In [163…

```
# Import the necessary packages to runtime
import scipy.stats as stats
import zipcodes as zcode
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
import warnings
import statsmodels.api as sm

#SkLearn library
from sklearn.metrics import confusion_matrix, classification_report
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score
from statsmodels.stats.outliers_influence import variance_inflation_factor
from sklearn import metrics
from sklearn.model_selection import train_test_split

#AUC ROC Curve
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve
from sklearn.metrics import precision_recall_curve

# To plot confusion matrix
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from sklearn.metrics import plot_confusion_matrix

# To tune different models
from sklearn.model_selection import GridSearchCV

# Build Model and Decision tree imports
from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier

# To get diferent metric scores
from sklearn.metrics import (
    f1_score,
    accuracy_score,
    recall_score,
    precision_score,
    confusion_matrix,
    plot_confusion_matrix,
    make_scorer,
)

pd.set_option('display.float_format', lambda x: '%.5f' % x)
pd.set_option('display.max_rows', 300)
pd.set_option('display.max_colwidth', 400)

warnings.filterwarnings('ignore')

plt.style.use('ggplot')
```

In [164…

```
df = pd.read_csv('backpain.csv')
```

In [165…
```
df.head()
```

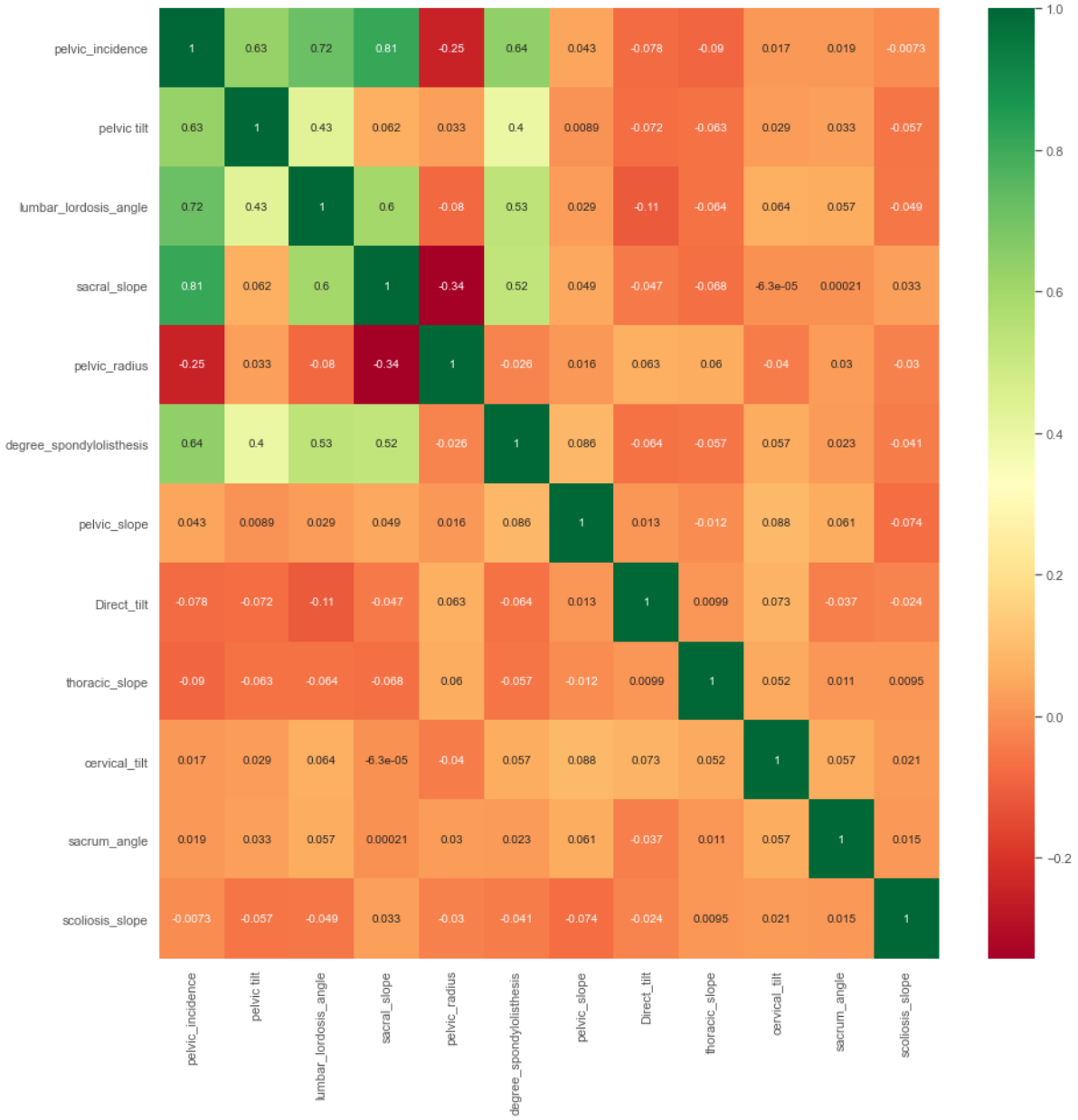
Out[165]:

	pelvic_incidence	pelvic tilt	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondyloli
0	63.02782	22.55259	39.60912	40.47523	98.67292	-0
1	39.05695	10.06099	25.01538	28.99596	114.40543	4
2	68.83202	22.21848	50.09219	46.61354	105.98514	-3
3	69.29701	24.65288	44.31124	44.64413	101.86850	11
4	49.71286	9.65207	28.31741	40.06078	108.16872	7

In [166…
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 310 entries, 0 to 309
Data columns (total 13 columns):
 #   Column                    Non-Null Count  Dtype  
---  ------                    --------------  -----  
 0   pelvic_incidence          310 non-null    float64
 1   pelvic tilt               310 non-null    float64
 2   lumbar_lordosis_angle     310 non-null    float64
 3   sacral_slope              310 non-null    float64
 4   pelvic_radius             310 non-null    float64
 5   degree_spondylolisthesis  310 non-null    float64
 6   pelvic_slope              310 non-null    float64
 7   Direct_tilt               310 non-null    float64
 8   thoracic_slope            310 non-null    float64
 9   cervical_tilt             310 non-null    float64
 10  sacrum_angle              310 non-null    float64
 11  scoliosis_slope           310 non-null    float64
 12  Status                    310 non-null    object 
dtypes: float64(12), object(1)
memory usage: 31.6+ KB
```

In [167…
```
plt.figure(figsize=(15,15))
p=sns.heatmap(df.corr(), annot=True,cmap='RdYlGn')
```



In [168…
```
df['Status'].replace({'Abnormal':1, 'Normal':0}, inplace=True)
```

In [169…
```
df.Status.value_counts()
```

Out[169]:
```
1    210
0    100
Name: Status, dtype: int64
```

In [170…
```
df.head()
```

Out[170]:

	pelvic_incidence	pelvic tilt	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondyloli
0	63.02782	22.55259	39.60912	40.47523	98.67292	-0
1	39.05695	10.06099	25.01538	28.99596	114.40543	4
2	68.83202	22.21848	50.09219	46.61354	105.98514	-3
3	69.29701	24.65288	44.31124	44.64413	101.86850	11
4	49.71286	9.65207	28.31741	40.06078	108.16872	7

In [171…
```
df.tail()
```

Out[171]:

	pelvic_incidence	pelvic tilt	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondyl
305	47.90357	13.61669	36.00000	34.28688	117.44906	
306	53.93675	20.72150	29.22053	33.21525	114.36584	
307	61.44660	22.69497	46.17035	38.75163	125.67072	
308	45.25279	8.69316	41.58313	36.55963	118.54584	
309	33.84164	5.07399	36.64123	28.76765	123.94524	

In [172…
```
X = df.drop(['Status'],axis = 1)
Y = df['Status']
```

In [173…
```
X.head()
```

Out[173]:

	pelvic_incidence	pelvic tilt	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondyloli
0	63.02782	22.55259	39.60912	40.47523	98.67292	-0
1	39.05695	10.06099	25.01538	28.99596	114.40543	4
2	68.83202	22.21848	50.09219	46.61354	105.98514	-3
3	69.29701	24.65288	44.31124	44.64413	101.86850	11
4	49.71286	9.65207	28.31741	40.06078	108.16872	7

In [174…
```
#importing train_test_split
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(X, Y, test_size=0.30, random_st
```

In [175…
```
print("{0:0.2f}% data is in training set".format((len(x_train)/len(df.index)) * 100
print("{0:0.2f}% data is in test set".format((len(x_test)/len(df.index)) * 100))
```

```
70.00% data is in training set
30.00% data is in test set
```

In [176…
```
print("Original Status True Values    : {0} ({1:0.2f}%)".format(len(df.loc[df['Stat
print("Original Status False Values   : {0} ({1:0.2f}%)".format(len(df.loc[df['Stat
```

```
print("")
print("Training Status True Values    : {0} ({1:0.2f}%)".format(len(y_train[y_train
print("Training Status False Values   : {0} ({1:0.2f}%)".format(len(y_train[y_train
print("")
print("Test Status True Values        : {0} ({1:0.2f}%)".format(len(y_test[y_test[:
print("Test Status False Values       : {0} ({1:0.2f}%)".format(len(y_test[y_test[:
print("")
```

```
Original Status True Values    : 210 (67.74%)
Original Status False Values   : 100 (32.26%)

Training Status True Values    : 147 (67.74%)
Training Status False Values   : 70 (32.26%)

Test Status True Values        : 63 (67.74%)
Test Status False Values       : 30 (32.26%)
```

In [177…
```
# Fit the model on train
model = LogisticRegression(solver="liblinear", random_state=1)
model.fit(x_train, y_train)
#predict on test
y_predict = model.predict(x_test)


coef_df = pd.DataFrame(model.coef_)
coef_df['intercept'] = model.intercept_
print(coef_df)
```

```
        0       1        2        3        4       5        6       7  \
0 0.02320 0.09967 -0.01676 -0.07647 -0.03163 0.17252 -0.14859 0.00865

         8       9       10       11  intercept
0 -0.01819 0.21316 -0.00896 -0.00247    1.12907
```

In [178…
```
model_score = model.score(x_test, y_test)
print(model_score)
```

```
0.8494623655913979
```

In [179…
```
# Print the confusion matrix
cm=metrics.confusion_matrix(y_test, y_predict, labels=[1, 0])

df_cm = pd.DataFrame(cm, index = [i for i in ["Status Actual 1","Status Actual 0"]]
                  columns = [i for i in ["Status Predict 1","Status Predict 0"]])
plt.figure(figsize = (7,5))
sns.heatmap(df_cm, annot=True,fmt='g')
plt.show()
```

In [180…

```
# Use the DecisionTreeClassifier
model = DecisionTreeClassifier(criterion='gini')
model.fit(x_train, y_train)
ytrain_predict = model.predict(x_train)
ytest_predict = model.predict(x_test)
print("Accuracy :: Train ", model.score(x_train, y_train), " :: Test ", model.score
print("Recall :: Train ", metrics.recall_score(y_train, ytrain_predict), " :: Test
```

```
Accuracy :: Train  1.0  :: Test  0.7956989247311828
Recall :: Train  1.0  :: Test  0.8253968253968254
```

In [181…

```
# defining a function to compute different metrics to check performance of a classi

def model_performance_classification_sklearn_with_threshold(model, predictors, targ
    """
    Function to compute different metrics, based on the threshold specified, to che

    model: classifier
    predictors: independent variables
    target: dependent variable
    threshold: threshold for classifying the observation as class 1
    """

    # predicting using the independent variables
    pred_prob = model.predict_proba(predictors)[:, 1]
    pred_thres = pred_prob > threshold
    pred = np.round(pred_thres)

    acc = accuracy_score(target, pred)  # to compute Accuracy
    recall = recall_score(target, pred)  # to compute Recall
    precision = precision_score(target, pred)  # to compute Precision
    f1 = f1_score(target, pred)  # to compute F1-score

    # creating a dataframe of metrics
    df_perf = pd.DataFrame(
        {
            "Accuracy": acc,
```

```
            "Recall": recall,
            "Precision": precision,
            "F1": f1,
        },
        index=[0],
    )

    return df_perf
```

In [182…
```
# defining a function to plot the confusion_matrix of a classification model built
def confusion_matrix_sklearn_with_threshold(model, predictors, target, threshold=0.
    """
    To plot the confusion_matrix, based on the threshold specified, with percentage

    model: classifier
    predictors: independent variables
    target: dependent variable
    threshold: threshold for classifying the observation as class 1
    """
    pred_prob = model.predict_proba(predictors)[:, 1]
    pred_thres = pred_prob > threshold
    y_pred = np.round(pred_thres)

    cm = confusion_matrix(target, y_pred)
    labels = np.asarray(
        [
            ["{0:0.0f}".format(item) + "\n{0:.2%}".format(item / cm.flatten().sum()
            for item in cm.flatten()
        ]
    ).reshape(2, 2)

    plt.figure(figsize=(6, 4))
    sns.heatmap(cm, annot=labels, fmt="")
    plt.ylabel("True label")
    plt.xlabel("Predicted label")
```

In [183…
```
model = LogisticRegression(solver="newton-cg", random_state=1)
lg = model.fit(x_train, y_train)
```

In [184…
```
log_reg_model_train_perf = model_performance_classification_sklearn_with_threshold(
    lg, x_train, y_train
)

print("Training performance:")
log_reg_model_train_perf
```

```
Training performance:
```

Out[184]:

	Accuracy	Recall	Precision	F1
0	0.86636	0.89796	0.90411	0.90102

In [195…
```
# defining a function to compute different metrics to check performance of a classi
def model_performance_classification_sklearn(model, predictors, target):
    """
```

```
    Function to compute different metrics to check classification model performance

    model: classifier
    predictors: independent variables
    target: dependent variable
    """

    # predicting using the independent variables
    pred = model.predict(predictors)

    acc = accuracy_score(target, pred)  # to compute Accuracy
    recall = recall_score(target, pred)  # to compute Recall
    precision = precision_score(target, pred)  # to compute Precision
    f1 = f1_score(target, pred)  # to compute F1-score

    # creating a dataframe of metrics
    df_perf = pd.DataFrame(
        {"Accuracy": acc, "Recall": recall, "Precision": precision, "F1": f1,},
        index=[0],
    )

    return df_perf
```

In [203…

```
# Choose the type of classifier.
estimator = DecisionTreeClassifier(random_state=42)

# Grid of parameters to choose from

parameters = {
    "max_depth": [np.arange(5, 10, 15), None],
    "criterion": ["gini", "entropy"],
    "splitter": ["best", "random"],
    "min_impurity_decrease": [0.000001, 0.00001, 0.0001],
}

# Type of scoring used to compare parameter combinations
acc_scorer = make_scorer(recall_score)

# Run the grid search
grid_obj = GridSearchCV(estimator, parameters, scoring=acc_scorer, cv=3)
grid_obj = grid_obj.fit(x_train, y_train)

# Set the clf to the best combination of parameters
estimator = grid_obj.best_estimator_

# Fit the best algorithm to the data.
estimator.fit(x_train, y_train)
```

Out[203]:

```
DecisionTreeClassifier(criterion='entropy', max_depth=array([5]),
                       min_impurity_decrease=1e-06, random_state=42)
```

In [204…

```
grid_obj.best_estimator_
```

Out[204]:

```
DecisionTreeClassifier(criterion='entropy', max_depth=array([5]),
                       min_impurity_decrease=1e-06, random_state=42)
```

In [205…
```
model = DecisionTreeClassifier(criterion="gini", random_state=1)
model.fit(x_train, y_train)
```

Out[205]:
```
DecisionTreeClassifier(random_state=1)
```

In [206…
```
decision_tree_tune_perf_train = model_performance_classification_sklearn(
    estimator, x_train, y_train
)
decision_tree_tune_perf_train
```

Out[206]:

	Accuracy	Recall	Precision	F1
0	0.93088	0.97959	0.92308	0.95050

In [207…
```
clf = DecisionTreeClassifier(random_state=1)
path = clf.cost_complexity_pruning_path(x_train, y_train)
ccp_alphas, impurities = path.ccp_alphas, path.impurities
```

In [193…
```
pd.DataFrame(path)
```

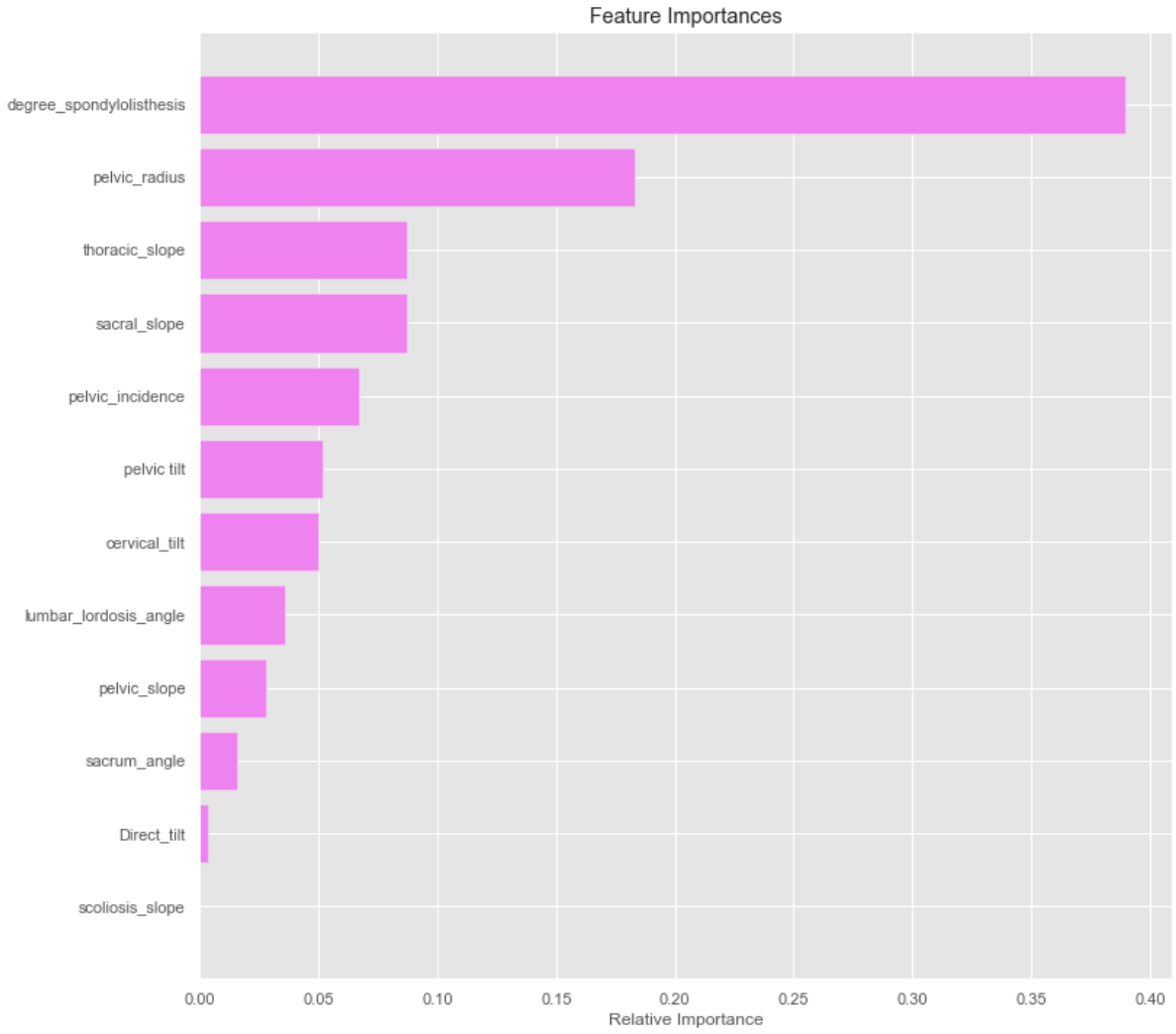
Out[193]:

	ccp_alphas	impurities
0	0.00000	0.00000
1	0.00456	0.00913
2	0.00691	0.01604
3	0.00691	0.02986
4	0.00737	0.03724
5	0.00776	0.06052
6	0.00889	0.06941
7	0.01083	0.09106
8	0.01158	0.10264
9	0.01317	0.11581
10	0.01317	0.12898
11	0.01436	0.14334
12	0.01467	0.17269
13	0.01496	0.18765
14	0.02655	0.21420
15	0.05259	0.26679
16	0.17025	0.43704

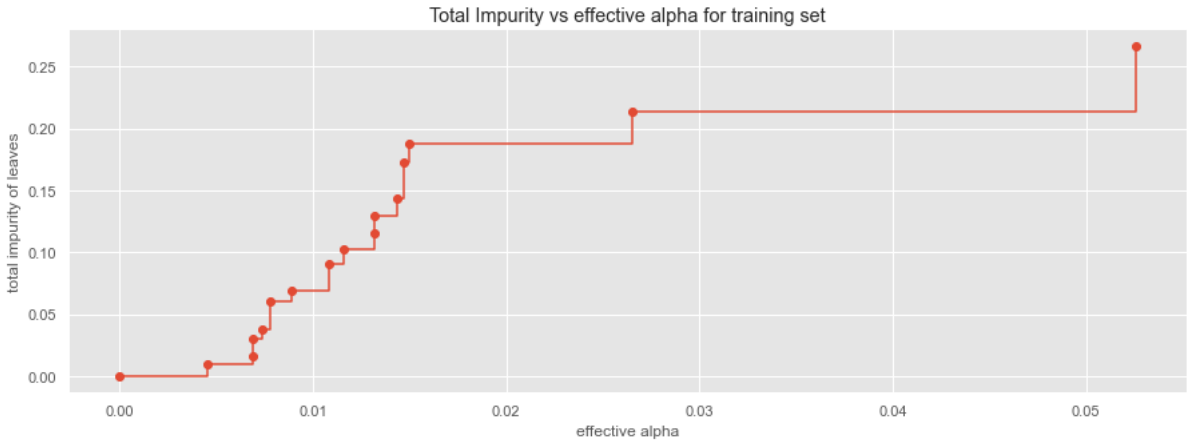
In [210…
```
column_names = list(X.columns)
feature_names = column_names
```

In [211…
```
importances = model.feature_importances_
indices = np.argsort(importances)

plt.figure(figsize=(12, 12))
plt.title("Feature Importances")
plt.barh(range(len(indices)), importances[indices], color="violet", align="center")
plt.yticks(range(len(indices)), [feature_names[i] for i in indices])
plt.xlabel("Relative Importance")
plt.show()
```



In [212…
```
fig, ax = plt.subplots(figsize=(15, 5))
ax.plot(ccp_alphas[:-1], impurities[:-1], marker="o", drawstyle="steps-post")
ax.set_xlabel("effective alpha")
ax.set_ylabel("total impurity of leaves")
ax.set_title("Total Impurity vs effective alpha for training set")
plt.show()
```



In [214…
```
clfs = []
for ccp_alpha in ccp_alphas:
    clf = DecisionTreeClassifier(random_state=1, ccp_alpha=ccp_alpha)
    clf.fit(x_train, y_train)
    clfs.append(clf)
print(
    "Number of nodes in the last tree is: {} with ccp_alpha: {}".format(
        clfs[-1].tree_.node_count, ccp_alphas[-1]
    )
)
```

```
Number of nodes in the last tree is: 1 with ccp_alpha: 0.17025215923580223
```

In [216…
```
recall_train = []
for clf in clfs:
    pred_train = clf.predict(x_train)
    values_train = recall_score(y_train, pred_train)
    recall_train.append(values_train)
```

In [217…
```
recall_test = []
for clf in clfs:
    pred_test = clf.predict(x_test)
    values_test = recall_score(y_test, pred_test)
    recall_test.append(values_test)
```

In [231…
```
fig, ax = plt.subplots(figsize=(15, 5))
values=range(len(ccp_alphas))
ax.set_xlabel("alpha")
ax.set_ylabel("Recall")
ax.set_title("Recall vs alpha for training and testing sets")
ax.plot(ccp_alphas, recall_train, marker="o", label="train", drawstyle="steps-post"
ax.plot(ccp_alphas, recall_test, marker="o", label="test", drawstyle="steps-post")
ax.legend()
#plt.xticks(ccp_alphas, values)
plt.show()
```


Recall vs alpha for training and testing sets
Recall
alpha
train
test
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

In [ ]: