Experiment No. 3
Apply Decision Tree Algorithm on Adult Census Income Dataset and analyze the performance of the model
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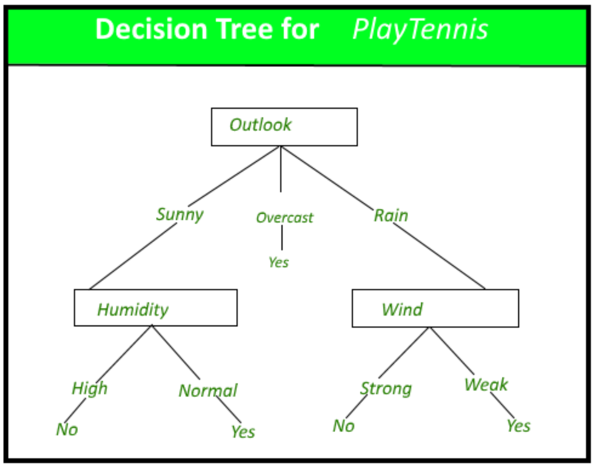
Aim: Apply Decision Tree Algorithm on Adult Census Income Dataset and analyze the performance of the model.

Objective: To perform various feature engineering tasks, apply Decision Tree Algorithm on the given dataset and maximize the accuracy, Precision, Recall, F1 score. Improve the performance by performing different data engineering and feature engineering tasks.

Theory:

Decision Tree is the most powerful and popular tool for classification and prediction. A Decision tree is a flowchart-like tree structure, where each internal node denotes a test on an attribute, each branch represents an outcome of the test, and each leaf node (terminal node) holds a class label.



Dataset:

Predict whether income exceeds $50K/yr based on census data. Also known as "Adult" dataset.

Attribute Information:

Listing of attributes:

>50K, <=50K.

age: continuous.

workclass: Private, Self-emp-not-inc, Self-emp-inc, Federal-gov, Local-gov, State-gov, Without-pay, Never-worked.

fnlwgt: continuous.

education: Bachelors, Some-college, 11th, HS-grad, Prof-school, Assoc-acdm, Assoc-voc, 9th, 7th-8th, 12th, Masters, 1st-4th, 10th, Doctorate, 5th-6th, Preschool.

education-num: continuous.

marital-status: Married-civ-spouse, Divorced, Never-married, Separated, Widowed, Married-spouse-absent, Married-AF-spouse.

occupation: Tech-support, Craft-repair, Other-service, Sales, Exec-managerial, Prof-specialty, Handlers-cleaners, Machine-op-inspct, Adm-clerical, Farming-fishing, Transport-moving, Priv-house-serv, Protective-serv, Armed-Forces.

relationship: Wife, Own-child, Husband, Not-in-family, Other-relative, Unmarried.

race: White, Asian-Pac-Islander, Amer-Indian-Eskimo, Other, Black.

sex: Female, Male.

capital-gain: continuous.

capital-loss: continuous.

hours-per-week: continuous.

native-country: United-States, Cambodia, England, Puerto-Rico, Canada, Germany, Outlying-US(Guam-USVI-etc), India, Japan, Greece, South, China, Cuba, Iran, Honduras, Philippines, Italy, Poland, Jamaica, Vietnam, Mexico, Portugal, Ireland, France, Dominican-Republic, Laos, Ecuador, Taiwan, Haiti, Columbia, Hungary, Guatemala, Nicaragua, Scotland, Thailand, Yugoslavia, El-Salvador, Trinadad&Tobago, Peru, Hong, Holand-Netherlands.

Code:

Conclusion:

The Decision Tree model demonstrated good performance on the Adult Census Income Dataset. It managed categorical attributes using one-hot encoding and performed necessary data preprocessing, such as handling missing values, dropping irrelevant tables, and separating columns, to enhance the model's effectiveness.

Hyperparameter tuning is a critical process for enhancing the Decision Tree model's performance, as it allows the control over the model's complexity by setting some limits on the parameters. To take performance to the next level, we need to improve the model by adjusting hyperparameters like max depth, min samples split, etc., using methods like Grid Search or Random Search.

Accuracy: Achieved an accuracy of 0.85, indicating that around 85% of predictions were correct.

Confusion Matrix: True positive = 9860, False positive = 481, False negative = 1823, True negative = 1646

Precision: Precision of 0.84 suggests that among the instances predicted as 0, about 0.77 are predicted for 1.

Recall: Recall of 0.95 indicates that the model captured the instances for 0 and 0.47 model captured the instances for 1.

F1 Score: The F1 score of 0.90 is the mean of precision and recall for 0 and 0.59 is the mean of precision and recall for 1 in the model's performance.

```
# Import libraries
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
# To ignore warning messages
import warnings
warnings.filterwarnings('ignore')
# Adult dataset path
adult_dataset_path = "/content/adult.csv"
```

```
# Function for loading adult dataset
def load_adult_data(adult_path=adult_dataset_path):
    csv_path = os.path.join(adult_path)
    return pd.read_csv(csv_path)
```

```
# Calling load adult function and assigning to a new variable df
df = load_adult_data()
# load top 3 rows values from adult dataset
df.head(3)
```

	age	workclass	fnlwgt	education	educational-num	marital-status	occupation	relationshi
0	25	Private	226802	11th	7	Never-married	Machine-op-inspct	Own-chil
1	38	Private	89814	HS-grad	9	Married-civ-spouse	Farming-fishing	Husban

```
print ("Rows : " ,df.shape[0])
print ("Columns : " ,df.shape[1])
print ("\nFeatures : \n" ,df.columns.tolist())
print ("\nMissing values : ", df.isnull().sum().values.sum())
print ("\nUnique values : \n",df.nunique())
```

```
Rows :  48842
Columns :  15

Features :
 ['age', 'workclass', 'fnlwgt', 'education', 'educational-num', 'marital-status', 'occupation', 'relationship', 'race', 'gender', '

Missing values :  0

Unique values :
 age                   74
workclass              9
fnlwgt             28523
education             16
educational-num       16
marital-status         7
occupation            15
relationship           6
race                   5
gender                 2
capital-gain         123
capital-loss          99
hours-per-week        96
native-country        42
income                 2
dtype: int64
```

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 48842 entries, 0 to 48841
Data columns (total 15 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   age              48842 non-null  int64
 1   workclass        48842 non-null  object
 2   fnlwgt           48842 non-null  int64
 3   education        48842 non-null  object
 4   educational-num  48842 non-null  int64
 5   marital-status   48842 non-null  object
 6   occupation       48842 non-null  object
```

```
 7   relationship     48842 non-null  object
 8   race             48842 non-null  object
 9   gender           48842 non-null  object
 10  capital-gain     48842 non-null  int64
 11  capital-loss     48842 non-null  int64
 12  hours-per-week   48842 non-null  int64
 13  native-country   48842 non-null  object
 14  income           48842 non-null  object
dtypes: int64(6), object(9)
memory usage: 5.6+ MB
```

```
df.describe()
```

	age	fnlwgt	educational-num	capital-gain	capital-loss	hours-pe we
count	48842.000000	4.884200e+04	48842.000000	48842.000000	48842.000000	48842.000(
mean	38.643585	1.896641e+05	10.078089	1079.067626	87.502314	40.4223
std	13.710510	1.056040e+05	2.570973	7452.019058	403.004552	12.3914
min	17.000000	1.228500e+04	1.000000	0.000000	0.000000	1.000(
25%	28.000000	1.175505e+05	9.000000	0.000000	0.000000	40.000(
50%	37.000000	1.781445e+05	10.000000	0.000000	0.000000	40.000(
75%	48.000000	2.376420e+05	12.000000	0.000000	0.000000	45.000(

```
df.head()
```

	age	workclass	fnlwgt	education	educational-num	marital-status	occupation	relationshi
0	25	Private	226802	11th	7	Never-married	Machine-op-inspct	Own-chil
1	38	Private	89814	HS-grad	9	Married-civ-spouse	Farming-fishing	Husban
2	28	Local-gov	336951	Assoc-acdm	12	Married-civ-spouse	Protective-serv	Husban
3	44	Private	160323	Some-	10	Married-civ-	Machine-	Husban

```
# checking "?" total values present in particular 'workclass' feature
df_check_missing_workclass = (df['workclass']=='?').sum()
df_check_missing_workclass
```

```
2799
```

```
# checking "?" total values present in particular 'occupation' feature
df_check_missing_occupation = (df['occupation']=='?').sum()
df_check_missing_occupation
```

```
2809
```

```
# checking "?" values, how many are there in the whole dataset
df_missing = (df=='?').sum()
df_missing
```

```
age                   0
workclass          2799
fnlwgt                0
education             0
educational-num       0
marital-status        0
occupation         2809
relationship          0
race                  0
gender                0
capital-gain          0
capital-loss          0
hours-per-week        0
```

```
native-country      857
income                0
dtype: int64
```

```
percent_missing = (df=='?').sum() * 100/len(df)
percent_missing
```

```
age                0.000000
workclass          5.730724
fnlwgt             0.000000
education          0.000000
educational-num    0.000000
marital-status     0.000000
occupation         5.751198
relationship       0.000000
race               0.000000
gender             0.000000
capital-gain       0.000000
capital-loss       0.000000
hours-per-week     0.000000
native-country     1.754637
income             0.000000
dtype: float64
```

```
# find total number of rows which doesn't contain any missing value as '?'
df.apply(lambda x: x !='?',axis=1).sum()
```

```
age                48842
workclass          46043
fnlwgt             48842
education          48842
educational-num    48842
marital-status     48842
occupation         46033
relationship       48842
race               48842
gender             48842
capital-gain       48842
capital-loss       48842
hours-per-week     48842
native-country     47985
income             48842
dtype: int64
```

```
# dropping the rows having missing values in workclass
df = df[df['workclass'] !='?']
df.head()
```

	age	workclass	fnlwgt	education	educational-num	marital-status	occupation	relationship	race	gender	capital-gain
0	25	Private	226802	11th	7	Never-married	Machine-op-inspct	Own-child	Black	Male	0
1	38	Private	89814	HS-grad	9	Married-civ-spouse	Farming-fishing	Husband	White	Male	0
2	28	Local-gov	336951	Assoc-acdm	12	Married-civ-spouse	Protective-serv	Husband	White	Male	0
3	44	Private	160323	Some-college	10	Married-civ-spouse	Machine-op-inspct	Husband	Black	Male	7688
5	34	Private	198693	10th	6	Never-married	Other-service	Not-in-family	White	Male	0

```
# select all categorical variables
df_categorical = df.select_dtypes(include=['object'])
# checking whether any other column contains '?' value
df_categorical.apply(lambda x: x=='?',axis=1).sum()
```

```
workclass           0
education           0
marital-status      0
occupation         10
relationship        0
race                0
gender              0
native-country    811
```

```
income            0
dtype: int64
```

```
from sklearn import preprocessing
# encode categorical variables using label Encoder
# select all categorical variables
df_categorical = df.select_dtypes(include=['object'])
df_categorical.head()
```

	workclass	education	marital-status	occupation	relationship	race	gender	native-country	i
0	Private	11th	Never-married	Machine-op-inspct	Own-child	Black	Male	United-States	
1	Private	HS-grad	Married-civ-spouse	Farming-fishing	Husband	White	Male	United-States	

```
# apply label encoder to df_categorical
le = preprocessing.LabelEncoder()
df_categorical = df_categorical.apply(le.fit_transform)
df_categorical.head()
```

	workclass	education	marital-status	occupation	relationship	race	gender	native-country	i
0	2	1	4	6	3	2	1	39	
1	2	11	2	4	0	4	1	39	
2	1	7	2	10	0	4	1	39	
3	2	15	2	6	0	2	1	39	

```
# Next, Concatenate df_categorical dataframe with original df (dataframe)
# first, Drop earlier duplicate columns which had categorical values
df = df.drop(df_categorical.columns,axis=1)
df = pd.concat([df,df_categorical],axis=1)
df.head()
```

	age	fnlwgt	educational-num	capital-gain	capital-loss	hours-per-week	workclass	education	marital-status	occupation	relati
0	25	226802	7	0	0	40	2	1	4	6	
1	38	89814	9	0	0	50	2	11	2	4	
2	28	336951	12	0	0	40	1	7	2	10	
3	44	160323	10	7688	0	40	2	15	2	6	
5	34	198693	6	0	0	30	2	0	4	7	

```
# look at column type
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 46033 entries, 0 to 48841
Data columns (total 15 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   age              46033 non-null  int64
 1   fnlwgt           46033 non-null  int64
 2   educational-num  46033 non-null  int64
 3   capital-gain     46033 non-null  int64
 4   capital-loss     46033 non-null  int64
 5   hours-per-week   46033 non-null  int64
 6   workclass        46033 non-null  int64
 7   education        46033 non-null  int64
 8   marital-status   46033 non-null  int64
 9   occupation       46033 non-null  int64
 10  relationship     46033 non-null  int64
 11  race             46033 non-null  int64
 12  gender           46033 non-null  int64
 13  native-country   46033 non-null  int64
 14  income           46033 non-null  int64
dtypes: int64(15)
memory usage: 5.6 MB
```

```
# convert target variable income to categorical
df['income'] = df['income'].astype('category')
# check df info again whether everything is in right format or not
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 46033 entries, 0 to 48841
Data columns (total 15 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   age              46033 non-null  int64
 1   fnlwgt           46033 non-null  int64
 2   educational-num  46033 non-null  int64
 3   capital-gain     46033 non-null  int64
 4   capital-loss     46033 non-null  int64
 5   hours-per-week   46033 non-null  int64
 6   workclass        46033 non-null  int64
 7   education        46033 non-null  int64
 8   marital-status   46033 non-null  int64
 9   occupation       46033 non-null  int64
 10  relationship     46033 non-null  int64
 11  race             46033 non-null  int64
 12  gender           46033 non-null  int64
 13  native-country   46033 non-null  int64
 14  income           46033 non-null  category
dtypes: category(1), int64(14)
memory usage: 5.3 MB
```

```
# Importing train_test_split
from sklearn.model_selection import train_test_split
# Putting independent variables/features to X
X = df.drop('income',axis=1)
# Putting response/dependent variable/feature to y
y = df['income']
```

```
X.head(3)
```

	age	fnlwgt	educational-num	capital-gain	capital-loss	hours-per-week	workclass	education	marital-status	occupation	relati
0	25	226802	7	0	0	40	2	1	4	6	
1	38	89814	9	0	0	50	2	11	2	4	
2	28	336951	12	0	0	40	1	7	2	10	

```
y.head(3)
```

```
0    0
1    0
2    1
Name: income, dtype: category
Categories (2, int64): [0, 1]
```

```
# Splitting the data into train and test
X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.30,random_state=99)
X_train.head()
```

	age	fnlwgt	educational-num	capital-gain	capital-loss	hours-per-week	workclass	education	marital-status	occupation	re
29293	39	203070	11	0	0	49	2	8	2	5	
3452	50	243115	9	0	0	40	2	11	3	0	
9788	31	154227	10	0	0	40	2	15	2	13	
44178	30	311913	9	0	0	40	1	11	2	0	
8912	68	99106	14	0	0	20	5	12	0	9	

```
# Importing decision tree classifier from sklearn library
from sklearn.tree import DecisionTreeClassifier
# Fitting the decision tree with default hyperparameters, apart from
# max_depth which is 5 so that we can plot and read the tree.
dt_default = DecisionTreeClassifier(max_depth=5)
dt_default.fit(X_train,y_train)
```

```
▾ DecisionTreeClassifier
DecisionTreeClassifier(max_depth=5)
```

```
# check the evaluation metrics of our default model
# Importing classification report and confusion matrix from sklearn metrics
from sklearn.metrics import classification_report,confusion_matrix,accuracy_score
# making predictions
y_pred_default = dt_default.predict(X_test)
# Printing classifier report after prediction
print(classification_report(y_test,y_pred_default))
```

```
              precision    recall  f1-score   support

           0       0.86      0.95      0.90     10341
           1       0.79      0.53      0.64      3469

    accuracy                           0.85     13810
   macro avg       0.83      0.74      0.77     13810
weighted avg       0.84      0.85      0.84     13810
```

```
# Printing confusion matrix and accuracy
print(confusion_matrix(y_test,y_pred_default))
print(accuracy_score(y_test,y_pred_default))
```

```
[[9861  480]
 [1616 1853]]
0.848225923244026
```

```
!pip install my-package
```

```
Collecting my-package
  Downloading my_package-0.0.0-py3-none-any.whl (2.0 kB)
Installing collected packages: my-package
Successfully installed my-package-0.0.0
```

```
!pip install pydotplus
```

```
Requirement already satisfied: pydotplus in /usr/local/lib/python3.10/dist-packages (2.0.2)
Requirement already satisfied: pyparsing>=2.0.1 in /usr/local/lib/python3.10/dist-packages (from pydotplus) (3.1.1)
```

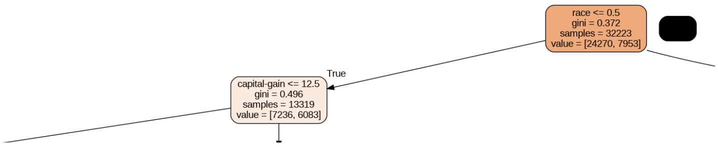
```
# Importing required packages for visualization
from IPython.display import Image
from six import StringIO
from sklearn.tree import export_graphviz
import pydotplus,graphviz
# Putting features
features = list(df.columns[1:])
features
```

```
['fnlwgt',
 'educational-num',
 'capital-gain',
 'capital-loss',
 'hours-per-week',
 'workclass',
 'education',
 'marital-status',
 'occupation',
 'relationship',
 'race',
 'gender',
 'native-country',
 'income']
```

```
!pip install graphviz
```

```
Requirement already satisfied: graphviz in /usr/local/lib/python3.10/dist-packages (0.20.1)
```

```
# plotting tree with max_depth=3
dot_data = StringIO()
export_graphviz(dt_default, out_file=dot_data,
feature_names=features, filled=True,rounded=True)
graph = pydotplus.graph_from_dot_data(dot_data.getvalue())
Image(graph.create_png())
```




```
# GridSearchCV to find optimal max_depth
from sklearn.model_selection import KFold
from sklearn.model_selection import GridSearchCV
# specify number of folds for k-fold CV
n_folds = 5
# parameters to build the model on
parameters = {'max_depth': range(1, 40)}
# instantiate the model
dtree = DecisionTreeClassifier(criterion = "gini",
random_state = 100)
# fit tree on training data
tree = GridSearchCV(dtree, parameters,
cv=n_folds,
scoring="accuracy")
tree.fit(X_train, y_train)
```

```
▸ GridSearchCV
▸ estimator: DecisionTreeClassifier
  ▸ DecisionTreeClassifier
```

```
# scores of GridSearch CV
scores = tree.cv_results_
pd.DataFrame(scores).head()
```

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	
0	0.017508	0.001094	0.003653	0.000255	1	{'m
1	0.026208	0.000638	0.003497	0.000050	2	{'m
2	0.035516	0.000600	0.003571	0.000109	3	{'m
3	0.046339	0.002691	0.003698	0.000265	4	{'m
4	0.054046	0.000881	0.003738	0.000126	5	{'m

```
# GridSearchCV to find optimal max_depth
from sklearn.model_selection import KFold
from sklearn.model_selection import GridSearchCV
# specify number of folds for k-fold CV
n_folds = 5
# parameters to build the model on
parameters = {'min_samples_leaf': range(5, 200, 20)}
# instantiate the model
dtree = DecisionTreeClassifier(criterion = "gini",
random_state = 100)
# fit tree on training data
tree = GridSearchCV(dtree, parameters,
cv=n_folds,
scoring="accuracy")
tree.fit(X_train, y_train)
```

```
▸ GridSearchCV
▸ estimator: DecisionTreeClassifier
  ▸ DecisionTreeClassifier
```

```
# scores of GridSearch CV
scores = tree.cv_results_
pd.DataFrame(scores).head()
```

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_min_samples_le
0	0.137336	0.004291	0.004951	0.000940	
1	0.115085	0.003973	0.004306	0.000304	
2	0.107868	0.005090	0.004147	0.000113	
3	0.101131	0.002170	0.004166	0.000221	

```
# GridSearchCV to find optimal min_samples_split
from sklearn.model_selection import KFold
from sklearn.model_selection import GridSearchCV
# specify number of folds for k-fold CV
n_folds = 5
# parameters to build the model on
parameters = {'min_samples_split': range(5, 200, 20)}
# instantiate the model
dtree = DecisionTreeClassifier(criterion = "gini",
random_state = 100)
# fit tree on training data
tree = GridSearchCV(dtree, parameters,
cv=n_folds,
scoring="accuracy")
tree.fit(X_train, y_train)
```

```
▸ GridSearchCV
▸ estimator: DecisionTreeClassifier
  ▸ DecisionTreeClassifier
```

```
# scores of GridSearch CV
scores = tree.cv_results_
pd.DataFrame(scores).head()
```

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_min_samples_sp
0	0.153947	0.002147	0.005929	0.000578	
1	0.143463	0.004214	0.005008	0.000071	
2	0.138373	0.001752	0.005027	0.000082	
3	0.133974	0.005993	0.004872	0.000038	
4	0.133274	0.005639	0.005146	0.000392	

```
# Create the parameter grid
param_grid = {
'max_depth': range(5, 15, 5),
'min_samples_leaf': range(50, 150, 50),
'min_samples_split': range(50, 150, 50),
'criterion': ["entropy", "gini"]
}
n_folds = 5
```

```
# Instantiate the grid search model
dtree = DecisionTreeClassifier()
grid_search = GridSearchCV(estimator = dtree, param_grid = param_grid,
cv = n_folds, verbose = 1)
# Fit the grid search to the data
grid_search.fit(X_train,y_train)
```

```
Fitting 5 folds for each of 16 candidates, totalling 80 fits
▸ GridSearchCV
▸ estimator: DecisionTreeClassifier
  ▸ DecisionTreeClassifier
```

```
# cv results
cv_results = pd.DataFrame(grid_search.cv_results_)
cv_results
```

```
# printing the optimal accuracy score and hyperparameters
print("best accuracy", grid_search.best_score_)
print(grid_search.best_estimator_)
```

```
best accuracy 0.8523105983446813
DecisionTreeClassifier(max_depth=10, min_samples_leaf=50, min_samples_split=50)
```

```
# model with optimal hyperparameters
clf_gini = DecisionTreeClassifier(criterion = "gini",
random_state = 100,
max_depth=10,
min_samples_leaf=50,
min_samples_split=50)
clf_gini.fit(X_train, y_train)
```

```
▾ DecisionTreeClassifier
DecisionTreeClassifier(max_depth=10, min_samples_leaf=50, min_samples_split=50,
                       random_state=100)
```

```
# accuracy score
clf_gini.score(X_test,y_test)
```

```
0.852860246198407
```

```
#plotting the tree
dot_data = StringIO()
export_graphviz(clf_gini, out_file=dot_data,feature_names=features,filled=True,rounded=True)
graph = pydotplus.graph_from_dot_data(dot_data.getvalue())
Image(graph.create_png())
```

1	0.058885	0.001184	0.004362	0.000257	entropy

```
# tree with max_depth = 3
clf_gini = DecisionTreeClassifier(criterion = "gini",
random_state = 100,
max_depth=3,
min_samples_leaf=50,
min_samples_split=50)
clf_gini.fit(X_train, y_train)
# score
print(clf_gini.score(X_test,y_test))
# plotting tree with max_depth=3
dot_data = StringIO()
export_graphviz(clf_gini, out_file=dot_data,feature_names=features,filled=True,rounded=True)
```

```
0.8331643736422882
```

```
# classification metrics
from sklearn.metrics import classification_report,confusion_matrix
y_pred = clf_gini.predict(X_test)
print(classification_report(y_test, y_pred))
# confusion matrix
print(confusion_matrix(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.84      0.95      0.90     10341
           1       0.77      0.47      0.59      3469

    accuracy                           0.83     13810
   macro avg       0.81      0.71      0.74     13810
weighted avg       0.83      0.83      0.82     13810

[[9860  481]
 [1823 1646]]
```

9	0.051650	0.000660	0.003619	0.000087	gini
10	0.051671	0.001334	0.003589	0.000080	gini