In [130…
```
from sklearn import datasets
import numpy as np
import pandas as pd
import matplotlib as plt
import seaborn as sns
import matplotlib.pyplot as plt

# imports for decision tree
from sklearn.preprocessing import StandardScaler
from sklearn.tree import DecisionTreeClassifier
from sklearn import tree

# remove unnecesary warnings
import warnings
warnings.filterwarnings('ignore')
```

In [130…
```
breast_cancer = datasets.load_breast_cancer()
```

In [130…
```
print (breast_cancer.feature_names)
print("======================================================================")
print (breast_cancer.target_names)
```

```
['mean radius' 'mean texture' 'mean perimeter' 'mean area'
 'mean smoothness' 'mean compactness' 'mean concavity'
 'mean concave points' 'mean symmetry' 'mean fractal dimension'
 'radius error' 'texture error' 'perimeter error' 'area error'
 'smoothness error' 'compactness error' 'concavity error'
 'concave points error' 'symmetry error' 'fractal dimension error'
 'worst radius' 'worst texture' 'worst perimeter' 'worst area'
 'worst smoothness' 'worst compactness' 'worst concavity'
 'worst concave points' 'worst symmetry' 'worst fractal dimension']
======================================================================
['malignant' 'benign']
```

In [131…
```
df = pd.DataFrame(data=breast_cancer.data, columns=breast_cancer.feature_names)
df['target'] = breast_cancer.target
df.head()
```

Out[131…

	mean radius	mean texture	mean perimeter	mean area	mean smoothness	mean compactness	mean concavity	mean concave points	mean symmetry	mean fractal dimension	...	worst texture	worst perimeter	wors are
0	17.99	10.38	122.80	1001.0	0.11840	0.27760	0.3001	0.14710	0.2419	0.07871	...	17.33	184.60	2019.
1	20.57	17.77	132.90	1326.0	0.08474	0.07864	0.0869	0.07017	0.1812	0.05667	...	23.41	158.80	1956.
2	19.69	21.25	130.00	1203.0	0.10960	0.15990	0.1974	0.12790	0.2069	0.05999	...	25.53	152.50	1709.
3	11.42	20.38	77.58	386.1	0.14250	0.28390	0.2414	0.10520	0.2597	0.09744	...	26.50	98.87	567.
4	20.29	14.34	135.10	1297.0	0.10030	0.13280	0.1980	0.10430	0.1809	0.05883	...	16.67	152.20	1575.

5 rows × 31 columns

In [131…

```
# df = df[df['Species'] != 0]
```

In [131…

```
df.info(), display(df.shape)
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 569 entries, 0 to 568
Data columns (total 31 columns):
 #   Column                   Non-Null Count  Dtype  
---  ------                   --------------  -----  
 0   mean radius              569 non-null    float64
 1   mean texture             569 non-null    float64
 2   mean perimeter           569 non-null    float64
 3   mean area                569 non-null    float64
 4   mean smoothness          569 non-null    float64
 5   mean compactness         569 non-null    float64
 6   mean concavity           569 non-null    float64
 7   mean concave points      569 non-null    float64
 8   mean symmetry            569 non-null    float64
 9   mean fractal dimension   569 non-null    float64
 10  radius error             569 non-null    float64
 11  texture error            569 non-null    float64
 12  perimeter error          569 non-null    float64
 13  area error               569 non-null    float64
 14  smoothness error         569 non-null    float64
 15  compactness error        569 non-null    float64
 16  concavity error          569 non-null    float64
 17  concave points error     569 non-null    float64
 18  symmetry error           569 non-null    float64
 19  fractal dimension error  569 non-null    float64
 20  worst radius             569 non-null    float64
 21  worst texture            569 non-null    float64
 22  worst perimeter          569 non-null    float64
 23  worst area               569 non-null    float64
 24  worst smoothness         569 non-null    float64
 25  worst compactness        569 non-null    float64
 26  worst concavity          569 non-null    float64
 27  worst concave points     569 non-null    float64
 28  worst symmetry           569 non-null    float64
 29  worst fractal dimension  569 non-null    float64
 30  target                   569 non-null    int32  
dtypes: float64(30), int32(1)
memory usage: 135.7 KB
(569, 31)
```

Out[131… (None, None)

In [131…
```
df.describe()
```

Out[131…

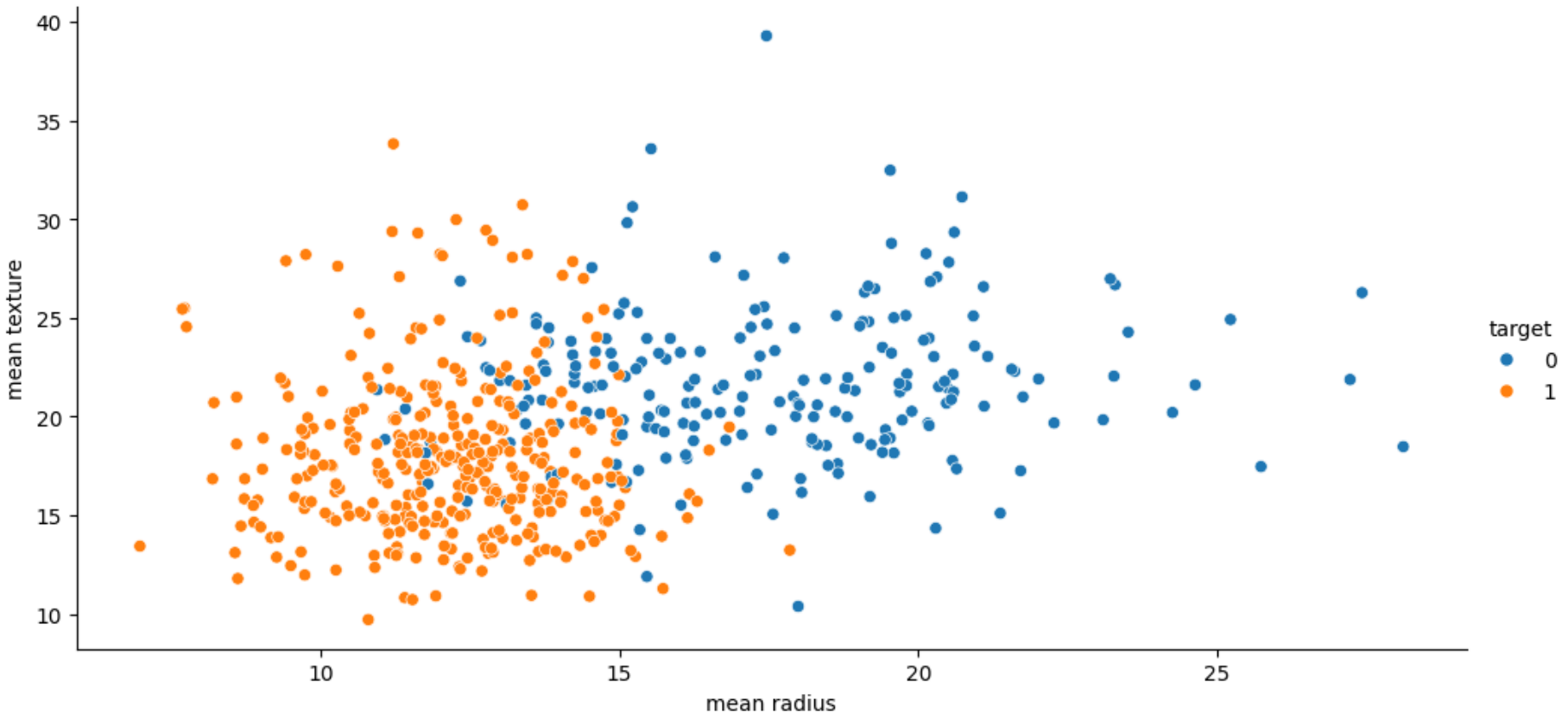
	mean radius	mean texture	mean perimeter	mean area	mean smoothness	mean compactness	mean concavity	mean concave points	mean symmetry	mean fractal dimension	...	
count	569.000000	569.000000	569.000000	569.000000	569.000000	569.000000	569.000000	569.000000	569.000000	569.000000	...	56
mean	14.127292	19.289649	91.969033	654.889104	0.096360	0.104341	0.088799	0.048919	0.181162	0.062798	...	2
std	3.524049	4.301036	24.298981	351.914129	0.014064	0.052813	0.079720	0.038803	0.027414	0.007060	...	
min	6.981000	9.710000	43.790000	143.500000	0.052630	0.019380	0.000000	0.000000	0.106000	0.049960	...	1
25%	11.700000	16.170000	75.170000	420.300000	0.086370	0.064920	0.029560	0.020310	0.161900	0.057700	...	2
50%	13.370000	18.840000	86.240000	551.100000	0.095870	0.092630	0.061540	0.033500	0.179200	0.061540	...	2
75%	15.780000	21.800000	104.100000	782.700000	0.105300	0.130400	0.130700	0.074000	0.195700	0.066120	...	2
max	28.110000	39.280000	188.500000	2501.000000	0.163400	0.345400	0.426800	0.201200	0.304000	0.097440	...	4

8 rows × 31 columns

In [131…
```
df['target'].value_counts()
```

Out[131…
```
target
1    357
0    212
Name: count, dtype: int64
```

In [131…
```
sns.relplot(x='mean radius', y='mean texture', hue='target', data=df, height=5, aspect=2)
plt.show()
```



In [131…
```
df.columns
```

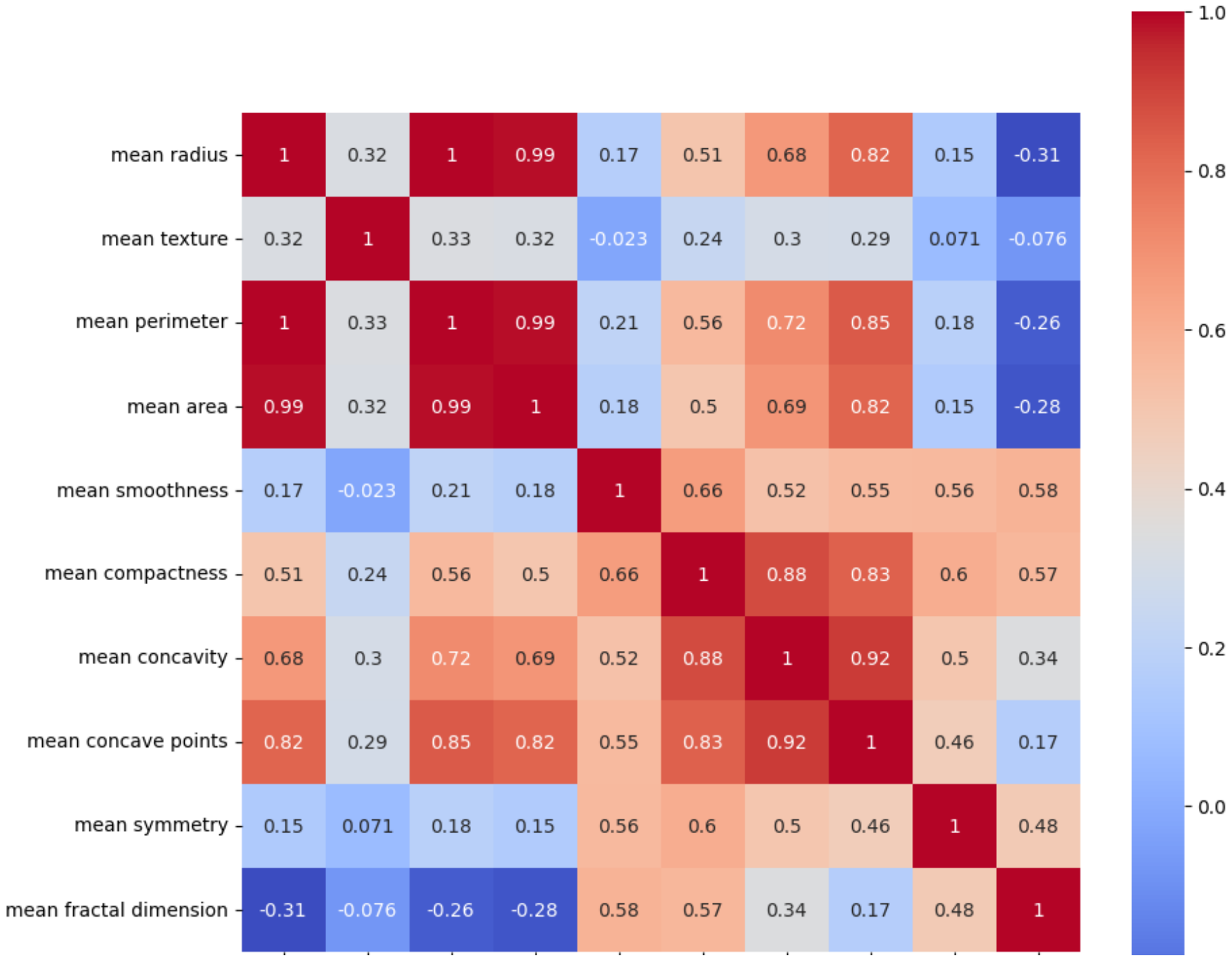
Out[131…
```
Index(['mean radius', 'mean texture', 'mean perimeter', 'mean area',
       'mean smoothness', 'mean compactness', 'mean concavity',
       'mean concave points', 'mean symmetry', 'mean fractal dimension',
       'radius error', 'texture error', 'perimeter error', 'area error',
       'smoothness error', 'compactness error', 'concavity error',
       'concave points error', 'symmetry error', 'fractal dimension error',
       'worst radius', 'worst texture', 'worst perimeter', 'worst area',
       'worst smoothness', 'worst compactness', 'worst concavity',
       'worst concave points', 'worst symmetry', 'worst fractal dimension',
       'target'],
      dtype='object')
```

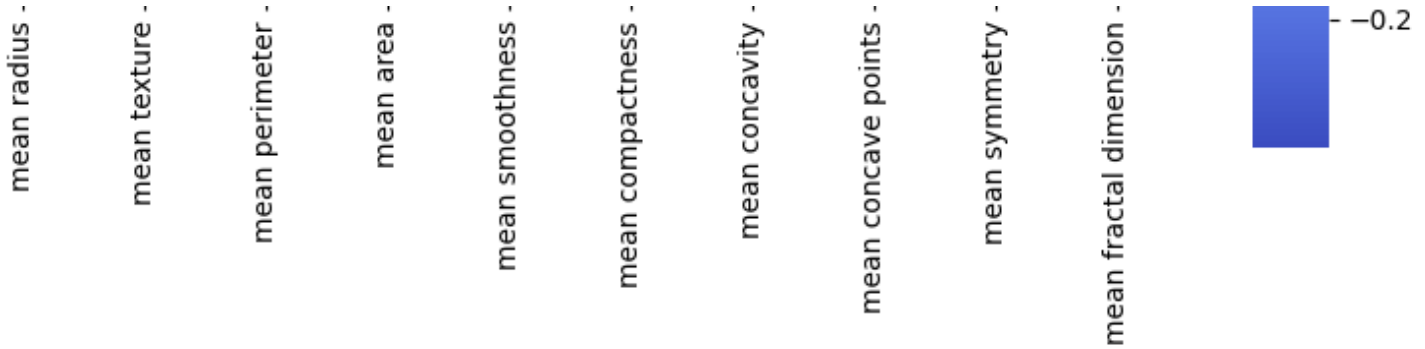
> Since we already have the means for the variables, we are just going to use the means themselves.

Find correlation between means

In [131…
```
featureMeans = list(df.columns[0:10])
```

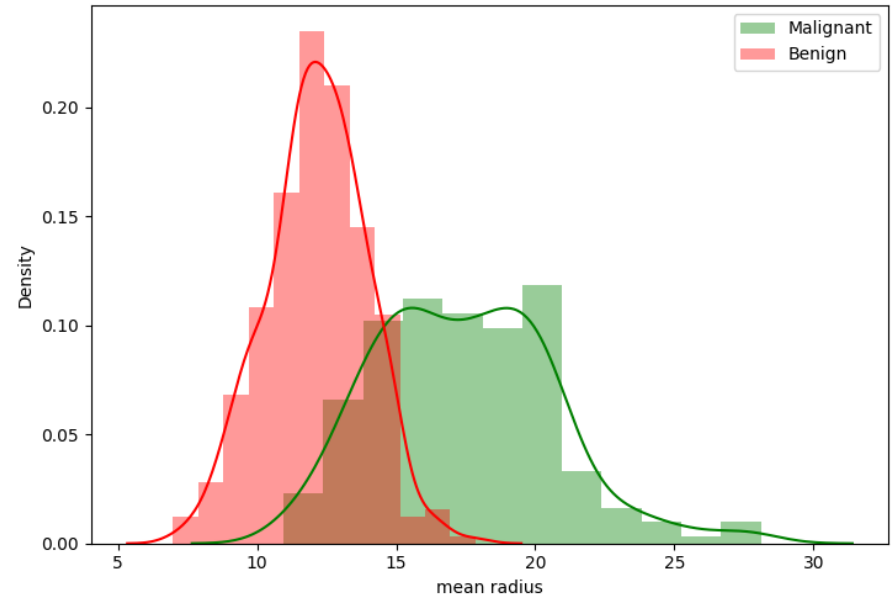
In [131…
```
plt.figure(figsize=(10,10))
sns.heatmap(df[featureMeans].corr(), annot=True, square=True, cmap='coolwarm')
plt.show()
```

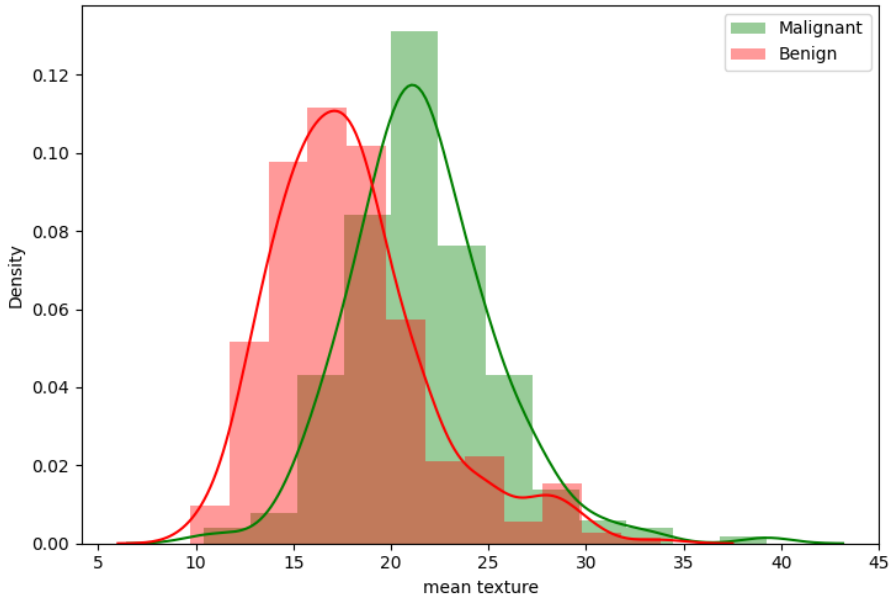

mean radius 1 0.32 1 0.99 0.17 0.51 0.68 0.82 0.15 -0.31
mean texture 0.32 1 0.33 0.32 -0.023 0.24 0.3 0.29 0.071 -0.076
mean perimeter 1 0.33 1 0.99 0.21 0.56 0.72 0.85 0.18 -0.26
mean area 0.99 0.32 0.99 1 0.18 0.5 0.69 0.82 0.15 -0.28
mean smoothness 0.17 -0.023 0.21 0.18 1 0.66 0.52 0.55 0.56 0.58
mean compactness 0.51 0.24 0.56 0.5 0.66 1 0.88 0.83 0.6 0.57
mean concavity 0.68 0.3 0.72 0.69 0.52 0.88 1 0.92 0.5 0.34
mean concave points 0.82 0.29 0.85 0.82 0.55 0.83 0.92 1 0.46 0.17
mean symmetry 0.15 0.071 0.18 0.15 0.56 0.6 0.5 0.46 1 0.48
mean fractal dimension -0.31 -0.076 -0.26 -0.28 0.58 0.57 0.34 0.17 0.48 1
1.0
0.8
0.6
0.4
0.2
0.0

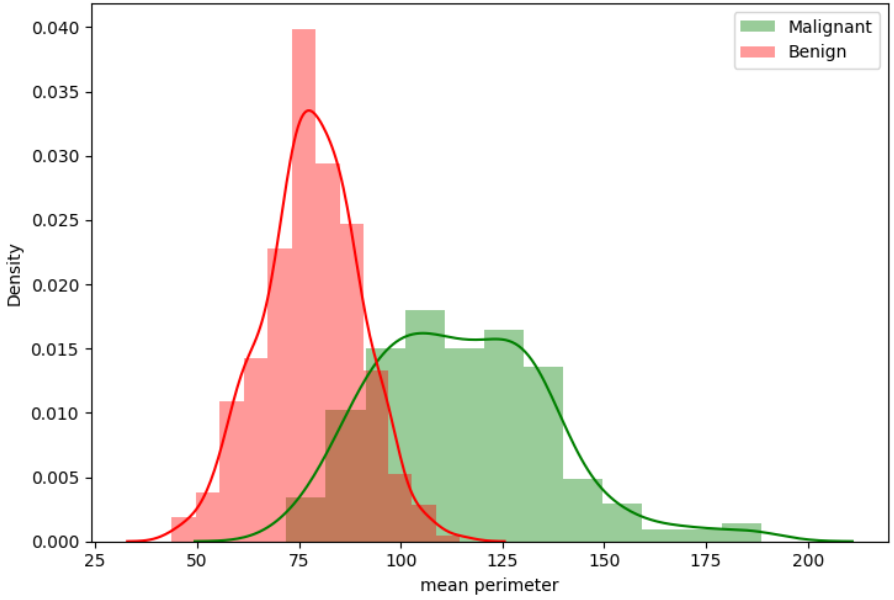


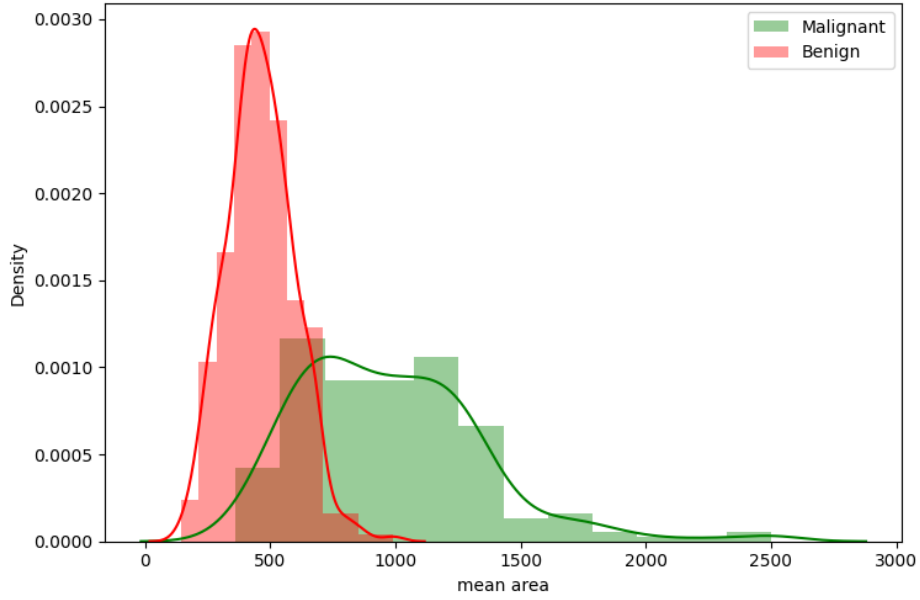
In [131…

```
bins = 12
plt.figure(figsize=(15,15))
plt.subplot(3, 2, 1)
sns.distplot(df[df['target']==0]['mean radius'], bins=bins, color='green', label='Malignant')
sns.distplot(df[df['target']==1]['mean radius'], bins=bins, color='red', label='Benign')
plt.legend(loc='upper right')
plt.subplot(3, 2, 2)
sns.distplot(df[df['target']==0]['mean texture'], bins=bins, color='green', label='Malignant')
sns.distplot(df[df['target']==1]['mean texture'], bins=bins, color='red', label='Benign')
plt.legend(loc='upper right')
plt.subplot(3, 2, 3)
sns.distplot(df[df['target']==0]['mean perimeter'], bins=bins, color='green', label='Malignant')
sns.distplot(df[df['target']==1]['mean perimeter'], bins=bins, color='red', label='Benign')
plt.legend(loc='upper right')
plt.subplot(3, 2, 4)
sns.distplot(df[df['target']==0]['mean area'], bins=bins, color='green', label='Malignant')
sns.distplot(df[df['target']==1]['mean area'], bins=bins, color='red', label='Benign')
plt.legend(loc='upper right')
plt.subplot(3, 2, 5)
sns.distplot(df[df['target']==0]['mean concavity'], bins=bins, color='green', label='Malignant')
sns.distplot(df[df['target']==1]['mean concavity'], bins=bins, color='red', label='Benign')
plt.legend(loc='upper right')
plt.subplot(3, 2, 6)
sns.distplot(df[df['target']==0]['mean symmetry'], bins=bins, color='green', label='Malignant')
sns.distplot(df[df['target']==1]['mean symmetry'], bins=bins, color='red', label='Benign')
plt.legend(loc='upper right')
plt.tight_layout()
plt.show()
```

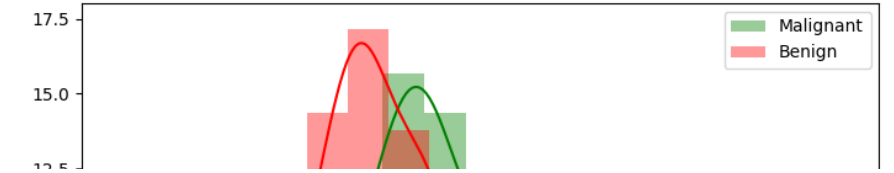

Malignant
Benign
Density
mean radius

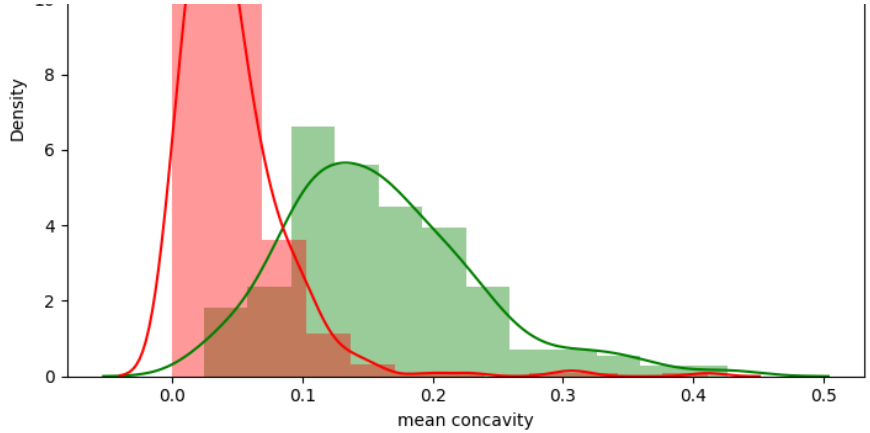

Malignant
Benign
Density
mean texture

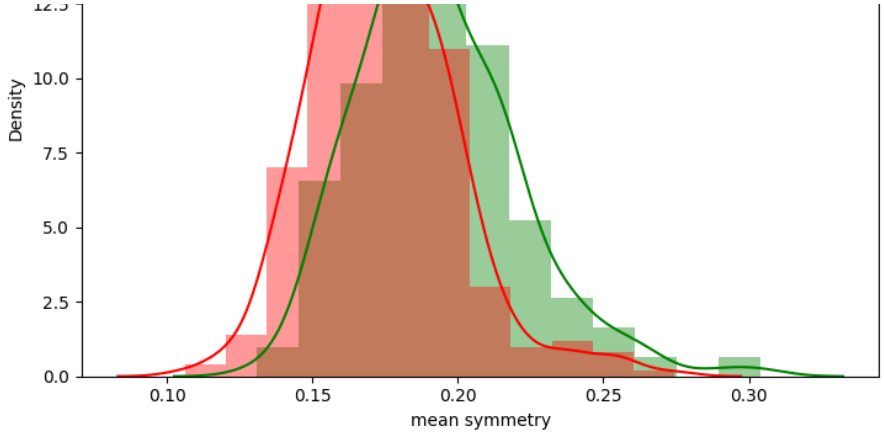

Malignant
Benign
Density
mean perimeter


Malignant
Benign
Density
mean area


Malignant
Benign


Malignant
Benign





Modelling

In [132…

```
# train-test split
from sklearn.model_selection import train_test_split

x = df[df.columns[:-1]]
x = df.drop(columns=['target'])
y = df['target']
print(x.shape, y.shape)

X_train, X_test, y_train, y_test = train_test_split(x, y, test_size=0.2)
```

```
(569, 30) (569,)
```

In [132…

```
X_train[:5]
```

Out[132…

	mean radius	mean texture	mean perimeter	mean area	mean smoothness	mean compactness	mean concavity	mean concave points	mean symmetry	mean fractal dimension	...	worst radius	worst texture	wo perime
124	13.37	16.39	86.10	553.5	0.07115	0.07325	0.08092	0.02800	0.1422	0.05823	...	14.26	22.75	9
494	13.16	20.54	84.06	538.7	0.07335	0.05275	0.01800	0.01256	0.1713	0.05888	...	14.50	28.46	9
529	12.07	13.44	77.83	445.2	0.11000	0.09009	0.03781	0.02798	0.1657	0.06608	...	13.45	15.77	8
30	18.63	25.11	124.80	1088.0	0.10640	0.18870	0.23190	0.12440	0.2183	0.06197	...	23.15	34.01	16
196	13.77	22.29	90.63	588.9	0.12000	0.12670	0.13850	0.06526	0.1834	0.06877	...	16.39	34.01	11

5 rows × 30 columns

In [132…

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

In [132…

```
X_train[:5]
```

Out[132…

```
array([[-0.20592894, -0.64911315, -0.23352648, -0.27975818, -1.8053916 ,
        -0.58774726, -0.10970352, -0.54269965, -1.39291807, -0.65312389,
        -0.87137163, -0.15629967, -0.81020195, -0.55278046, -0.4080412 ,
         0.37938674,  0.52713868, -0.25075954, -1.03903225,  0.07852891,
        -0.40396832, -0.44661471, -0.44423955, -0.42569854, -1.29530906,
         0.00354111,  0.27813685, -0.36408861, -1.33457958, -0.41003446],
       [-0.26522126,  0.32336946, -0.31704835, -0.32142595, -1.64855579,
        -0.96962357, -0.89137252, -0.93914652, -0.35611099, -0.5634074 ,
        -0.30586175,  0.43817087, -0.28031753, -0.31076333,  0.22692762,
        -0.28600414, -0.6002502 , -1.01227598,  0.0162432 , -0.41264627,
        -0.35489663,  0.49695566, -0.34743771, -0.39773103, -0.88871735,
        -0.55592762, -0.91621878, -1.08326492, -0.31651432, -0.51784051],
       [-0.57297661, -1.34039597, -0.57211757, -0.5846649 ,  0.96418609,
        -0.27404984, -0.64526853, -0.54321319, -0.555634  ,  0.43037522,
        -0.56207524, -1.29168486, -0.57432412, -0.47048191,  0.06675227,
        -0.77712597, -0.4577677 , -0.62930405, -0.13279343, -0.57946723,
        -0.56958528, -1.600051  , -0.59296239, -0.5676078 ,  0.8731801 ,
        -0.56477797, -0.51521418, -0.60241068, -0.16675198, -0.18033715],
       [ 1.27920238,  1.394272  ,  1.35093241,  1.22506772,  0.70754568,
         1.56286837,  1.76595422,  1.9325256 ,  1.31845715, -0.13690903,
         1.48834042,  0.4256745 ,  1.28003115,  1.36341831, -0.29709869,
         0.43620173,  0.60165359, -0.06101292, -0.07870756,  0.25142258,
         1.41372893,  1.41408623,  1.56542539,  1.36612158,  0.74202148,
         1.09466319,  1.60744685,  1.06464092,  0.88955048,  0.7568712 ],
       [-0.0929912 ,  0.73345249, -0.04805882, -0.18009338,  1.67707609,
         0.40792538,  0.60562548,  0.41401085,  0.07500123,  0.80166345,
         0.73951758,  1.57891165,  0.959122  ,  0.19045183,  2.24952081,
         0.42199798,  0.43609953,  1.36524917,  0.74099387,  0.16068913,
         0.03154294,  1.41408623,  0.13099807, -0.12392558,  1.81752215,
         0.37715244,  0.5138835 ,  0.80150929,  0.30961972,  0.51363042]])
```

In [132…

```
classifier = DecisionTreeClassifier()
classifier.fit(X_train, y_train)
```

Out[132…

▾ DecisionTreeClassifier

```
DecisionTreeClassifier()
```

In [132…

```
text_rep = tree.export_text(classifier)
```

```
print(text_rep)
```

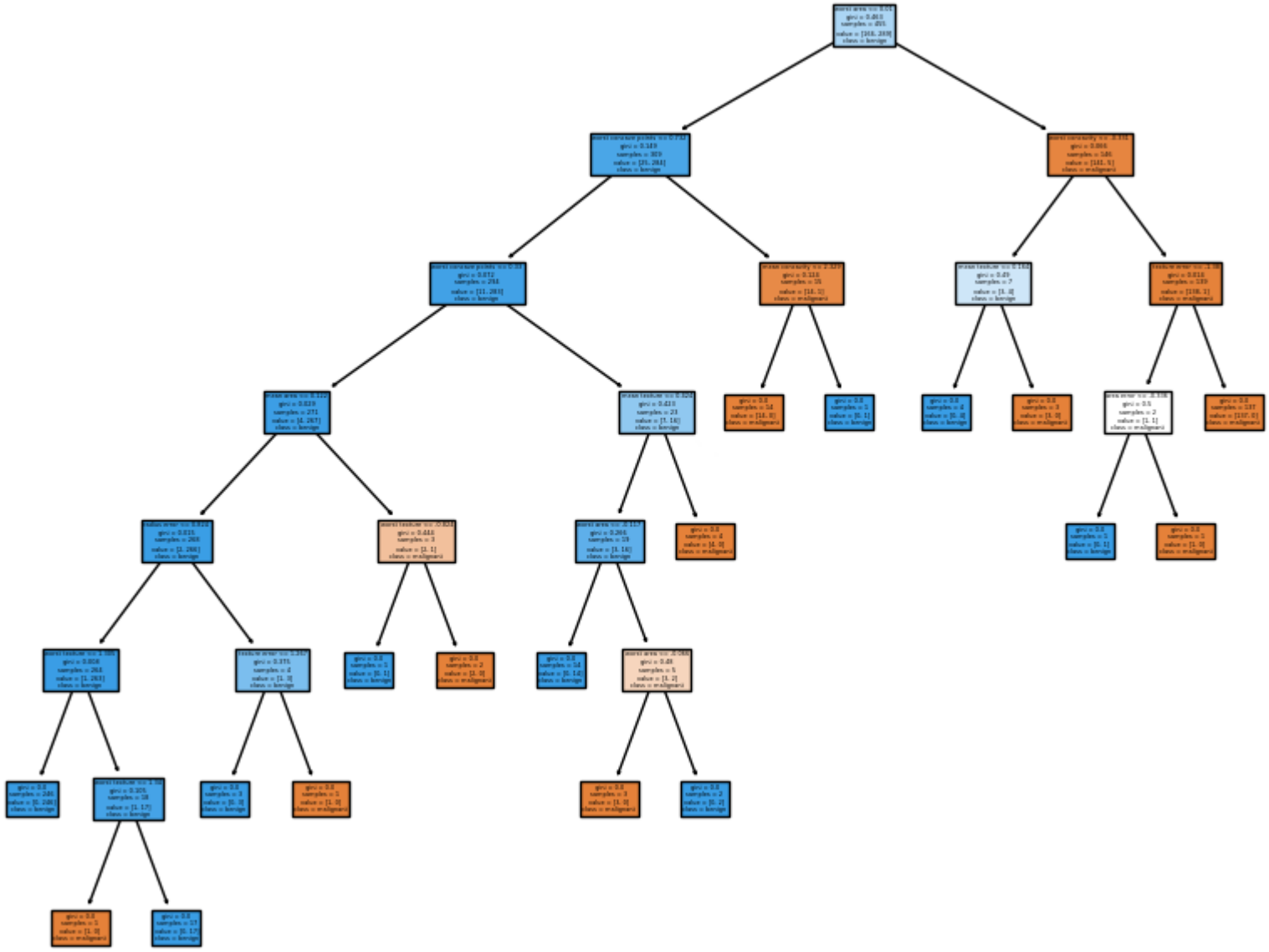
```
|--- feature_23 <= 0.01
|   |--- feature_27 <= 0.73
|   |   |--- feature_27 <= 0.33
|   |   |   |--- feature_3 <= 0.12
|   |   |   |   |--- feature_10 <= 0.82
|   |   |   |   |   |--- feature_21 <= 1.31
|   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_21 >  1.31
|   |   |   |   |   |   |--- feature_21 <= 1.34
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- feature_21 >  1.34
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |--- feature_10 >  0.82
|   |   |   |   |   |--- feature_11 <= 1.27
|   |   |   |   |   |   |--- class: 1
|   |   |   |   |   |--- feature_11 >  1.27
|   |   |   |   |   |   |--- class: 0
|   |   |   |--- feature_3 >  0.12
|   |   |   |   |--- feature_21 <= -0.82
|   |   |   |   |   |--- class: 1
|   |   |   |   |--- feature_21 >  -0.82
|   |   |   |   |   |--- class: 0
|   |   |--- feature_27 >  0.33
|   |   |   |--- feature_1 <= 0.42
|   |   |   |   |--- feature_23 <= -0.12
|   |   |   |   |   |--- class: 1
|   |   |   |   |--- feature_23 >  -0.12
|   |   |   |   |   |--- feature_23 <= -0.07
|   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- feature_23 >  -0.07
|   |   |   |   |   |   |--- class: 1
|   |   |   |--- feature_1 >  0.42
|   |   |   |   |--- class: 0
|   |--- feature_27 >  0.73
|   |   |--- feature_6 <= 2.33
|   |   |   |--- class: 0
|   |   |--- feature_6 >  2.33
|   |   |   |--- class: 1
|--- feature_23 >  0.01
|   |--- feature_26 <= -0.33
|   |   |--- feature_1 <= 0.16
```

```
|   |   |   |--- class: 1
|   |   |--- feature_1 >  0.16
|   |   |   |--- class: 0
|   |--- feature_26 >  -0.33
|   |   |--- feature_11 <= -1.38
|   |   |   |--- feature_13 <= -0.34
|   |   |   |   |--- class: 1
|   |   |   |--- feature_13 >  -0.34
|   |   |   |   |--- class: 0
|   |   |--- feature_11 >  -1.38
|   |   |   |--- class: 0
```

imports the tree and the purities per feature/node

In [132…

```
fig = plt.figure(figsize = (10, 8))
_ = tree.plot_tree(classifier, feature_names=breast_cancer.feature_names,
                   class_names=breast_cancer.target_names,
                   filled=True)
```



Manual Hyperparameter Tuning

In [132…
```
from sklearn.metrics import classification_report, confusion_matrix, accuracy_score

y_pred = classifier.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print('Accuracy: ', accuracy_score(y_test, y_pred))
```

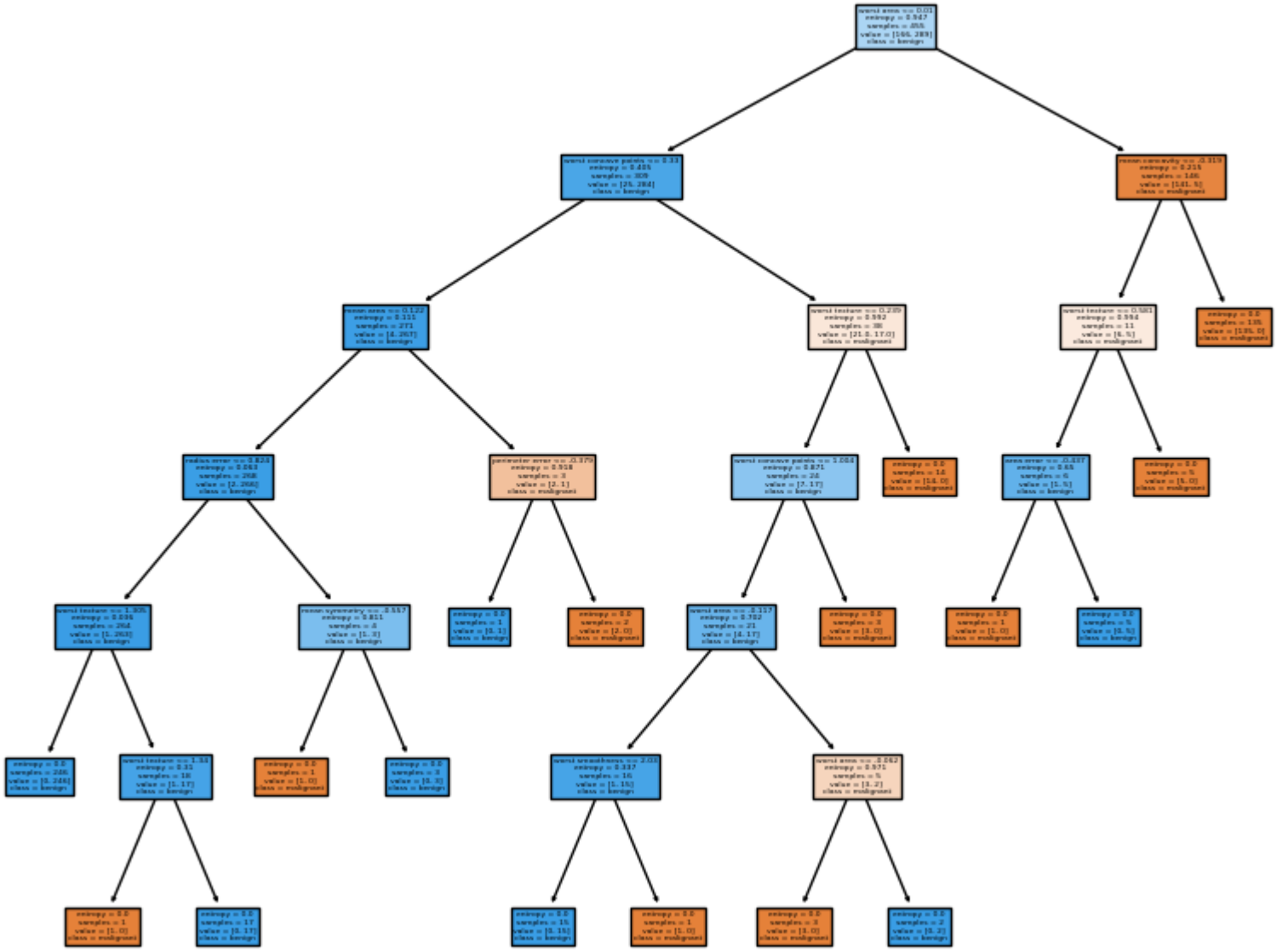
```
[[42  4]
 [ 2 66]]
Accuracy:  0.9473684210526315
```

In [132…
```
# Using Entropy

classifier = DecisionTreeClassifier(criterion='entropy')
classifier.fit(X_train, y_train)
```

Out[132…
```
DecisionTreeClassifier(criterion='entropy')
```

In [132…
```
fig = plt.figure(figsize = (10, 8))
_ = tree.plot_tree(classifier, feature_names=breast_cancer.feature_names,
                   class_names=breast_cancer.target_names,
                   filled=True)

y_pred = classifier.predict(X_test)
print("Confusion Matrix:")
print(confusion_matrix(y_test, y_pred))
print('Accuracy: ', accuracy_score(y_test, y_pred))
```

```
Confusion Matrix:
[[41  5]
 [ 3 65]]
Accuracy:  0.9298245614035088
```



In [133…

```
# Entropy with max_depth=2
```

```
classifier = DecisionTreeClassifier(max_depth=2, criterion='entropy')
classifier.fit(X_train, y_train)
```

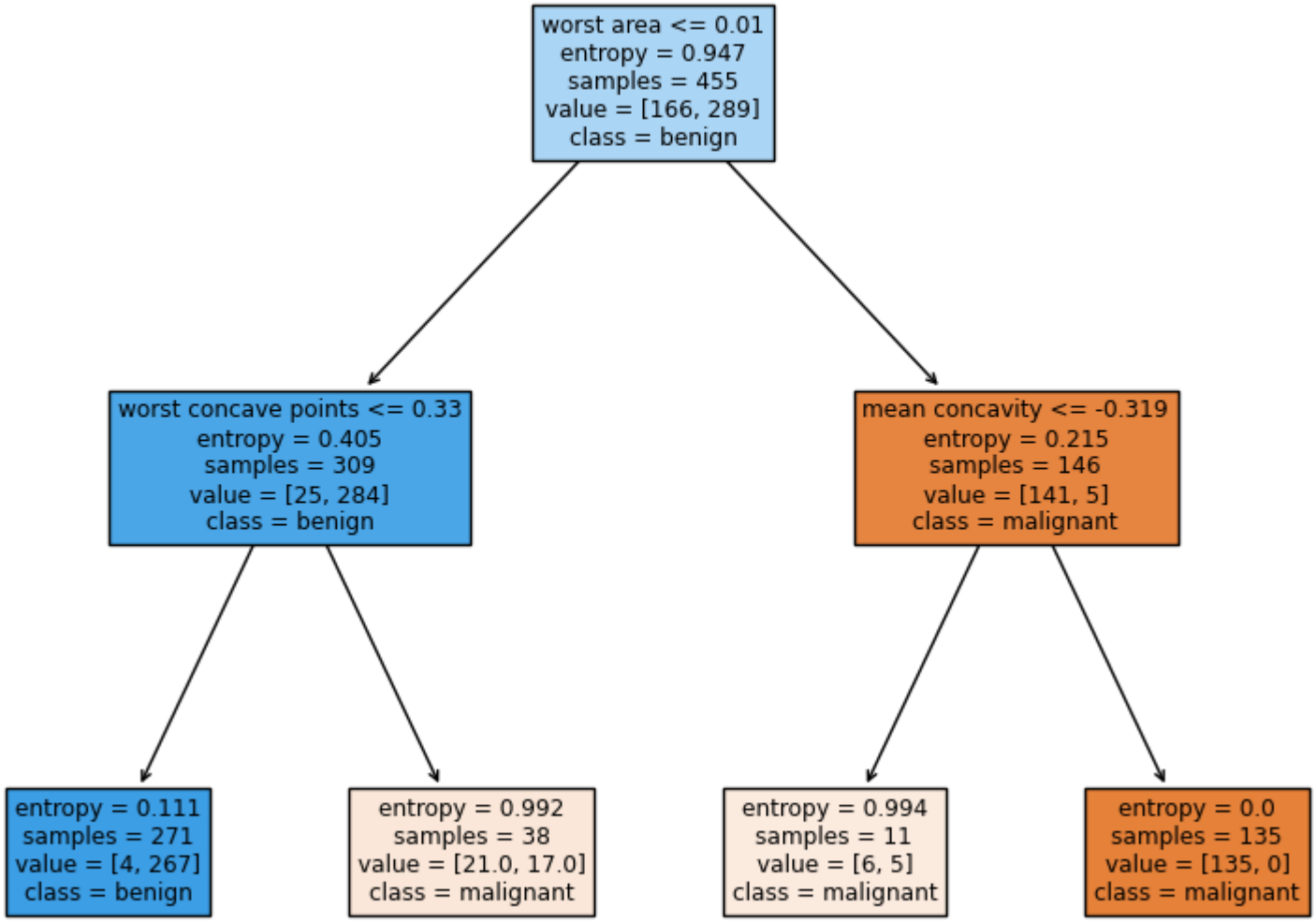
Out[133…

```
▾                DecisionTreeClassifier                    i ?

DecisionTreeClassifier(criterion='entropy', max_depth=2)
```

In [133…

```
fig = plt.figure(figsize = (10, 8))
_ = tree.plot_tree(classifier, feature_names=breast_cancer.feature_names,
                   class_names=breast_cancer.target_names,
                   filled=True)

y_pred = classifier.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print('Accuracy: ', accuracy_score(y_test, y_pred))
```

```
[[42  4]
 [ 5 63]]
Accuracy:  0.9210526315789473
```



In [133…

```
def tree_depth_tree_hyp_tuning(d) :
    classifier = DecisionTreeClassifier(max_depth=d, criterion='entropy')
```

```
    classifier.fit(X_train, y_train)
    y_pred = classifier.predict(X_test)
    print(confusion_matrix(y_test, y_pred))
    print('Accuracy: ', accuracy_score(y_test, y_pred))
    return accuracy_score(y_test, y_pred)
```

In [133…

```
tree_result = pd.DataFrame({'D': np.arange(1, 10)})

tree_result['Accuracy'] = tree_result['D'].apply(tree_depth_tree_hyp_tuning)
tree_result
```

```
[[34 12]
 [ 3 65]]
Accuracy:  0.868421052631579
[[42  4]
 [ 5 63]]
Accuracy:  0.9210526315789473
[[40  6]
 [ 3 65]]
Accuracy:  0.9210526315789473
[[40  6]
 [ 3 65]]
Accuracy:  0.9210526315789473
[[40  6]
 [ 4 64]]
Accuracy:  0.9122807017543859
[[41  5]
 [ 2 66]]
Accuracy:  0.9385964912280702
[[42  4]
 [ 3 65]]
Accuracy:  0.9385964912280702
[[41  5]
 [ 3 65]]
Accuracy:  0.9298245614035088
[[42  4]
 [ 2 66]]
Accuracy:  0.9473684210526315
```

Out[133…

	D	Accuracy
0	1	0.868421
1	2	0.921053
2	3	0.921053
3	4	0.921053
4	5	0.912281
5	6	0.938596
6	7	0.938596
7	8	0.929825
8	9	0.947368

assignment:

tree pruning = max depth
criteria = gini index, goodness, etc.
visualization = any (like seaborn or matplotlib)

> Submission: Pagbalik after undas break (Apr 25)

In [133…

```
# Entropy with max_depth=3

classifier = DecisionTreeClassifier(max_depth=3, criterion='entropy')
classifier.fit(X_train, y_train)
```

Out[133…

```
▾                DecisionTreeClassifier                i ?

DecisionTreeClassifier(criterion='entropy', max_depth=3)
```

In [133…
```
def tree_depth_tree_hyp_tuning_gini(d) :
    classifier = DecisionTreeClassifier(max_depth=d, criterion='gini')
    classifier.fit(X_train, y_train)
    y_pred = classifier.predict(X_test)
    print(confusion_matrix(y_test, y_pred))
    print('Accuracy: ', accuracy_score(y_test, y_pred))
    return accuracy_score(y_test, y_pred)
```

In [133…
```
def tree_depth_tree_hyp_tuning_information_gain(d) :
    classifier = DecisionTreeClassifier(max_depth=d, criterion='entropy')
    classifier.fit(X_train, y_train)
    y_pred = classifier.predict(X_test)
    print(confusion_matrix(y_test, y_pred))
    print('Accuracy: ', accuracy_score(y_test, y_pred))
    return accuracy_score(y_test, y_pred)
```

In [133…
```
tree_result_gini = pd.DataFrame({'D': np.arange(1, 10)})
```

In [133…
```
tree_result_gini['Accuracy'] = tree_result['D'].apply(tree_depth_tree_hyp_tuning_gini)
tree_result_gini
```

```
[[34 12]
 [ 3 65]]
Accuracy:  0.868421052631579
[[38  8]
 [ 3 65]]
Accuracy:  0.9035087719298246
[[39  7]
 [ 3 65]]
Accuracy:  0.9122807017543859
[[42  4]
 [ 3 65]]
Accuracy:  0.9385964912280702
[[41  5]
 [ 2 66]]
Accuracy:  0.9385964912280702
[[40  6]
 [ 2 66]]
Accuracy:  0.9298245614035088
[[42  4]
 [ 2 66]]
Accuracy:  0.9473684210526315
[[41  5]
 [ 3 65]]
Accuracy:  0.9298245614035088
[[41  5]
 [ 2 66]]
Accuracy:  0.9385964912280702
```

Out[133...

	D	Accuracy
0	1	0.868421
1	2	0.903509
2	3	0.912281
3	4	0.938596
4	5	0.938596
5	6	0.929825
6	7	0.947368
7	8	0.929825
8	9	0.938596

In [133...
```
tree_result_ig = pd.DataFrame({'D': np.arange(1, 10)})
```

In [134...
```
tree_result_ig['Accuracy'] = tree_result['D'].apply(tree_depth_tree_hyp_tuning_information_gain)
tree_result_ig
```

```
[[34 12]
 [ 3 65]]
Accuracy:  0.868421052631579
[[42  4]
 [ 5 63]]
Accuracy:  0.9210526315789473
[[41  5]
 [ 3 65]]
Accuracy:  0.9298245614035088
[[40  6]
 [ 2 66]]
Accuracy:  0.9298245614035088
[[42  4]
 [ 2 66]]
Accuracy:  0.9473684210526315
[[41  5]
 [ 3 65]]
Accuracy:  0.9298245614035088
[[42  4]
 [ 2 66]]
Accuracy:  0.9473684210526315
[[42  4]
 [ 2 66]]
Accuracy:  0.9473684210526315
[[41  5]
 [ 3 65]]
Accuracy:  0.9298245614035088
```

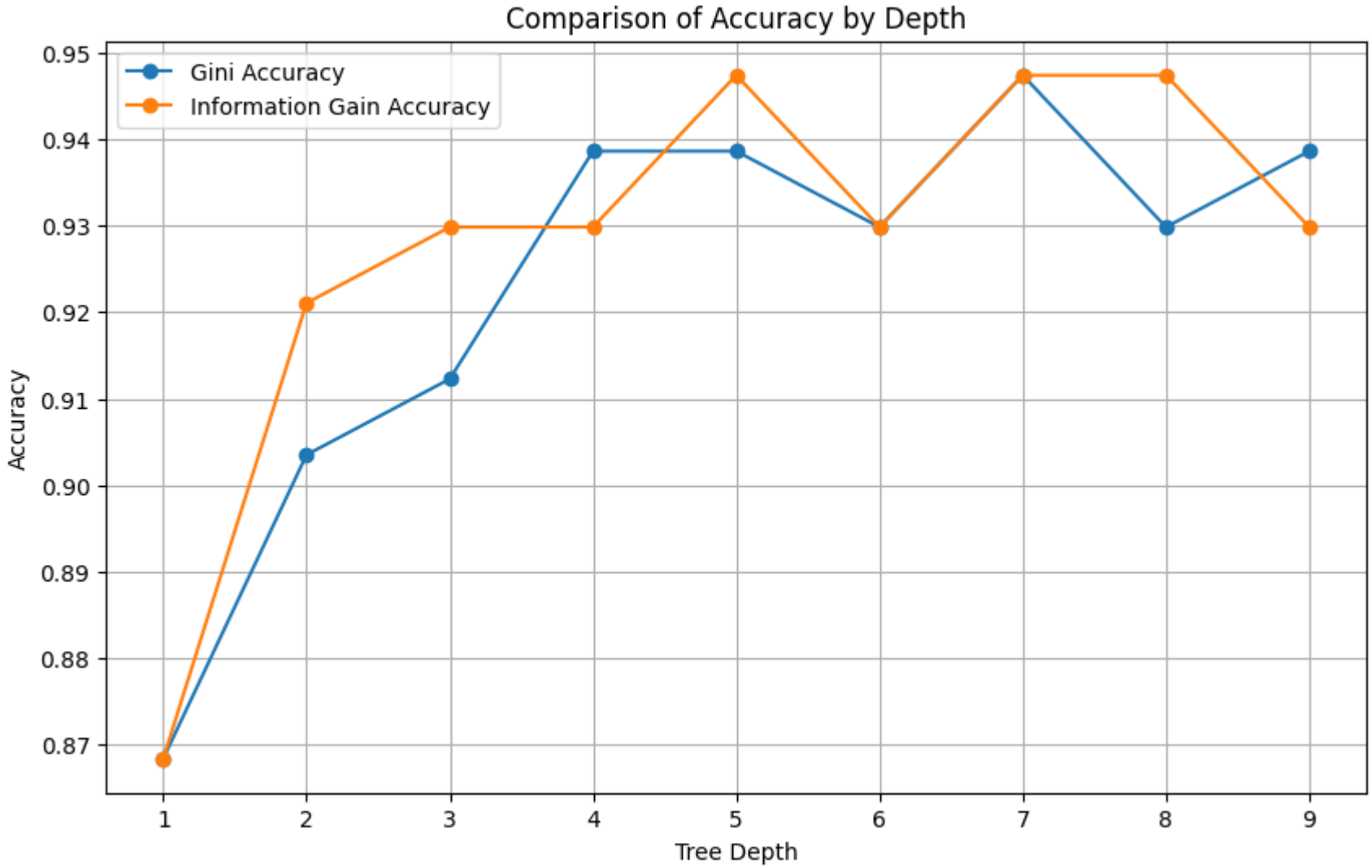
Out[134...

	D	Accuracy
0	1	0.868421
1	2	0.921053
2	3	0.929825
3	4	0.929825
4	5	0.947368
5	6	0.929825
6	7	0.947368
7	8	0.947368
8	9	0.929825

In [134...

```
comparison_df = pd.DataFrame({
    'Depth': tree_result_gini['D'],
    'Gini Accuracy': tree_result_gini['Accuracy'],
    'Information Gain Accuracy': tree_result_ig['Accuracy']
})
display(comparison_df)

comparison_df.plot(x='Depth', y=['Gini Accuracy', 'Information Gain Accuracy'], kind='line', marker='o', figsize=(10, 6), titl
plt.xlabel('Tree Depth')
plt.ylabel('Accuracy')
plt.grid(True)
plt.legend(loc='best')
plt.show()
```

	Depth	Gini Accuracy	Information Gain Accuracy
0	1	0.868421	0.868421
1	2	0.903509	0.921053
2	3	0.912281	0.929825
3	4	0.938596	0.929825
4	5	0.938596	0.947368
5	6	0.929825	0.929825
6	7	0.947368	0.947368
7	8	0.929825	0.947368
8	9	0.938596	0.929825



Base Model

In [134…

```
# train-test split
from sklearn.model_selection import train_test_split
```

In [134...
```
# x = df[df.columns[:-1]]
x = df[:-1]
x = df.drop(columns=['target'])
y = df['target']
print(x.shape, y.shape)

X_train, X_test, y_train, y_test = train_test_split(x, y, test_size=0.2)
```

```
(569, 30) (569,)
```

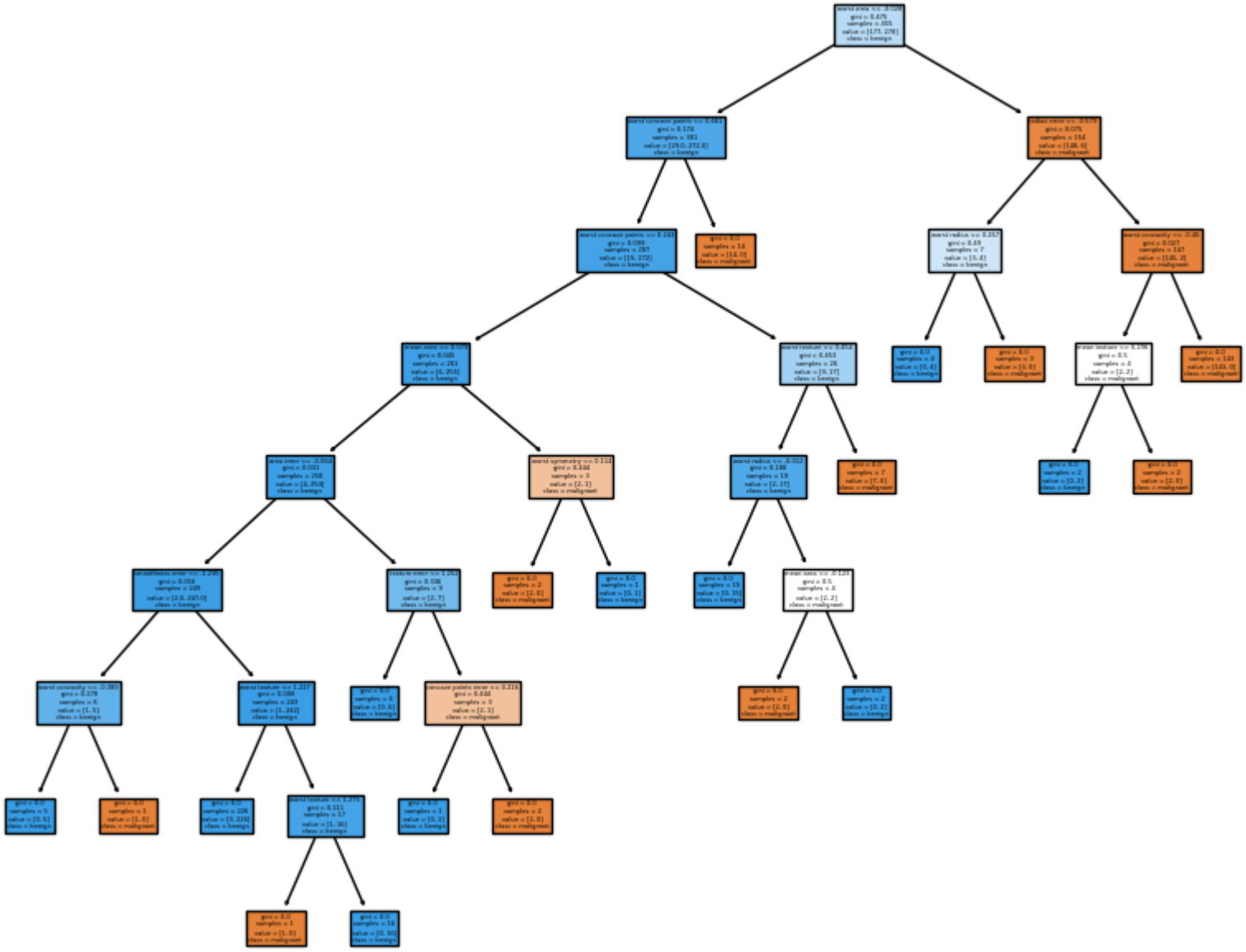
In [134...
```
scaler = StandardScaler()
scaler.fit(X_train)
X_train = scaler.transform(X_train)
X_test = scaler.transform(X_test)

classifier = DecisionTreeClassifier()
classifier.fit(X_train, y_train)
```

Out[134...
```
▾ DecisionTreeClassifier i ?

DecisionTreeClassifier()
```

Base Tree and metrics

In [134...
```
fig = plt.figure(figsize = (10, 8))
_ = tree.plot_tree(classifier, feature_names=breast_cancer.feature_names,
                   class_names=breast_cancer.target_names,
                   filled=True)

y_pred = classifier.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print('Accuracy: ', accuracy_score(y_test, y_pred))
```

```
[[34  1]
 [ 7 72]]
Accuracy:  0.9298245614035088
```



Automatic hyperparameter Tuning using Optuna

In [134…

```
import optuna

from sklearn.metrics import accuracy_score

from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import train_test_split, GridSearchCV
import time
```

In [134…

```
start_time_g = time.time()  # Record the start time

def objective(trial):
    # Define the hyperparameters to tune
    max_depth = trial.suggest_int('max_depth', 1, 20)
    min_samples_leaf = trial.suggest_int('min_samples_leaf', 1, 10)
    ccp_alpha = trial.suggest_float('ccp_alpha', 0.0, 0.1)
    random_state = 42  # Fixed for reproducibility
    criterion = trial.suggest_categorical('criterion', ['gini'])

    # Create and train the DecisionTreeClassifier
    classifier = DecisionTreeClassifier(
        max_depth=max_depth,
        min_samples_leaf=min_samples_leaf,
        ccp_alpha=ccp_alpha,
        random_state=random_state,
        criterion=criterion
    )
    classifier.fit(X_train, y_train)

    # Predict and calculate accuracy
    y_pred = classifier.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)

    return accuracy

# Create a study and optimize the objective function
study = optuna.create_study(direction='maximize')
```

```
study.optimize(objective, n_trials=200)

# Display the best parameters and accuracy
print("Best Parameters:", study.best_params)
print("Best Accuracy:", study.best_value)

best_max_depth_g = study.best_params['max_depth']
best_min_samples_leaf_g = study.best_params['min_samples_leaf']
best_ccp_alpha_g = study.best_params['ccp_alpha']

end_time_g = time.time()  # Record the end time
print(f"Total Runtime: {end_time_g - start_time_g:.2f} seconds")
```

```
[I 2025-04-24 18:54:23,977] A new study created in memory with name: no-name-c620c000-3e9d-492d-b325-871eb27ed4df
[I 2025-04-24 18:54:23,992] Trial 0 finished with value: 0.9122807017543859 and parameters: {'max_depth': 5, 'min_samples_leaf'
: 4, 'ccp_alpha': 0.07817335917413298, 'criterion': 'gini'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:24,013] Trial 1 finished with value: 0.9122807017543859 and parameters: {'max_depth': 5, 'min_samples_leaf'
: 3, 'ccp_alpha': 0.0727025667922592, 'criterion': 'gini'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:24,043] Trial 2 finished with value: 0.9122807017543859 and parameters: {'max_depth': 19, 'min_samples_leaf
': 8, 'ccp_alpha': 0.06017712542692011, 'criterion': 'gini'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:24,062] Trial 3 finished with value: 0.9473684210526315 and parameters: {'max_depth': 10, 'min_samples_leaf
': 7, 'ccp_alpha': 0.029757705816383186, 'criterion': 'gini'}. Best is trial 3 with value: 0.9473684210526315.
[I 2025-04-24 18:54:24,079] Trial 4 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_leaf
': 4, 'ccp_alpha': 0.0360680920077744, 'criterion': 'gini'}. Best is trial 3 with value: 0.9473684210526315.
[I 2025-04-24 18:54:24,085] Trial 5 finished with value: 0.9122807017543859 and parameters: {'max_depth': 1, 'min_samples_leaf'
: 8, 'ccp_alpha': 0.05252881650289977, 'criterion': 'gini'}. Best is trial 3 with value: 0.9473684210526315.
[I 2025-04-24 18:54:24,099] Trial 6 finished with value: 0.956140350877193 and parameters: {'max_depth': 6, 'min_samples_leaf':
4, 'ccp_alpha': 0.013582364004914261, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,108] Trial 7 finished with value: 0.9122807017543859 and parameters: {'max_depth': 3, 'min_samples_leaf'
: 5, 'ccp_alpha': 0.0815346112884067, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,121] Trial 8 finished with value: 0.9122807017543859 and parameters: {'max_depth': 7, 'min_samples_leaf'
: 4, 'ccp_alpha': 0.08408959475334238, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,133] Trial 9 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_leaf
': 9, 'ccp_alpha': 0.020044858135989697, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,164] Trial 10 finished with value: 0.9122807017543859 and parameters: {'max_depth': 12, 'min_samples_lea
f': 1, 'ccp_alpha': 0.001145738856044562, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,191] Trial 11 finished with value: 0.9473684210526315 and parameters: {'max_depth': 10, 'min_samples_lea
f': 7, 'ccp_alpha': 0.024609221971662945, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,216] Trial 12 finished with value: 0.9385964912280702 and parameters: {'max_depth': 10, 'min_samples_lea
f': 6, 'ccp_alpha': 0.0017760700210185804, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,242] Trial 13 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_lea
f': 10, 'ccp_alpha': 0.0345178829550995, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,271] Trial 14 finished with value: 0.9122807017543859 and parameters: {'max_depth': 7, 'min_samples_leaf
': 2, 'ccp_alpha': 0.09909835854857355, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,299] Trial 15 finished with value: 0.9473684210526315 and parameters: {'max_depth': 8, 'min_samples_leaf
': 6, 'ccp_alpha': 0.01551273648643432, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,325] Trial 16 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_lea
f': 7, 'ccp_alpha': 0.038400560922229286, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,352] Trial 17 finished with value: 0.956140350877193 and parameters: {'max_depth': 15, 'min_samples_leaf
': 5, 'ccp_alpha': 0.01049178872109535, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,379] Trial 18 finished with value: 0.956140350877193 and parameters: {'max_depth': 16, 'min_samples_leaf
': 2, 'ccp_alpha': 0.011941365166109904, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,408] Trial 19 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_lea
```

```
f': 5, 'ccp_alpha': 0.04600554657205965, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,437] Trial 20 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_leaf
': 3, 'ccp_alpha': 0.01047076157649908, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,468] Trial 21 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_leaf
': 1, 'ccp_alpha': 0.01029250621126301, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,499] Trial 22 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_leaf
': 2, 'ccp_alpha': 0.011284136308869918, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,527] Trial 23 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_lea
f': 3, 'ccp_alpha': 0.021364256750907574, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,554] Trial 24 finished with value: 0.9210526315789473 and parameters: {'max_depth': 20, 'min_samples_lea
f': 2, 'ccp_alpha': 0.0008109564734094504, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,580] Trial 25 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_lea
f': 5, 'ccp_alpha': 0.027249164742959027, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,605] Trial 26 finished with value: 0.9473684210526315 and parameters: {'max_depth': 8, 'min_samples_leaf
': 4, 'ccp_alpha': 0.015503221434444712, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,629] Trial 27 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_lea
f': 3, 'ccp_alpha': 0.044259389249462135, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,656] Trial 28 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_leaf
': 2, 'ccp_alpha': 0.006937187629691325, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,680] Trial 29 finished with value: 0.9122807017543859 and parameters: {'max_depth': 4, 'min_samples_leaf
': 4, 'ccp_alpha': 0.05637790901790332, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,702] Trial 30 finished with value: 0.9122807017543859 and parameters: {'max_depth': 1, 'min_samples_leaf
': 1, 'ccp_alpha': 0.019364845283688294, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,728] Trial 31 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_leaf
': 3, 'ccp_alpha': 0.01005807505048008, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,755] Trial 32 finished with value: 0.9473684210526315 and parameters: {'max_depth': 20, 'min_samples_lea
f': 3, 'ccp_alpha': 0.007645578048552205, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,780] Trial 33 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_lea
f': 5, 'ccp_alpha': 0.015775626877878323, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,805] Trial 34 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_lea
f': 6, 'ccp_alpha': 0.0301029176217816, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,830] Trial 35 finished with value: 0.9122807017543859 and parameters: {'max_depth': 18, 'min_samples_lea
f': 4, 'ccp_alpha': 0.06753295404667461, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,858] Trial 36 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_lea
f': 2, 'ccp_alpha': 0.004544571843548828, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,884] Trial 37 finished with value: 0.9473684210526315 and parameters: {'max_depth': 5, 'min_samples_leaf
': 4, 'ccp_alpha': 0.03141478508634756, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,916] Trial 38 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_lea
f': 3, 'ccp_alpha': 0.023591979457841264, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:24,941] Trial 39 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_leaf
': 3, 'ccp_alpha': 0.011447186316346565, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
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[I 2025-04-24 18:54:24,971] Trial 40 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 5, 'ccp_alpha': 0.039810064680737715, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,002] Trial 41 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 1, 'ccp_alpha': 0.014474809176478844, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,030] Trial 42 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_lea
f': 1, 'ccp_alpha': 0.008683926315737564, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,059] Trial 43 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_lea
f': 2, 'ccp_alpha': 0.0192160885531746, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,090] Trial 44 finished with value: 0.9298245614035088 and parameters: {'max_depth': 17, 'min_samples_lea
f': 1, 'ccp_alpha': 0.003818511276128018, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,117] Trial 45 finished with value: 0.9473684210526315 and parameters: {'max_depth': 3, 'min_samples_leaf
': 2, 'ccp_alpha': 0.026233655741955214, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,145] Trial 46 finished with value: 0.956140350877193 and parameters: {'max_depth': 11, 'min_samples_leaf
': 3, 'ccp_alpha': 0.01224635928809573, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,176] Trial 47 finished with value: 0.9298245614035088 and parameters: {'max_depth': 16, 'min_samples_lea
f': 4, 'ccp_alpha': 0.004729607921033163, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,202] Trial 48 finished with value: 0.9473684210526315 and parameters: {'max_depth': 9, 'min_samples_leaf
': 1, 'ccp_alpha': 0.018818721457947444, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,227] Trial 49 finished with value: 0.9122807017543859 and parameters: {'max_depth': 6, 'min_samples_leaf
': 4, 'ccp_alpha': 0.07362301053222206, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,261] Trial 50 finished with value: 0.9473684210526315 and parameters: {'max_depth': 13, 'min_samples_lea
f': 7, 'ccp_alpha': 0.022670036419992698, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,297] Trial 51 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_leaf
': 2, 'ccp_alpha': 0.011714352574730283, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,329] Trial 52 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_leaf
': 2, 'ccp_alpha': 0.007223824724671173, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,356] Trial 53 finished with value: 0.9122807017543859 and parameters: {'max_depth': 15, 'min_samples_lea
f': 1, 'ccp_alpha': 0.09230647989452988, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,380] Trial 54 finished with value: 0.9473684210526315 and parameters: {'max_depth': 13, 'min_samples_lea
f': 3, 'ccp_alpha': 0.016577732254376816, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,406] Trial 55 finished with value: 0.9210526315789473 and parameters: {'max_depth': 11, 'min_samples_lea
f': 2, 'ccp_alpha': 0.0008106482714298497, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,433] Trial 56 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_leaf
': 5, 'ccp_alpha': 0.013299799520187231, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,463] Trial 57 finished with value: 0.9385964912280702 and parameters: {'max_depth': 16, 'min_samples_lea
f': 8, 'ccp_alpha': 2.69560245141319e-05, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,485] Trial 58 finished with value: 0.9473684210526315 and parameters: {'max_depth': 2, 'min_samples_leaf
': 6, 'ccp_alpha': 0.027568019716394145, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,512] Trial 59 finished with value: 0.956140350877193 and parameters: {'max_depth': 12, 'min_samples_leaf
': 2, 'ccp_alpha': 0.00930090532757971, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,539] Trial 60 finished with value: 0.9473684210526315 and parameters: {'max_depth': 20, 'min_samples_lea
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f': 3, 'ccp_alpha': 0.03516765491722734, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,566] Trial 61 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 1, 'ccp_alpha': 0.0059123068988571744, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,593] Trial 62 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 2, 'ccp_alpha': 0.018044742375174855, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,620] Trial 63 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_lea
f': 4, 'ccp_alpha': 0.008501305284485321, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,648] Trial 64 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_lea
f': 2, 'ccp_alpha': 0.004736364396710675, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,676] Trial 65 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_leaf
': 1, 'ccp_alpha': 0.014006943430795964, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,703] Trial 66 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_lea
f': 3, 'ccp_alpha': 0.022447502208066156, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,729] Trial 67 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_leaf
': 5, 'ccp_alpha': 0.010873698184114945, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,754] Trial 68 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_lea
f': 10, 'ccp_alpha': 0.05027405484491318, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,780] Trial 69 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_lea
f': 3, 'ccp_alpha': 0.0028672929614946318, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,806] Trial 70 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 2, 'ccp_alpha': 0.017315047719656237, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,834] Trial 71 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_leaf
': 3, 'ccp_alpha': 0.010431161680611306, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,861] Trial 72 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_lea
f': 4, 'ccp_alpha': 0.0070184947738252505, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,889] Trial 73 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_leaf
': 2, 'ccp_alpha': 0.014137550950414865, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,920] Trial 74 finished with value: 0.956140350877193 and parameters: {'max_depth': 15, 'min_samples_leaf
': 3, 'ccp_alpha': 0.009914437757441375, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,948] Trial 75 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_lea
f': 4, 'ccp_alpha': 0.020760777979244183, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:25,980] Trial 76 finished with value: 0.9122807017543859 and parameters: {'max_depth': 16, 'min_samples_lea
f': 1, 'ccp_alpha': 0.002827404058746775, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,006] Trial 77 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_leaf
': 3, 'ccp_alpha': 0.00677241987331193, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,034] Trial 78 finished with value: 0.9473684210526315 and parameters: {'max_depth': 9, 'min_samples_leaf
': 2, 'ccp_alpha': 0.02493094280828812, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,062] Trial 79 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_lea
f': 5, 'ccp_alpha': 0.0165517361242949, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,089] Trial 80 finished with value: 0.956140350877193 and parameters: {'max_depth': 20, 'min_samples_leaf
': 4, 'ccp_alpha': 0.013125623661866592, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
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[I 2025-04-24 18:54:26,119] Trial 81 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_leaf
': 3, 'ccp_alpha': 0.012084656498835857, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,148] Trial 82 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_leaf
': 3, 'ccp_alpha': 0.009748183533245249, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,179] Trial 83 finished with value: 0.9385964912280702 and parameters: {'max_depth': 16, 'min_samples_lea
f': 2, 'ccp_alpha': 0.0038278449920488063, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,209] Trial 84 finished with value: 0.9473684210526315 and parameters: {'max_depth': 13, 'min_samples_lea
f': 1, 'ccp_alpha': 0.01991127200608086, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,240] Trial 85 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_lea
f': 4, 'ccp_alpha': 0.01554358167171232, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,266] Trial 86 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 6, 'ccp_alpha': 0.006222746492437156, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,304] Trial 87 finished with value: 0.9122807017543859 and parameters: {'max_depth': 6, 'min_samples_leaf
': 3, 'ccp_alpha': 0.062088844740472215, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,345] Trial 88 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_leaf
': 2, 'ccp_alpha': 0.0108387391592741, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,376] Trial 89 finished with value: 0.9473684210526315 and parameters: {'max_depth': 11, 'min_samples_lea
f': 3, 'ccp_alpha': 0.008045253640413415, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,405] Trial 90 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_lea
f': 2, 'ccp_alpha': 0.03297275785506083, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,430] Trial 91 finished with value: 0.956140350877193 and parameters: {'max_depth': 10, 'min_samples_leaf
': 4, 'ccp_alpha': 0.012756507904928419, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,457] Trial 92 finished with value: 0.9473684210526315 and parameters: {'max_depth': 11, 'min_samples_lea
f': 3, 'ccp_alpha': 0.01826469235215208, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,484] Trial 93 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_leaf
': 3, 'ccp_alpha': 0.0020413129890195208, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,509] Trial 94 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_lea
f': 1, 'ccp_alpha': 0.014853904248349993, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,538] Trial 95 finished with value: 0.956140350877193 and parameters: {'max_depth': 12, 'min_samples_leaf
': 2, 'ccp_alpha': 0.01247051420059055, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,572] Trial 96 finished with value: 0.956140350877193 and parameters: {'max_depth': 4, 'min_samples_leaf'
: 9, 'ccp_alpha': 0.00827152303741145, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,607] Trial 97 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_lea
f': 4, 'ccp_alpha': 0.0057403791322280925, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,641] Trial 98 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_lea
f': 3, 'ccp_alpha': 0.0216082097487802, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,675] Trial 99 finished with value: 0.9473684210526315 and parameters: {'max_depth': 8, 'min_samples_leaf
': 5, 'ccp_alpha': 0.027959360326245533, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,702] Trial 100 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 2, 'ccp_alpha': 0.01155669050613195, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,729] Trial 101 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_le
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af': 2, 'ccp_alpha': 0.016079010109305344, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,759] Trial 102 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_lea
f': 2, 'ccp_alpha': 0.009865066327806439, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,787] Trial 103 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_lea
f': 1, 'ccp_alpha': 0.012014014583041455, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,813] Trial 104 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 3, 'ccp_alpha': 0.005074932991216294, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,839] Trial 105 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_le
af': 2, 'ccp_alpha': 0.014509483138080943, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,865] Trial 106 finished with value: 0.9473684210526315 and parameters: {'max_depth': 10, 'min_samples_le
af': 3, 'ccp_alpha': 0.04303728227076394, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,893] Trial 107 finished with value: 0.9473684210526315 and parameters: {'max_depth': 11, 'min_samples_le
af': 1, 'ccp_alpha': 0.018255081648005867, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,918] Trial 108 finished with value: 0.9122807017543859 and parameters: {'max_depth': 16, 'min_samples_le
af': 2, 'ccp_alpha': 0.08222958388646368, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,944] Trial 109 finished with value: 0.9210526315789473 and parameters: {'max_depth': 12, 'min_samples_le
af': 4, 'ccp_alpha': 9.44424259877643e-05, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,969] Trial 110 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_le
af': 3, 'ccp_alpha': 0.007714096798698751, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:26,995] Trial 111 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_le
af': 2, 'ccp_alpha': 0.008932800852078713, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,021] Trial 112 finished with value: 0.9385964912280702 and parameters: {'max_depth': 15, 'min_samples_le
af': 2, 'ccp_alpha': 0.0033342526099666347, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,047] Trial 113 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_lea
f': 2, 'ccp_alpha': 0.006567774298873655, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,075] Trial 114 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 1, 'ccp_alpha': 0.011089877022638217, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,102] Trial 115 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_lea
f': 3, 'ccp_alpha': 0.014071708443343031, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,130] Trial 116 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_le
af': 2, 'ccp_alpha': 0.01730387694813821, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,157] Trial 117 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_le
af': 6, 'ccp_alpha': 0.00901031931958271, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,183] Trial 118 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_le
af': 3, 'ccp_alpha': 0.00223508761337009, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,211] Trial 119 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_le
af': 5, 'ccp_alpha': 0.00472157351623142, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,239] Trial 120 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 2, 'ccp_alpha': 0.012693186028573035, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,265] Trial 121 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 5, 'ccp_alpha': 0.010941128947783135, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
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[I 2025-04-24 18:54:27,292] Trial 122 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 5, 'ccp_alpha': 0.013996960507524336, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,320] Trial 123 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 4, 'ccp_alpha': 0.00689778038466834, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,346] Trial 124 finished with value: 0.9122807017543859 and parameters: {'max_depth': 14, 'min_samples_le
af': 5, 'ccp_alpha': 0.08806917893272559, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,374] Trial 125 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 4, 'ccp_alpha': 0.009604753286536148, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,403] Trial 126 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_le
af': 1, 'ccp_alpha': 0.01608224262041401, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,430] Trial 127 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 3, 'ccp_alpha': 0.019791541530694054, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,459] Trial 128 finished with value: 0.956140350877193 and parameters: {'max_depth': 15, 'min_samples_lea
f': 6, 'ccp_alpha': 0.012612250875639658, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,481] Trial 129 finished with value: 0.9122807017543859 and parameters: {'max_depth': 2, 'min_samples_lea
f': 3, 'ccp_alpha': 0.05530038539523035, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,525] Trial 130 finished with value: 0.9122807017543859 and parameters: {'max_depth': 6, 'min_samples_lea
f': 2, 'ccp_alpha': 0.09957312469363601, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,566] Trial 131 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_le
af': 2, 'ccp_alpha': 0.007942849326604303, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,596] Trial 132 finished with value: 0.956140350877193 and parameters: {'max_depth': 11, 'min_samples_lea
f': 2, 'ccp_alpha': 0.010306997014700538, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,623] Trial 133 finished with value: 0.9473684210526315 and parameters: {'max_depth': 13, 'min_samples_le
af': 1, 'ccp_alpha': 0.005747447880730965, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,650] Trial 134 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_le
af': 2, 'ccp_alpha': 0.01518769923244324, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,679] Trial 135 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_lea
f': 3, 'ccp_alpha': 0.012287614509756364, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,705] Trial 136 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_le
af': 2, 'ccp_alpha': 0.008552499360010249, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,733] Trial 137 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_lea
f': 4, 'ccp_alpha': 0.010683682211763716, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,764] Trial 138 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_le
af': 3, 'ccp_alpha': 0.004268294127679495, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,792] Trial 139 finished with value: 0.9473684210526315 and parameters: {'max_depth': 20, 'min_samples_le
af': 5, 'ccp_alpha': 0.006773135496525964, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,818] Trial 140 finished with value: 0.9473684210526315 and parameters: {'max_depth': 11, 'min_samples_le
af': 2, 'ccp_alpha': 0.017120532083487218, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,845] Trial 141 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 1, 'ccp_alpha': 0.013646685373867476, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,872] Trial 142 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
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f': 1, 'ccp_alpha': 0.013760199543628933, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,902] Trial 143 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 1, 'ccp_alpha': 0.00923065799496182, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,929] Trial 144 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_le
af': 1, 'ccp_alpha': 0.023832684481949168, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,958] Trial 145 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_le
af': 2, 'ccp_alpha': 0.015726909875018694, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:27,992] Trial 146 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 1, 'ccp_alpha': 0.01179442525587707, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,025] Trial 147 finished with value: 0.9122807017543859 and parameters: {'max_depth': 20, 'min_samples_le
af': 3, 'ccp_alpha': 0.07361828280368432, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,059] Trial 148 finished with value: 0.9122807017543859 and parameters: {'max_depth': 14, 'min_samples_le
af': 2, 'ccp_alpha': 0.07727691670614309, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,092] Trial 149 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_le
af': 2, 'ccp_alpha': 0.018306955067164253, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,126] Trial 150 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_le
af': 7, 'ccp_alpha': 0.020890988769791896, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,158] Trial 151 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 5, 'ccp_alpha': 0.010964091402412699, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,189] Trial 152 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_le
af': 5, 'ccp_alpha': 0.007046132915039182, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,229] Trial 153 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 5, 'ccp_alpha': 0.013952375611696415, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,261] Trial 154 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 4, 'ccp_alpha': 0.009867392832198904, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,297] Trial 155 finished with value: 0.9385964912280702 and parameters: {'max_depth': 10, 'min_samples_le
af': 5, 'ccp_alpha': 0.0027626216788875276, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,329] Trial 156 finished with value: 0.9473684210526315 and parameters: {'max_depth': 13, 'min_samples_le
af': 6, 'ccp_alpha': 0.008242231282504103, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,362] Trial 157 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 3, 'ccp_alpha': 0.012354836936751191, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,392] Trial 158 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_le
af': 2, 'ccp_alpha': 0.004627894871726811, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,420] Trial 159 finished with value: 0.9473684210526315 and parameters: {'max_depth': 7, 'min_samples_lea
f': 1, 'ccp_alpha': 0.037659499456397995, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,447] Trial 160 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_le
af': 2, 'ccp_alpha': 0.01490083354686509, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,476] Trial 161 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 3, 'ccp_alpha': 0.010511988190216788, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,509] Trial 162 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 3, 'ccp_alpha': 0.008906123970310516, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
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[I 2025-04-24 18:54:28,541] Trial 163 finished with value: 0.956140350877193 and parameters: {'max_depth': 16, 'min_samples_lea
f': 4, 'ccp_alpha': 0.011719429817843845, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,571] Trial 164 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_le
af': 3, 'ccp_alpha': 0.016180785934563922, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,600] Trial 165 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 3, 'ccp_alpha': 0.006835268273102845, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,635] Trial 166 finished with value: 0.956140350877193 and parameters: {'max_depth': 12, 'min_samples_lea
f': 2, 'ccp_alpha': 0.012941522005969373, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,669] Trial 167 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_lea
f': 3, 'ccp_alpha': 0.01039365103553845, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,710] Trial 168 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_le
af': 5, 'ccp_alpha': 0.006176805034784631, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,744] Trial 169 finished with value: 0.9473684210526315 and parameters: {'max_depth': 17, 'min_samples_le
af': 4, 'ccp_alpha': 0.00857847533672196, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,781] Trial 170 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 2, 'ccp_alpha': 0.014392231576701935, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,818] Trial 171 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 2, 'ccp_alpha': 0.01351430858788761, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,878] Trial 172 finished with value: 0.956140350877193 and parameters: {'max_depth': 16, 'min_samples_lea
f': 2, 'ccp_alpha': 0.011106818476871734, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,951] Trial 173 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 2, 'ccp_alpha': 0.017584171378321672, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:28,997] Trial 174 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 3, 'ccp_alpha': 0.009854837781316081, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,040] Trial 175 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 1, 'ccp_alpha': 0.015426432176457443, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,082] Trial 176 finished with value: 0.9122807017543859 and parameters: {'max_depth': 4, 'min_samples_lea
f': 2, 'ccp_alpha': 0.06491508948258547, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,119] Trial 177 finished with value: 0.956140350877193 and parameters: {'max_depth': 11, 'min_samples_lea
f': 3, 'ccp_alpha': 0.012278903181318314, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,158] Trial 178 finished with value: 0.956140350877193 and parameters: {'max_depth': 15, 'min_samples_lea
f': 2, 'ccp_alpha': 0.0068769385790820375, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,191] Trial 179 finished with value: 0.9473684210526315 and parameters: {'max_depth': 14, 'min_samples_le
af': 1, 'ccp_alpha': 0.018945948790530125, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,229] Trial 180 finished with value: 0.9473684210526315 and parameters: {'max_depth': 13, 'min_samples_le
af': 5, 'ccp_alpha': 0.004917858724740444, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,267] Trial 181 finished with value: 0.956140350877193 and parameters: {'max_depth': 15, 'min_samples_lea
f': 3, 'ccp_alpha': 0.009601221340671134, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,308] Trial 182 finished with value: 0.956140350877193 and parameters: {'max_depth': 15, 'min_samples_lea
f': 3, 'ccp_alpha': 0.013645874799191242, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,346] Trial 183 finished with value: 0.9473684210526315 and parameters: {'max_depth': 16, 'min_samples_le
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af': 3, 'ccp_alpha': 0.007870026246866555, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,391] Trial 184 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 4, 'ccp_alpha': 0.011413759553438376, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,428] Trial 185 finished with value: 0.956140350877193 and parameters: {'max_depth': 14, 'min_samples_lea
f': 3, 'ccp_alpha': 0.009947181603968427, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,469] Trial 186 finished with value: 0.9473684210526315 and parameters: {'max_depth': 19, 'min_samples_le
af': 2, 'ccp_alpha': 0.01593186177655112, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,509] Trial 187 finished with value: 0.956140350877193 and parameters: {'max_depth': 16, 'min_samples_lea
f': 2, 'ccp_alpha': 0.012981302707830917, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,549] Trial 188 finished with value: 0.9473684210526315 and parameters: {'max_depth': 12, 'min_samples_le
af': 3, 'ccp_alpha': 0.008251113817575553, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,587] Trial 189 finished with value: 0.9298245614035088 and parameters: {'max_depth': 17, 'min_samples_le
af': 1, 'ccp_alpha': 0.003029905994473404, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,625] Trial 190 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 2, 'ccp_alpha': 0.005762260456461157, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,656] Trial 191 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 3, 'ccp_alpha': 0.010563614404649885, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,689] Trial 192 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 3, 'ccp_alpha': 0.0077031175075680785, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,733] Trial 193 finished with value: 0.956140350877193 and parameters: {'max_depth': 18, 'min_samples_lea
f': 3, 'ccp_alpha': 0.011668748042015719, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,781] Trial 194 finished with value: 0.9473684210526315 and parameters: {'max_depth': 18, 'min_samples_le
af': 5, 'ccp_alpha': 0.014654008162457557, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,828] Trial 195 finished with value: 0.956140350877193 and parameters: {'max_depth': 17, 'min_samples_lea
f': 3, 'ccp_alpha': 0.005953848917022505, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,867] Trial 196 finished with value: 0.9473684210526315 and parameters: {'max_depth': 15, 'min_samples_le
af': 4, 'ccp_alpha': 0.009050640734623177, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,908] Trial 197 finished with value: 0.956140350877193 and parameters: {'max_depth': 19, 'min_samples_lea
f': 2, 'ccp_alpha': 0.012393557450313229, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,940] Trial 198 finished with value: 0.9473684210526315 and parameters: {'max_depth': 11, 'min_samples_le
af': 3, 'ccp_alpha': 0.004145461935998108, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
[I 2025-04-24 18:54:29,973] Trial 199 finished with value: 0.956140350877193 and parameters: {'max_depth': 13, 'min_samples_lea
f': 2, 'ccp_alpha': 0.01003422655698576, 'criterion': 'gini'}. Best is trial 6 with value: 0.956140350877193.
Best Parameters: {'max_depth': 6, 'min_samples_leaf': 4, 'ccp_alpha': 0.013582364004914261, 'criterion': 'gini'}
Best Accuracy: 0.956140350877193
Total Runtime: 6.00 seconds
```

In [134…

```python
start_time_e = time.time()  # Record the start time

def objective(trial):
    # Define the hyperparameters to tune
```

```
    max_depth = trial.suggest_int('max_depth', 1, 20)
    min_samples_leaf = trial.suggest_int('min_samples_leaf', 1, 10)
    ccp_alpha = trial.suggest_float('ccp_alpha', 0.0, 0.1)
    random_state = 42  # Fixed for reproducibility
    criterion = trial.suggest_categorical('criterion',['entropy'])

    # Create and train the DecisionTreeClassifier
    classifier = DecisionTreeClassifier(
        max_depth=max_depth,
        min_samples_leaf=min_samples_leaf,
        ccp_alpha=ccp_alpha,
        random_state=random_state,
        criterion=criterion
    )
    classifier.fit(X_train, y_train)

    # Predict and calculate accuracy
    y_pred = classifier.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)

    return accuracy

# Create a study and optimize the objective function
study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=200)

# Display the best parameters and accuracy
print("Best Parameters:", study.best_params)
print("Best Accuracy:", study.best_value)

best_max_depth_e = study.best_params['max_depth']
best_min_samples_leaf_e = study.best_params['min_samples_leaf']
best_ccp_alpha_e = study.best_params['ccp_alpha']

end_time_e = time.time()  # Record the end time
print(f"Total Runtime: {end_time_e - start_time_e:.2f} seconds")
```

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[I 2025-04-24 18:54:29,989] A new study created in memory with name: no-name-2d479192-a1f5-45a6-9ed9-2ffaa8834f9a
[I 2025-04-24 18:54:30,007] Trial 0 finished with value: 0.9122807017543859 and parameters: {'max_depth': 10, 'min_samples_leaf
': 2, 'ccp_alpha': 0.012466571993919685, 'criterion': 'entropy'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:30,023] Trial 1 finished with value: 0.9035087719298246 and parameters: {'max_depth': 10, 'min_samples_leaf
': 10, 'ccp_alpha': 0.061422159070454764, 'criterion': 'entropy'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:30,044] Trial 2 finished with value: 0.9122807017543859 and parameters: {'max_depth': 14, 'min_samples_leaf
': 1, 'ccp_alpha': 0.024806774134682377, 'criterion': 'entropy'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:30,059] Trial 3 finished with value: 0.9035087719298246 and parameters: {'max_depth': 1, 'min_samples_leaf'
: 5, 'ccp_alpha': 0.09461871858293557, 'criterion': 'entropy'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:30,106] Trial 4 finished with value: 0.9122807017543859 and parameters: {'max_depth': 7, 'min_samples_leaf'
: 3, 'ccp_alpha': 0.028383350903078565, 'criterion': 'entropy'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:30,120] Trial 5 finished with value: 0.9035087719298246 and parameters: {'max_depth': 6, 'min_samples_leaf'
: 6, 'ccp_alpha': 0.05716249487174138, 'criterion': 'entropy'}. Best is trial 0 with value: 0.9122807017543859.
[I 2025-04-24 18:54:30,142] Trial 6 finished with value: 0.9210526315789473 and parameters: {'max_depth': 16, 'min_samples_leaf
': 1, 'ccp_alpha': 0.03970730163224656, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,156] Trial 7 finished with value: 0.9210526315789473 and parameters: {'max_depth': 5, 'min_samples_leaf'
: 4, 'ccp_alpha': 0.031705046575928174, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,167] Trial 8 finished with value: 0.9035087719298246 and parameters: {'max_depth': 4, 'min_samples_leaf'
: 3, 'ccp_alpha': 0.052899190214043115, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,174] Trial 9 finished with value: 0.9035087719298246 and parameters: {'max_depth': 1, 'min_samples_leaf'
: 1, 'ccp_alpha': 0.07961069583007853, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,202] Trial 10 finished with value: 0.9122807017543859 and parameters: {'max_depth': 20, 'min_samples_lea
f': 7, 'ccp_alpha': 0.008326465755727833, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,227] Trial 11 finished with value: 0.9122807017543859 and parameters: {'max_depth': 15, 'min_samples_lea
f': 4, 'ccp_alpha': 0.028747002520059947, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,259] Trial 12 finished with value: 0.9210526315789473 and parameters: {'max_depth': 19, 'min_samples_lea
f': 8, 'ccp_alpha': 0.04093671444697051, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,290] Trial 13 finished with value: 0.9210526315789473 and parameters: {'max_depth': 15, 'min_samples_lea
f': 4, 'ccp_alpha': 0.04002217531862488, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,330] Trial 14 finished with value: 0.9035087719298246 and parameters: {'max_depth': 13, 'min_samples_lea
f': 2, 'ccp_alpha': 0.07420038840469709, 'criterion': 'entropy'}. Best is trial 6 with value: 0.9210526315789473.
[I 2025-04-24 18:54:30,360] Trial 15 finished with value: 0.9298245614035088 and parameters: {'max_depth': 17, 'min_samples_lea
f': 5, 'ccp_alpha': 0.04199522470300826, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,387] Trial 16 finished with value: 0.9122807017543859 and parameters: {'max_depth': 17, 'min_samples_lea
f': 9, 'ccp_alpha': 0.000691100702312944, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,420] Trial 17 finished with value: 0.9298245614035088 and parameters: {'max_depth': 18, 'min_samples_lea
f': 6, 'ccp_alpha': 0.04409399405756608, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,444] Trial 18 finished with value: 0.9035087719298246 and parameters: {'max_depth': 18, 'min_samples_lea
f': 6, 'ccp_alpha': 0.068001264746148, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,468] Trial 19 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_lea
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f': 7, 'ccp_alpha': 0.04722444740011055, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,493] Trial 20 finished with value: 0.9122807017543859 and parameters: {'max_depth': 20, 'min_samples_lea
f': 5, 'ccp_alpha': 0.01899927405370131, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,523] Trial 21 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_lea
f': 7, 'ccp_alpha': 0.045078535203723104, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,553] Trial 22 finished with value: 0.9035087719298246 and parameters: {'max_depth': 17, 'min_samples_lea
f': 7, 'ccp_alpha': 0.05257640729771374, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,587] Trial 23 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_lea
f': 8, 'ccp_alpha': 0.06228024632541778, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,616] Trial 24 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_leaf
': 6, 'ccp_alpha': 0.04718960312662741, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,644] Trial 25 finished with value: 0.9210526315789473 and parameters: {'max_depth': 18, 'min_samples_lea
f': 8, 'ccp_alpha': 0.03487999124951786, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,674] Trial 26 finished with value: 0.9035087719298246 and parameters: {'max_depth': 14, 'min_samples_lea
f': 5, 'ccp_alpha': 0.08390230507332175, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,701] Trial 27 finished with value: 0.9035087719298246 and parameters: {'max_depth': 9, 'min_samples_leaf
': 7, 'ccp_alpha': 0.048522481077010945, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,733] Trial 28 finished with value: 0.9210526315789473 and parameters: {'max_depth': 12, 'min_samples_lea
f': 9, 'ccp_alpha': 0.01969016291651091, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,769] Trial 29 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_lea
f': 6, 'ccp_alpha': 0.058608213831837355, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,801] Trial 30 finished with value: 0.9035087719298246 and parameters: {'max_depth': 16, 'min_samples_lea
f': 5, 'ccp_alpha': 0.06864071828321669, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,829] Trial 31 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04523554957465939, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,861] Trial 32 finished with value: 0.9210526315789473 and parameters: {'max_depth': 9, 'min_samples_leaf
': 7, 'ccp_alpha': 0.036453201292921386, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,891] Trial 33 finished with value: 0.9035087719298246 and parameters: {'max_depth': 14, 'min_samples_lea
f': 9, 'ccp_alpha': 0.05081587417739521, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,920] Trial 34 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_lea
f': 10, 'ccp_alpha': 0.043641707505580295, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,948] Trial 35 finished with value: 0.9210526315789473 and parameters: {'max_depth': 10, 'min_samples_lea
f': 8, 'ccp_alpha': 0.022901716360573112, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:30,975] Trial 36 finished with value: 0.9035087719298246 and parameters: {'max_depth': 18, 'min_samples_lea
f': 6, 'ccp_alpha': 0.060585291248203124, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,003] Trial 37 finished with value: 0.9210526315789473 and parameters: {'max_depth': 16, 'min_samples_lea
f': 5, 'ccp_alpha': 0.03209910404180576, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,034] Trial 38 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_lea
f': 4, 'ccp_alpha': 0.05564313728850474, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,073] Trial 39 finished with value: 0.9035087719298246 and parameters: {'max_depth': 19, 'min_samples_lea
f': 6, 'ccp_alpha': 0.09920598443398816, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
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[I 2025-04-24 18:54:31,162] Trial 40 finished with value: 0.9122807017543859 and parameters: {'max_depth': 15, 'min_samples_lea
f': 3, 'ccp_alpha': 0.028131177061683933, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,201] Trial 41 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_leaf
': 6, 'ccp_alpha': 0.04789241733636524, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,236] Trial 42 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_leaf
': 7, 'ccp_alpha': 0.04557905596157614, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,265] Trial 43 finished with value: 0.9210526315789473 and parameters: {'max_depth': 5, 'min_samples_leaf
': 5, 'ccp_alpha': 0.03717168243611219, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,295] Trial 44 finished with value: 0.9298245614035088 and parameters: {'max_depth': 3, 'min_samples_leaf
': 6, 'ccp_alpha': 0.04264610551883467, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,323] Trial 45 finished with value: 0.9035087719298246 and parameters: {'max_depth': 7, 'min_samples_leaf
': 7, 'ccp_alpha': 0.06430323625368196, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,358] Trial 46 finished with value: 0.9035087719298246 and parameters: {'max_depth': 9, 'min_samples_leaf
': 8, 'ccp_alpha': 0.05497820843799528, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,396] Trial 47 finished with value: 0.9210526315789473 and parameters: {'max_depth': 10, 'min_samples_lea
f': 4, 'ccp_alpha': 0.03875015215975752, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,431] Trial 48 finished with value: 0.9035087719298246 and parameters: {'max_depth': 6, 'min_samples_leaf
': 6, 'ccp_alpha': 0.050111395319886586, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,464] Trial 49 finished with value: 0.9210526315789473 and parameters: {'max_depth': 13, 'min_samples_lea
f': 5, 'ccp_alpha': 0.03439685139912298, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,505] Trial 50 finished with value: 0.9210526315789473 and parameters: {'max_depth': 19, 'min_samples_lea
f': 2, 'ccp_alpha': 0.030414372383930625, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,545] Trial 51 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_lea
f': 7, 'ccp_alpha': 0.0462500567402129, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,583] Trial 52 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_lea
f': 7, 'ccp_alpha': 0.042648300148964216, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,617] Trial 53 finished with value: 0.9035087719298246 and parameters: {'max_depth': 17, 'min_samples_lea
f': 8, 'ccp_alpha': 0.05218188774831093, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,648] Trial 54 finished with value: 0.9210526315789473 and parameters: {'max_depth': 14, 'min_samples_lea
f': 6, 'ccp_alpha': 0.04040545713441497, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,680] Trial 55 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_leaf
': 7, 'ccp_alpha': 0.04631712672436825, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,713] Trial 56 finished with value: 0.9035087719298246 and parameters: {'max_depth': 13, 'min_samples_lea
f': 6, 'ccp_alpha': 0.05663003398515518, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,744] Trial 57 finished with value: 0.9035087719298246 and parameters: {'max_depth': 10, 'min_samples_lea
f': 7, 'ccp_alpha': 0.06512039062674405, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,785] Trial 58 finished with value: 0.9122807017543859 and parameters: {'max_depth': 15, 'min_samples_lea
f': 5, 'ccp_alpha': 0.023884874962345166, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,822] Trial 59 finished with value: 0.9210526315789473 and parameters: {'max_depth': 20, 'min_samples_lea
f': 8, 'ccp_alpha': 0.03317260091954247, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,856] Trial 60 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_lea
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f': 4, 'ccp_alpha': 0.0537475906704897, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,887] Trial 61 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_lea
f': 9, 'ccp_alpha': 0.044194729459288894, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,920] Trial 62 finished with value: 0.9210526315789473 and parameters: {'max_depth': 11, 'min_samples_lea
f': 10, 'ccp_alpha': 0.04118633861976948, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,951] Trial 63 finished with value: 0.9035087719298246 and parameters: {'max_depth': 16, 'min_samples_lea
f': 10, 'ccp_alpha': 0.04906634761108647, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:31,984] Trial 64 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_lea
f': 10, 'ccp_alpha': 0.04427832033262183, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,021] Trial 65 finished with value: 0.9210526315789473 and parameters: {'max_depth': 14, 'min_samples_lea
f': 9, 'ccp_alpha': 0.03800299834698267, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,054] Trial 66 finished with value: 0.9035087719298246 and parameters: {'max_depth': 9, 'min_samples_leaf
': 6, 'ccp_alpha': 0.059688631345503826, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,088] Trial 67 finished with value: 0.9122807017543859 and parameters: {'max_depth': 17, 'min_samples_lea
f': 5, 'ccp_alpha': 0.026720639325893587, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,122] Trial 68 finished with value: 0.9035087719298246 and parameters: {'max_depth': 13, 'min_samples_lea
f': 3, 'ccp_alpha': 0.05129336706994527, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,155] Trial 69 finished with value: 0.9298245614035088 and parameters: {'max_depth': 15, 'min_samples_lea
f': 8, 'ccp_alpha': 0.04789736297589694, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,186] Trial 70 finished with value: 0.9210526315789473 and parameters: {'max_depth': 18, 'min_samples_lea
f': 6, 'ccp_alpha': 0.036307649098265615, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,219] Trial 71 finished with value: 0.9035087719298246 and parameters: {'max_depth': 8, 'min_samples_leaf
': 6, 'ccp_alpha': 0.048597591924703844, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,249] Trial 72 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_leaf
': 7, 'ccp_alpha': 0.0423391561752691, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,284] Trial 73 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_lea
f': 7, 'ccp_alpha': 0.045692338161358245, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,313] Trial 74 finished with value: 0.9210526315789473 and parameters: {'max_depth': 7, 'min_samples_leaf
': 5, 'ccp_alpha': 0.03951590127847156, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,363] Trial 75 finished with value: 0.9035087719298246 and parameters: {'max_depth': 6, 'min_samples_leaf
': 6, 'ccp_alpha': 0.0552822507170464, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,406] Trial 76 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_lea
f': 6, 'ccp_alpha': 0.050386643033800735, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,441] Trial 77 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_leaf
': 5, 'ccp_alpha': 0.047307309207838655, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,469] Trial 78 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_leaf
': 7, 'ccp_alpha': 0.04399532100159613, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,501] Trial 79 finished with value: 0.9035087719298246 and parameters: {'max_depth': 19, 'min_samples_lea
f': 4, 'ccp_alpha': 0.057383894359769275, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,533] Trial 80 finished with value: 0.9210526315789473 and parameters: {'max_depth': 12, 'min_samples_lea
f': 7, 'ccp_alpha': 0.03506486751254573, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
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[I 2025-04-24 18:54:32,559] Trial 81 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_leaf
': 8, 'ccp_alpha': 0.045788137659355216, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,584] Trial 82 finished with value: 0.9035087719298246 and parameters: {'max_depth': 10, 'min_samples_lea
f': 7, 'ccp_alpha': 0.0531156972395376, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,615] Trial 83 finished with value: 0.9210526315789473 and parameters: {'max_depth': 5, 'min_samples_leaf
': 6, 'ccp_alpha': 0.04032425451025998, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,645] Trial 84 finished with value: 0.9210526315789473 and parameters: {'max_depth': 8, 'min_samples_leaf
': 7, 'ccp_alpha': 0.03086230825119086, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,677] Trial 85 finished with value: 0.9210526315789473 and parameters: {'max_depth': 9, 'min_samples_leaf
': 6, 'ccp_alpha': 0.03790224910606923, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,707] Trial 86 finished with value: 0.9298245614035088 and parameters: {'max_depth': 6, 'min_samples_leaf
': 8, 'ccp_alpha': 0.04324801935994269, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,738] Trial 87 finished with value: 0.9035087719298246 and parameters: {'max_depth': 4, 'min_samples_leaf
': 5, 'ccp_alpha': 0.049443657659662306, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,769] Trial 88 finished with value: 0.9122807017543859 and parameters: {'max_depth': 11, 'min_samples_lea
f': 7, 'ccp_alpha': 0.012825061953789699, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,797] Trial 89 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_leaf
': 6, 'ccp_alpha': 0.04564687841206735, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,826] Trial 90 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_lea
f': 6, 'ccp_alpha': 0.05308828327010026, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,849] Trial 91 finished with value: 0.9035087719298246 and parameters: {'max_depth': 2, 'min_samples_leaf
': 7, 'ccp_alpha': 0.0420376994248848, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,874] Trial 92 finished with value: 0.9298245614035088 and parameters: {'max_depth': 3, 'min_samples_leaf
': 1, 'ccp_alpha': 0.04775102073595905, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,904] Trial 93 finished with value: 0.9298245614035088 and parameters: {'max_depth': 3, 'min_samples_leaf
': 5, 'ccp_alpha': 0.04152683343933814, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,943] Trial 94 finished with value: 0.9035087719298246 and parameters: {'max_depth': 13, 'min_samples_lea
f': 6, 'ccp_alpha': 0.08337038820737637, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:32,981] Trial 95 finished with value: 0.9298245614035088 and parameters: {'max_depth': 5, 'min_samples_leaf
': 8, 'ccp_alpha': 0.04422741996281718, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,018] Trial 96 finished with value: 0.9210526315789473 and parameters: {'max_depth': 17, 'min_samples_lea
f': 6, 'ccp_alpha': 0.033079376839868745, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,050] Trial 97 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_lea
f': 7, 'ccp_alpha': 0.05133749145125547, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,091] Trial 98 finished with value: 0.9210526315789473 and parameters: {'max_depth': 14, 'min_samples_lea
f': 4, 'ccp_alpha': 0.03927142246336844, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,116] Trial 99 finished with value: 0.9035087719298246 and parameters: {'max_depth': 1, 'min_samples_leaf
': 5, 'ccp_alpha': 0.062468150921448765, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,150] Trial 100 finished with value: 0.9210526315789473 and parameters: {'max_depth': 10, 'min_samples_le
af': 9, 'ccp_alpha': 0.03552013040793173, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,184] Trial 101 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
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af': 7, 'ccp_alpha': 0.045481327549242175, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,214] Trial 102 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 7, 'ccp_alpha': 0.04652942639754995, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,243] Trial 103 finished with value: 0.9035087719298246 and parameters: {'max_depth': 18, 'min_samples_le
af': 6, 'ccp_alpha': 0.048801570766813185, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,269] Trial 104 finished with value: 0.9298245614035088 and parameters: {'max_depth': 16, 'min_samples_le
af': 7, 'ccp_alpha': 0.04278771813666512, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,296] Trial 105 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_le
af': 8, 'ccp_alpha': 0.05419748704365062, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,320] Trial 106 finished with value: 0.9035087719298246 and parameters: {'max_depth': 13, 'min_samples_le
af': 6, 'ccp_alpha': 0.05082724578396871, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,347] Trial 107 finished with value: 0.9210526315789473 and parameters: {'max_depth': 10, 'min_samples_le
af': 7, 'ccp_alpha': 0.03798024700319213, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,377] Trial 108 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 6, 'ccp_alpha': 0.04702349319651755, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,405] Trial 109 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_le
af': 5, 'ccp_alpha': 0.05740606010451529, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,431] Trial 110 finished with value: 0.9210526315789473 and parameters: {'max_depth': 13, 'min_samples_le
af': 7, 'ccp_alpha': 0.04045888638409024, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,458] Trial 111 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
af': 7, 'ccp_alpha': 0.04263489756612293, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,486] Trial 112 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 7, 'ccp_alpha': 0.04309738554752512, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,519] Trial 113 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_le
af': 6, 'ccp_alpha': 0.04507586509640122, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,563] Trial 114 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_le
af': 8, 'ccp_alpha': 0.04933704568362155, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,602] Trial 115 finished with value: 0.9210526315789473 and parameters: {'max_depth': 19, 'min_samples_le
af': 6, 'ccp_alpha': 0.036636513637610606, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,631] Trial 116 finished with value: 0.9210526315789473 and parameters: {'max_depth': 20, 'min_samples_le
af': 7, 'ccp_alpha': 0.039323896672633966, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,658] Trial 117 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 8, 'ccp_alpha': 0.04771476815902995, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,687] Trial 118 finished with value: 0.9035087719298246 and parameters: {'max_depth': 18, 'min_samples_le
af': 6, 'ccp_alpha': 0.05152401884167414, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,720] Trial 119 finished with value: 0.9210526315789473 and parameters: {'max_depth': 14, 'min_samples_le
af': 10, 'ccp_alpha': 0.04091896073604859, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,751] Trial 120 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_le
af': 7, 'ccp_alpha': 0.04430442494928326, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,779] Trial 121 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04702425951488876, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
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[I 2025-04-24 18:54:33,806] Trial 122 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.0455923466517459, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,834] Trial 123 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.0427098876164278, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,861] Trial 124 finished with value: 0.9035087719298246 and parameters: {'max_depth': 6, 'min_samples_lea
f': 5, 'ccp_alpha': 0.04988769928571231, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,890] Trial 125 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_le
af': 8, 'ccp_alpha': 0.05297420751301923, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,917] Trial 126 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_lea
f': 6, 'ccp_alpha': 0.04146256245688452, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,943] Trial 127 finished with value: 0.9210526315789473 and parameters: {'max_depth': 9, 'min_samples_lea
f': 6, 'ccp_alpha': 0.03840564994480236, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:33,974] Trial 128 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
af': 7, 'ccp_alpha': 0.04693302529418225, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,006] Trial 129 finished with value: 0.9035087719298246 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.0557986121973789, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,038] Trial 130 finished with value: 0.9035087719298246 and parameters: {'max_depth': 2, 'min_samples_lea
f': 9, 'ccp_alpha': 0.04419839157513273, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,070] Trial 131 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_le
af': 10, 'ccp_alpha': 0.04444918082161879, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,102] Trial 132 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 9, 'ccp_alpha': 0.04790183615448507, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,134] Trial 133 finished with value: 0.9210526315789473 and parameters: {'max_depth': 13, 'min_samples_le
af': 10, 'ccp_alpha': 0.04121523538770038, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,173] Trial 134 finished with value: 0.9035087719298246 and parameters: {'max_depth': 15, 'min_samples_le
af': 9, 'ccp_alpha': 0.04903810004026035, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,202] Trial 135 finished with value: 0.9210526315789473 and parameters: {'max_depth': 12, 'min_samples_le
af': 7, 'ccp_alpha': 0.034375381945430064, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,232] Trial 136 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_le
af': 8, 'ccp_alpha': 0.04544639132501032, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,259] Trial 137 finished with value: 0.9035087719298246 and parameters: {'max_depth': 4, 'min_samples_lea
f': 6, 'ccp_alpha': 0.05189400781823938, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,291] Trial 138 finished with value: 0.9210526315789473 and parameters: {'max_depth': 14, 'min_samples_le
af': 5, 'ccp_alpha': 0.037226352710704645, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,327] Trial 139 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
af': 6, 'ccp_alpha': 0.04319043957969252, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,371] Trial 140 finished with value: 0.9122807017543859 and parameters: {'max_depth': 10, 'min_samples_le
af': 10, 'ccp_alpha': 0.001501076516175058, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,400] Trial 141 finished with value: 0.9210526315789473 and parameters: {'max_depth': 12, 'min_samples_le
af': 10, 'ccp_alpha': 0.039841181486015474, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,432] Trial 142 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
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af': 10, 'ccp_alpha': 0.04611977748586588, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,462] Trial 143 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 10, 'ccp_alpha': 0.04383587391503722, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,491] Trial 144 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_le
af': 9, 'ccp_alpha': 0.04980898816839606, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,522] Trial 145 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04843312391899891, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,552] Trial 146 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_le
af': 7, 'ccp_alpha': 0.041480660985809124, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,584] Trial 147 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 6, 'ccp_alpha': 0.04629209828226071, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,615] Trial 148 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_le
af': 10, 'ccp_alpha': 0.043723974096684895, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,709] Trial 149 finished with value: 0.9210526315789473 and parameters: {'max_depth': 17, 'min_samples_le
af': 6, 'ccp_alpha': 0.03894620902706936, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,749] Trial 150 finished with value: 0.9035087719298246 and parameters: {'max_depth': 8, 'min_samples_lea
f': 8, 'ccp_alpha': 0.09293372649539006, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,778] Trial 151 finished with value: 0.9298245614035088 and parameters: {'max_depth': 15, 'min_samples_le
af': 8, 'ccp_alpha': 0.047538350240466175, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,808] Trial 152 finished with value: 0.9035087719298246 and parameters: {'max_depth': 17, 'min_samples_le
af': 9, 'ccp_alpha': 0.050326557092734425, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,840] Trial 153 finished with value: 0.9298245614035088 and parameters: {'max_depth': 14, 'min_samples_le
af': 7, 'ccp_alpha': 0.0452720717586699, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,871] Trial 154 finished with value: 0.9298245614035088 and parameters: {'max_depth': 18, 'min_samples_le
af': 7, 'ccp_alpha': 0.04146805077500669, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,900] Trial 155 finished with value: 0.9035087719298246 and parameters: {'max_depth': 12, 'min_samples_le
af': 8, 'ccp_alpha': 0.05306559533726757, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,930] Trial 156 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
af': 9, 'ccp_alpha': 0.04743588704770309, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,963] Trial 157 finished with value: 0.9298245614035088 and parameters: {'max_depth': 16, 'min_samples_le
af': 7, 'ccp_alpha': 0.04391594610349278, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:34,998] Trial 158 finished with value: 0.9035087719298246 and parameters: {'max_depth': 16, 'min_samples_le
af': 5, 'ccp_alpha': 0.05086151087467625, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,027] Trial 159 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_le
af': 7, 'ccp_alpha': 0.04220249856408299, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,055] Trial 160 finished with value: 0.9035087719298246 and parameters: {'max_depth': 14, 'min_samples_le
af': 6, 'ccp_alpha': 0.04847320314826559, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,086] Trial 161 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04533480556628773, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,116] Trial 162 finished with value: 0.9210526315789473 and parameters: {'max_depth': 7, 'min_samples_lea
f': 7, 'ccp_alpha': 0.039864002821064545, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
```

```
[I 2025-04-24 18:54:35,147] Trial 163 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04253466203765671, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,178] Trial 164 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
f': 8, 'ccp_alpha': 0.04578850635248199, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,204] Trial 165 finished with value: 0.9210526315789473 and parameters: {'max_depth': 15, 'min_samples_le
af': 7, 'ccp_alpha': 0.036239752749590126, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,232] Trial 166 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 6, 'ccp_alpha': 0.043204274321235824, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,260] Trial 167 finished with value: 0.9298245614035088 and parameters: {'max_depth': 6, 'min_samples_lea
f': 7, 'ccp_alpha': 0.047248834479668246, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,287] Trial 168 finished with value: 0.9210526315789473 and parameters: {'max_depth': 19, 'min_samples_le
af': 8, 'ccp_alpha': 0.03843525683113334, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,314] Trial 169 finished with value: 0.9210526315789473 and parameters: {'max_depth': 12, 'min_samples_le
af': 10, 'ccp_alpha': 0.04117273734142252, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,342] Trial 170 finished with value: 0.9298245614035088 and parameters: {'max_depth': 13, 'min_samples_le
af': 9, 'ccp_alpha': 0.04458309279722375, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,372] Trial 171 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_le
af': 7, 'ccp_alpha': 0.04645274963520784, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,401] Trial 172 finished with value: 0.9035087719298246 and parameters: {'max_depth': 11, 'min_samples_le
af': 7, 'ccp_alpha': 0.04874943901664144, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,429] Trial 173 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_lea
f': 7, 'ccp_alpha': 0.044336753046491956, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,454] Trial 174 finished with value: 0.9035087719298246 and parameters: {'max_depth': 8, 'min_samples_lea
f': 6, 'ccp_alpha': 0.05131899178819347, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,482] Trial 175 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04231142589391487, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,514] Trial 176 finished with value: 0.9210526315789473 and parameters: {'max_depth': 11, 'min_samples_le
af': 7, 'ccp_alpha': 0.04009935713470794, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,541] Trial 177 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 6, 'ccp_alpha': 0.04656168323895568, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,574] Trial 178 finished with value: 0.9035087719298246 and parameters: {'max_depth': 18, 'min_samples_le
af': 7, 'ccp_alpha': 0.04932502999379421, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,604] Trial 179 finished with value: 0.9035087719298246 and parameters: {'max_depth': 13, 'min_samples_le
af': 6, 'ccp_alpha': 0.05445552056940035, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,633] Trial 180 finished with value: 0.9298245614035088 and parameters: {'max_depth': 3, 'min_samples_lea
f': 8, 'ccp_alpha': 0.04481341102823094, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,664] Trial 181 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 5, 'ccp_alpha': 0.04758817162053619, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,693] Trial 182 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_le
af': 5, 'ccp_alpha': 0.0458342578400445, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,725] Trial 183 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
```

```
f': 5, 'ccp_alpha': 0.042412330563856744, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,757] Trial 184 finished with value: 0.9035087719298246 and parameters: {'max_depth': 9, 'min_samples_lea
f': 5, 'ccp_alpha': 0.048895080994982285, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,809] Trial 185 finished with value: 0.9298245614035088 and parameters: {'max_depth': 10, 'min_samples_le
af': 4, 'ccp_alpha': 0.04400978647974006, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,872] Trial 186 finished with value: 0.9035087719298246 and parameters: {'max_depth': 9, 'min_samples_lea
f': 7, 'ccp_alpha': 0.050904558966523225, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,902] Trial 187 finished with value: 0.9298245614035088 and parameters: {'max_depth': 11, 'min_samples_le
af': 5, 'ccp_alpha': 0.04693258665918748, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,931] Trial 188 finished with value: 0.9210526315789473 and parameters: {'max_depth': 8, 'min_samples_lea
f': 6, 'ccp_alpha': 0.04014165307722947, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,961] Trial 189 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_lea
f': 2, 'ccp_alpha': 0.04357550902217285, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:35,991] Trial 190 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04550051119245995, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,019] Trial 191 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.042557446906677496, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,050] Trial 192 finished with value: 0.9298245614035088 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04790884813199868, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,080] Trial 193 finished with value: 0.9298245614035088 and parameters: {'max_depth': 7, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04452099897259517, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,107] Trial 194 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 10, 'ccp_alpha': 0.042041237269280066, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,135] Trial 195 finished with value: 0.9210526315789473 and parameters: {'max_depth': 10, 'min_samples_le
af': 7, 'ccp_alpha': 0.038033106030013475, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,163] Trial 196 finished with value: 0.9035087719298246 and parameters: {'max_depth': 8, 'min_samples_lea
f': 7, 'ccp_alpha': 0.04985051850457729, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,194] Trial 197 finished with value: 0.9298245614035088 and parameters: {'max_depth': 9, 'min_samples_lea
f': 6, 'ccp_alpha': 0.04628565447524841, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,222] Trial 198 finished with value: 0.9210526315789473 and parameters: {'max_depth': 11, 'min_samples_le
af': 6, 'ccp_alpha': 0.04036049508980906, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
[I 2025-04-24 18:54:36,249] Trial 199 finished with value: 0.9298245614035088 and parameters: {'max_depth': 12, 'min_samples_le
af': 8, 'ccp_alpha': 0.043759597577084995, 'criterion': 'entropy'}. Best is trial 15 with value: 0.9298245614035088.
Best Parameters: {'max_depth': 17, 'min_samples_leaf': 5, 'ccp_alpha': 0.04199522470300826, 'criterion': 'entropy'}
Best Accuracy: 0.9298245614035088
Total Runtime: 6.26 seconds
```

In [134…

```python
# Define the parameter grid for gini-based Decision Tree
param_grid_gini = {
    'criterion': ['gini'],
    'max_depth': [best_max_depth_g],
```

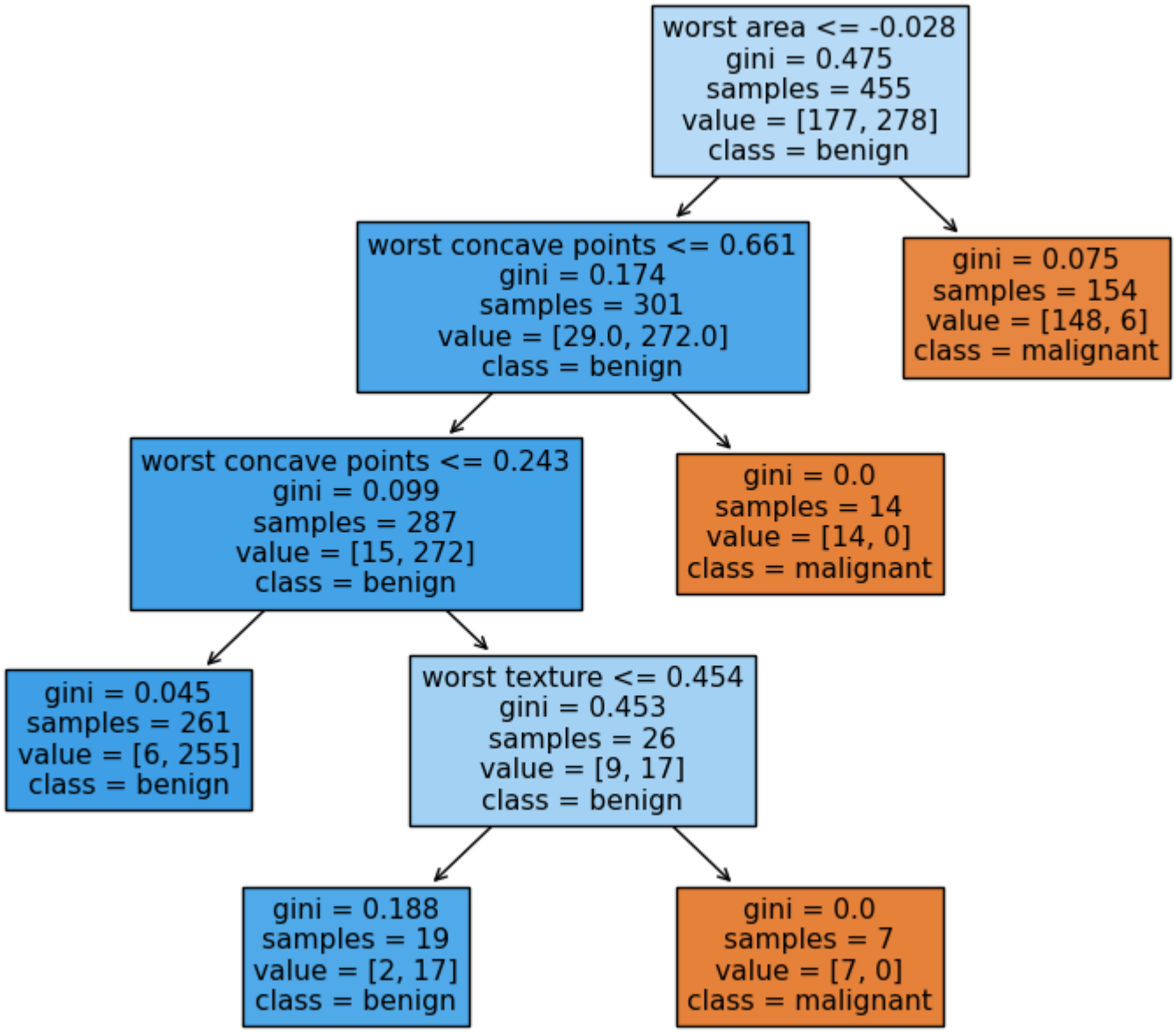
```
    'min_samples_leaf': [best_min_samples_leaf_g],
    'ccp_alpha': [best_ccp_alpha_g]
}

# Perform Grid Search with 5-fold cross-validation
dt_gini = DecisionTreeClassifier(random_state=42)
grid_gini = GridSearchCV(dt_gini, param_grid_gini, cv=5, scoring='accuracy', n_jobs=-1)
grid_gini.fit(X_train, y_train)

# Display the best parameters and cross-validation accuracy
print("Best params (Gini):", grid_gini.best_params_)
print("Best CV accuracy (Gini): {:.4f}".format(grid_gini.best_score_))

# Evaluate the best model on the test set
best_dt_gini = grid_gini.best_estimator_
test_acc_gini = best_dt_gini.score(X_test, y_test)
print("Test accuracy (Gini): {:.4f}".format(test_acc_gini))
```

```
Best params (Gini): {'ccp_alpha': 0.013582364004914261, 'criterion': 'gini', 'max_depth': 6, 'min_samples_leaf': 4}
Best CV accuracy (Gini): 0.9341
Test accuracy (Gini): 0.9561
```

In [135…

```
fig = plt.figure(figsize = (10, 8))
_ = tree.plot_tree(best_dt_gini, feature_names=breast_cancer.feature_names,
                   class_names=breast_cancer.target_names,
                   filled=True)

y_pred = grid_gini.best_estimator_.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print('Accuracy: ', accuracy_score(y_test, y_pred))
```

```
[[34  1]
 [ 4 75]]
Accuracy:  0.956140350877193
```



In [135…

```
# Define the parameter grid for entropy-based Decision Tree
param_grid_entropy = {
```

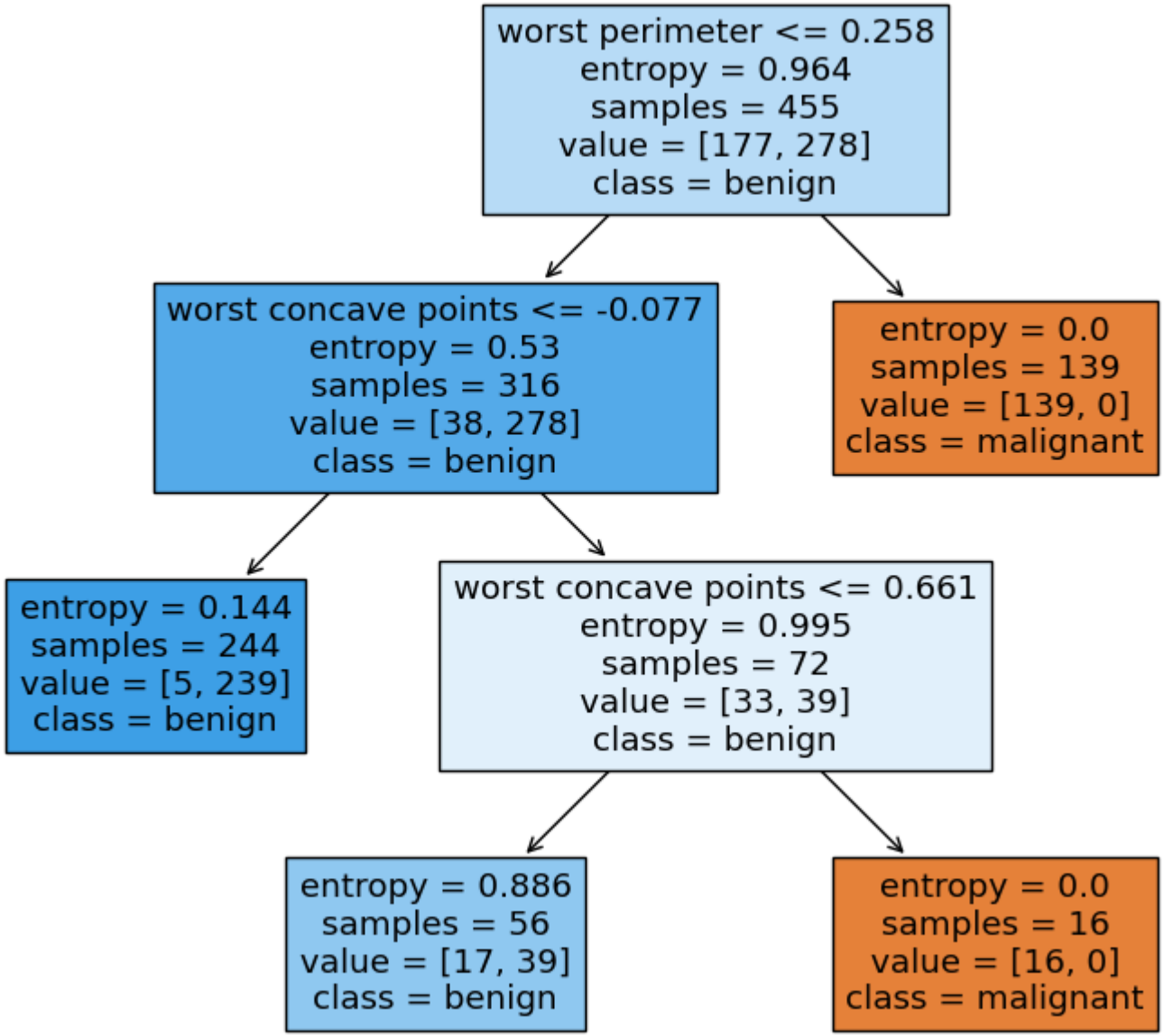
```
    'criterion': ['entropy'],
    'max_depth': [best_max_depth_e],
    'min_samples_leaf': [best_min_samples_leaf_e],
    'ccp_alpha': [best_ccp_alpha_e]
}

# Perform Grid Search with 5-fold cross-validation
dt_entropy = DecisionTreeClassifier(random_state=42)
grid_entropy = GridSearchCV(dt_entropy, param_grid_entropy, cv=5, scoring='accuracy', n_jobs=-1)
grid_entropy.fit(X_train, y_train)

# Display the best parameters and cross-validation accuracy
print("Best params (Entropy):", grid_entropy.best_params_)
print("Best CV accuracy (Entropy): {:.4f}".format(grid_entropy.best_score_))

# Evaluate the best model on the test set
best_dt_entropy = grid_entropy.best_estimator_
test_acc_entropy = best_dt_entropy.score(X_test, y_test)
print("Test accuracy (Entropy): {:.4f}".format(test_acc_entropy))
```

```
Best params (Entropy): {'ccp_alpha': 0.04199522470300826, 'criterion': 'entropy', 'max_depth': 17, 'min_samples_leaf': 5}
Best CV accuracy (Entropy): 0.9187
Test accuracy (Entropy): 0.9298
```

In [135…

```
fig = plt.figure(figsize = (10, 8))
_ = tree.plot_tree(best_dt_entropy, feature_names=breast_cancer.feature_names,
                   class_names=breast_cancer.target_names,
                   filled=True)

y_pred = grid_gini.best_estimator_.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print('Accuracy: ', accuracy_score(y_test, y_pred))
```

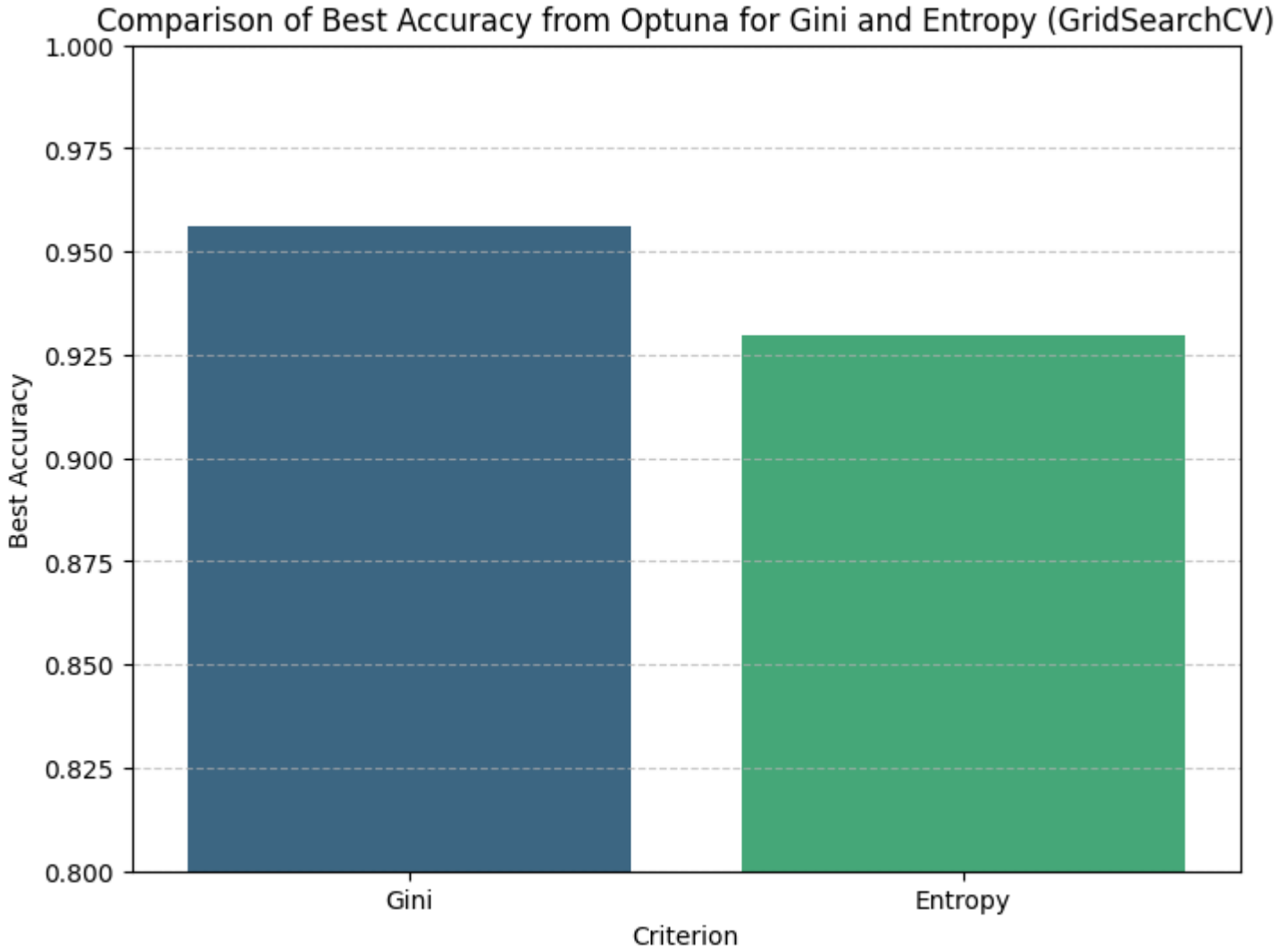
```
[[34  1]
 [ 4 75]]
Accuracy:  0.956140350877193
```


worst perimeter <= 0.258
entropy = 0.964
samples = 455
value = [177, 278]
class = benign
worst concave points <= -0.077
entropy = 0.53
samples = 316
value = [38, 278]
class = benign
entropy = 0.0
samples = 139
value = [139, 0]
class = malignant
entropy = 0.144
samples = 244
value = [5, 239]
class = benign
worst concave points <= 0.661
entropy = 0.995
samples = 72
value = [33, 39]
class = benign
entropy = 0.886
samples = 56
value = [17, 39]
class = benign
entropy = 0.0
samples = 16
value = [16, 0]
class = malignant

Visualizations

In [136…

```
# Create a DataFrame for visualization
optuna_results = pd.DataFrame({
    'Criterion': ['Gini', 'Entropy'],
    'Best Accuracy': [test_acc_gini, test_acc_entropy]
})

# Plot the comparison
plt.figure(figsize=(8, 6))
sns.barplot(x='Criterion', y='Best Accuracy', data=optuna_results, palette='viridis')
plt.title('Comparison of Best Accuracy from Optuna for Gini and Entropy (GridSearchCV)')
plt.ylabel('Best Accuracy')
plt.xlabel('Criterion')
plt.ylim(0.8, 1.0)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.show()
```

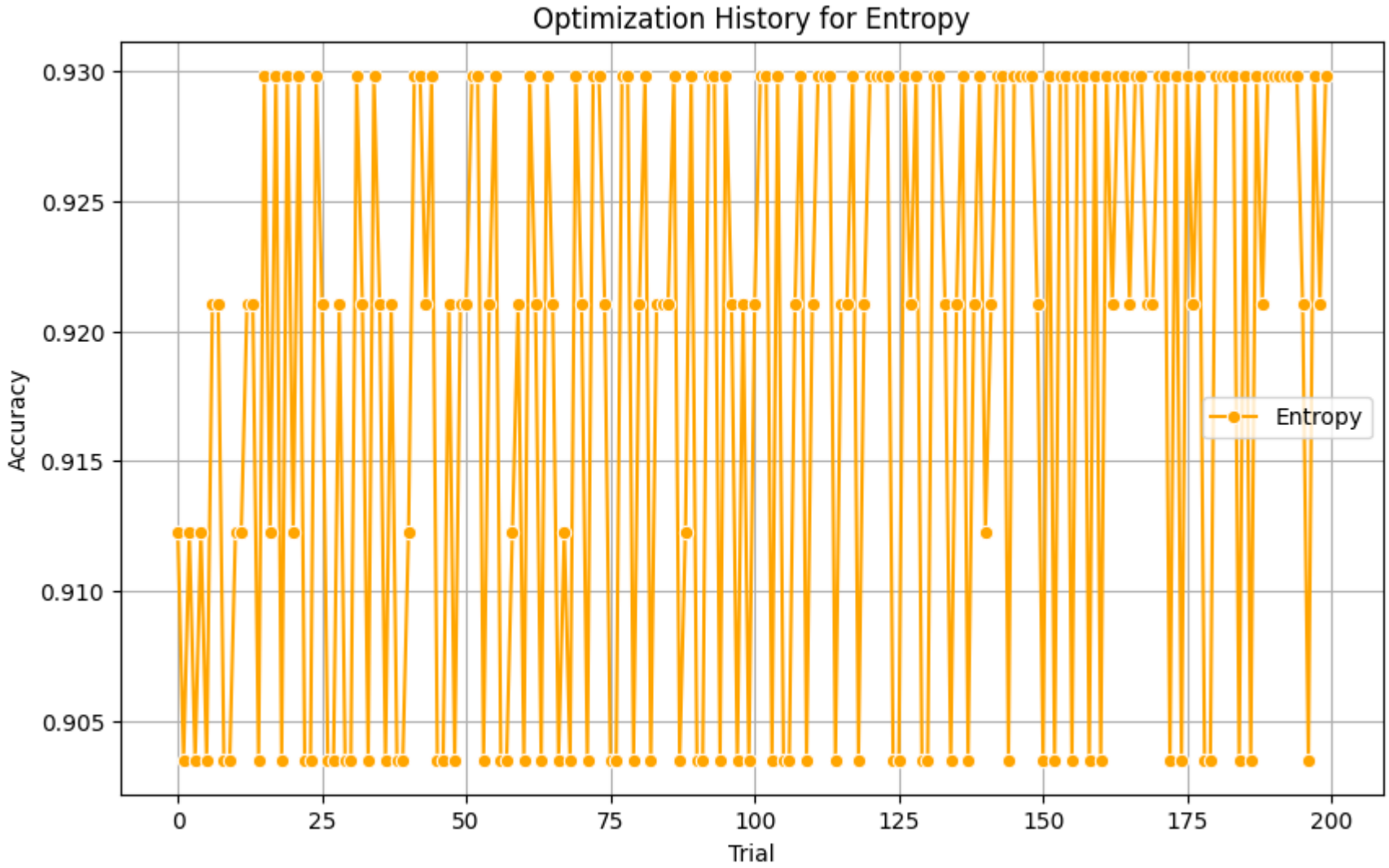


In [135…

```
# Extract optimization history for Gini
gini_trials = study.trials_dataframe()
gini_trials = gini_trials[['number', 'value']].rename(columns={'number': 'Trial', 'value': 'Accuracy'})
gini_trials['Criterion'] = 'Gini'

# Extract optimization history for Entropy
entropy_trials = study.trials_dataframe()
```

```
entropy_trials = entropy_trials[['number', 'value']].rename(columns={'number': 'Trial', 'value': 'Accuracy'})
entropy_trials['Criterion'] = 'Entropy'

# Plot the optimization history for Gini
plt.figure(figsize=(10, 6))
sns.lineplot(data=gini_trials, x='Trial', y='Accuracy', marker='o', label='Gini')
plt.title('Optimization History for Gini')
plt.xlabel('Trial')
plt.ylabel('Accuracy')
plt.grid(True)
plt.legend(loc='best')
plt.show()

# Plot the optimization history for Entropy
plt.figure(figsize=(10, 6))
sns.lineplot(data=entropy_trials, x='Trial', y='Accuracy', marker='o', label='Entropy', color='orange')
plt.title('Optimization History for Entropy')
plt.xlabel('Trial')
plt.ylabel('Accuracy')
plt.grid(True)
plt.legend(loc='best')
plt.show()
```


Optimization History for Gini
Gini
Accuracy
0.930
0.925
0.920
0.915
0.910
0.905
0
25
50
75
100
125
150
175
200
Trial



In [135…

```
from optuna.visualization import plot_param_importances

# Plot hyperparameter importance for Gini
print("Hyperparameter Importance for Gini:")
plot_param_importances(study).show()

# Plot hyperparameter importance for Entropy
```

```
print("Hyperparameter Importance for Entropy:")
plot_param_importances(study).show()
```

```
Hyperparameter Importance for Gini:
Hyperparameter Importance for Entropy:
```

In [135…

```
# Extract feature importances for entropy-based decision tree
entropy_importances = best_dt_entropy.feature_importances_
entropy_features = pd.DataFrame({
    'Feature': breast_cancer.feature_names,
    'Importance': entropy_importances
}).sort_values(by='Importance', ascending=False)

print("Top Features for Entropy:")
display(entropy_features)

# Extract feature importances for gini-based decision tree
gini_importances = best_dt_gini.feature_importances_
gini_features = pd.DataFrame({
    'Feature': breast_cancer.feature_names,
    'Importance': gini_importances
}).sort_values(by='Importance', ascending=False)

print("Top Features for Gini:")
display(gini_features)

# Plot feature importances for both
plt.figure(figsize=(12, 6))
plt.bar(entropy_features['Feature'][:10], entropy_features['Importance'][:10], alpha=0.7, label='Entropy')
plt.bar(gini_features['Feature'][:10], gini_features['Importance'][:10], alpha=0.7, label='Gini')
plt.xticks(rotation=45, ha='right')
plt.title('Top Contributing Features for Entropy and Gini')
plt.ylabel('Importance')
plt.legend()
plt.tight_layout()
plt.show()
```

```
Top Features for Entropy:
```

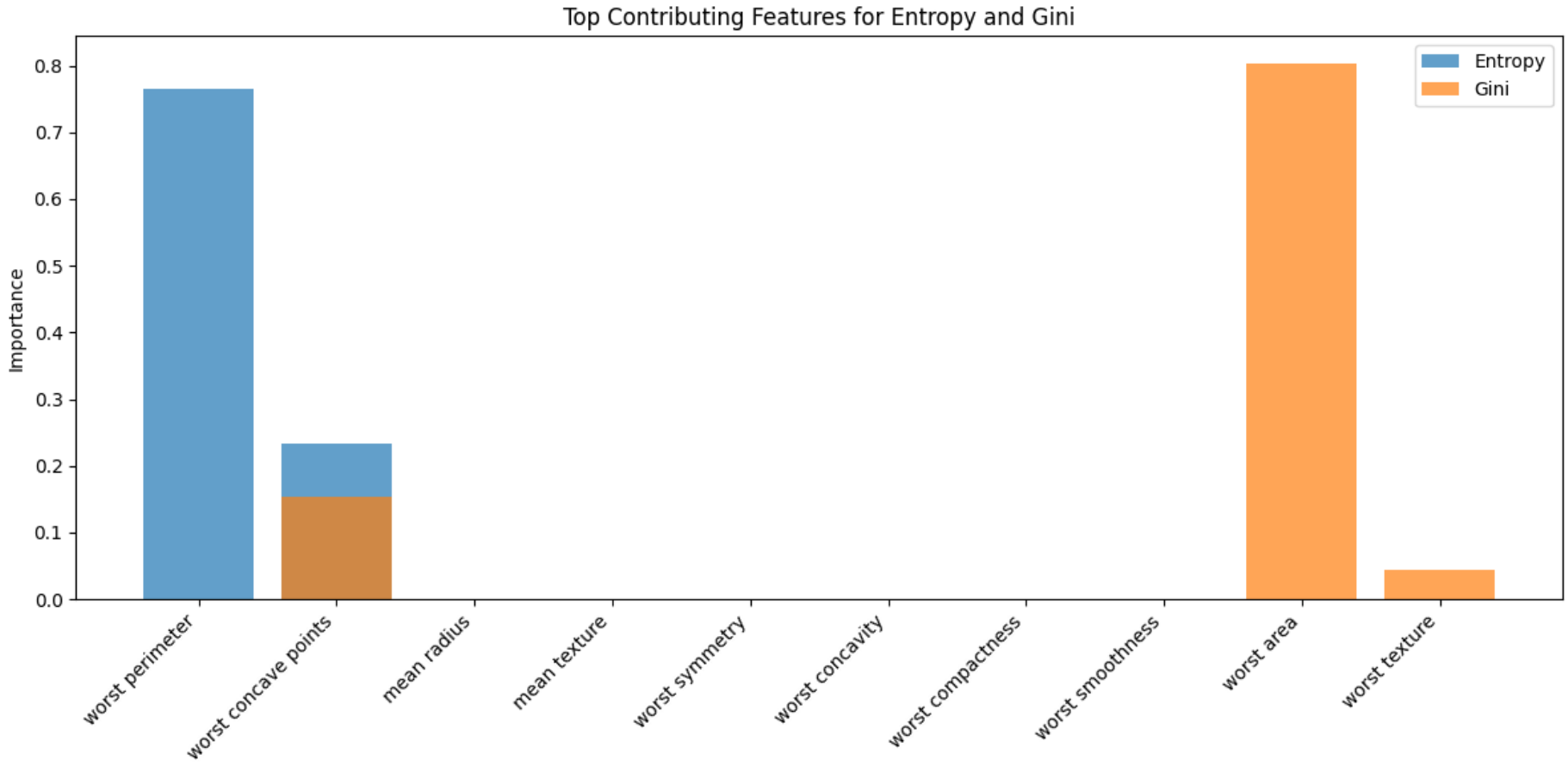
	Feature	Importance
22	worst perimeter	0.766242
27	worst concave points	0.233758
0	mean radius	0.000000
1	mean texture	0.000000
28	worst symmetry	0.000000
26	worst concavity	0.000000
25	worst compactness	0.000000
24	worst smoothness	0.000000
23	worst area	0.000000
21	worst texture	0.000000
20	worst radius	0.000000
19	fractal dimension error	0.000000
18	symmetry error	0.000000
17	concave points error	0.000000
16	concavity error	0.000000
15	compactness error	0.000000
14	smoothness error	0.000000
13	area error	0.000000
12	perimeter error	0.000000
11	texture error	0.000000
10	radius error	0.000000
9	mean fractal dimension	0.000000

	Feature	Importance
8	mean symmetry	0.000000
7	mean concave points	0.000000
6	mean concavity	0.000000
5	mean compactness	0.000000
4	mean smoothness	0.000000
3	mean area	0.000000
2	mean perimeter	0.000000
29	worst fractal dimension	0.000000

```
Top Features for Gini:
```

	Feature	Importance
23	worst area	0.804128
27	worst concave points	0.152641
21	worst texture	0.043231
0	mean radius	0.000000
1	mean texture	0.000000
28	worst symmetry	0.000000
26	worst concavity	0.000000
25	worst compactness	0.000000
24	worst smoothness	0.000000
22	worst perimeter	0.000000
20	worst radius	0.000000
19	fractal dimension error	0.000000
18	symmetry error	0.000000
17	concave points error	0.000000
16	concavity error	0.000000
15	compactness error	0.000000
14	smoothness error	0.000000
13	area error	0.000000
12	perimeter error	0.000000
11	texture error	0.000000
10	radius error	0.000000
9	mean fractal dimension	0.000000

	Feature	Importance
8	mean symmetry	0.000000
7	mean concave points	0.000000
6	mean concavity	0.000000
5	mean compactness	0.000000
4	mean smoothness	0.000000
3	mean area	0.000000
2	mean perimeter	0.000000
29	worst fractal dimension	0.000000



Summary of results

Best parameters for Decition tree using Gini (sklearn GridSearchCV)

ccp_alpha: 0.013582364004914261
max_depth 6
min_samples_leaf: 4

Hyperparameter Importances (GINI)
CCP Alpha (Pruning) = 0.98
Max Depth = <0.01
min samples leaf = <0.01\

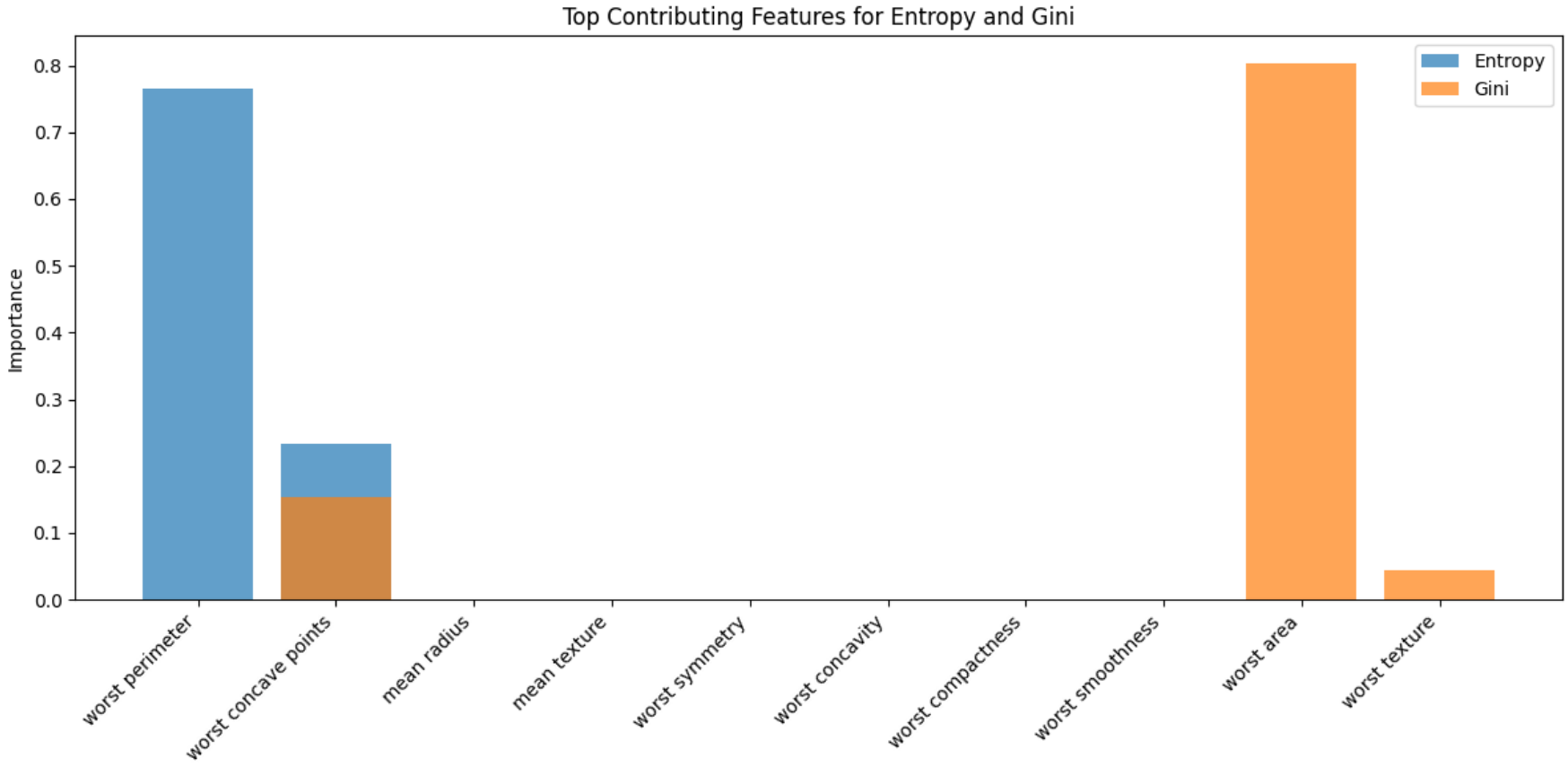
Best CV accuracy (Gini): **0.9341**
Test accuracy (Gini): **0.9561**

Best parameters for Decition tree using Entropy (sklearn GridSearchCV)

ccp_alpha: 0.04199522470300826
max_depth 17
min_samples_leaf: 5

Hyperparameter Importances (Entropy)
CCP Alpha (Pruning) = 0.98
Max Depth = <0.01
min samples leaf = <0.01\

Best CV accuracy (Entropy): **0.9187**
Test accuracy (Entropy): **0.9298**



The top contributing features for Entropy are:

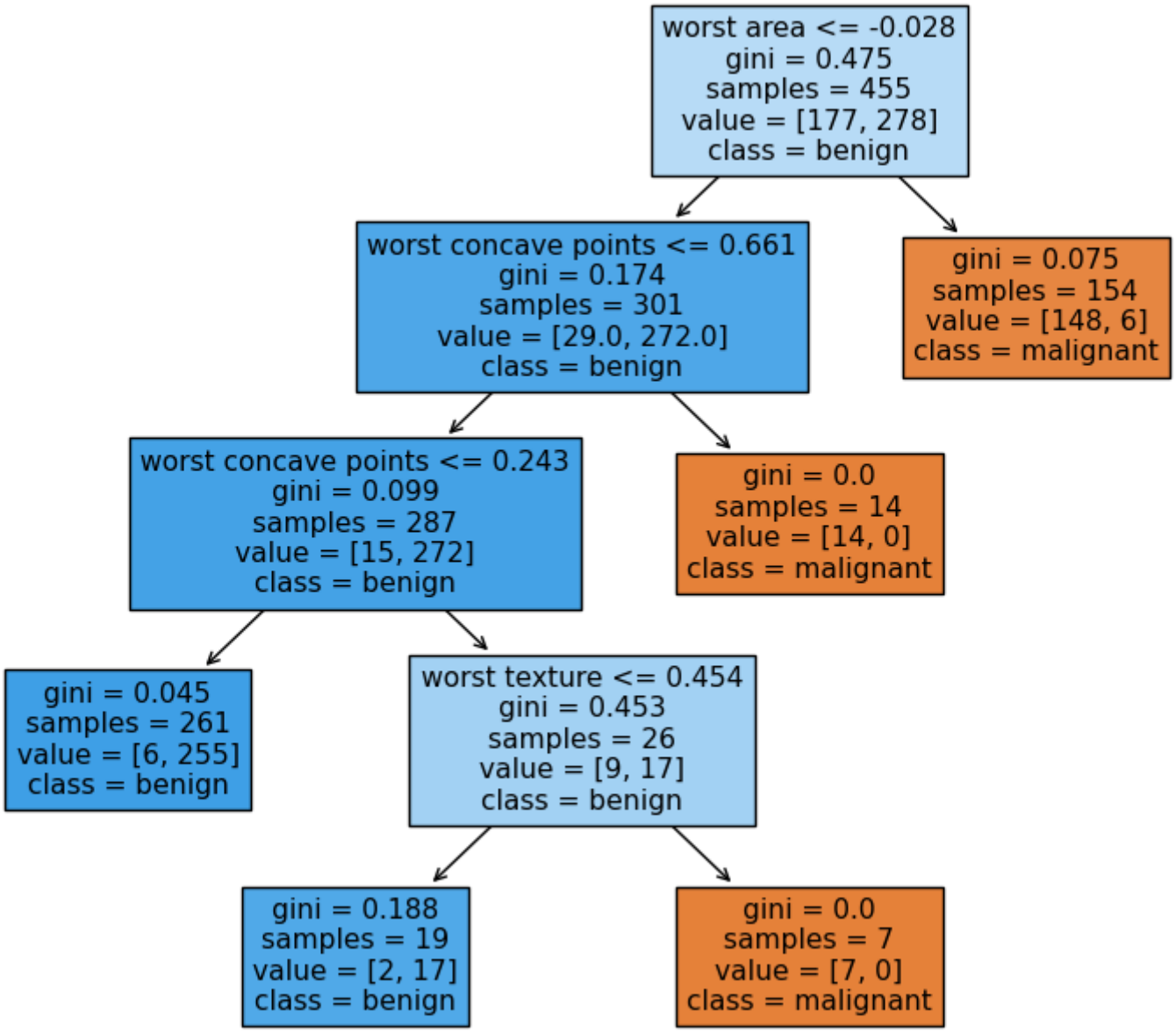
1. worst perimeter
2. worst concave points

The top contributing features for Gini are:

1. worst area
2. worst concave points
3. worst texture

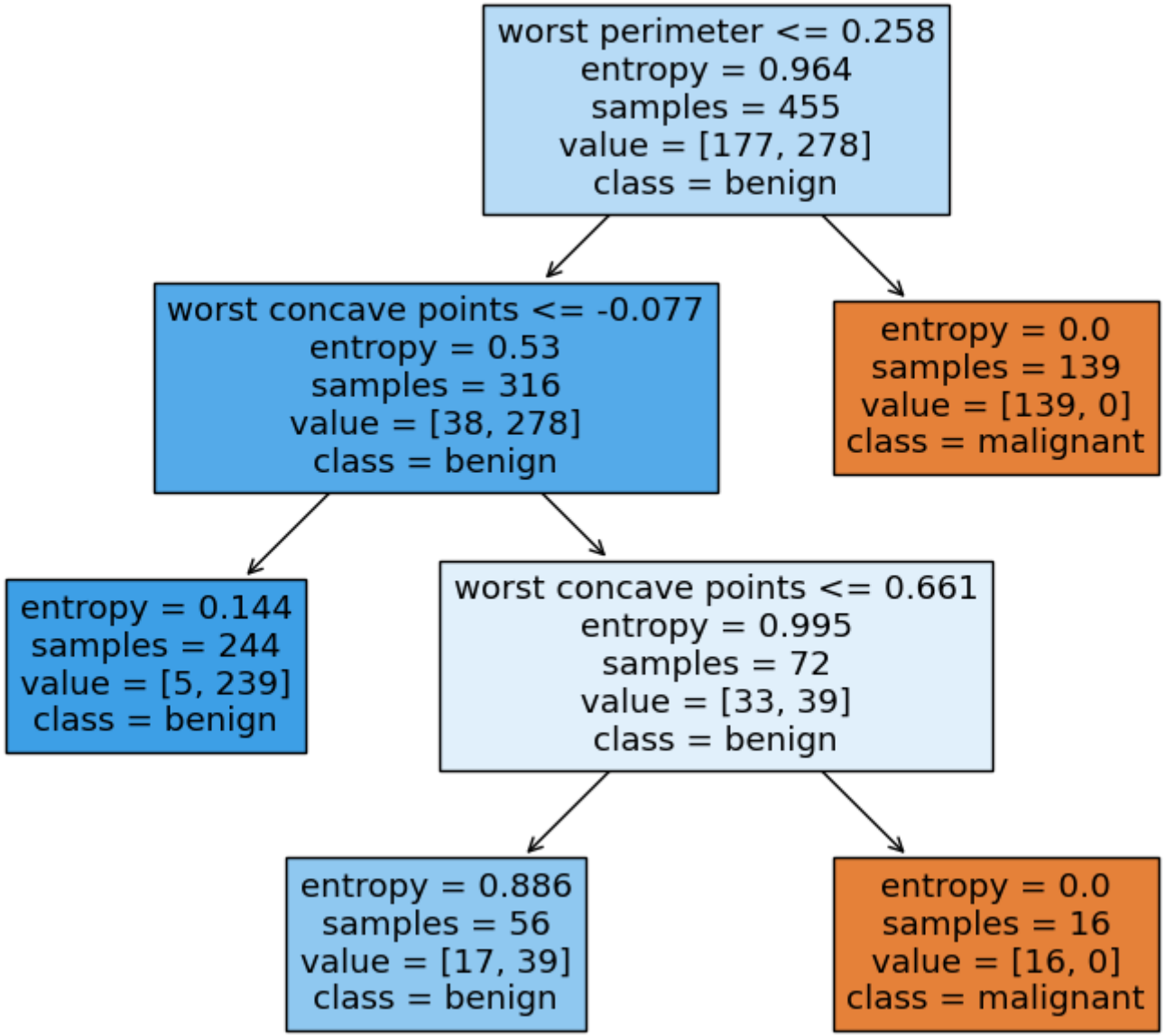
Gini-based Decision tree

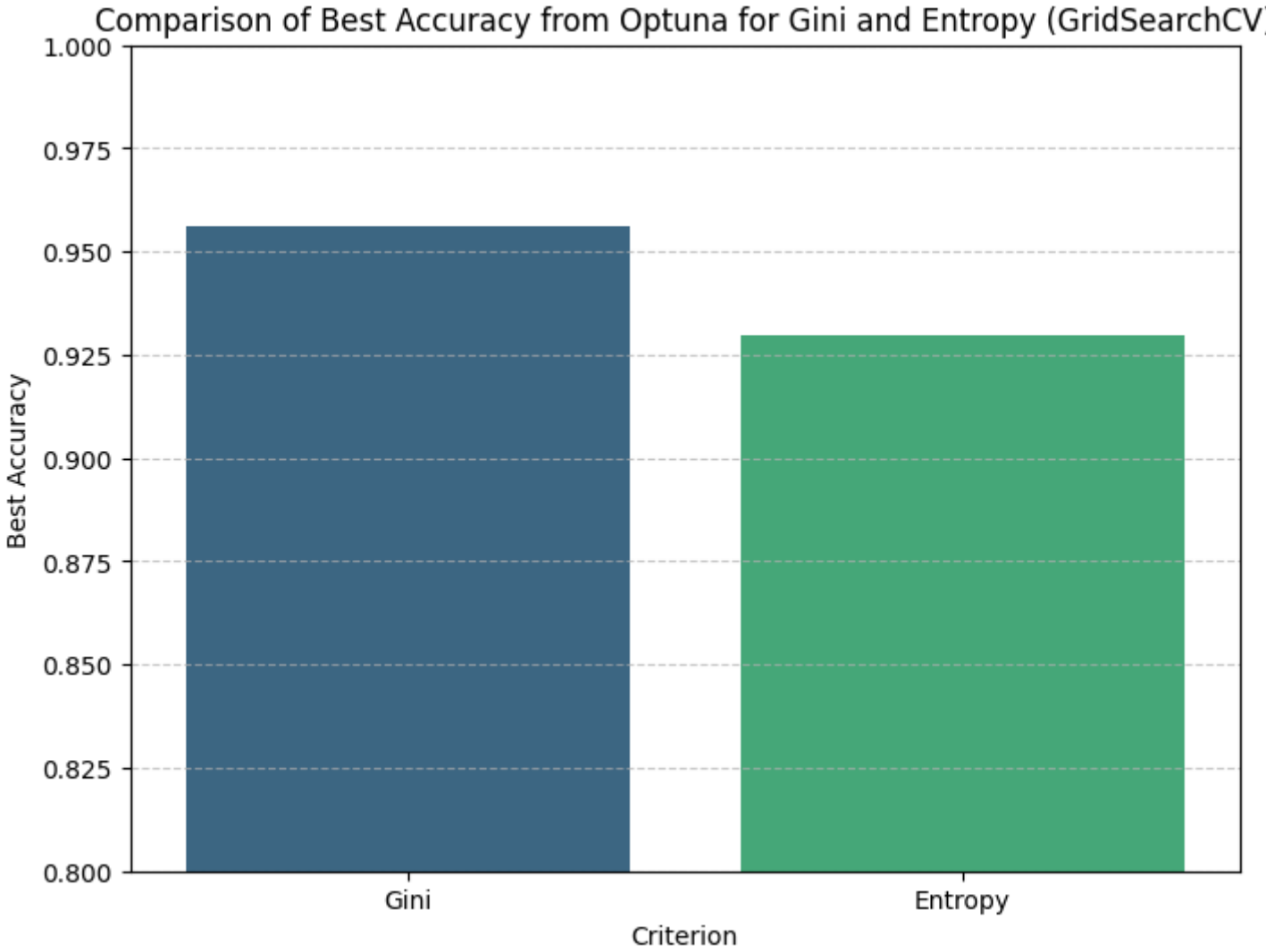
Accuracy: 0.956140350877193


worst area <= -0.028
gini = 0.475
samples = 455
value = [177, 278]
class = benign
worst concave points <= 0.661
gini = 0.174
samples = 301
value = [29.0, 272.0]
class = benign
gini = 0.075
samples = 154
value = [148, 6]
class = malignant
worst concave points <= 0.243
gini = 0.099
samples = 287
value = [15, 272]
class = benign
gini = 0.0
samples = 14
value = [14, 0]
class = malignant
gini = 0.045
samples = 261
value = [6, 255]
class = benign
worst texture <= 0.454
gini = 0.453
samples = 26
value = [9, 17]
class = benign
gini = 0.188
samples = 19
value = [2, 17]
class = benign
gini = 0.0
samples = 7
value = [7, 0]
class = malignant

Entropy-based Decision Tree

Accuracy: 0.956140350877193


worst perimeter <= 0.258
entropy = 0.964
samples = 455
value = [177, 278]
class = benign
worst concave points <= -0.077
entropy = 0.53
samples = 316
value = [38, 278]
class = benign
entropy = 0.0
samples = 139
value = [139, 0]
class = malignant
entropy = 0.144
samples = 244
value = [5, 239]
class = benign
worst concave points <= 0.661
entropy = 0.995
samples = 72
value = [33, 39]
class = benign
entropy = 0.886
samples = 56
value = [17, 39]
class = benign
entropy = 0.0
samples = 16
value = [16, 0]
class = malignant



Findings and Conclusion:

From the decision trees generated, a **higher max depth** usually contributes to a **lower accuracy**; however, a **higher ccp_alpha** (pruning) **contradicts the effects of a high max_depth** with the example of the best parameters for entropy-based decision tree having a high max

depth, but also a higher ccp_alpha as compared to the best parameters for gini-based decision tree. This was also proven by Optuna's measurement for hyperparameter importances wherein it shows that **ccp_alpha** is what has the **greatest contribution** when it comes to getting the best accuracy in decision trees.

Another contributing factor for the high accuracy in the decision trees could also be the way the top contributing features were also chosen with the decision tree only choosing 2 to 3 features at most which further proves the point that a **smaller decision tree** has **more accuracy**.