Classification Models

November 19, 2021

```
[1]: import pandas as pd
     import seaborn as sns
     import numpy as np
     import matplotlib.pyplot as plt
     from sklearn.ensemble import RandomForestClassifier
     from sklearn.model_selection import train_test_split
     from sklearn.preprocessing import StandardScaler
     from sklearn.metrics import accuracy_score
     from sklearn.model_selection import cross_val_score
     from sklearn.model_selection import KFold
     from sklearn.model_selection import GridSearchCV
     from sklearn.model_selection import cross_validate
     from sklearn import metrics
     from sklearn.metrics import confusion_matrix
     from sklearn.metrics import classification_report
     from sklearn.model_selection import StratifiedKFold
     from sklearn import ensemble
     import xgboost as xgb
     from sklearn.metrics import mean_squared_error
```

Import Dataset

```
[2]: df =pd.read_csv ('/home/jovyan/Onlineshoppersdata(1).csv')
```

1 Classification Algortihms with imbalanced dataset

1.1 Random Forest

1.1.1 Separate the data into Train and Test

```
[3]: x = df.drop(['Revenue'],axis=1).values   # independant features
     y = df['Revenue'].values                                      # dependant␣
      ↪variable

     x_trainrf, x_testrf, y_trainrf, y_testrf = train_test_split(x, y, test_size=0.
      ↪2, random_state=42)
```

```
[4]: forest  = RandomForestClassifier()

     forest.fit(x_trainrf,y_trainrf)

     y_predrf =forest.predict(x_testrf)
```

```
[5]: accuracy_forest = (metrics.accuracy_score(y_testrf,y_predrf)*100)
     print('Acurracy is ', str(round(accuracy_forest,2)))
```

```
Acurracy is  89.13
```

```
[6]: rmse = np.sqrt(mean_squared_error(y_testrf, y_predrf))
     print("RMSE (root-mean-square error): %f" % (rmse))
```

```
RMSE (root-mean-square error): 0.329663
```

```
[7]: # View confusion matrix for test data and predictions
     matrix_rf = confusion_matrix(y_testrf, y_predrf)
     print(matrix_rf )
```

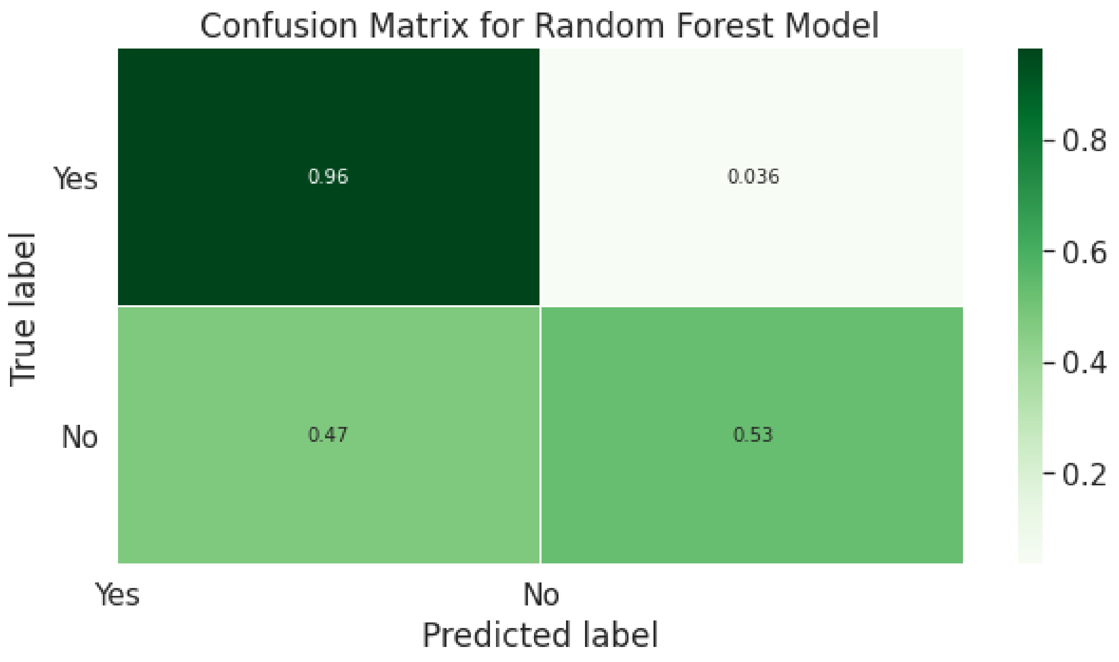
```
[[1982   73]
 [ 195  216]]
```

```
[8]: # Get and reshape confusion matrix data

     matrix_rforest = matrix_rf.astype('float') / matrix_rf.sum(axis=1)[:, np.
      ↪newaxis]

     # Build the plot
     plt.figure(figsize=(10,5))
     sns.set(font_scale=1.4)
     sns.heatmap(matrix_rforest, annot=True, annot_kws={'size':10},
                 cmap=plt.cm.Greens, linewidths=0.2)

     # Add labels to the plot
     class_names = ['Yes', 'No']
     tick_marks = np.arange(len(class_names))
     tick_marks2 = tick_marks + 0.5
     plt.xticks(tick_marks, class_names, rotation=0,)
     plt.yticks(tick_marks2, class_names, rotation=0,  )
plt.xlabel('Predicted label')
plt.ylabel('True label')
plt.title('Confusion Matrix for Random Forest Model')
plt.savefig('output14.png', dpi=300, bbox_inches='tight')
plt.show()
```



[9]:
```
# View the classification report for test data and predictions
print(classification_report(y_testrf, y_predrf))
```

```
              precision    recall  f1-score   support

           0       0.91      0.96      0.94      2055
           1       0.75      0.53      0.62       411

    accuracy                           0.89      2466
   macro avg       0.83      0.75      0.78      2466
weighted avg       0.88      0.89      0.88      2466
```

1.2 K-Fold Cross Validation for Random Forest

[34]:
```
X = df.drop(['Revenue'],axis=1).values   # independant features
y = df['Revenue'].values                                      # dependant␣
↪variable
```

```
model= RandomForestClassifier()
kf = KFold(n_splits=10,random_state=42,shuffle=True)
kf.get_n_splits(X)
i=1
print("confusion matrix:")
for train_index, test_index in kf.split(X):

    X_train, X_test = X[train_index], X[test_index]

    y_train, y_test_kfold = y[train_index], y[test_index]

    model.fit(X_train, y_train)


    print (i,"\n",confusion_matrix(y_test, model.predict(X_test)))
    i=i+1
    print(10* '#')
```

```
confusion matrix:
1
 [[925 124]
 [154  30]]
##########
2
 [[930 119]
 [151  33]]
##########
3
 [[928 121]
 [160  24]]
##########
4
 [[931 118]
 [162  22]]
##########
5
 [[932 117]
 [161  23]]
##########
6
 [[928 121]
 [165  19]]
##########
7
 [[933 116]
 [153  31]]
##########
```

```
8
 [[908 141]
 [159  25]]
##########
9
 [[929 120]
 [151  33]]
##########
10
 [[1011   38]
 [  91   93]]
##########
```

[35]:
```
y_pred_kfold=model.predict(X_test)
```

[36]:
```
# View the classification report for test data and predictions
print(classification_report(y_test_kfold, y_pred_kfold))
```

```
              precision    recall  f1-score   support

           0       0.92      0.96      0.94      1049
           1       0.71      0.51      0.59       184

    accuracy                           0.90      1233
   macro avg       0.81      0.73      0.77      1233
weighted avg       0.89      0.90      0.89      1233
```

[37]:
```
scores = cross_val_score(model, X, y, cv=kf)
scores
print("%0.2f accuracy with a standard deviation of %0.2f" % (scores.mean(),␣
 ↪scores.std()))
```

```
0.90 accuracy with a standard deviation of 0.01
```

After applying K-fold to Random Forest we can observe that the average score remains at 90%

1.3 XGBoost

[14]:
```
x = df.drop(['Revenue'],axis=1).values   # independant features
y = df['Revenue'].values                                        # dependant␣
 ↪variable

data_dmatrix = xgb.DMatrix(data=x,label=y)
X_trainxg, X_testxg, y_trainxg, y_testxg = train_test_split(x, y, test_size=0.
 ↪2, random_state=42)
```

```
xg_model = xgb.XGBClassifier()
print(xg_model)
```

```
XGBClassifier(base_score=None, booster=None, colsample_bylevel=None,
              colsample_bynode=None, colsample_bytree=None,
              enable_categorical=False, gamma=None, gpu_id=None,
              importance_type=None, interaction_constraints=None,
              learning_rate=None, max_delta_step=None, max_depth=None,
              min_child_weight=None, missing=nan, monotone_constraints=None,
              n_estimators=100, n_jobs=None, num_parallel_tree=None,
              objective='binary:logistic', predictor=None, random_state=None,
              reg_alpha=None, reg_lambda=None, scale_pos_weight=None,
              subsample=None, tree_method=None, use_label_encoder=True,
              validate_parameters=None, verbosity=None)
```

[15]:
```
xg_model.fit(X_trainxg,y_trainxg)

preds_xg = xg_model.predict(X_testxg)# make predictions for test data

predictions = [round(value) for value in preds_xg]
```

```
[17:27:13] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

[16]:
```
accuracy_xg = (metrics.accuracy_score(y_testxg,preds_xg)*100)
print('Acurracy is ', str(round(accuracy_forest,2)))
```

```
Acurracy is  89.13
```

[17]:
```
rmse = np.sqrt(mean_squared_error(y_testxg, preds_xg))
print("RMSE (root-mean-square error): %f" % (rmse))
```

```
RMSE (root-mean-square error): 0.338165
```

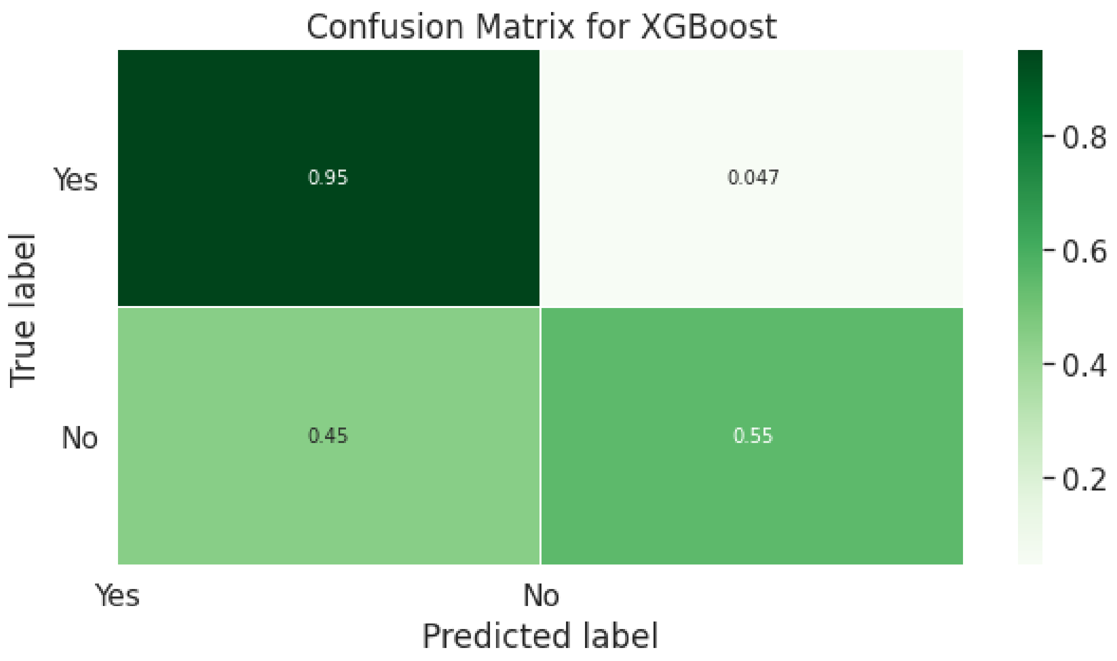
[18]:
```
# View confusion matrix for test data and predictions
matrix_xgboost=confusion_matrix(y_testxg, preds_xg)
print(matrix_xgboost)
```

```
[[1958   97]
 [ 185  226]]
```

[19]:
```
# Get and reshape confusion matrix data
matrix_xg = matrix_xgboost.astype('float') / matrix_xgboost.sum(axis=1)[:, np.
 ↪newaxis]

# Build the plot
plt.figure(figsize=(10,5))
sns.set(font_scale=1.4)
sns.heatmap(matrix_xg, annot=True, annot_kws={'size':10},
            cmap=plt.cm.Greens, linewidths=0.2)

# Add labels to the plot
class_names = ['Yes', 'No']
tick_marks = np.arange(len(class_names))
tick_marks2 = tick_marks + 0.5
plt.xticks(tick_marks, class_names, rotation=0,)
plt.yticks(tick_marks2, class_names, rotation=0,  )
plt.xlabel('Predicted label')
plt.ylabel('True label')
plt.title('Confusion Matrix for XGBoost')
plt.savefig('output15.png', dpi=300, bbox_inches='tight')
plt.show()
```



[20]:
```
print(classification_report(y_testxg, preds_xg))
```

```
              precision    recall  f1-score   support

           0       0.91      0.95      0.93      2055
           1       0.70      0.55      0.62       411

    accuracy                           0.89      2466
   macro avg       0.81      0.75      0.77      2466
weighted avg       0.88      0.89      0.88      2466
```

1.4 XGBoost Model With k-Fold Cross Validation

Using Kfold

```
[40]: x = df.drop(['Revenue'],axis=1).values   # independant features
      y = df['Revenue'].values                                       # dependant␣
       ↪variable

      # CV model
      modelxg = xgb.XGBClassifier()
      kf = KFold(n_splits=10,random_state=42,shuffle=True)
      kf.get_n_splits(X)
      i=1
      print("confusion matrix:")
      for train_index, test_index in kf.split(X):

          X_train, X_test = X[train_index], X[test_index]

          y_train, y_test_xg = y[train_index], y[test_index]

          modelxg.fit(X_train, y_train)


          print (i,"\n",confusion_matrix(y_test, model.predict(X_test)))
          i=i+1
          print(10* '#')
```

```
confusion matrix:
[17:45:02] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.

/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
```

```
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)

1
 [[880 169]
 [150  34]]
##########
[17:45:04] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.

/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)

2
 [[881 168]
 [144  40]]
##########
[17:45:06] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.

/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)

3
 [[910 139]
 [159  25]]
##########
[17:45:08] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.

/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
4
 [[890 159]
 [156  28]]
##########
[17:45:10] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
5
 [[895 154]
 [157  27]]
##########
[17:45:12] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
6
 [[879 170]
 [160  24]]
##########
[17:45:14] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
7
 [[895 154]
 [152  32]]
```

```
##########
[17:45:16] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
8
 [[879 170]
 [151  33]]
##########
[17:45:18] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
9
 [[892 157]
 [144  40]]
##########
[17:45:20] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/opt/conda/lib/python3.7/site-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
10
 [[1011   38]
 [  91   93]]
##########
```

```
[45]: y_pred_xg=modelxg.predict(X_test)
      print(classification_report(y_test_xg, y_pred_xg))
```

```
              precision    recall  f1-score   support

           0       0.93      0.96      0.94      1049
           1       0.70      0.57      0.63       184

    accuracy                           0.90      1233
   macro avg       0.81      0.76      0.79      1233
weighted avg       0.89      0.90      0.90      1233
```

```
[50]: results = cross_val_score(modelxg, X, y, cv=kf)
      print("%0.2f accuracy with a standard deviation of %0.2f" % (results.
       ↪mean()*100, results.std()*100))
```

```
[17:50:34] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:36] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:38] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:40] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:41] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:43] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:45] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:47] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
```

```
the old behavior.
[17:50:49] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
[17:50:51] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
89.70 accuracy with a standard deviation of 0.87
```

After applying K-fold to the XGBoost model we can observe that the average score remains at 88-89%

```
[ ]:
```