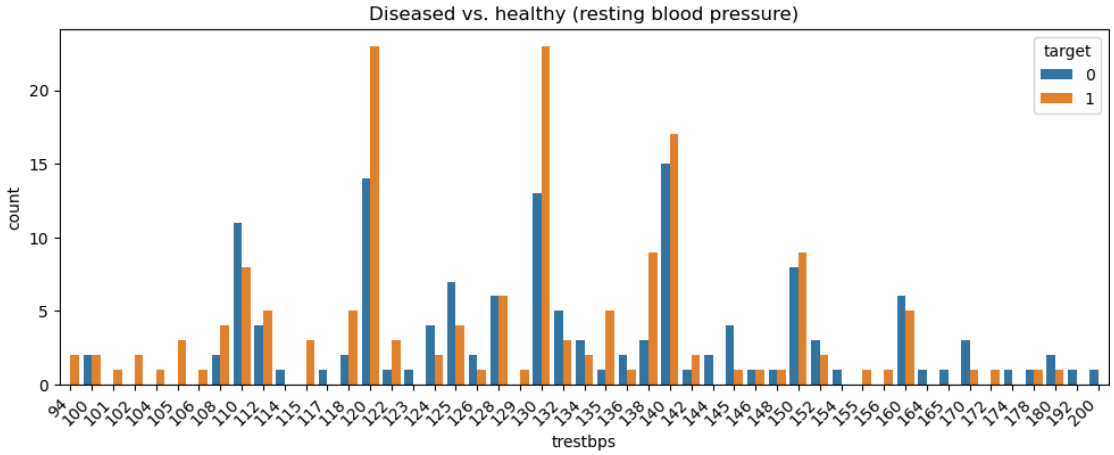
# Cholesterol has such a wide range of values, making plotting difficult
# Let's categorize (normal: <200, borderline high:200 to 239, high: >=240)
# Let's give them numerical values [0,1,2]

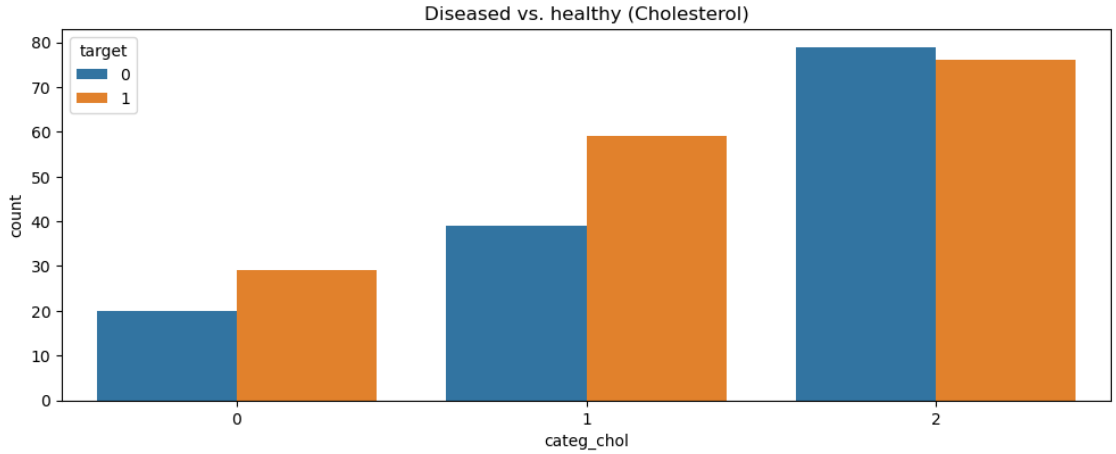
chol_labels = [0,1,2]
max_chol = data['chol'].max()
min_chol = data['chol'].min()
cut_bins = [min_chol,199, 239, max_chol]
categ_chol = pd.cut(data['chol'], bins = cut_bins,labels = chol_labels,␣
 ↪include_lowest=True)
data.insert(5,'categ_chol',categ_chol)
plt.figure(figsize=(10, 4))
sns.countplot(x="categ_chol", data=data, linewidth=2, hue = "target")
plt.tight_layout()
plt.title("Diseased vs. healthy (Cholesterol)")
```

```
plt.show()
```


Diseased vs. healthy (age)
target
0
1
count
age


Diseased vs. healthy (sex)
target
0
1
count
sex


Diseased vs. healthy (resting blood pressure)
target
0
1
count
trestbps



[10]:
```
# Let's see how the features look in each group
data.head()
```

[10]:

	age	sex	cp	trestbps	chol	categ_chol	fbs	restecg	thalach	exang	\
0	52	1	0	125	212	1	0	1	168	0	
1	53	1	0	140	203	1	1	0	155	1	
2	70	1	0	145	174	0	0	1	125	1	
3	61	1	0	148	203	1	0	1	161	0	
4	62	0	0	138	294	2	1	1	106	0	

	oldpeak	slope	ca	thal	target
0	1.0	2	2	3	0
1	3.1	0	0	3	0
2	2.6	0	0	3	0
3	0.0	2	1	3	0
4	1.9	1	3	2	0

[11]:
```
# Let's see what kind of values we have
data.dtypes
```

[11]:
```
age              int64
sex              int64
cp               int64
trestbps         int64
chol             int64
categ_chol    category
fbs              int64
restecg          int64
thalach          int64
```

```
exang            int64
oldpeak        float64
slope            int64
ca               int64
thal             int64
target           int64
dtype: object
```

[12]:
```
# Let's also check that we don't have invalid values
data.isnull().sum()
```

[12]:
```
age           0
sex           0
cp            0
trestbps      0
chol          0
categ_chol    0
fbs           0
restecg       0
thalach       0
exang         0
oldpeak       0
slope         0
ca            0
thal          0
target        0
dtype: int64
```

[13]:
```
# Since there are a lot of variables wtih little data, Random Forest will most␣
 ↪likely be our best bet
# Let's extract the data
X=data.iloc[:,0:-1]
y=data["target"]
```

[14]:
```
y.head()
```

[14]:
```
0    0
1    0
2    0
3    0
4    0
Name: target, dtype: int64
```

[15]:
```
X.head()
```

[15]:
```
   age  sex  cp  trestbps  chol categ_chol  fbs  restecg  thalach  exang  \
0   52    1   0       125   212          1    0        1      168      0
```

```
1   53    1   0        140   203          1    1         0       155       1
2   70    1   0        145   174          0    0         1       125       1
3   61    1   0        148   203          1    0         1       161       0
4   62    0   0        138   294          2    1         1       106       0

   oldpeak  slope  ca  thal
0      1.0      2   2     3
1      3.1      0   0     3
2      2.6      0   0     3
3      0.0      2   1     3
4      1.9      1   3     2
```

[16]:
```
# Let's drop our categorial cholestrol so we get our original data back
X = X.drop(columns = ["categ_chol"])
```

[17]:
```
# Let's do a basic split of 80:20 in repect to training set and test set
X_train, X_test, y_train, y_test= train_test_split(X,y,test_size=0.
 ↪2,random_state=42)
rf = RandomForestClassifier()
print(X_train.shape)
print(y_train.shape)
```

```
(241, 13)
(241,)
```

[34]:
```
rf.fit(X_train, y_train)
y_pred = rf.predict(X_test)
acc = accuracy_score(y_test, y_pred)
prec = precision_score(y_test, y_pred)
print("Accuracy:",acc,"\nPrecision:",prec)
```

```
Accuracy: 0.8524590163934426
Precision: 0.8125
```

[19]:
```
# Let's analyse the performance score with cross validation
np.mean(cross_val_score(RandomForestClassifier(),X,y,scoring='accuracy'))
```

[19]:
```
0.8343169398907104
```

[20]:
```
# Since RandomForest can takes so many different parameters, such as number of␣
 ↪trees, depth, samples, which may affect the result as they vary.
# Let's try to find the most optimal parameters using GridSearchCV
```

[21]:
```
# Some parameter values for GridSearch to analyse, when our model is␣
 ↪RandomForest

# Number of trees in random forest
```

```
n_estimators=[20,60,100,120]

# Number of features to consider at every split
max_features=[0.2,0.6,1.0]

# Maximum number of levels in tree
max_depth=[2,4,8,None]

#Number of samples
max_samples=[0.5,0.75,1.0]
```

[22]:
```
parameter_grid={'n_estimators':n_estimators,
           'max_features': max_features,
           'max_depth':max_depth,
           'max_samples': max_samples
           }
print(parameter_grid)
```

```
{'n_estimators': [20, 60, 100, 120], 'max_features': [0.2, 0.6, 1.0],
'max_depth': [2, 4, 8, None], 'max_samples': [0.5, 0.75, 1.0]}
```

[23]:
```
# Let's initialize our GridSearch
rf_grid=GridSearchCV(estimator=RandomForestClassifier(),
                     param_grid=parameter_grid,
                     cv=5,
                     verbose=2,
                     n_jobs=-1)
# And execute
rf_grid.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 144 candidates, totalling 720 fits
[CV] END max_depth=2, max_features=0.2, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=0.2, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.2, max_samples=0.5, n_estimators=120; total
time=   0.3s
[CV] END max_depth=2, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=2, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
```

```
[CV] END max_depth=2, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=2, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.2, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.2, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.2, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=0.6, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=0.6, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=2, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
```

```
[CV] END max_depth=2, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=1.0, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=1.0, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=2, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=2, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=2, max_features=1.0, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=1.0, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=2, max_features=1.0, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=1.0, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=2, max_features=1.0, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=2, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.2, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
```

```
[CV] END max_depth=4, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.2, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=0.6, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=1.0, max_samples=0.5, n_estimators=100; total
time=   0.2s
```

```
[CV] END max_depth=4, max_features=1.0, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=4, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=4, max_features=1.0, max_samples=1.0, n_estimators=20; total
time=   0.0s
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time=   0.2s
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time=   0.0s
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total time=   0.3s
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time=   0.2s
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time=   0.1s
[CV] END max_depth=2, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
```

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[CV] END max_depth=2, max_features=0.6, max_samples=0.75, n_estimators=20; total
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[CV] END max_depth=2, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
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total time=   0.2s
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total time=   0.2s
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total time=   0.2s
```

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total time=   0.2s
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time=   0.2s
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time=   0.0s
```

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time=   0.2s
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time=   0.1s
```

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total time=   0.2s
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total time=   0.2s
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time=   0.1s
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time=   0.1s
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time=   0.1s
[CV] END max_depth=2, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
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time=   0.1s
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total time=   0.2s
```

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[CV] END max_depth=2, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
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time=   0.2s
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total time=   0.2s
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time=   0.2s
```

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total time=   0.2s
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total time=   0.2s
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total time=   0.2s
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time=   0.1s
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time=   0.2s
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time=   0.2s
```

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time=   0.1s
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time=   0.2s
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total time=   0.2s
```

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time=   0.2s
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time=   0.1s
```

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time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=60; total
time=   0.1s
```

```
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=100; total
time=   0.2s
```

```
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=20;
total time=   0.0s
```

```
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=60;
total time=   0.1s
```

```
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=60;
total time=   0.1s[CV] END max_depth=4, max_features=1.0, max_samples=1.0,
n_estimators=60; total time=   0.1s
[CV] END max_depth=4, max_features=1.0, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=4, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=100; total
```

```
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=100; total
```

```
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=120; total
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[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=120;
```

```
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=4, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=20; total
```

```
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.2, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=100;
```

```
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=0.6, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.5, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=20; total
time=   0.0s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=60; total
time=   0.1s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=100; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=8, max_features=1.0, max_samples=1.0, n_estimators=120; total
time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=100;
```

```
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.2, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=0.6, max_samples=1.0, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=20;
```

```
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.5, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=60;
total time=   0.1s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=100;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=0.75, n_estimators=120;
total time=   0.2s
[CV] END max_depth=None, max_features=1.0, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=1.0, n_estimators=20;
total time=   0.0s
[CV] END max_depth=None, max_features=1.0, max_samples=1.0, n_estimators=20;
total time=   0.0s
```

[23]:
```
GridSearchCV(cv=5, estimator=RandomForestClassifier(), n_jobs=-1,
             param_grid={'max_depth': [2, 4, 8, None],
                         'max_features': [0.2, 0.6, 1.0],
                         'max_samples': [0.5, 0.75, 1.0],
                         'n_estimators': [20, 60, 100, 120]},
             verbose=2)
```

[24]:
```
rf_grid.best_params_
```

[24]:
```
{'max_depth': 8, 'max_features': 0.2, 'max_samples': 0.5, 'n_estimators': 60}
```

[25]:
```
rf_grid.best_score_
```

[25]:
```
0.842517006802721
```

[26]:
```
# We can also do RandomSearchCV.
# The parameters of the estimator used to apply these methods are optimized by␣
 ↪cross-validated search over parameter settings.

# In contrast to GridSearchCV, not all parameter values are tried out, but␣
 ↪rather a fixed number of parameter settings is sampled from the specified␣
 ↪distributions.
# The number of parameter settings that are tried is given by n_iter.
```

```
# If all parameters are presented as a list, sampling without replacement is␣
 ↪performed.
# If at least one parameter is given as a distribution, sampling with␣
 ↪replacement is used. It is highly recommended to use continuous␣
 ↪distributions for continuous parameters.

# Number of trees in random forest
n_estimators = [20,60,100,120]

# Number of features to consider at every split
max_features = [0.2,0.6,1.0]

# Maximum number of levels in tree
max_depth = [2,8,None]

# Number of samples
max_samples = [0.5,0.75,1.0]

# Bootstrap samples
bootstrap = [True,False]

# Minimum number of samples required to split a node
min_samples_split = [2, 5]

# Minimum number of samples required at each leaf node
min_samples_leaf = [1, 2]
```

[27]:
```
parameter_grid={'n_estimators':n_estimators,
                'max_features': max_features,
                'max_depth':max_depth,
                'max_samples': max_samples,
                'bootstrap': bootstrap,
                'min_samples_split': min_samples_split,
                'min_samples_leaf': min_samples_leaf
           }
print(parameter_grid)
```

```
{'n_estimators': [20, 60, 100, 120], 'max_features': [0.2, 0.6, 1.0],
'max_depth': [2, 8, None], 'max_samples': [0.5, 0.75, 1.0], 'bootstrap': [True,
False], 'min_samples_split': [2, 5], 'min_samples_leaf': [1, 2]}
```

[30]:
```
rf_grid=RandomizedSearchCV(estimator= RandomForestClassifier(),
                           param_distributions=parameter_grid,
                           cv=5,
                           verbose=2,
                           n_jobs=-1)
```

[31]:
```
rf_grid.fit(X_train,y_train)
```

```
Fitting 5 folds for each of 10 candidates, totalling 50 fits

/opt/software/lib/python3.10/site-
packages/sklearn/model_selection/_validation.py:378: FitFailedWarning:
25 fits failed out of a total of 50.
The score on these train-test partitions for these parameters will be set to
nan.
If these failures are not expected, you can try to debug them by setting
error_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
25 fits failed with the following error:
Traceback (most recent call last):
  File "/opt/software/lib/python3.10/site-
packages/sklearn/model_selection/_validation.py", line 686, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/software/lib/python3.10/site-packages/sklearn/ensemble/_forest.py",
line 397, in fit
    raise ValueError(
ValueError: `max_sample` cannot be set if `bootstrap=False`. Either switch to
`bootstrap=True` or set `max_sample=None`.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/opt/software/lib/python3.10/site-
packages/sklearn/model_selection/_search.py:952: UserWarning: One or more of the
test scores are non-finite: [       nan 0.81760204 0.79676871 0.81335034
nan 0.77185374
        nan        nan 0.82168367        nan]
  warnings.warn(
```

[31]:
```
RandomizedSearchCV(cv=5, estimator=RandomForestClassifier(), n_jobs=-1,
                   param_distributions={'bootstrap': [True, False],
                                        'max_depth': [2, 8, None],
                                        'max_features': [0.2, 0.6, 1.0],
                                        'max_samples': [0.5, 0.75, 1.0],
                                        'min_samples_leaf': [1, 2],
                                        'min_samples_split': [2, 5],
                                        'n_estimators': [20, 60, 100, 120]},
                   verbose=2)
```

[32]:
```
rf_grid.best_params_
```

[32]:
```
{'n_estimators': 120,
 'min_samples_split': 2,
 'min_samples_leaf': 2,
```

```
 'max_samples': 1.0,
 'max_features': 0.2,
 'max_depth': 8,
 'bootstrap': True}
```

[33]:
```
rf_grid.best_score_
```

[33]:
```
0.8216836734693878
```

[ ]:
```

```