Project Code: For Different Tree Boosts

Comparative analysis of different tree Boosts for IDS on Intrusion Detection

Tree Boosts to Be Compared:

1. XGB Boost

2. LGB Boost

3. Cat Boost

4. Extra Trees

5. Random forests

6. Decision trees

Import Libraries

1. Pandas
2. Numpy
3. matplotlib
4. Libraries for different Tree Models (LightGBM,xgBoost,CatBoost)
5. other libraries as needed.

```
import warnings
warnings.filterwarnings("ignore")
```

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn.metrics import
classification_report,confusion_matrix,accuracy_score,
precision_score, recall_score, f1_score
import lightgbm as lgb
!pip3 install catboost
```

```
import catboost as cbt
import xgboost as xgb
import time
!pip3 install river
from river import stream
from statistics import mode
```

```
Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting catboost
  Downloading catboost-1.1.1-cp38-none-manylinux1_x86_64.whl (76.6 MB)
ent already satisfied: scipy in /usr/local/lib/python3.8/dist-packages
(from catboost) (1.7.3)
Requirement already satisfied: matplotlib in
/usr/local/lib/python3.8/dist-packages (from catboost) (3.2.2)
Requirement already satisfied: plotly in
/usr/local/lib/python3.8/dist-packages (from catboost) (5.5.0)
Requirement already satisfied: graphviz in
/usr/local/lib/python3.8/dist-packages (from catboost) (0.10.1)
Requirement already satisfied: pandas>=0.24.0 in
/usr/local/lib/python3.8/dist-packages (from catboost) (1.3.5)
Requirement already satisfied: six in /usr/local/lib/python3.8/dist-
packages (from catboost) (1.15.0)
Requirement already satisfied: numpy>=1.16.0 in
/usr/local/lib/python3.8/dist-packages (from catboost) (1.21.6)
Requirement already satisfied: python-dateutil>=2.7.3 in
/usr/local/lib/python3.8/dist-packages (from pandas>=0.24.0->catboost)
(2.8.2)
Requirement already satisfied: pytz>=2017.3 in
/usr/local/lib/python3.8/dist-packages (from pandas>=0.24.0->catboost)
(2022.6)
Requirement already satisfied: cycler>=0.10 in
/usr/local/lib/python3.8/dist-packages (from matplotlib->catboost)
(0.11.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.8/dist-packages (from matplotlib->catboost)
(1.4.4)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!
=2.1.6,>=2.0.1 in /usr/local/lib/python3.8/dist-packages (from
matplotlib->catboost) (3.0.9)
Requirement already satisfied: tenacity>=6.2.0 in
/usr/local/lib/python3.8/dist-packages (from plotly->catboost) (8.1.0)
Installing collected packages: catboost
Successfully installed catboost-1.1.1
Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting river
  Downloading river-0.14.0-cp38-cp38-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (3.2 MB)
ent already satisfied: scipy>=1.5 in /usr/local/lib/python3.8/dist-
```

```
packages (from river) (1.7.3)
Requirement already satisfied: pandas>=1.3 in
/usr/local/lib/python3.8/dist-packages (from river) (1.3.5)
Collecting numpy>=1.23.4
  Downloading numpy-1.24.1-cp38-cp38-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (17.3 MB)
ent already satisfied: pytz>=2017.3 in /usr/local/lib/python3.8/dist-
packages (from pandas>=1.3->river) (2022.6)
Requirement already satisfied: python-dateutil>=2.7.3 in
/usr/local/lib/python3.8/dist-packages (from pandas>=1.3->river)
(2.8.2)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.8/dist-packages (from python-dateutil>=2.7.3-
>pandas>=1.3->river) (1.15.0)
Collecting scipy>=1.5
  Downloading scipy-1.9.3-cp38-cp38-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (33.8 MB)
py, scipy, river
  Attempting uninstall: numpy
    Found existing installation: numpy 1.21.6
    Uninstalling numpy-1.21.6:
      Successfully uninstalled numpy-1.21.6
  Attempting uninstall: scipy
    Found existing installation: scipy 1.7.3
    Uninstalling scipy-1.7.3:
      Successfully uninstalled scipy-1.7.3
ERROR: pip's dependency resolver does not currently take into account
all the packages that are installed. This behaviour is the source of
the following dependency conflicts.
numba 0.56.4 requires numpy<1.24,>=1.18, but you have numpy 1.24.1
which is incompatible.
Successfully installed numpy-1.24.1 river-0.14.0 scipy-1.9.3
```

{"pip_warning":{"packages":["numpy"]}}

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

DATA SET TO BE USED: CICIDS2017 dataset

```
df = pd.read_csv("/content/drive/MyDrive/ISM/Intrusion-Detection-
System-Using-Machine-Learning-main/data/CICIDS2017_sample_km.csv")
```

```
df.Label.value_counts()
```

```
0    18225
3     3042
6     2180
1     1966
```

```
5     1255
2       96
4       36
Name: Label, dtype: int64
```

```
df.head()
```

```
   Flow Duration  Total Fwd Packets  Total Backward Packets  \
0   5.416666e-07                0.0                0.000003   
1   5.416666e-07                0.0                0.000003   
2   4.416666e-07                0.0                0.000003   
3   7.499999e-07                0.0                0.000003   
4   7.249999e-07                0.0                0.000003   

   Total Length of Fwd Packets  Total Length of Bwd Packets  \
0                 4.651163e-07                 9.153974e-09   
1                 4.651163e-07                 9.153974e-09   
2                 4.651163e-07                 9.153974e-09   
3                 4.651163e-07                 9.153974e-09   
4                 4.651163e-07                 9.153974e-09   

   Fwd Packet Length Max  Fwd Packet Length Min  Fwd Packet Length
Mean  \
0               0.000242               0.002581                
0.00101   
1               0.000242               0.002581                
0.00101   
2               0.000242               0.002581                
0.00101   
3               0.000242               0.002581                
0.00101   
4               0.000242               0.002581                
0.00101   

   Fwd Packet Length Std  Bwd Packet Length Max  ...
min_seg_size_forward  \
0                    0.0               0.000307  ...                  
1.0   
1                    0.0               0.000307  ...                  
1.0   
2                    0.0               0.000307  ...                  
1.0   
3                    0.0               0.000307  ...                  
1.0   
4                    0.0               0.000307  ...                  
1.0   

   Active Mean  Active Std  Active Max  Active Min  Idle Mean  Idle
Std  \
0          0.0         0.0         0.0         0.0        0.0
```

```
0.0
1          0.0          0.0          0.0          0.0          0.0
0.0
2          0.0          0.0          0.0          0.0          0.0
0.0
3          0.0          0.0          0.0          0.0          0.0
0.0
4          0.0          0.0          0.0          0.0          0.0
0.0

   Idle Max  Idle Min  Label
0       0.0       0.0      0
1       0.0       0.0      0
2       0.0       0.0      0
3       0.0       0.0      0
4       0.0       0.0      0

[5 rows x 78 columns]
```

Corresponding Attack Types:

1.	0 BENIGN	18225
2.	1 Bot	1966
3.	2 BruteForce	96
4.	3 DoS	3042
5.	4 Infiltration	36
6.	5 PortScan	1255
7.	6 WebAttack	2180

Spliting train set and test set for training purpose.

train_size = 0.8, test_size = 0.2

```
X = df.drop(['Label'],axis=1)
y = df['Label']
X_train, X_test, y_train, y_test = train_test_split(X,y, train_size =
0.8, test_size = 0.2, random_state = 0) #shuffle=False
```

SMOTE to solve class-imbalance

```
pd.Series(y_train).value_counts()
```

```
0    14569
3     2430
6     1728
1     1579
5     1024
```

```
2       82
4       28
Name: Label, dtype: int64
```

```
from imblearn.over_sampling import SMOTE
smote=SMOTE(n_jobs=-1,sampling_strategy={2:1000,4:1000})
```

```
X_train, y_train = smote.fit_resample(X_train, y_train)
```

```
pd.Series(y_train).value_counts()
```

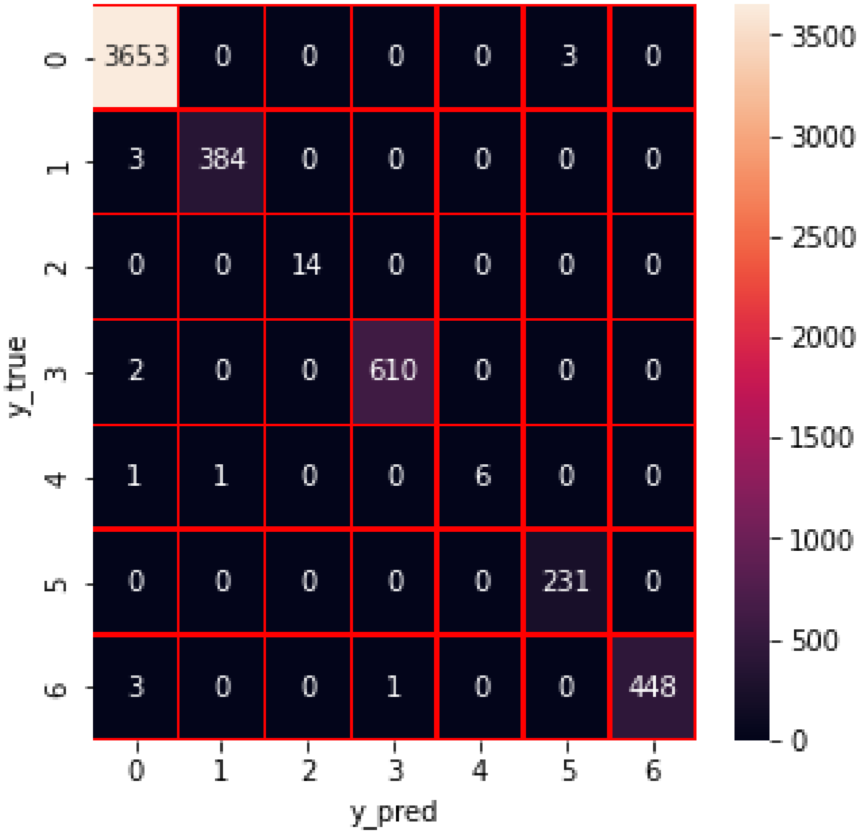
```
0    14569
3     2430
6     1728
1     1579
5     1024
2     1000
4     1000
Name: Label, dtype: int64
```

Machine Learning (ML) model training

Training three base learners: LightGBM, XGBoost, CatBoost

```
%%time
# Train the LightGBM algorithm
import lightgbm as lgb
lg = lgb.LGBMClassifier()
lg.fit(X_train, y_train)
y_pred = lg.predict(X_test)
print(classification_report(y_test,y_pred))
print("Accuracy of LightGBM: "+ str(accuracy_score(y_test, y_pred)))
print("Precision of LightGBM: "+ str(precision_score(y_test, y_pred, 
average='weighted')))
print("Recall of LightGBM: "+ str(recall_score(y_test, y_pred, 
average='weighted')))
print("Average F1 of LightGBM: "+ str(f1_score(y_test, y_pred, 
average='weighted')))
print("F1 of LightGBM for each type of attack: "+ str(f1_score(y_test, 
y_pred, average=None)))
lg_f1=f1_score(y_test, y_pred, average=None)

# Plot the confusion matrix
cm=confusion_matrix(y_test,y_pred)
f,ax=plt.subplots(figsize=(5,5))
sns.heatmap(cm,annot=True,linewidth=0.5,linecolor="red",fmt=".0f",ax=a
x)
plt.xlabel("y_pred")
plt.ylabel("y_true")
plt.show()
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      3656
           1       1.00      0.99      0.99       387
           2       1.00      1.00      1.00        14
           3       1.00      1.00      1.00       612
           4       1.00      0.75      0.86         8
           5       0.99      1.00      0.99       231
           6       1.00      0.99      1.00       452

    accuracy                           1.00      5360
   macro avg       1.00      0.96      0.98      5360
weighted avg       1.00      1.00      1.00      5360

Accuracy of LightGBM: 0.9973880597014926
Precision of LightGBM: 0.9973967119612819
Recall of LightGBM: 0.9973880597014926
Average F1 of LightGBM: 0.9973612766651317
F1 of LightGBM for each type of attack: [0.99836021 0.99481865 1.
0.99754702 0.85714286 0.99354839
 0.99555556]
```

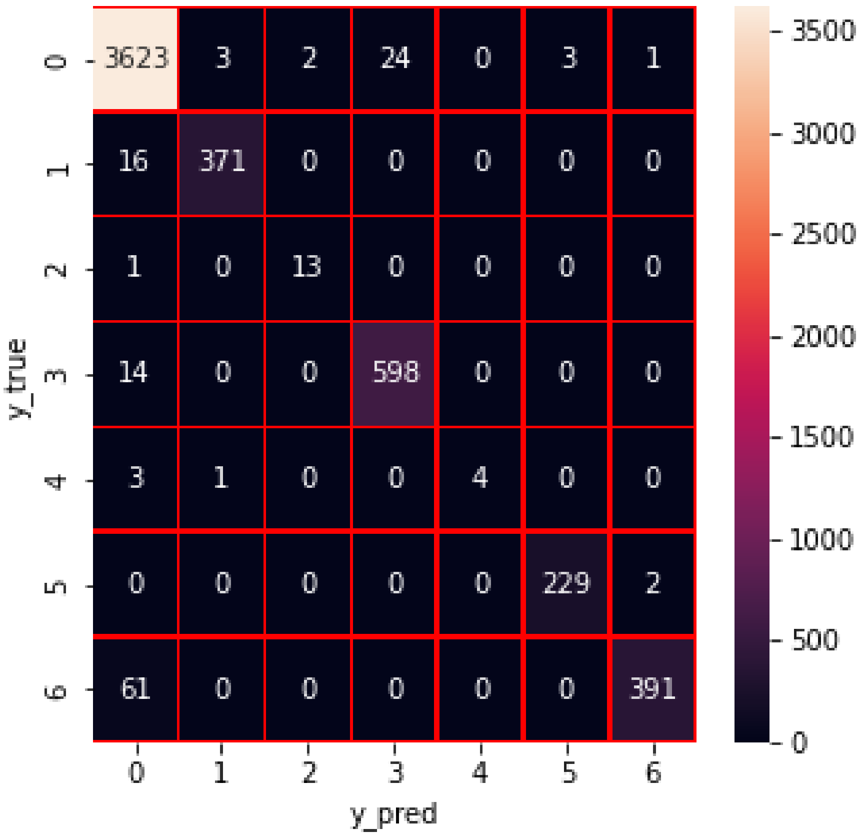


```
CPU times: user 18.8 s, sys: 184 ms, total: 19 s
Wall time: 10 s
```

```
%%time
# Train the XGBoost algorithm
import xgboost as xgb
xg = xgb.XGBClassifier()

X_train_x = X_train.values
X_test_x = X_test.values

xg.fit(X_train_x, y_train)

y_pred = xg.predict(X_test_x)
print(classification_report(y_test,y_pred))
print("Accuracy of XGBoost: "+ str(accuracy_score(y_test, y_pred)))
print("Precision of XGBoost: "+ str(precision_score(y_test, y_pred,
average='weighted')))
print("Recall of XGBoost: "+ str(recall_score(y_test, y_pred,
average='weighted')))
print("Average F1 of XGBoost: "+ str(f1_score(y_test, y_pred,
average='weighted')))
print("F1 of XGBoost for each type of attack: "+ str(f1_score(y_test,
y_pred, average=None)))
xg_f1=f1_score(y_test, y_pred, average=None)

# Plot the confusion matrix
cm=confusion_matrix(y_test,y_pred)
f,ax=plt.subplots(figsize=(5,5))
sns.heatmap(cm,annot=True,linewidth=0.5,linecolor="red",fmt=".0f",ax=a
x)
plt.xlabel("y_pred")
plt.ylabel("y_true")
plt.show()
```

```
              precision    recall  f1-score   support

           0       0.97      0.99      0.98      3656
           1       0.99      0.96      0.97       387
           2       0.87      0.93      0.90        14
           3       0.96      0.98      0.97       612
           4       1.00      0.50      0.67         8
           5       0.99      0.99      0.99       231
           6       0.99      0.87      0.92       452

    accuracy                           0.98      5360
   macro avg       0.97      0.89      0.91      5360
weighted avg       0.98      0.98      0.98      5360

Accuracy of XGBoost: 0.9755597014925373
Precision of XGBoost: 0.9758482606600912
Recall of XGBoost: 0.9755597014925373
Average F1 of XGBoost: 0.9751364180942107
```

```
F1 of XGBoost for each type of attack: [0.98264171 0.97375328
0.89655172 0.96920583 0.66666667 0.98920086
 0.92434988]
```

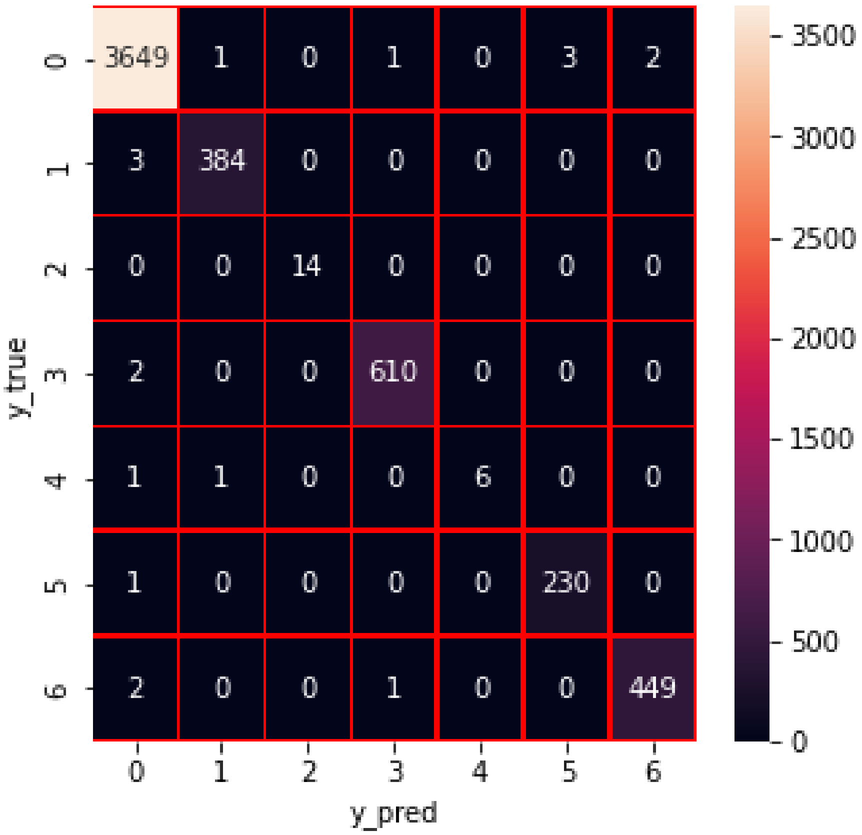


```
CPU times: user 38.7 s, sys: 175 ms, total: 38.9 s
Wall time: 39 s
```

```
%%time
# Train the CatBoost algorithm
import catboost as cbt
cb = cbt.CatBoostClassifier(verbose=0,boosting_type='Plain')
#cb = cbt.CatBoostClassifier()

cb.fit(X_train, y_train)
y_pred = cb.predict(X_test)
print(classification_report(y_test,y_pred))
print("Accuracy of CatBoost: "+ str(accuracy_score(y_test, y_pred)))
print("Precision of CatBoost: "+ str(precision_score(y_test, y_pred,
average='weighted')))
print("Recall of CatBoost: "+ str(recall_score(y_test, y_pred,
average='weighted')))
print("Average F1 of CatBoost: "+ str(f1_score(y_test, y_pred,
average='weighted')))
print("F1 of CatBoost for each type of attack: "+ str(f1_score(y_test,
y_pred, average=None)))
```

```
cb_f1=f1_score(y_test, y_pred, average=None)

# Plot the confusion matrix
cm=confusion_matrix(y_test,y_pred)
f,ax=plt.subplots(figsize=(5,5))
sns.heatmap(cm,annot=True,linewidth=0.5,linecolor="red",fmt=".0f",ax=a
x)
plt.xlabel("y_pred")
plt.ylabel("y_true")
plt.show()
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      3656
           1       0.99      0.99      0.99       387
           2       1.00      1.00      1.00        14
           3       1.00      1.00      1.00       612
           4       1.00      0.75      0.86         8
           5       0.99      1.00      0.99       231
           6       1.00      0.99      0.99       452

    accuracy                           1.00      5360
   macro avg       1.00      0.96      0.98      5360
weighted avg       1.00      1.00      1.00      5360

Accuracy of CatBoost: 0.9966417910447761
Precision of CatBoost: 0.9966457193764396
Recall of CatBoost: 0.9966417910447761
Average F1 of CatBoost: 0.99661603515491
F1 of CatBoost for each type of attack: [0.99781241 0.99353169 1.
0.99673203 0.85714286 0.99137931
 0.9944629 ]
```

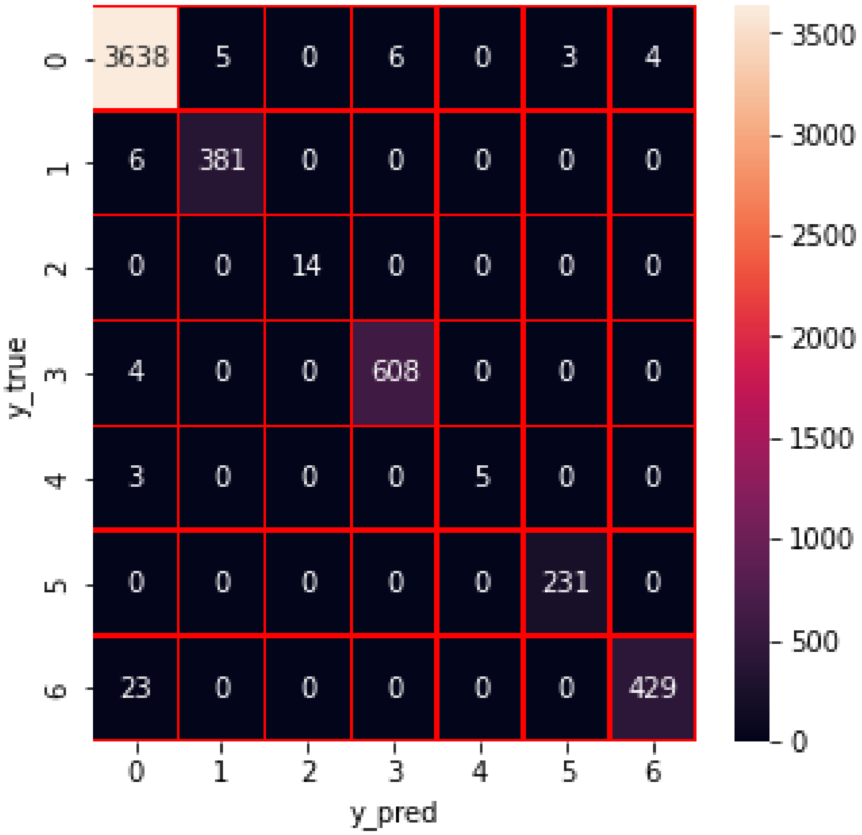


```
CPU times: user 3min 50s, sys: 1.59 s, total: 3min 51s
Wall time: 2min 3s
```

```
%%time
from sklearn.ensemble import
RandomForestClassifier,ExtraTreesClassifier
from sklearn.metrics import
classification_report,confusion_matrix,accuracy_score,precision_recall
_fscore_support
from sklearn.metrics import f1_score,roc_auc_score
rf = RandomForestClassifier(random_state = 0)
rf.fit(X_train,y_train)
rf_score=rf.score(X_test,y_test)
y_predict=rf.predict(X_test)
y_true=y_test
print('Accuracy of RF: '+ str(rf_score))
precision,recall,fscore,none= precision_recall_fscore_support(y_true,
y_predict, average='weighted')
print('Precision of RF: '+(str(precision)))
print('Recall of RF: '+(str(recall)))
print('F1-score of RF: '+(str(fscore)))
print(classification_report(y_true,y_predict))
cm=confusion_matrix(y_true,y_predict)
f,ax=plt.subplots(figsize=(5,5))
```

```
sns.heatmap(cm,annot=True,linewidth=0.5,linecolor="red",fmt=".0f",ax=a
x)
plt.xlabel("y_pred")
plt.ylabel("y_true")
plt.show()
```

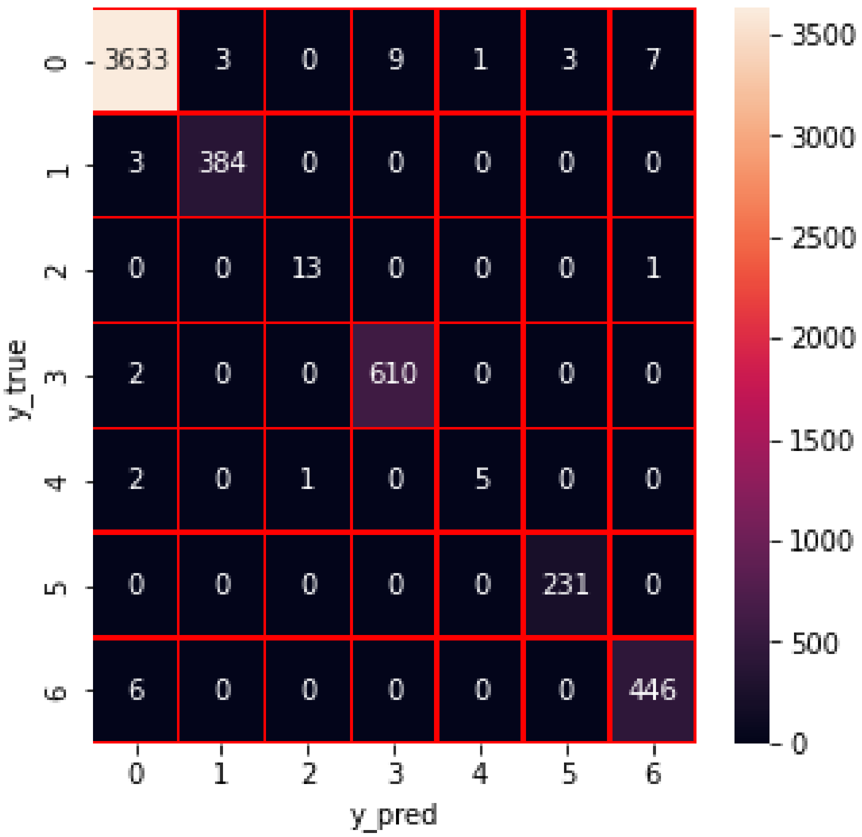
```
Accuracy of RF: 0.9899253731343284
Precision of RF: 0.9899339378801721
Recall of RF: 0.9899253731343284
F1-score of RF: 0.9898210890672914
              precision    recall  f1-score   support

           0       0.99      1.00      0.99      3656
           1       0.99      0.98      0.99       387
           2       1.00      1.00      1.00        14
           3       0.99      0.99      0.99       612
           4       1.00      0.62      0.77         8
           5       0.99      1.00      0.99       231
           6       0.99      0.95      0.97       452

    accuracy                           0.99      5360
   macro avg       0.99      0.94      0.96      5360
weighted avg       0.99      0.99      0.99      5360
```



```
CPU times: user 4.59 s, sys: 139 ms, total: 4.72 s
Wall time: 4.61 s
Compiler : 125 ms
```

```
%%time
from sklearn.tree import DecisionTreeClassifier
dt = DecisionTreeClassifier(random_state = 0)
dt.fit(X_train,y_train)
dt_score=dt.score(X_test,y_test)
y_predict=dt.predict(X_test)
y_true=y_test
print('Accuracy of DT: '+ str(dt_score))
precision,recall,fscore,none= precision_recall_fscore_support(y_true,
y_predict, average='weighted')
print('Precision of DT: '+(str(precision)))
print('Recall of DT: '+(str(recall)))
print('F1-score of DT: '+(str(fscore)))
print(classification_report(y_true,y_predict))
cm=confusion_matrix(y_true,y_predict)
f,ax=plt.subplots(figsize=(5,5))
sns.heatmap(cm,annot=True,linewidth=0.5,linecolor="red",fmt=".0f",ax=a
x)
plt.xlabel("y_pred")
plt.ylabel("y_true")
plt.show()
```

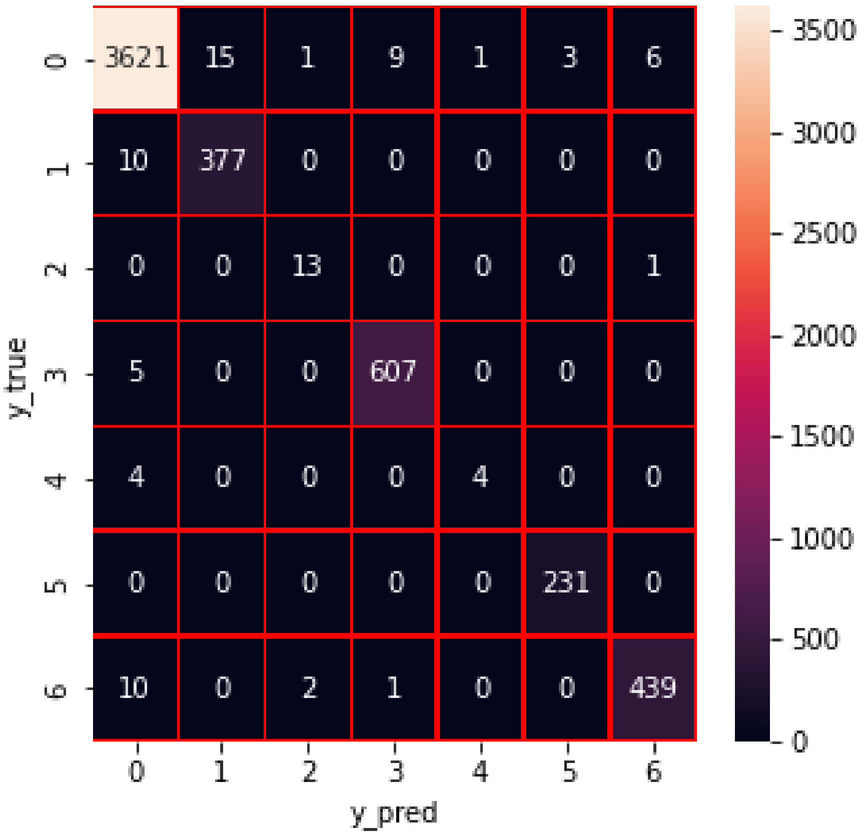
```
Accuracy of DT: 0.9929104477611941
Precision of DT: 0.9928743455303658
Recall of DT: 0.9929104477611941
F1-score of DT: 0.9928630672159569
              precision    recall  f1-score   support

           0       1.00      0.99      1.00      3656
           1       0.99      0.99      0.99       387
           2       0.93      0.93      0.93        14
           3       0.99      1.00      0.99       612
           4       0.83      0.62      0.71         8
           5       0.99      1.00      0.99       231
           6       0.98      0.99      0.98       452

    accuracy                           0.99      5360
   macro avg       0.96      0.93      0.94      5360
weighted avg       0.99      0.99      0.99      5360
```



```
CPU times: user 1.33 s, sys: 68 ms, total: 1.4 s
Wall time: 1.44 s
```

```
%%time
et = ExtraTreesClassifier(random_state = 0)
et.fit(X_train,y_train)
et_score=et.score(X_test,y_test)
y_predict=et.predict(X_test)
y_true=y_test
print('Accuracy of ET: '+ str(et_score))
precision,recall,fscore,none= precision_recall_fscore_support(y_true,
y_predict, average='weighted')
print('Precision of ET: '+(str(precision)))
print('Recall of ET: '+(str(recall)))
print('F1-score of ET: '+(str(fscore)))
print(classification_report(y_true,y_predict))
cm=confusion_matrix(y_true,y_predict)
f,ax=plt.subplots(figsize=(5,5))
sns.heatmap(cm,annot=True,linewidth=0.5,linecolor="red",fmt=".0f",ax=a
x)
plt.xlabel("y_pred")
plt.ylabel("y_true")
plt.show()
```

```
Accuracy of ET: 0.9873134328358208
Precision of ET: 0.9873029820354025
Recall of ET: 0.9873134328358208
F1-score of ET: 0.9872357717235625
              precision    recall  f1-score   support

           0       0.99      0.99      0.99      3656
           1       0.96      0.97      0.97       387
           2       0.81      0.93      0.87        14
           3       0.98      0.99      0.99       612
           4       0.80      0.50      0.62         8
           5       0.99      1.00      0.99       231
           6       0.98      0.97      0.98       452

    accuracy                           0.99      5360
   macro avg       0.93      0.91      0.91      5360
weighted avg       0.99      0.99      0.99      5360
```



y_true \ y_pred	0	1	2	3	4	5	6
0	3621	15	1	9	1	3	6
1	10	377	0	0	0	0	0
2	0	0	13	0	0	0	1
3	5	0	0	607	0	0	0
4	4	0	0	0	4	0	0
5	0	0	0	0	0	231	0
6	10	0	2	1	0	0	439

```
CPU times: user 3.68 s, sys: 135 ms, total: 3.81 s
Wall time: 3.81 s
```