Experiment No. 6
Apply Boosting Algorithm on Adult Census Income Dataset and analyze the performance of the model
Date of Performance: 04-09-2023
Date of Submission: 13-09-2023

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—creates 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. Computer error(M_i), the error rate of M_i
6. Error(M_i)=$\sum w_j$*err(X_j)
7. If Error(M_i)>0.5 then
8. Go back to step 3 and try again
9. endif
10. for each tuple in D_i that was correctly classified do
11. Multiply the weight of the tuple by error(Mi)/(1-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_i=log((1-error(M_i))/error(M_i))//weight of the classifiers vote
4. C=M_i(X) // get class prediction for X from M_i
5. Add w_i to weight for class C
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.

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.

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September 12, 2023

[ ]:
```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import io
from sklearn.metrics import accuracy_score, precision_score, f1_score,␣
 ↪confusion_matrix, classification_report
from sklearn.model_selection import cross_val_score
from sklearn.metrics import mean_squared_error
```

[ ]:
```python
import os
for dirname, _, filenames in os.walk('/kaggle/input'):
    for filename in filenames:
        print(os.path.join(dirname, filename))
```

[ ]:
```python
file = ('/content/adult.csv')
df = pd.read_csv(file)
```

[ ]:
```python
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
```

[ ]:
```python
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
```

[ ]:
```python
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
```

[ ]:
```
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
```

[ ]:
```python
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
```

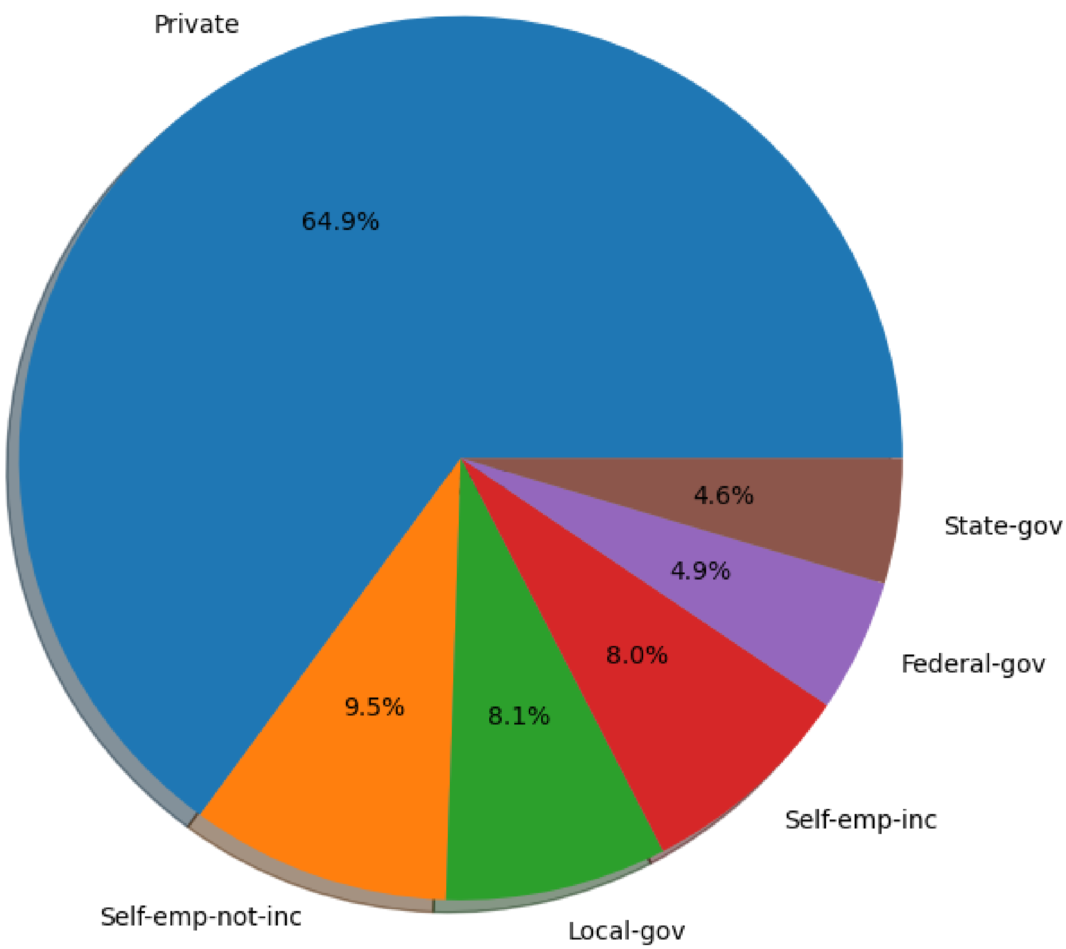
[ ]:
```python
df_more=df.loc[df['income'] == 1]
print(df_more.head())
```

```
    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
```

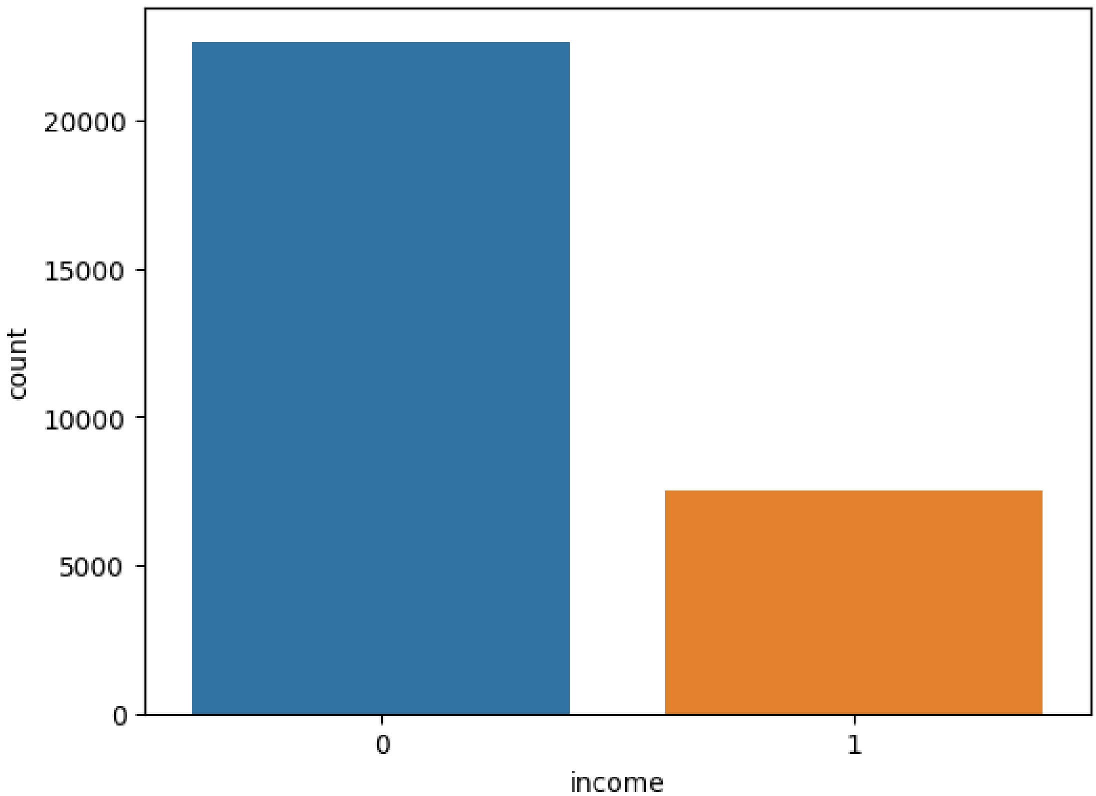
[ ]:
```
workclass_types = df_more['workclass'].value_counts()
labels = list(workclass_types.index)
aggregate = list(workclass_types)
print(workclass_types)
print(aggregate)
print(labels)
```

```
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']
```

[ ]:
```
plt.figure(figsize=(7,7))
plt.pie(aggregate, labels=labels, autopct='%1.1f%%', shadow = True)
plt.axis('equal')
plt.show()
```



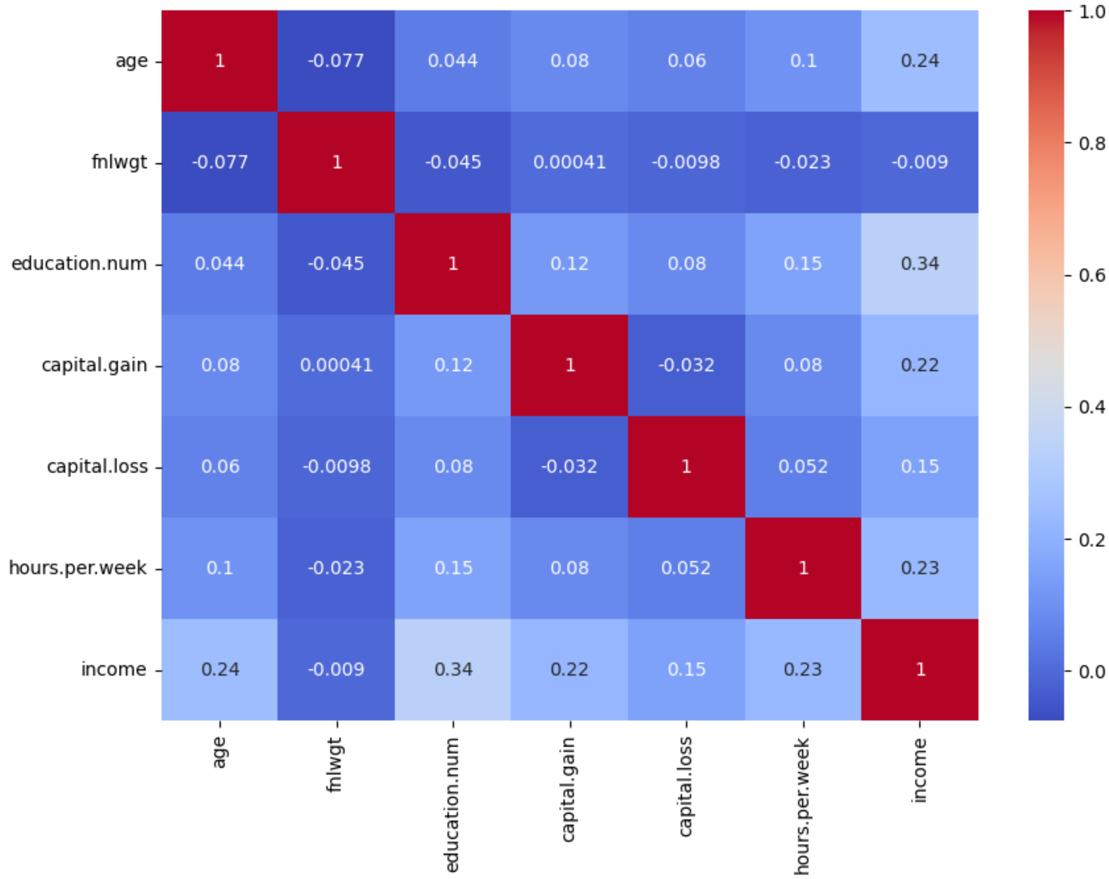
[ ]:
```
#Count plot on single categorical variable
sns.countplot(x ='income', data = df)
plt.show()
df['income'].value_counts()
```




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

```
[ ]: #Plot figsize
     plt.figure(figsize=(10,7))
     sns.heatmap(df.corr(), cmap='coolwarm', annot=True)
     print(plt.show())
```

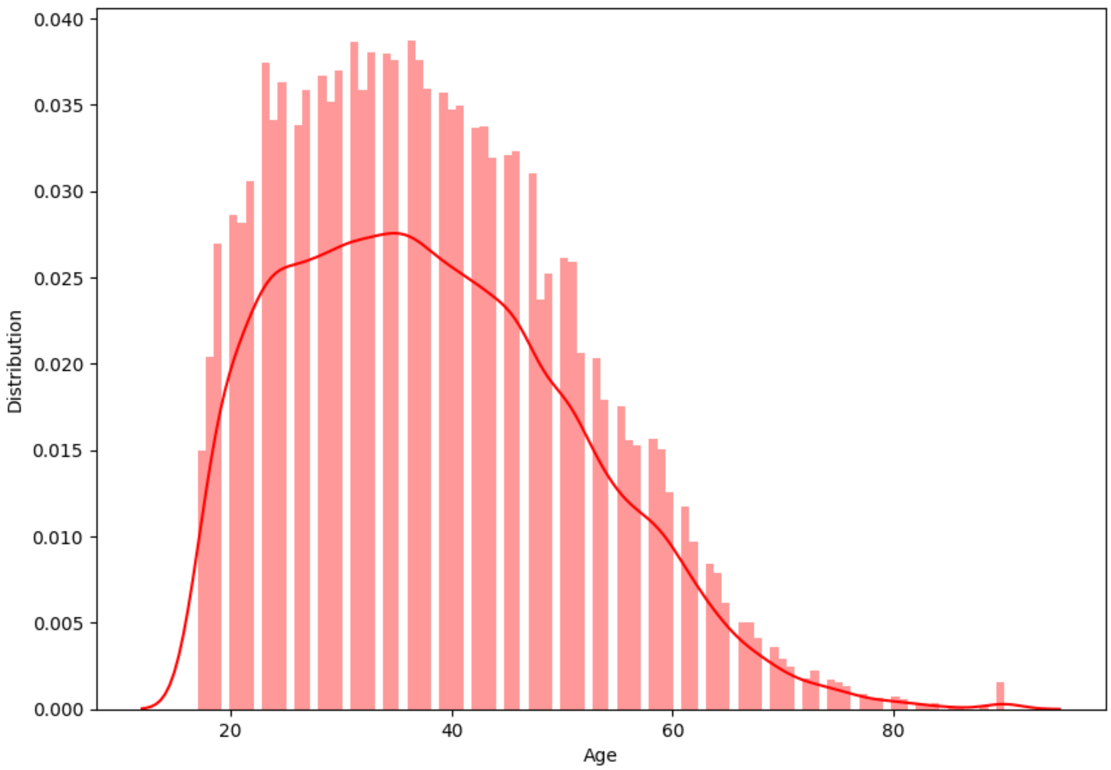
```
<ipython-input-13-6201d8194dba>:3: FutureWarning: The default value of
numeric_only in DataFrame.corr is deprecated. In a future version, it will
default to False. Select only valid columns or specify the value of numeric_only
to silence this warning.
  sns.heatmap(df.corr(), cmap='coolwarm', annot=True)
```



None

[ ]:
```
plt.figure(figsize=(10,7))
sns.distplot(df['age'], color="red", bins=100)
plt.ylabel("Distribution", fontsize = 10)
plt.xlabel("Age", fontsize = 10)
plt.show()
```

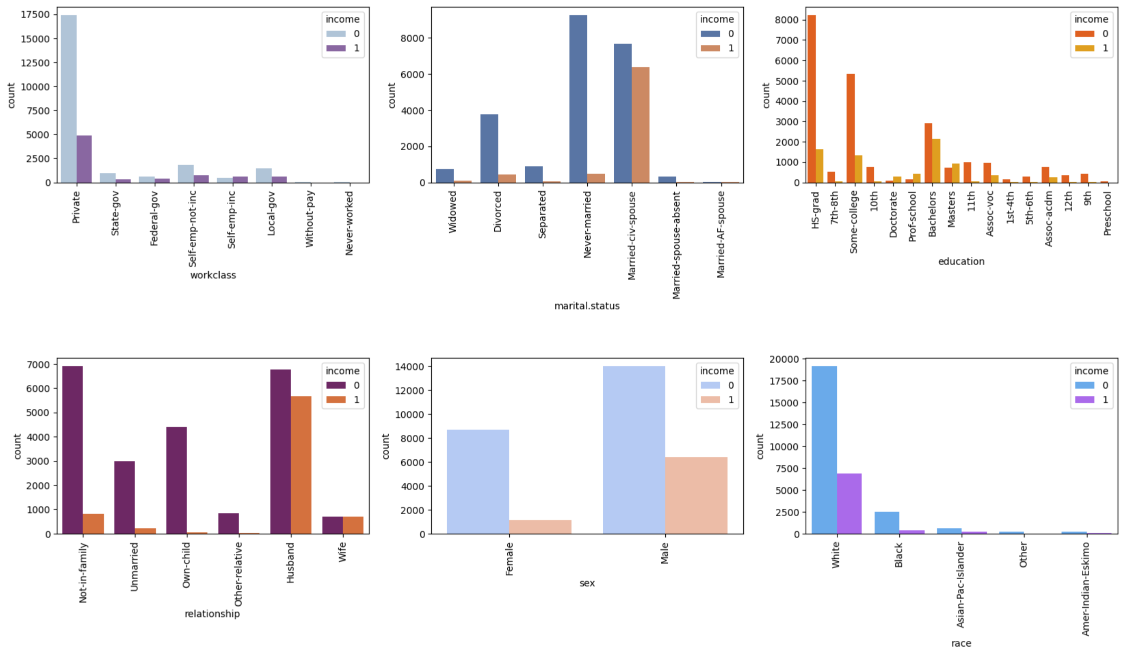
```
<ipython-input-14-1b72b8b67fa9>:2: UserWarning:

`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(df['age'], color="red", bins=100)
```



[ ]:
```
#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,
              palette="BuPu")
plt.xticks(rotation=90)

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

plt.subplot(233)
sns.countplot(x ='education',
              hue='income',
              data = df,
              palette = "autumn")
```

```python
plt.xticks(rotation=90)

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

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

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

```
<ipython-input-15-f6a96c604872>:4: MatplotlibDeprecationWarning: Auto-removal of
overlapping axes is deprecated since 3.6 and will be removed two minor releases
later; explicitly call ax.remove() as needed.
  plt.subplot(231)
```



[ ]:
```python
df1 = df.copy()
```

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

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

[ ]:
```
       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
…      …        …       …          …            …                 …
32556   22   Private  310152  Some-college             10       Never-married
32557   27   Private  257302    Assoc-acdm             12  Married-civ-spouse
32558   40   Private  154374       HS-grad              9  Married-civ-spouse
32559   58   Private  151910       HS-grad              9             Widowed
32560   22   Private  201490       HS-grad              9       Never-married

              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
…                      …              …     …     …           …
32556     Protective-serv  Not-in-family  White    Male            0
32557        Tech-support           Wife  White  Female            0
32558   Machine-op-inspct        Husband  White    Male            0
32559        Adm-clerical      Unmarried  White  Female            0
32560        Adm-clerical      Own-child  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
…                 …              …              …    …
32556             0              40  United-States       0
32557             0              38  United-States       0
32558             0              40  United-States       1
32559             0              40  United-States       0
32560             0              20  United-States       0

[30169 rows x 15 columns]
```

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

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

       occupation  relationship  race  sex  capital.gain  capital.loss  \
1               4             1     4    0             0          4356
3               7             4     4    0             0          3900
4              10             3     4    0             0          3900
```

```
5          8        4   4   0        0      3770
6          1        4   4   1        0      3770
…        …        …   …   …        …      …
32556     11        1   4   1        0         0
32557     13        5   4   0        0         0
32558      7        0   4   1        0         0
32559      1        4   4   0        0         0
32560      1        3   4   1        0         0

       hours.per.week  native.country  income
1                  18              38       0
3                  40              38       0
4                  40              38       0
5                  45              38       0
6                  40              38       0
…                 …             …     …
32556              40              38       0
32557              38              38       0
32558              40              38       1
32559              40              38       0
32560              20              38       0

[30169 rows x 15 columns]
```

[ ]:
```python
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 = 0)

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

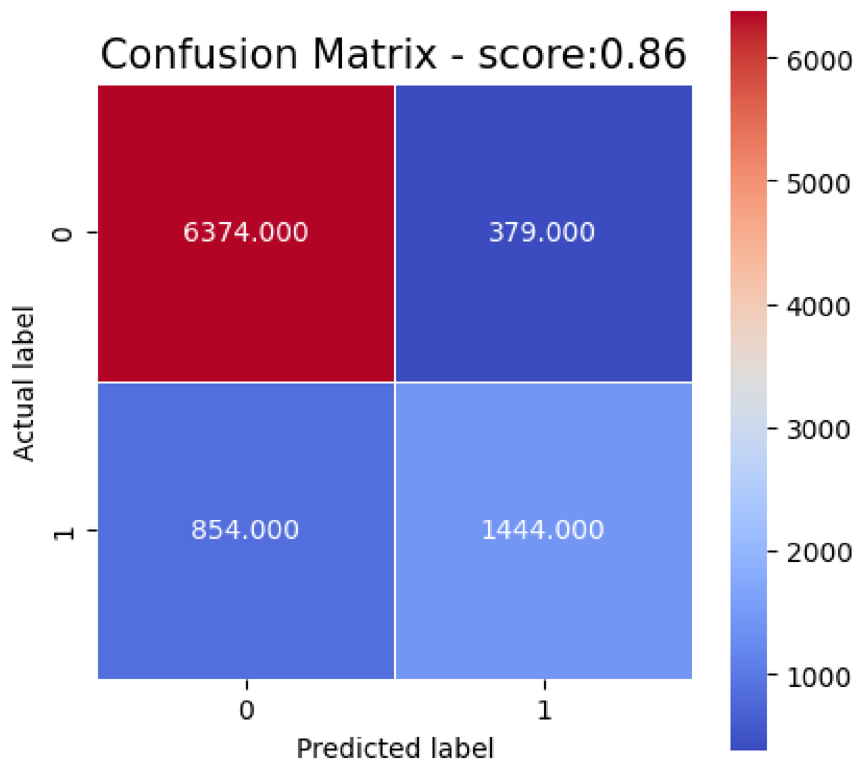
```
Train set size:  (21118, 14)
Test set size:  (9051, 14)
```

[ ]:
```python
from sklearn.ensemble import AdaBoostClassifier

# Train Adaboost Classifer
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
```

[ ]:
```
cm = confusion_matrix(y_test, y_pred_abc)
plt.figure(figsize=(5,5))
sns.heatmap(cm, annot=True, fmt=".3f", linewidths=.5, square = True, cmap =␣
↪"coolwarm");
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion Matrix - score:' + str(round(accuracy_score(y_test,␣
↪y_pred_abc), 2)), size = 15);
plt.show()
print(classification_report(y_test, y_pred_abc))
```




```
              precision    recall  f1-score   support

           0       0.88      0.94      0.91      6753
```

```
           1       0.79      0.63      0.70      2298

    accuracy                           0.86      9051
   macro avg       0.84      0.79      0.81      9051
weighted avg       0.86      0.86      0.86      9051
```

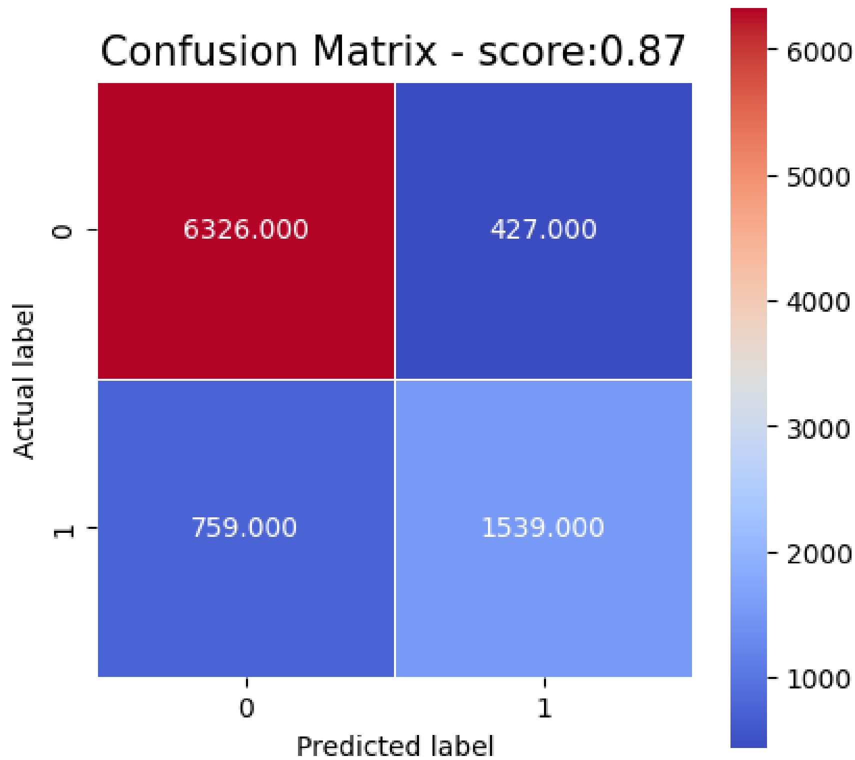
[ ]:
```
from sklearn.ensemble import GradientBoostingClassifier

#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
```

[ ]:
```
rms = np.sqrt(mean_squared_error(y_test, y_pred_gbc))
print("RMSE for gradient boost: ", rms)
```

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

[ ]:
```
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, cmap␣
 ↪= "coolwarm");
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion Matrix - score:' + str(round(accuracy_score(y_test,␣
 ↪y_pred_gbc),2)), size = 15);
plt.show()
print(classification_report(y_test, y_pred_gbc))
```




```
              precision    recall  f1-score   support

           0       0.89      0.94      0.91      6753
           1       0.78      0.67      0.72      2298

    accuracy                           0.87      9051
   macro avg       0.84      0.80      0.82      9051
weighted avg       0.86      0.87      0.87      9051
```

[ ]:
```
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)
```

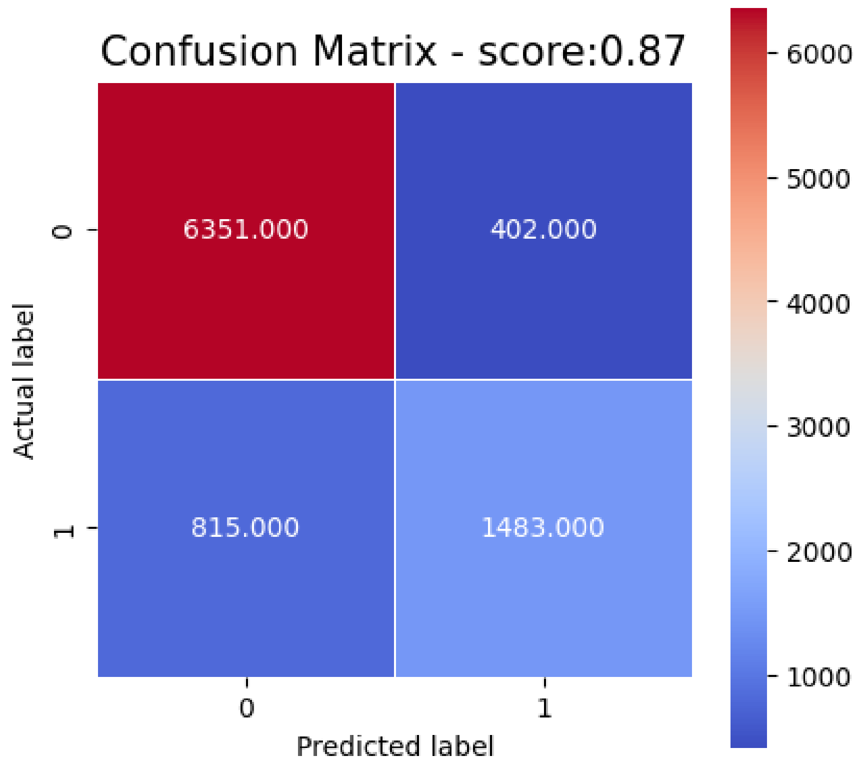
```
# Predictions
y_pred_xgboost = xgboost_model.predict(X_test)

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 :  0.8655397193680257
F1 score :  0.7090604829070045
Precision :  0.786737400530504
```

[ ]:
```
rms = np.sqrt(mean_squared_error(y_test, y_pred_xgboost))
print("RMSE for xgboost: ", rms)
```

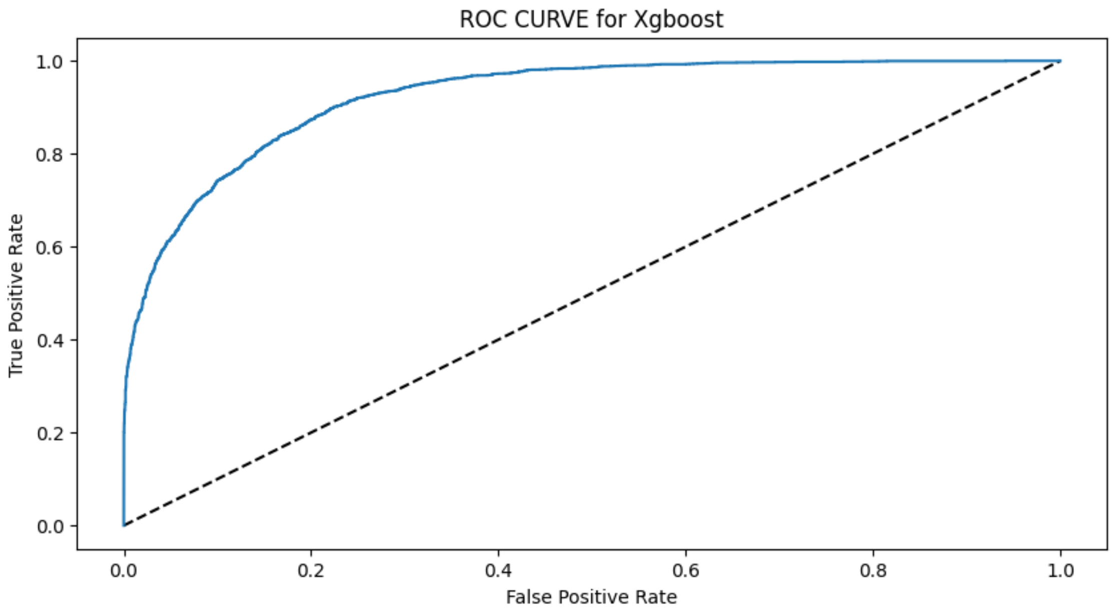
```
RMSE for xgboost:  0.3666882608319693
```

[ ]:
```
cm = confusion_matrix(y_test, y_pred_xgboost)
plt.figure(figsize=(5,5))
sns.heatmap(cm, annot=True, fmt=".3f", linewidths=.5, square = True, cmap =␣
 ↪"coolwarm");
plt.ylabel('Actual label');
plt.xlabel('Predicted label');
plt.title('Confusion Matrix - score:'+str(round(accuracy_score(y_test,␣
 ↪y_pred_xgboost),2)), size = 15);
plt.show()
print(classification_report(y_test,y_pred_xgboost))
```




```
              precision    recall  f1-score   support

           0       0.89      0.94      0.91      6753
           1       0.79      0.65      0.71      2298

    accuracy                           0.87      9051
   macro avg       0.84      0.79      0.81      9051
weighted avg       0.86      0.87      0.86      9051
```

[ ]:
```
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()
```


ROC CURVE for Xgboost
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0

Conclusion:

1. The GradientBoostingClassifier has the highest accuracy (0.8690) and F1 score (0.7219) among the three classifiers, indicating that it performs the best on this dataset.
2. The AdaBoostClassifier and XGBClassifier also have good performance but slightly lower than the GradientBoostingClassifier in terms of accuracy and F1 score.
3. All three classifiers have relatively high precision, indicating that when they predict a positive class (1), they are often correct.
4. The recall values vary among the classifiers, with the GradientBoostingClassifier having the highest recall for the positive class (1), indicating that it correctly identifies more positive cases.
5. The F1 score, which balances precision and recall, shows how well the classifiers perform in classifying both classes.

Comparison between boosting algorithms and random forest classifier:

1. The boosting algorithms (AdaBoost, Gradient Boosting, and XGBoost) generally outperform the Random Forest Classifier in terms of accuracy, precision, and F1 score.
2. The Random Forest Classifier performs reasonably well, with an accuracy of around 85% and a balanced F1 score. However, it falls slightly behind the boosting algorithms.
3. The boosting algorithms tend to have higher precision and recall for the positive class (income > 50K), indicating better ability to correctly classify high-income individuals.

All these models perform reasonably well on the Adult Census Income Dataset; the boosting algorithms, especially Gradient Boosting, appear to provide slightly better results in terms of accuracy and F1 score compared to the Random Forest Classifier.