



**Vidyavardhini's College of Engineering & Technology**

Department of Computer Engineering

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**Experiment No. 6**

Apply Boosting Algorithm on Adult Census Income Dataset  
and analyze the performance of the model

Date of Performance: 05/10/2023

Date of Submission: 12/10/2023



### CSL701: Machine Learning Lab

**Aim:** Apply Boosting algorithm on Adult Census Income Dataset and analyze the performance of the model.

**Objective:** Apply Boosting algorithm on the given dataset and maximize the accuracy, Precision, Recall, F1 score.

#### Theory:

Suppose that as a patient, you have certain symptoms. Instead of consulting one doctor, you choose to consult several. Suppose you assign weights to the value or worth of each doctor's diagnosis, based on the accuracies of previous diagnosis they have made. The final diagnosis is then a combination of the weighted diagnosis. This is the essence behind boosting.

Algorithm: Adaboost- A boosting algorithm—create an ensemble of classifiers. Each one gives a weighted vote.

#### Input:

- $D$ , a set of  $d$  class labelled training tuples
- $k$ , the number of rounds (one classifier is generated per round)
- a classification learning scheme

**Output:** A composite model

#### Method

1. Initialize the weight of each tuple in  $D$  is  $1/d$
2. For  $i=1$  to  $k$  do // for each round
3. Sample  $D$  with replacement according to the tuple weights to obtain  $D_i$
4. Use training set  $D_i$  to derive a model  $M_i$
5. Compute error( $M_i$ ), the error rate of  $M_i$
6.  $\text{Error}(M_i) = \sum w_i * \text{err}(X_i)$
7. If  $\text{Error}(M_i) > 0.5$  then
8. Go back to step 3 and try again

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9. endif
10. for each tuple in D that was correctly classified do
  - i
  11. Multiply the weight of the tuple by  $\text{error}(M_i)/(1-\text{error}(M_i))$
  12. Normalize the weight of each tuple
  13. end for

### To use the ensemble to classify tuple X

1. Initialize the weight of each class to 0
2. for  $i=1$  to  $k$  do // for each classifier
3.  $w = \log((1-\text{error}(M_i))/\text{error}(M_i)) / \text{weight of the classifiers vote}_i$
4.  $C = M_i(X)$  // get class prediction for X from  $M_i$
5. Add  $w$  to weight for class  $C_i$
6. end for
7. Return the class with the largest weight.

### 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.

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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, Profspecialty, Handlers-cleaners, Machine-op-inspct, Adm-clerical, Farming-fishing, Transportmoving, 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, DominicanRepublic, Laos, Ecuador, Taiwan, Haiti, Columbia, Hungary, Guatemala, Nicaragua, Scotland, Thailand, Yugoslavia, El-Salvador, Trinidad & Tobago, Peru, Hong, HolandNetherlands.



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```
In [4]: # Import Libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import io
from sklearn.metrics import accuracy_score, precision_score, f1_score, confusion_matrix
from sklearn.model_selection import cross_val_score
from sklearn.metrics import mean_squared_error
%matplotlib inline
import warnings
warnings.filterwarnings('ignore')

df = pd.read_csv('adult.csv')
print(df.head())
```

	age	workclass	fnlwgt	education	education.num	marital.status	\
0	90	?	77053	HS-grad	9	Widowed	
1	82	Private	132870	HS-grad	9	Widowed	
2	66	?	186061	Some-college	10	Widowed	
3	54	Private	140359	7th-8th	4	Divorced	
4	41	Private	264663	Some-college	10	Separated	

	occupation	relationship	race	sex	capital.gain	\
0	?	Not-in-family	White	Female	0	
1	Exec-managerial	Not-in-family	White	Female	0	
2	?	Unmarried	Black	Female	0	
3	Machine-op-inspct	Unmarried	White	Female	0	
4	Prof-specialty	Own-child	White	Female	0	

	capital.loss	hours.per.week	native.country	income
0	4356	40	United-States	<=50K
1	4356	18	United-States	<=50K
2	4356	40	United-States	<=50K
3	3900	40	United-States	<=50K
4	3900	40	United-States	<=50K

In [ ]:

```
5   print(df.info())
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 32561 entries, 0 to 32560
Data columns (total 15 columns):
 #   Column            Non-Null Count  Dtype  
--- 
 0   age               32561 non-null   int64  
 1   workclass         32561 non-null   object  
 2   fnlwgt            32561 non-null   int64  
 3   education         32561 non-null   object  
 4   education.num    32561 non-null   int64  
 5   marital.status   32561 non-null   object  
 6   occupation        32561 non-null   object  
 7   relationship      32561 non-null   object  
 8   race              32561 non-null   object  
 9   sex               32561 non-null   object  
 10  capital.gain    32561 non-null   int64  
 11  capital.loss    32561 non-null   int64  
 12  hours.per.week  32561 non-null   int64  
 13  native.country   32561 non-null   object  
 14  income            32561 non-null   object  
dtypes: int64(6), object(9)
memory usage: 3.7+ MB
None
```

In [ ]:

```
6 #Count the occuring of the '?' in all the columns
for i in df.columns:
    t = df[i].value_counts()
    index = list(t.index)
    print ("Count of ? in", i)
    for i in index:
        temp = 0
        if i == '?':
            print (t['?'])
            temp = 1
            break
    if temp == 0:
        print ("0")
```

```
Count of ? in age
0
Count of ? in workclass
1836
Count of ? in fnlwgt
0
Count of ? in education
0
Count of ? in education.num
0
Count of ? in marital.status
0
Count of ? in occupation
1843
Count of ? in relationship
0
Count of ? in race
0
Count of ? in sex
0
Count of ? in capital.gain
0
Count of ? in capital.loss
0
Count of ? in hours.per.week
0
Count of ? in native.country
583
Count of ? in income
0
```

In [ ]:

```
7 df=df.loc[(df['workclass'] != '?') & (df['native.country'] != '?')]
print(df.head())
```

	age	workclass	fnlwgt	education	education.num	marital.status	\
1	82	Private	132870	HS-grad	9	Widowed	
3	54	Private	140359	7th-8th	4	Divorced	
4	41	Private	264663	Some-college	10	Separated	
5	34	Private	216864	HS-grad	9	Divorced	
6	38	Private	150601	10th	6	Separated	

	occupation	relationship	race	sex	capital.gain	\
1	Exec-managerial	Not-in-family	White	Female	0	
3	Machine-op-inspct	Unmarried	White	Female	0	
4	Prof-specialty	Own-child	White	Female	0	
5	Other-service	Unmarried	White	Female	0	
6	Adm-clerical	Unmarried	White	Male	0	

	capital.loss	hours.per.week	native.country	income	
1	4356	18	United-States	<=50K	
3	3900	40	United-States	<=50K	
4	3900	40	United-States	<=50K	
5	3770	45	United-States	<=50K	
6	3770	40	United-States	<=50K	

In [8]: df["income"] = [1 if i=='>50K' else 0 for i in df["income"]]
print(df.head())

```
age workclass fnlwgt education education.num marital.status \
1 82 Private 132870 HS-grad 9 Widowed
3 54 Private 140359 7th-8th 4 Divorced
4 41 Private 264663 Some-college 10 Separated
5 34 Private 216864 HS-grad 9 Divorced
6 38 Private 150601 10th 6 Separated

occupation relationship race sex capital.gain \
1 Exec-managerial Not-in-family White Female 0
3 Machine-op-inspct Unmarried White Female 0
4 Prof-specialty Own-child White Female 0
5 Other-service Unmarried White Female 0
6 Adm-clerical Unmarried White Male 0

capital.loss hours.per.week native.country income
1 4356 18 United-States 0
3 3900 40 United-States 0
4 3900 40 United-States 0
5 3770 45 United-States 0
6 3770 40 United-States 0
```

In [ ]:

```
9 df_more=df.loc[df['income'] == 1]
print(df_more.head())
```

	age	workclass	fnlwgt	education	education.num	marital.status
7	74	State-gov	88638	Doctorate	16	Never-married
10	45	Private	172274	Doctorate	16	Divorced
11	38	Self-emp-not-inc	164526	Prof-school	15	Never-married
12	52	Private	129177	Bachelors	13	Widowed
13	32	Private	136204	Masters	14	Separated

	occupation	relationship	race	sex	capital.gain	\
7	Prof-specialty	Other-relative	White	Female	0	
10	Prof-specialty	Unmarried	Black	Female	0	
11	Prof-specialty	Not-in-family	White	Male	0	
12	Other-service	Not-in-family	White	Female	0	
13	Exec-managerial	Not-in-family	White	Male	0	

	capital.loss	hours.per.week	native.country	income
7	3683	20	United-States	1
10	3004	35	United-States	1
11	2824	45	United-States	1
12	2824	20	United-States	1
13	2824	55	United-States	1

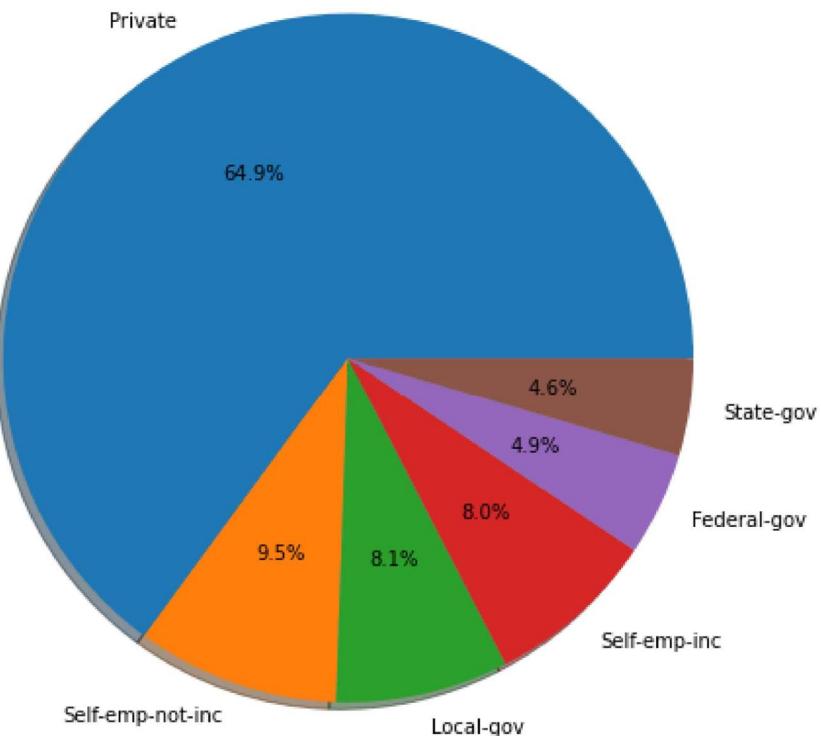
In [10]:

```
workclass_types = df_more['workclass'].value_counts()
labels = list(workclass_types.index)
aggregate = list(workclass_types)
print(workclass_types)
print(aggregate)
print(labels)
```

```
Private           4876
Self-emp-not-inc    714
Local-gov          609
Self-emp-inc        600
Federal-gov         365
State-gov           344
Name: workclass, dtype: int64
[4876, 714, 609, 600, 365, 344]
['Private', 'Self-emp-not-inc', 'Local-gov', 'Self-emp-inc', 'Federal-gov',
 'State-gov']
```

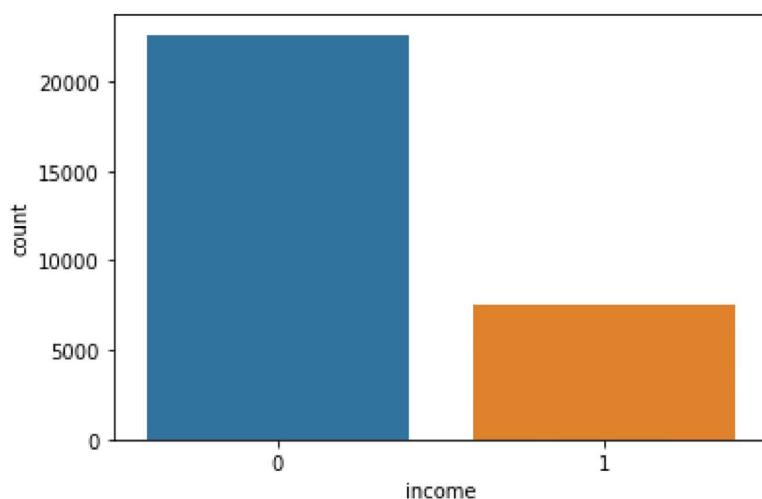
In [ ]:

```
11 plt.figure(figsize=(7,7))
plt.pie(aggregate, labels=labels, autopct='%.1f%%', shadow = True)
plt.axis('equal')
plt.show()
```



In [12]: *#Count plot on single categorical variable*

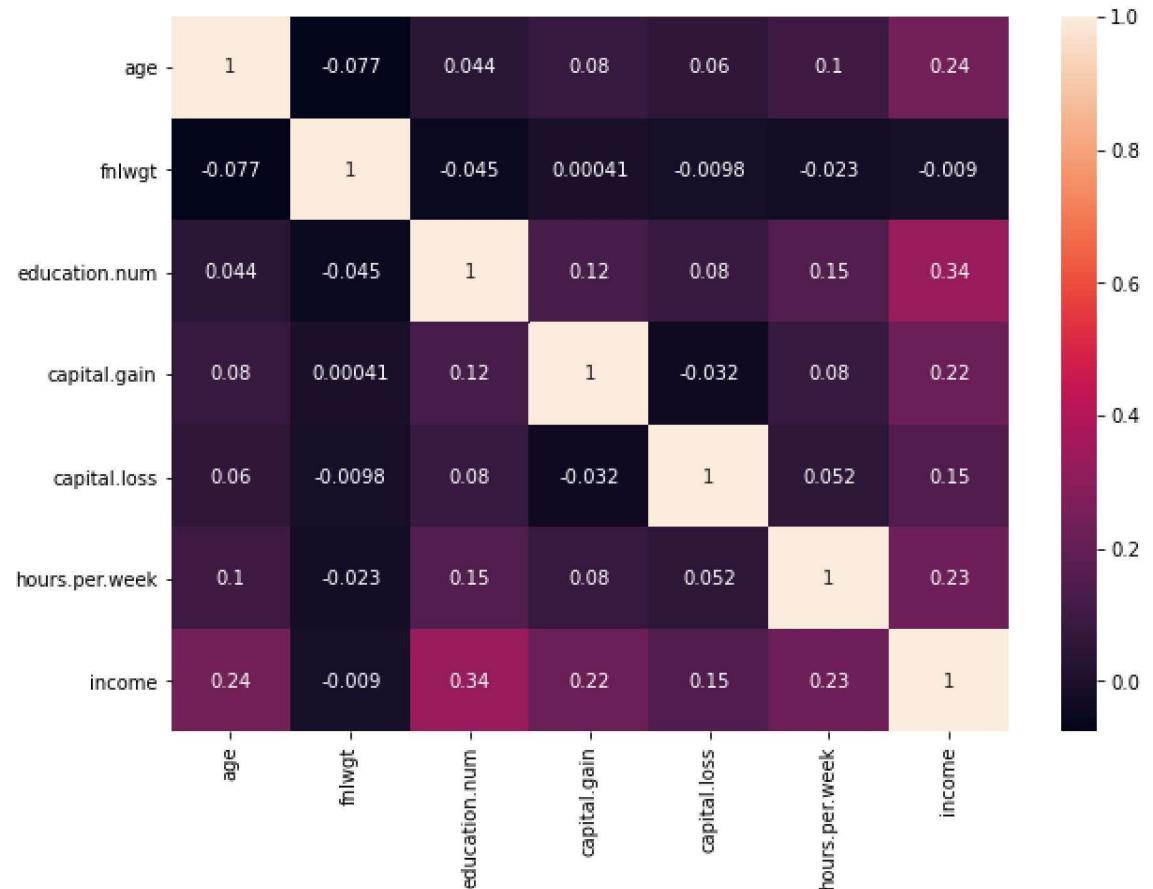
```
sns.countplot(x ='income', data = df)
plt.show()
df['income'].value_counts()
```



Out[12]: 0 22661  
1 7508  
Name: income, dtype: int64

In [3] :

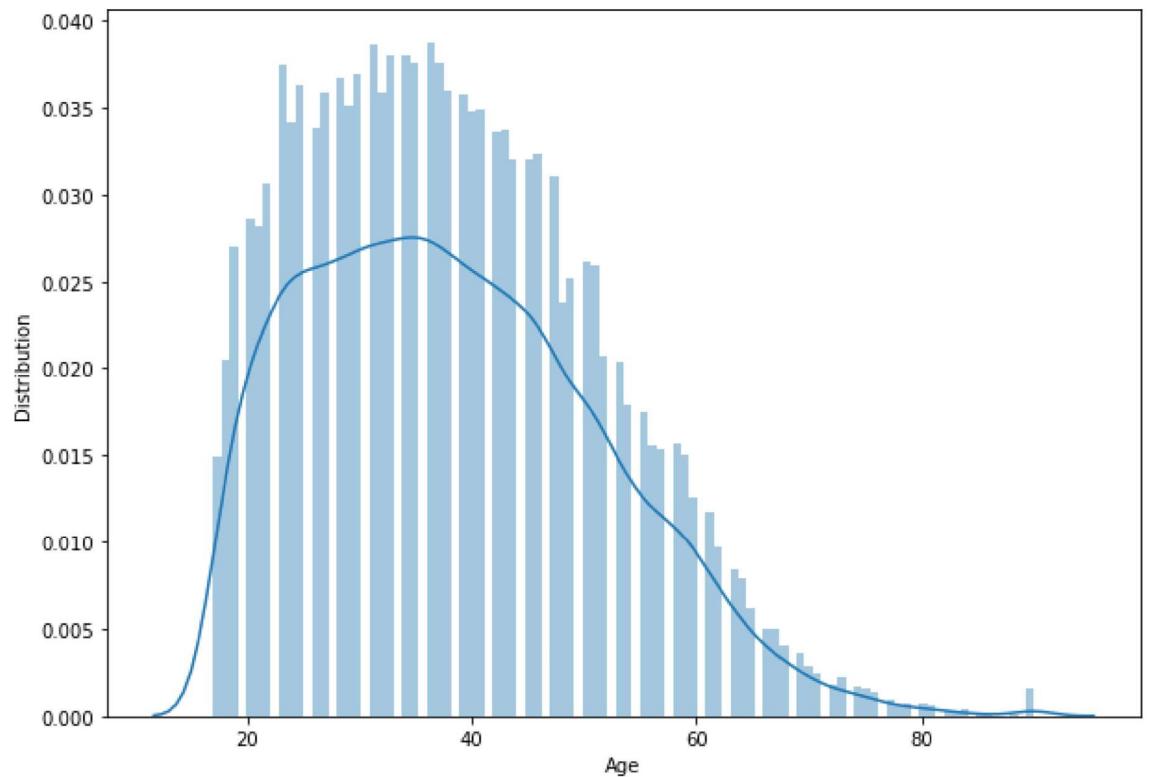
```
2 #Plot figsize
plt.figure(figsize=(10,7))
sns.heatmap(df.corr(), annot=True)
print(plt.show())
```



None

In [3] :

```
1 plt.figure(figsize=(10,7))
2 sns.distplot(df['age'], bins=100)
3 plt.ylabel("Distribution", fontsize = 10)
4 plt.xlabel("Age", fontsize = 10)
5 plt.show()
```



In [3] :

```
0 #To find distribution of categorical columns w.r.t income
fig, axes = plt.subplots(figsize=(20, 10))

plt.subplot(231)
sns.countplot(x ='workclass',
               hue='income',
               data = df,
               )
plt.xticks(rotation=90)

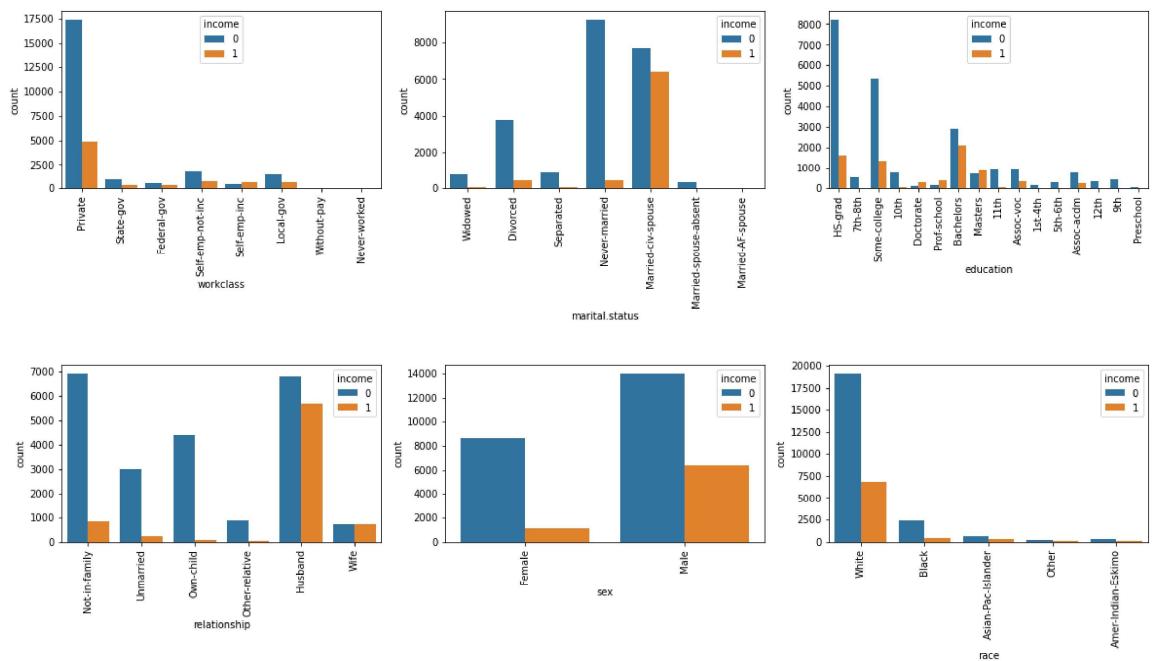
plt.subplot(232)
sns.countplot(x ='marital.status',
               hue='income',
               data = df,
               )
plt.xticks(rotation=90)

plt.subplot(233)
sns.countplot(x ='education',
               hue='income',
               data = df,
               )
plt.xticks(rotation=90)

plt.subplot(234)
sns.countplot(x ='relationship',
               hue='income',
               data = df,
               )
plt.xticks(rotation=90)

plt.subplot(235)
sns.countplot(x ='sex',
               hue='income',
               data = df,
               )
plt.xticks(rotation=90)

plt.subplot(236)
sns.countplot(x ='race',
               hue='income',
               data = df,
               )
plt.xticks(rotation=90)
plt.subplots_adjust(hspace=1)
plt.show()
```



```
In [16]: df1 = df.copy()
```

In [ ]:

```
n 17 categorical_features = list(df1.select_dtypes(include=['object']).columns)
print(categorical_features)
df1
```

```
['workclass', 'education', 'marital.status', 'occupation', 'relationship',
'race', 'sex', 'native.country']
```

Out[17]:

	age	workclass	fnlwgt	education	education.num	marital.status	occupation	relationship
1	82	Private	132870	HS-grad		9	Widowed	Exec-managerial
3	54	Private	140359	7th-8th		4	Divorced	Machine-op-inspct
4	41	Private	264663	Some-college		10	Separated	Prof-specialty
5	34	Private	216864	HS-grad		9	Divorced	Other-service
6	38	Private	150601	10th		6	Separated	Adm-clerical
...	...	...	...	...	...	...	...	...
32556	22	Private	310152	Some-college		10	Never-married	Protective-serv
32557	27	Private	257302	Assoc-acdm		12	Married-civ-spouse	Tech-support
32558	40	Private	154374	HS-grad		9	Married-civ-spouse	Machine-op-inspct
32559	58	Private	151910	HS-grad		9	Widowed	Adm-clerical
32560	22	Private	201490	HS-grad		9	Never-married	Adm-clerical

30169 rows × 15 columns



In [ ]:

```
18 from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
for feat in categorical_features:
    df1[feat] = le.fit_transform(df1[feat].astype(str))
df1
```

Out[18]:

	age	workclass	fnlwgt	education	education.num	marital.status	occupation	relationship
1	82	3	132870	11	9	6	4	
3	54	3	140359	5	4	0	7	
4	41	3	264663	15	10	5	10	
5	34	3	216864	11	9	0	8	
6	38	3	150601	0	6	5	1	
...	...	...	...	...	...	...	...	...
32556	22	3	310152	15	10	4	11	
32557	27	3	257302	7	12	2	13	
32558	40	3	154374	11	9	2	7	
32559	58	3	151910	11	9	6	1	
32560	22	3	201490	11	9	4	1	

30169 rows × 15 columns



In [19]:

```
X = df1.drop(columns = ['income'])
y = df1['income'].values

# Splitting the data set into train and test set
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.3, random_state = 42)

print ("Train set size: ", X_train.shape)
print ("Test set size: ", X_test.shape)
```

```
Train set size: (21118, 14)
Test set size: (9051, 14)
```

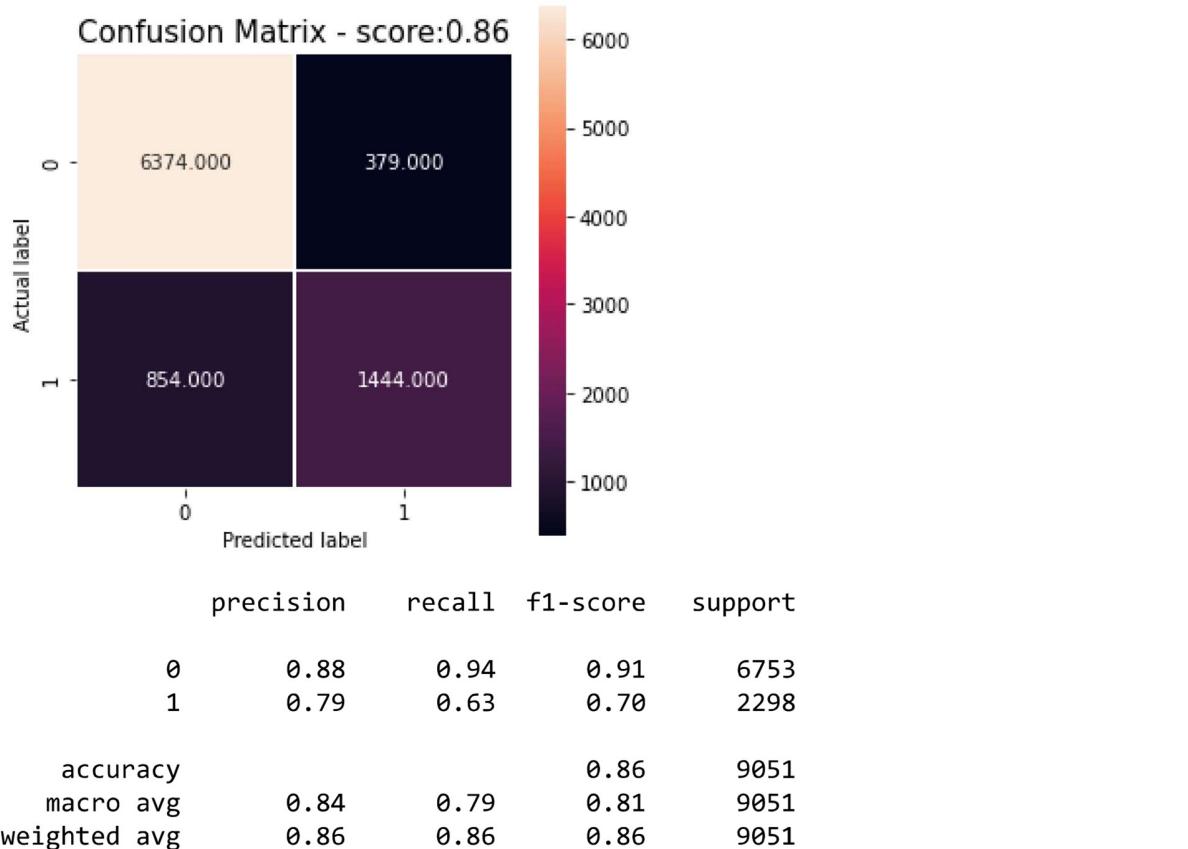
In [2] :

```
0  from sklearn.ensemble import AdaBoostClassifier  
  
# Train Adaboost Classifier  
abc = AdaBoostClassifier(n_estimators = 300, learning_rate=1)  
abc_model = abc.fit(X_train, y_train)  
  
#Prediction  
y_pred_abc = abc_model.predict(X_test)  
  
print("Accuracy: ", accuracy_score(y_test, y_pred_abc))  
print("F1 score : ",f1_score(y_test, y_pred_abc, average='binary'))  
print("Precision : ", precision_score(y_test, y_pred_abc))
```

Accuracy: 0.8637719588995691  
F1 score : 0.7008007765105557  
Precision : 0.7921009325287987

In [23]:

```
cm = confusion_matrix(y_test, y_pred_abc)  
plt.figure(figsize=(5,5))  
sns.heatmap(cm, annot=True, fmt=".3f", linewidths=.5, square = True);  
plt.ylabel('Actual label');  
plt.xlabel('Predicted label');  
plt.title('Confusion Matrix - score:' + str(round(accuracy_score(y_test, y_pred_abc), 2)))  
plt.show()  
print(classification_report(y_test, y_pred_abc))
```



In [2] :

```
2 from sklearn.ensemble import GradientBoostingClassifier

#Training the model with gradient boosting
gbc = GradientBoostingClassifier(
    learning_rate = 0.1,
    n_estimators = 500,
    max_depth = 5,
    subsample = 0.9,
    min_samples_split = 100,
    max_features='sqrt',
    random_state=10)
gbc.fit(X_train,y_train)

# Predictions
y_pred_gbc = gbc.predict(X_test)

print("Accuracy : ",accuracy_score(y_test, y_pred_gbc))
print("F1 score : ", f1_score(y_test, y_pred_gbc, average = 'binary'))
print("Precision : ", precision_score(y_test, y_pred_gbc))

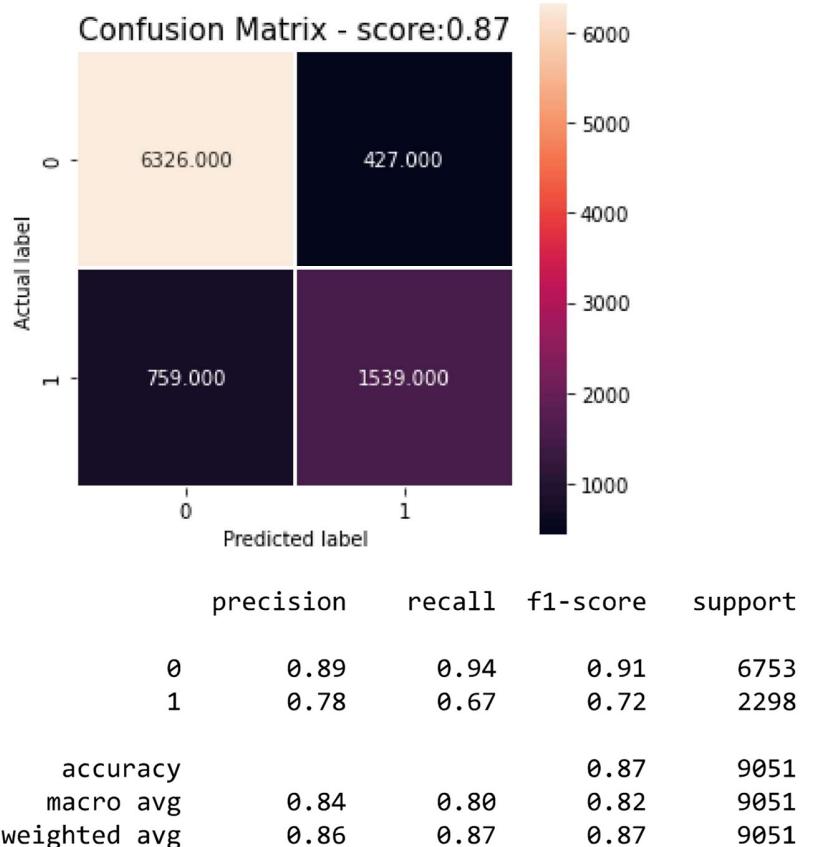
Accuracy :  0.8689647552756602
F1 score :  0.7218574108818011
Precision :  0.7828077314343845
```

In [24]: rms = np.sqrt(mean\_squared\_error(y\_test, y\_pred\_gbc))
print("RMSE for gradient boost: ", rms)

```
RMSE for gradient boost:  0.3619879068758235
```

In [2] :

```
5 cm = confusion_matrix(y_test, y_pred_gbc)
plt.figure(figsize=(5,5))
sns.heatmap(cm, annot = True, fmt=".3f", linewidths = 0.5, square = True);
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion Matrix - score:' + str(round(accuracy_score(y_test, y_pred_gbc), 2)))
plt.show()
print(classification_report(y_test, y_pred_gbc))
```



In [2] :

```
6 import xgboost as xgb
from xgboost import XGBClassifier

#Training the model with gradient boosting
xgboost = XGBClassifier(learning_rate=0.01,
                       colsample_bytree = 0.4,
                       n_estimators=1000,
                       max_depth=20,
                       gamma=1)

xgboost_model = xgboost.fit(X_train, y_train)

# Predictions
y_pred_xgboost = xgboost_model.predict(X_test)

print("Accuracy : ",accuracy_score(y_test, y_pred_xgboost))
print("F1 score : ", f1_score(y_test, y_pred_xgboost, average = 'binary'))
print("Precision : ", precision_score(y_test, y_pred_xgboost))

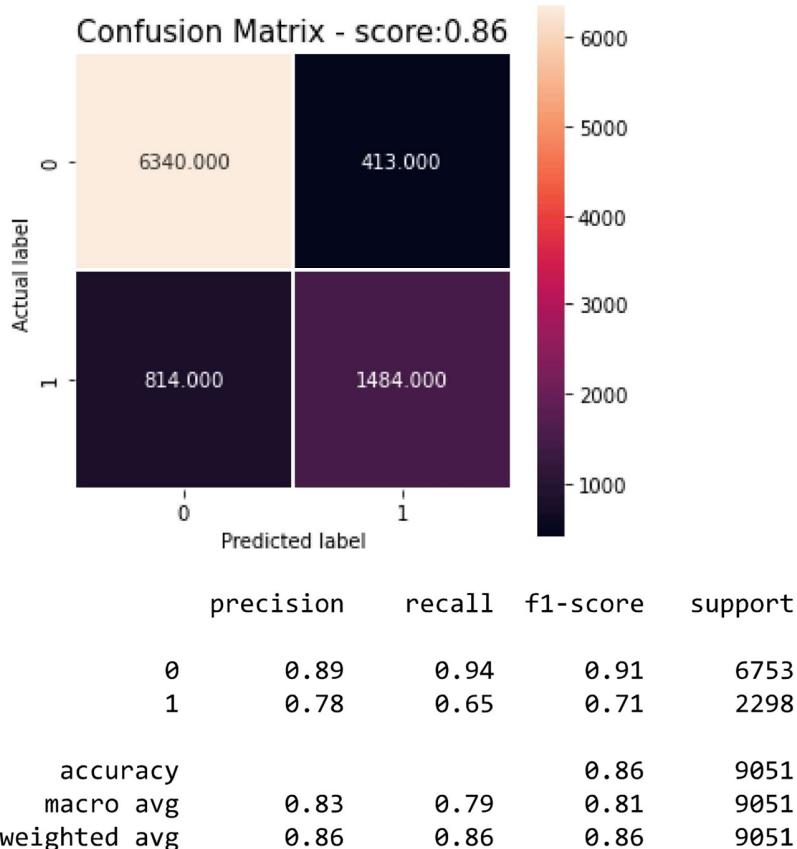
Accuracy :  0.8644348690752403
F1 score :  0.7075089392133492
Precision :  0.7822878228782287
```

In [27]: rms = np.sqrt(mean\_squared\_error(y\_test, y\_pred\_xgboost))
print("RMSE for xgboost: ", rms)

```
RMSE for xgboost:  0.36819170404119606
```

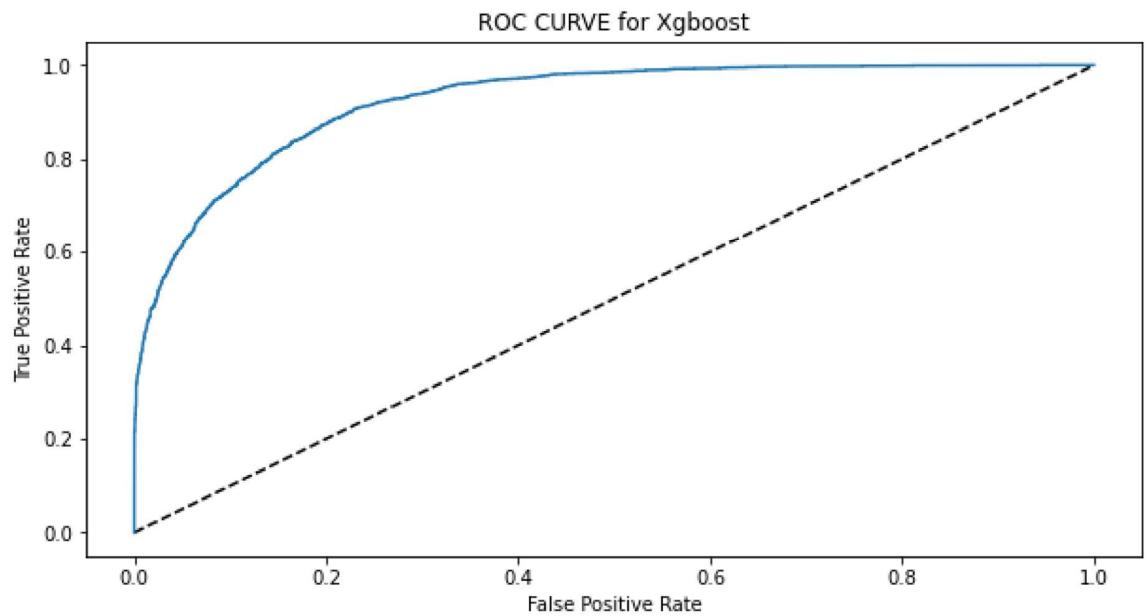
In [2] :

```
8 cm = confusion_matrix(y_test, y_pred_xgboost)
plt.figure(figsize=(5,5))
sns.heatmap(cm, annot=True, fmt=".3f", linewidths=.5, square = True);
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion Matrix - score:' + str(round(accuracy_score(y_test, y_pred_xgboost), 3)))
plt.show()
print(classification_report(y_test,y_pred_xgboost))
```



In [2] :

```
9 from sklearn.metrics import roc_curve
fpr, tpr, thresholds = roc_curve(y_test, xgboost.predict_proba(X_test)[:,1])
plt.figure(figsize = (10,5))
plt.plot([0,1],[0,1], 'k--')
plt.plot(fpr, tpr)
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC CURVE for Xgboost')
plt.show()
```



I would like to conclude this notebook by mentioning that here, I have tuned the hyperparameters myself instead of using Grid Search or random search as it didn't seem to increase my accuracies. I would appreciate any suggestions or improvements that I can make to make this better.



**Conclusion:**

1. The Accuracy score obtained by applying boosting algo on the testing data is 0.86 which means our model is 86% accurate on the testing data.
2. Confusion matrix is used to assess the performance of a classification model, in our case the no. of TP is 1444, no. of TN is 6374, no. of FP is 379 and no. of FN are 854 which means our model is better in predicting negative cases than the positive cases.
3. Precision measures the accuracy of the positive predictions and the precision score obtained by our model is 0.88
4. Recall measures the ability of the model to correctly identify all relevant instances and the Recall score obtained by our model is 0.94
5. F1-score is the harmonic mean of precision and recall and provides a balance between the 2 metrics and the F1-score obtained by our model is 0.91
6. In the random forest algorithm, the accuracy, precision, recall and F1-score obtained respectively is 84%, 88%, 95%, 91%. and the accuracy, precision, recall and F1-score obtained by boosting algorithm respectively is 86%, 88%, 94%, 91%. Thus we can conclude that boosting algorithm is slightly better than the random forest algorithm

