EE_627_Dylan_Zenner_HW_9

November 21, 2021

[1]:
```
!pip3 install pyspark
```

```
Requirement already satisfied: pyspark in ./opt/anaconda3/lib/python3.8/site-
packages (3.2.0)
Requirement already satisfied: py4j==0.10.9.2 in
./opt/anaconda3/lib/python3.8/site-packages (from pyspark) (0.10.9.2)
```

[2]:
```
from pyspark.sql import SparkSession
from pyspark.sql.functions import col
from pyspark.sql.functions import lit
from pyspark.ml.feature import OneHotEncoder, StringIndexer, VectorAssembler
from pyspark.ml.evaluation import MulticlassClassificationEvaluator
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
```

[3]:
```
spark = SparkSession.builder.appName('HW 9').getOrCreate()
```

```
21/11/21 18:02:00 WARN Utils: Your hostname, dylans-MacBook-Pro.local resolves
to a loopback address: 127.0.0.1; using 192.168.1.125 instead (on interface en0)
21/11/21 18:02:00 WARN Utils: Set SPARK_LOCAL_IP if you need to bind to another
address
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use
setLogLevel(newLevel).
21/11/21 18:02:00 WARN NativeCodeLoader: Unable to load native-hadoop library
for your platform… using builtin-java classes where applicable
```

[4]:
```
spark
```

[4]:
```
<pyspark.sql.session.SparkSession at 0x7ff1633c84c0>
```

[5]:
```
data_df = pd.read_csv("test2_new.txt", sep='|', names=['userID', 'trackID',␣
↪'predictions'])
data_df.head()
```

[5]:
```
   userID  trackID  predictions
0  200031    30877            1
```

```
1  200031    8244            1
2  200031  130183            0
3  200031  198762            0
4  200031   34503            1
```

[6]:
```
data2_df = pd.read_csv("output1.txt", sep='|', names=['userID', 'trackID',␣
↪'album_score', 'artist_score'])
data2_df.head()
```

[6]:
```
   userID  trackID  album_score  artist_score
0  199810   208019          0.0           0.0
1  199810    74139          0.0           0.0
2  199810     9903          0.0           0.0
3  199810   242681          0.0           0.0
4  199810    18515          0.0          70.0
```

[7]:
```
data2_df.columns[data2_df.isnull().any()] # check for null values
```

[7]:
```
Index([], dtype='object')
```

[8]:
```
scores_df = data_df.merge(data2_df, how='inner', on=['userID', 'trackID']) #␣
↪inner join the dataframes
scores_df.head()
```

[8]:
```
   userID  trackID  predictions  album_score  artist_score
0  200031    30877            1         90.0          50.0
1  200031     8244            1         90.0           0.0
2  200031   130183            0          0.0           0.0
3  200031   198762            0          0.0           0.0
4  200031    34503            1         90.0          50.0
```

[9]:
```
scores_df.columns[scores_df.isnull().any()] # check for null values
```

[9]:
```
Index([], dtype='object')
```

[10]:
```
scores_df.to_csv('ratings.csv', index=False)
scores_df.count()
```

[10]:
```
userID          6000
trackID         6000
predictions     6000
album_score     6000
artist_score    6000
dtype: int64
```

[11]:
```
scores_df = spark.read.csv('ratings.csv', header=True, inferSchema=True)
scores_df.printSchema()
```

```
root
 |-- userID: integer (nullable = true)
 |-- trackID: integer (nullable = true)
 |-- predictions: integer (nullable = true)
 |-- album_score: double (nullable = true)
 |-- artist_score: double (nullable = true)
```

[12]:
```
numericCols = ['album_score', 'artist_score']
stages = []
assemblerInputs =  numericCols
assembler = VectorAssembler(inputCols=assemblerInputs, outputCol="features")
stages += [assembler]
```

[13]:
```
label_stringIdx = StringIndexer(inputCol = 'predictions', outputCol = 'label')
stages += [label_stringIdx]
```

[14]:
```
from pyspark.ml import Pipeline
pipeline = Pipeline(stages = stages)
pipelineModel = pipeline.fit(scores_df)
df = pipelineModel.transform(scores_df)
cols = scores_df.columns
selectedCols = ['label', 'features'] + cols
df = df.select(selectedCols)
df.printSchema()
```

```
root
 |-- label: double (nullable = false)
 |-- features: vector (nullable = true)
 |-- userID: integer (nullable = true)
 |-- trackID: integer (nullable = true)
 |-- predictions: integer (nullable = true)
 |-- album_score: double (nullable = true)
 |-- artist_score: double (nullable = true)
```

[15]:
```
pd.DataFrame(df.take(5), columns=df.columns).transpose()
```

[15]:
```
                       0            1           2           3            4
label                1.0          1.0         0.0         0.0          1.0
features     [90.0, 50.0]  [90.0, 0.0]  (0.0, 0.0)  (0.0, 0.0)  [90.0, 50.0]
userID            200031       200031      200031      200031       200031
trackID            30877         8244      130183      198762        34503
predictions            1            1           0           0            1
album_score         90.0         90.0         0.0         0.0         90.0
```

```
artist_score        50.0       0.0       0.0       0.0        50.0
```

[16]:
```
# below is the typical random split
# of the train and test data sets
# HOWEVER, our testing users have 6 tracks for each
# We cannot use random split here
train, test = df.randomSplit([0.7, 0.3], seed = 2018)
print("Training Dataset Count: " + str(train.count()))
print("Test Dataset Count: " + str(test.count()))
```

```
Training Dataset Count: 4260
Test Dataset Count: 1740
```

[17]:
```
predictions_df = spark.read.csv('output1.txt', sep='|', inferSchema=True)
```

[18]:
```
predictions_df.count()
```

[18]:
```
120000
```

[19]:
```
predictions_df
```

[19]:
```
DataFrame[_c0: int, _c1: int, _c2: double, _c3: double]
```

[20]:
```
predictions_df = predictions_df.withColumnRenamed("_c0", "userID").
 ↪withColumnRenamed("_c1", "trackID").withColumnRenamed("_c2", "album_score").
 ↪withColumnRenamed("_c3", "artist_score")
```

[21]:
```
predictions_columns = predictions_df.columns
predictions_columns
```

[21]:
```
['userID', 'trackID', 'album_score', 'artist_score']
```

[22]:
```
predictions_df = predictions_df.withColumn('prediction', lit('0'))
```

[23]:
```
pd.DataFrame(predictions_df.take(10), columns=predictions_df.columns).
 ↪transpose()
```

[23]:
```
                   0       1       2       3       4       5       6       7  \
userID        199810  199810  199810  199810  199810  199810  199812  199812
trackID       208019   74139    9903  242681   18515  105760  276940  142408
album_score      0.0     0.0     0.0     0.0     0.0     0.0     0.0   100.0
artist_score     0.0     0.0     0.0     0.0    70.0    90.0     0.0   100.0
prediction         0       0       0       0       0       0       0       0

                   8       9
userID        199812  199812
trackID       130023   29189
album_score    100.0     0.0
```

```
artist_score   100.0     0.0
prediction         0       0
```

[24]:
```
predictions_df.printSchema()
```

```
root
 |-- userID: integer (nullable = true)
 |-- trackID: integer (nullable = true)
 |-- album_score: double (nullable = true)
 |-- artist_score: double (nullable = true)
 |-- prediction: string (nullable = false)
```

[25]:
```
numericCols = ['album_score', 'artist_score']
stages = []
assemblerInputs =  numericCols
assembler = VectorAssembler(inputCols=assemblerInputs, outputCol="features")
stages += [assembler]
```

[26]:
```
label_stringIdx = StringIndexer(inputCol = 'prediction', outputCol = 'label')
stages += [label_stringIdx]
```

[27]:
```
predictions_pipeline = Pipeline(stages=stages)
predictions_pipeline_model = predictions_pipeline.fit(predictions_df)
predictions_df = predictions_pipeline_model.transform(predictions_df)
```

[28]:
```
selected_columns = ['label', 'features'] + predictions_columns
predictions_df = predictions_df.select(selected_columns)
predictions_df.printSchema()
```

```
root
 |-- label: double (nullable = false)
 |-- features: vector (nullable = true)
 |-- userID: integer (nullable = true)
 |-- trackID: integer (nullable = true)
 |-- album_score: double (nullable = true)
 |-- artist_score: double (nullable = true)
```

[29]:
```
pd.DataFrame(predictions_df.take(10), columns=predictions_df.columns).
 ↪transpose()
```

[29]:
```
                       0           1           2           3            4  \
label                0.0         0.0         0.0         0.0          0.0
features      (0.0, 0.0)  (0.0, 0.0)  (0.0, 0.0)  (0.0, 0.0)  [0.0, 70.0]
userID            199810      199810      199810      199810       199810
trackID           208019       74139        9903      242681        18515
album_score          0.0         0.0         0.0         0.0          0.0
```

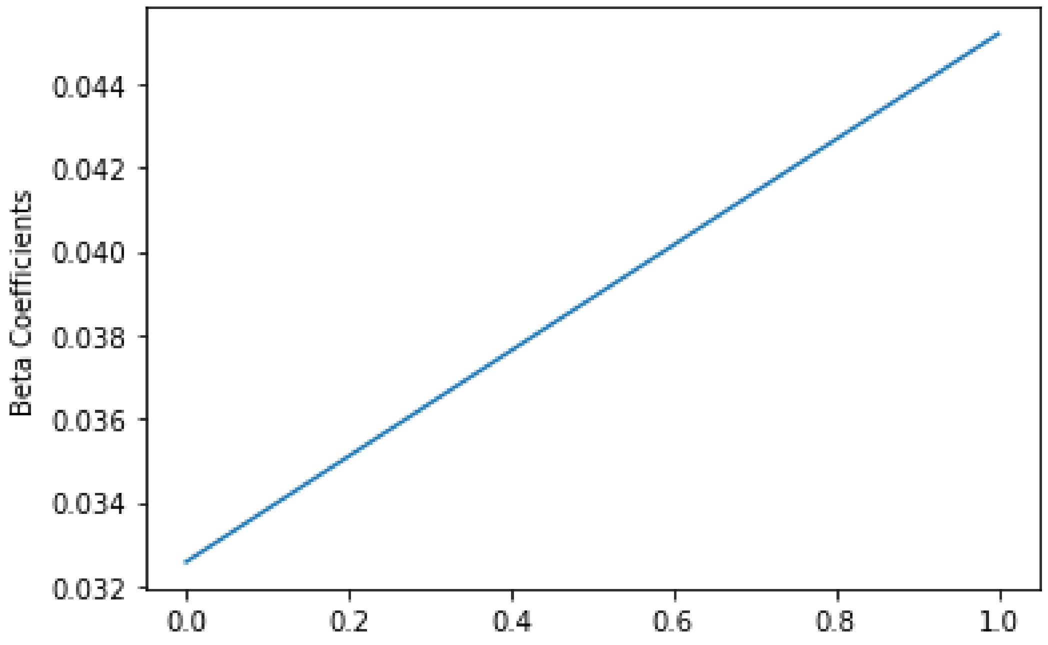
```
artist_score         0.0          0.0          0.0          0.0          70.0

                            5            6               7               8  \
label                     0.0          0.0             0.0             0.0
features         [0.0, 90.0]   (0.0, 0.0)  [100.0, 100.0]  [100.0, 100.0]
userID                 199810       199812          199812          199812
trackID                105760       276940          142408          130023
album_score               0.0          0.0           100.0           100.0
artist_score             90.0          0.0           100.0           100.0

                          9
label                   0.0
features         (0.0, 0.0)
userID               199812
trackID               29189
album_score             0.0
artist_score            0.0
```

1 Logistic regression model

[30]:
```python
from pyspark.ml.classification import LogisticRegression
```

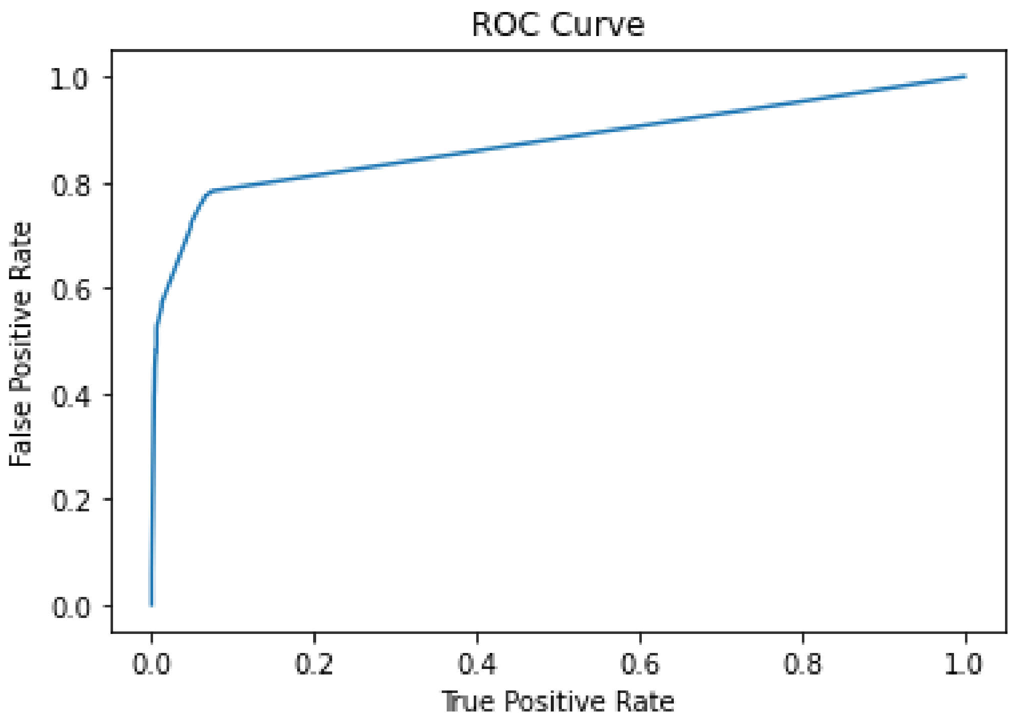
[31]:
```python
logistic_regression = LogisticRegression(featuresCol = 'features', labelCol =␣
 ↪'label',)
logistic_regression_model = logistic_regression.fit(train)
```

[32]:
```python
beta = np.sort(logistic_regression_model.coefficients)
plt.plot(beta)
plt.ylabel('Beta Coefficients')
plt.show()
```



[33]:
```
trainingSummary = logistic_regression_model.summary
roc = trainingSummary.roc.toPandas()
plt.plot(roc['FPR'],roc['TPR'])
plt.ylabel('False Positive Rate')
plt.xlabel('True Positive Rate')
plt.title('ROC Curve')
plt.show()
print('Training set areaUnderROC: ' + str(trainingSummary.areaUnderROC))
```

```
/Users/dylan/opt/anaconda3/lib/python3.8/site-
packages/pyspark/sql/context.py:125: FutureWarning: Deprecated in 3.0.0. Use
SparkSession.builder.getOrCreate() instead.
  warnings.warn(
```



```
Training set areaUnderROC: 0.8737133978552075
```

[34]:
```
predictions = logistic_regression_model.transform(test)
predictions.select('userID', 'trackID', 'label', 'probability',
                   'rawPrediction', 'prediction' ).show(12)
```

```
+------+-------+-----+--------------------+--------------------+----------+
|userID|trackID|label|         probability|       rawPrediction|prediction|
+------+-------+-----+--------------------+--------------------+----------+
|200031| 130183|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200065| 179571|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200070| 124239|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200070| 271459|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200085| 134106|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200099|  41892|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200106| 152491|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200124| 284066|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200143| 131171|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200143| 187136|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200160| 231680|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
|200166| 193878|  0.0|[0.80218276453714...|[1.39999291666030...|       0.0|
+------+-------+-----+--------------------+--------------------+----------+
only showing top 12 rows
```

[35]:
```
# col("userID").asc() sort the user ascending
# col("probability").desc() sort the probability descending (from large to␣
 ↪small)
from pyspark.sql.functions import col
sort_predictions = predictions.select('userID', 'trackID',
                                      'label', 'probability',
                                      'rawPrediction', 'prediction'
                                     ).sort(col("userID").asc(),␣
 ↪col("probability").desc())
sort_predictions.show(6)
```

```
+------+-------+-----+--------------------+--------------------+----------+
|userID|trackID|label|         probability|       rawPrediction|prediction|
+------+-------+-----+--------------------+--------------------+----------+
|200031| 130183|  0.0|[0.80218276453714…|[1.39999291666030…|       0.0|
|200031|   8244|  1.0|[0.06488875729218…|[-2.6679911209111…|       1.0|
|200031|  30877|  1.0|[0.01343471003408…|[-4.2963878477543…|       1.0|
|200055|  56695|  1.0|[0.00368752576332…|[-5.5991052292289…|       1.0|
|200065| 179571|  0.0|[0.80218276453714…|[1.39999291666030…|       0.0|
|200065| 119451|  1.0|[0.17782970128751…|[-1.5311211916575…|       1.0|
+------+-------+-----+--------------------+--------------------+----------+
only showing top 6 rows
```

[36]:
```
# probability column is where you can decide
# the 3 tracks with highest "probability" for "1" and
# the 3 tracks with lowest "probability" for "0"
# tracks "198762", "34503", "130183" with "1"
# tracks "30877", "8244", "227283" with "0"
sort_predictions.show(6)
```

```
+------+-------+-----+--------------------+--------------------+----------+
|userID|trackID|label|         probability|       rawPrediction|prediction|
+------+-------+-----+--------------------+--------------------+----------+
|200031| 130183|  0.0|[0.80218276453714…|[1.39999291666030…|       0.0|
|200031|   8244|  1.0|[0.06488875729218…|[-2.6679911209111…|       1.0|
|200031|  30877|  1.0|[0.01343471003408…|[-4.2963878477543…|       1.0|
|200055|  56695|  1.0|[0.00368752576332…|[-5.5991052292289…|       1.0|
|200065| 179571|  0.0|[0.80218276453714…|[1.39999291666030…|       0.0|
|200065| 119451|  1.0|[0.17782970128751…|[-1.5311211916575…|       1.0|
+------+-------+-----+--------------------+--------------------+----------+
only showing top 6 rows
```

[37]:
```
logistic_regression_model_predictions = logistic_regression_model.
 ↪transform(predictions_df)
logistic_regression_model_predictions.select('userID', 'trackID',␣
 ↪'probability', 'rawPrediction', 'prediction').show(12)
```

```
+------+-------+--------------------+--------------------+----------+
|userID|trackID|         probability|       rawPrediction|prediction|
+------+-------+--------------------+--------------------+----------+
|199810| 208019|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810|  74139|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810|   9903|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810| 242681|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810|  18515|[0.29322699696820…|[-0.8797625009202…|       1.0|
|199810| 105760|[0.17782970128751…|[-1.5311211916575…|       1.0|
|199812| 276940|[0.80218276453714…|[1.39999291666030…|       0.0|
|199812| 142408|[0.00169769820591…|[-6.3767828009944…|       1.0|
|199812| 130023|[0.00169769820591…|[-6.3767828009944…|       1.0|
|199812|  29189|[0.80218276453714…|[1.39999291666030…|       0.0|
|199812| 223706|[0.13507641145138…|[-1.8568005370262…|       1.0|
|199812| 211361|[0.80218276453714…|[1.39999291666030…|       0.0|
+------+-------+--------------------+--------------------+----------+
only showing top 12 rows
```

[38]:
```
sort_logistic_regression_model_predictions =␣
↪logistic_regression_model_predictions.select('userID', 'trackID',␣
↪'probability', 'rawPrediction', 'prediction').sort(col('userID').asc(),␣
↪col('probability').desc())
sort_logistic_regression_model_predictions.show(6)
```

```
+------+-------+--------------------+--------------------+----------+
|userID|trackID|         probability|       rawPrediction|prediction|
+------+-------+--------------------+--------------------+----------+
|199810| 208019|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810| 242681|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810|  74139|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810|   9903|[0.80218276453714…|[1.39999291666030…|       0.0|
|199810|  18515|[0.29322699696820…|[-0.8797625009202…|       1.0|
|199810| 105760|[0.17782970128751…|[-1.5311211916575…|       1.0|
+------+-------+--------------------+--------------------+----------+
only showing top 6 rows
```

[39]:
```
sort_logistic_regression_model_predictions_df =␣
↪sort_logistic_regression_model_predictions.toPandas()
sort_logistic_regression_model_predictions_df.
↪columns[sort_logistic_regression_model_predictions_df.isnull().any()]
```

[39]:
```
Index([], dtype='object')
```

[40]:
```
sort_logistic_regression_model_predictions_df.head()
```

[40]:
```
   userID  trackID                               probability  \
0  199810   208019  [0.8021827645371431, 0.1978172354628569]
1  199810    74139  [0.8021827645371431, 0.1978172354628569]
2  199810     9903  [0.8021827645371431, 0.1978172354628569]
3  199810   242681  [0.8021827645371431, 0.1978172354628569]
4  199810    18515  [0.2932269969682032, 0.7067730030317968]

                                 rawPrediction  prediction
0  [1.3999929166603091, -1.3999929166603091]         0.0
1  [1.3999929166603091, -1.3999929166603091]         0.0
2  [1.3999929166603091, -1.3999929166603091]         0.0
3  [1.3999929166603091, -1.3999929166603091]         0.0
4  [-0.8797625009202483, 0.8797625009202483]         1.0
```

[41]:
```
columns = ['userID', 'trackID']
sort_logistic_regression_model_predictions_df.
 ↪to_csv('logistic_regression_predictions.csv', index=False, header=None,␣
 ↪columns=columns)
```

[42]:
```
logistic_regression_predictions_file = open('logistic_regression_predictions.
 ↪csv')
final_logistic_regression_predictions_file =␣
 ↪open('logistic_regression_submission.csv', 'w')
```

[43]:
```
final_logistic_regression_predictions_file.write('TrackID,Predictor\n')
```

[43]:
```
18
```

[44]:
```
last_user_id = -1
track_id_out_vec = [0] * 6
```

[45]:
```
for line in logistic_regression_predictions_file:
    arr_out = line.strip().split(',')
    user_id_out = arr_out[0]
    track_id_out = arr_out[1]

    if user_id_out != last_user_id:
        i = 0

    track_id_out_vec[i] = track_id_out

    i = i + 1
    last_user_id = user_id_out

    if i == 6:
        predictions = np.ones(shape=(6))
        for index in range(0, 3):
            predictions[index] = 0

        for ii in range(0, 6):
            out_str = str(user_id_out) + '_' + str(track_id_out_vec[ii]) + ',' ␣
↪+ str(int(predictions[ii]))
            final_logistic_regression_predictions_file.write(out_str + '\n')
```

```
[46]: logistic_regression_predictions_file.close()
      final_logistic_regression_predictions_file.close()
```

2 Decision Tree Classifier

```
[47]: from pyspark.ml.classification import DecisionTreeClassifier
```

```
[48]: decision_tree_classifier = DecisionTreeClassifier(featuresCol='features',␣
       ↪labelCol='label', maxDepth=3)
      decision_tree_classifier_model = decision_tree_classifier.fit(train)
```

```
[49]: predictions_decision_tree_classifier = decision_tree_classifier_model.
       ↪transform(test)
```

```
[50]: evaluator = MulticlassClassificationEvaluator(labelCol='label',␣
       ↪predictionCol='prediction', metricName='accuracy')
      accuracy = evaluator.evaluate(predictions_decision_tree_classifier)
      print('Test Error: {}'.format((1.0 - accuracy) * 100))
```

```
Test Error: 14.482758620689651
```

```
[51]: sort_predictions_decision_tree_classifier =␣
       ↪predictions_decision_tree_classifier.select('userID', 'trackID', 'label',␣
       ↪'probability', 'rawPrediction', 'prediction').sort(col('userID').asc(),␣
       ↪col('probability').desc())
      sort_predictions_decision_tree_classifier.show(6)
```

```
+------+-------+-----+--------------------+--------------+----------+
|userID|trackID|label|         probability| rawPrediction|prediction|
+------+-------+-----+--------------------+--------------+----------+
|200031| 130183|  0.0|[0.80858085808580…|[1960.0,464.0]|       0.0|
|200031|  30877|  1.0|[0.08880090497737…|[157.0,1611.0]|       1.0|
|200031|   8244|  1.0|[0.01470588235294…|    [1.0,67.0]|       1.0|
|200055|  56695|  1.0|[0.08880090497737…|[157.0,1611.0]|       1.0|
|200065| 179571|  0.0|[0.80858085808580…|[1960.0,464.0]|       0.0|
|200065| 119451|  1.0|[0.08880090497737…|[157.0,1611.0]|       1.0|
+------+-------+-----+--------------------+--------------+----------+
only showing top 6 rows
```

[52]:
```
predictions_decision_tree_classifier = decision_tree_classifier_model.
 ↪transform(predictions_df)
predictions_decision_tree_classifier.select('userID', 'trackID', 'probability',␣
 ↪'rawPrediction', 'prediction').show(12)
```

```
+------+-------+--------------------+-------------+----------+
|userID|trackID|         probability|rawPrediction|prediction|
+------+-------+--------------------+-------------+----------+
|199810| 208019|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810|  74139|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810|   9903|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810| 242681|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810|  18515|[0.08880090497737…|[157.0,1611.0]|       1.0|
|199810| 105760|[0.08880090497737…|[157.0,1611.0]|       1.0|
|199812| 276940|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199812| 142408|[0.08880090497737…|[157.0,1611.0]|       1.0|
|199812| 130023|[0.08880090497737…|[157.0,1611.0]|       1.0|
|199812|  29189|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199812| 223706|[0.08880090497737…|[157.0,1611.0]|       1.0|
|199812| 211361|[0.80858085808580…|[1960.0,464.0]|       0.0|
+------+-------+--------------------+-------------+----------+
only showing top 12 rows
```

[53]:
```
sort_predictions_decision_tree_classifier =␣
 ↪predictions_decision_tree_classifier.select('userID', 'trackID',␣
 ↪'probability', 'rawPrediction', 'prediction').sort(col('userID').asc(),␣
 ↪col('probability').desc())
sort_predictions_decision_tree_classifier.show(6)
```

```
+------+-------+--------------------+-------------+----------+
|userID|trackID|         probability|rawPrediction|prediction|
+------+-------+--------------------+-------------+----------+
|199810| 208019|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810| 242681|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810|  74139|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810|   9903|[0.80858085808580…|[1960.0,464.0]|       0.0|
|199810|  18515|[0.08880090497737…|[157.0,1611.0]|       1.0|
|199810| 105760|[0.08880090497737…|[157.0,1611.0]|       1.0|
+------+-------+--------------------+-------------+----------+
only showing top 6 rows
```

[54]:
```
sort_predictions_decision_tree_classifier_df =␣
 ↪sort_predictions_decision_tree_classifier.toPandas()
sort_predictions_decision_tree_classifier_df.
 ↪columns[sort_predictions_decision_tree_classifier_df.isnull().any()]
```

[54]:
```
Index([], dtype='object')
```

[55]:
```
sort_predictions_decision_tree_classifier_df.head()
```

[55]:
```
   userID  trackID                                probability  \
0  199810   208019  [0.8085808580858086, 0.19141914191419143]
1  199810    74139  [0.8085808580858086, 0.19141914191419143]
2  199810     9903  [0.8085808580858086, 0.19141914191419143]
3  199810   242681  [0.8085808580858086, 0.19141914191419143]
4  199810    18515  [0.08880090497737557, 0.9111990950226244]

     rawPrediction  prediction
0  [1960.0, 464.0]         0.0
1  [1960.0, 464.0]         0.0
2  [1960.0, 464.0]         0.0
3  [1960.0, 464.0]         0.0
4  [157.0, 1611.0]         1.0
```

[56]:
```
columns = ['userID', 'trackID']
sort_predictions_decision_tree_classifier_df.
 ↪to_csv('decision_tree_classifier_predictions.csv', index=False, header=None,␣
 ↪columns=columns)
```

[57]:
```
decision_tree_classifier_file = open('decision_tree_classifier_predictions.csv')
final_decision_tree_classifier_file = open('decision_tree_classifier_submission.
 ↪csv', 'w')
```

[58]:
```
final_decision_tree_classifier_file.write('TrackID,Predictor\n')
```

[58]:
```
18
```

[59]:
```
last_user_id = -1
track_id_out_vec = [0] * 6
```

[60]:
```
for line in decision_tree_classifier_file:
    arr_out = line.strip().split(',')
    user_id_out = arr_out[0]
    track_id_out = arr_out[1]

    if user_id_out != last_user_id:
        i = 0

    track_id_out_vec[i] = track_id_out

    i = i + 1
    last_user_id = user_id_out
    if i == 6:
        predictions = np.ones(shape=(6))
        for index in range(0, 3):
            predictions[index] = 0

        for ii in range(0, 6):
            out_str = str(user_id_out) + '_' + str(track_id_out_vec[ii]) + ','␣
↪+ str(int(predictions[ii]))
            final_decision_tree_classifier_file.write(out_str + '\n')
```

[61]:
```
decision_tree_classifier_file.close()
final_decision_tree_classifier_file.close()
```

3 Random Forest Classifier

[62]:
```
from pyspark.ml.classification import RandomForestClassifier
```

[63]:
```
random_forest = RandomForestClassifier(featuresCol='features', labelCol='label')
random_forest_model = random_forest.fit(train)
```

[64]:
```
random_forest_predictions = random_forest_model.transform(test)
```

[65]:
```
evaluator = MulticlassClassificationEvaluator(labelCol='label',␣
↪predictionCol='prediction', metricName='accuracy')
accuracy = evaluator.evaluate(random_forest_predictions)
print('Test Error: {}'.format((1.0 - accuracy) * 100))
```

```
Test Error: 14.482758620689651
```

[66]:
```
sort_random_forest_predictions = random_forest_predictions.select('userID',␣
↪'trackID', 'label', 'probability', 'rawPrediction', 'prediction').
↪sort(col('userID').asc(), col('probability').desc())
sort_random_forest_predictions.show(6)
```

```
+------+-------+-----+--------------------+--------------------+----------+
|userID|trackID|label|         probability|       rawPrediction|prediction|
+------+-------+-----+--------------------+--------------------+----------+
|200031| 130183|  0.0|[0.80878408351365…|[16.1756816702730…|       0.0|
|200031|  30877|  1.0|[0.01263507637292…|[0.25270152745857…|       1.0|
|200031|   8244|  1.0|[8.06451612903225…|[0.01612903225806…|       1.0|
|200055|  56695|  1.0|[0.01263507637292…|[0.25270152745857…|       1.0|
|200065| 179571|  0.0|[0.80878408351365…|[16.1756816702730…|       0.0|
|200065| 119451|  1.0|[0.18553913276044…|[3.71078265520889…|       1.0|
+------+-------+-----+--------------------+--------------------+----------+
only showing top 6 rows
```

[67]:
```
random_forest_predictions = random_forest_model.transform(predictions_df)
```

```
random_forest_predictions.select('userID', 'trackID', 'probability',␣
↪'rawPrediction', 'prediction').show(12)
```

```
+------+-------+--------------------+--------------------+----------+
|userID|trackID|         probability|       rawPrediction|prediction|
+------+-------+--------------------+--------------------+----------+
|199810| 208019|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810|  74139|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810|   9903|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810| 242681|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810|  18515|[0.19467261212938...|[3.89345224258761...|       1.0|
|199810| 105760|[0.18553913276044...|[3.71078265520889...|       1.0|
|199812| 276940|[0.80878408351365...|[16.1756816702730...|       0.0|
|199812| 142408|[0.01263507637292...|[0.25270152745857...|       1.0|
|199812| 130023|[0.01263507637292...|[0.25270152745857...|       1.0|
|199812|  29189|[0.80878408351365...|[16.1756816702730...|       0.0|
|199812| 223706|[0.18553913276044...|[3.71078265520889...|       1.0|
|199812| 211361|[0.80878408351365...|[16.1756816702730...|       0.0|
+------+-------+--------------------+--------------------+----------+
only showing top 12 rows
```

[68]:
```
sort_random_forest_predictions = random_forest_predictions.select('userID',␣
↪'trackID', 'probability', 'rawPrediction', 'prediction').sort(col('userID').
↪asc(), col('probability').desc())
sort_random_forest_predictions.show(6)
```

```
+------+-------+--------------------+--------------------+----------+
|userID|trackID|         probability|       rawPrediction|prediction|
+------+-------+--------------------+--------------------+----------+
|199810| 208019|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810| 242681|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810|  74139|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810|   9903|[0.80878408351365...|[16.1756816702730...|       0.0|
|199810|  18515|[0.19467261212938...|[3.89345224258761...|       1.0|
|199810| 105760|[0.18553913276044...|[3.71078265520889...|       1.0|
+------+-------+--------------------+--------------------+----------+
only showing top 6 rows
```

[69]:
```
sort_random_forest_predictions_df = sort_random_forest_predictions.toPandas()
sort_random_forest_predictions_df.columns[sort_random_forest_predictions_df.
↪isnull().any()]
```

[69]:
```
Index([], dtype='object')
```

[70]:
```
sort_random_forest_predictions_df.head()
```

[70]:
```
   userID  trackID                                probability  \
0  199810   208019  [0.8087840835136524, 0.19121591648634775]
1  199810    74139  [0.8087840835136524, 0.19121591648634775]
2  199810     9903  [0.8087840835136524, 0.19121591648634775]
3  199810   242681  [0.8087840835136524, 0.19121591648634775]
4  199810    18515   [0.1946726121293807, 0.8053273878706193]

                             rawPrediction  prediction
0  [16.175681670273047, 3.824318329726955]         0.0
1  [16.175681670273047, 3.824318329726955]         0.0
2  [16.175681670273047, 3.824318329726955]         0.0
3  [16.175681670273047, 3.824318329726955]         0.0
4  [3.893452242587614, 16.106547757412386]         1.0
```

[71]:
```
columns= ['userID', 'trackID']
sort_random_forest_predictions_df.to_csv('random_forest_classifier_predictions.
 ↪csv', index=False, header=None, columns=columns)
```

[72]:
```
random_forest_predictions_file = open('random_forest_classifier_predictions.
 ↪csv')
final_random_forest_predictions_file =␣
 ↪open('random_forest_classifier_submission.csv', 'w')
```

[73]:
```
final_random_forest_predictions_file.write('TrackID,Predictor\n')
```

[73]:
```
18
```

[74]:
```
last_user_id = -1
track_id_out_vec = [0] * 6
```

[75]:
```
for line in random_forest_predictions_file:
    arr_out = line.strip().split(',')
    user_id_out = arr_out[0]
    track_id_out = arr_out[1]

    if user_id_out != last_user_id:
        i = 0

    track_id_out_vec[i] = track_id_out

    i = i + 1
    last_user_id = user_id_out

    if i == 6:
        predictions = np.ones(shape=(6))
        for index in range(0, 3):
            predictions[index] = 0

        for ii in range(0, 6):
            out_str = str(user_id_out) + '_' + str(track_id_out_vec[ii]) + ','␣
 ↪+ str(int(predictions[ii]))
            final_random_forest_predictions_file.write(out_str + '\n')
```

[76]:
```
random_forest_predictions_file.close()
final_random_forest_predictions_file.close()
```

4 Gradient Boosted Tree Classifier

[77]:
```
from pyspark.ml.classification import GBTClassifier
```

[78]:
```
gradient_boosted_tree_classifier = GBTClassifier(maxIter=100)
gradient_boosted_tree_classifier_model = gradient_boosted_tree_classifier.
 ↪fit(train)
```

[79]:
```
gradient_boosted_tree_classifier_predictions =␣
 ↪gradient_boosted_tree_classifier_model.transform(test)
```

[80]:
```
evaluator = MulticlassClassificationEvaluator(labelCol='label',␣
 ↪predictionCol='prediction', metricName='accuracy')
accuracy = evaluator.evaluate(gradient_boosted_tree_classifier_predictions)
print('Test Error: {}'.format((1.0 - accuracy) * 100))
```

```
Test Error: 14.482758620689651
```

```
21/11/21 18:03:08 WARN InstanceBuilder$NativeBLAS: Failed to load implementation
from:dev.ludovic.netlib.blas.JNIBLAS
21/11/21 18:03:08 WARN InstanceBuilder$NativeBLAS: Failed to load implementation
from:dev.ludovic.netlib.blas.ForeignLinkerBLAS
```

[81]:
```
sort_gradient_boosted_tree_classifier_predictions =␣
 ↪gradient_boosted_tree_classifier_predictions.select('userID', 'trackID',␣
 ↪'label', 'probability', 'rawPrediction', 'prediction').sort(col('userID').
 ↪asc(), col('probability').desc())
sort_gradient_boosted_tree_classifier_predictions.show(6)
```

```
+------+-------+-----+--------------------+--------------------+----------+
|userID|trackID|label|         probability|       rawPrediction|prediction|
+------+-------+-----+--------------------+--------------------+----------+
|200031| 130183|  0.0|[0.80853359039673...|[0.72025491912707...|       0.0|
|200031|  30877|  1.0|[0.01165681655269...|[-2.2200694341913...|       1.0|
|200031|   8244|  1.0|[0.01165681655269...|[-2.2200694341913...|       1.0|
|200055|  56695|  1.0|[0.01632026531261...|[-2.0494463824457...|       1.0|
|200065| 179571|  0.0|[0.80853359039673...|[0.72025491912707...|       0.0|
|200065| 119451|  1.0|[0.19777096337535…|[-0.7001422692047…|       1.0|
+------+-------+-----+--------------------+--------------------+----------+
only showing top 6 rows
```

[82]:
```
gradient_boosted_tree_classifier_predictions =␣
 ↪gradient_boosted_tree_classifier_model.transform(predictions_df)
gradient_boosted_tree_classifier_predictions.select('userID', 'trackID',␣
 ↪'probability', 'rawPrediction', 'prediction').show(12)
```

```
+------+-------+--------------------+--------------------+----------+
|userID|trackID|         probability|       rawPrediction|prediction|
+------+-------+--------------------+--------------------+----------+
|199810| 208019|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810|  74139|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810|   9903|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810| 242681|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810|  18515|[0.24633418901301…|[-0.5591299711568…|       1.0|
|199810| 105760|[0.19777096337535…|[-0.7001422692047…|       1.0|
|199812| 276940|[0.80853359039673…|[0.72025491912707…|       0.0|
|199812| 142408|[0.01161609118736…|[-2.2218399428711…|       1.0|
|199812| 130023|[0.01161609118736…|[-2.2218399428711…|       1.0|
|199812|  29189|[0.80853359039673…|[0.72025491912707…|       0.0|
|199812| 223706|[0.12602709898363…|[-0.9682762071735…|       1.0|
|199812| 211361|[0.80853359039673…|[0.72025491912707…|       0.0|
+------+-------+--------------------+--------------------+----------+
only showing top 12 rows
```

[83]:
```
sort_gradient_boosted_tree_classifier_predictions =␣
 ↪gradient_boosted_tree_classifier_predictions.select('userID', 'trackID',␣
 ↪'probability', 'rawPrediction', 'prediction').sort(col('userID').asc(),␣
 ↪col('probability').desc())
sort_gradient_boosted_tree_classifier_predictions.show(6)
```

```
[Stage 1106:>                                                       (0 + 1) / 1]

+------+-------+--------------------+--------------------+----------+
|userID|trackID|         probability|       rawPrediction|prediction|
+------+-------+--------------------+--------------------+----------+
|199810| 208019|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810| 242681|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810|  74139|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810|   9903|[0.80853359039673…|[0.72025491912707…|       0.0|
|199810|  18515|[0.24633418901301…|[-0.5591299711568…|       1.0|
|199810| 105760|[0.19777096337535…|[-0.7001422692047…|       1.0|
+------+-------+--------------------+--------------------+----------+
only showing top 6 rows
```

[84]:
```
sort_gradient_boosted_tree_classifier_predictions_df =␣
 ↪sort_gradient_boosted_tree_classifier_predictions.toPandas()
sort_gradient_boosted_tree_classifier_predictions_df.
 ↪columns[sort_gradient_boosted_tree_classifier_predictions_df.isnull().any()]
```

[84]:
```
Index([], dtype='object')
```

[85]:
```
sort_gradient_boosted_tree_classifier_predictions_df.head()
```

[85]:
```
   userID  trackID                               probability  \
0  199810   208019   [0.8085335903967381, 0.1914664096032619]
1  199810    74139   [0.8085335903967381, 0.1914664096032619]
2  199810     9903   [0.8085335903967381, 0.1914664096032619]
3  199810   242681   [0.8085335903967381, 0.1914664096032619]
4  199810    18515  [0.24633418901301743, 0.7536658109869826]

                             rawPrediction  prediction
0  [0.7202549191270777, -0.7202549191270777]         0.0
1  [0.7202549191270777, -0.7202549191270777]         0.0
2  [0.7202549191270777, -0.7202549191270777]         0.0
3  [0.7202549191270777, -0.7202549191270777]         0.0
4  [-0.5591299711568518, 0.5591299711568518]         1.0
```

[86]:
```
columns = ['userID', 'trackID']
sort_gradient_boosted_tree_classifier_predictions_df.
 ↪to_csv('gradient_boosted_tree_classifier_predictions.csv', index=False,␣
 ↪header=None, columns=columns)
```

[87]:
```
gradient_boosted_tree_classifier_predictions_file =␣
 ↪open('gradient_boosted_tree_classifier_predictions.csv')
final_gradient_boosted_tree_classifier_predictions_file =␣
 ↪open('gradient_boosted_tree_classifier_submission.csv', 'w')
```

[88]:
```
final_gradient_boosted_tree_classifier_predictions_file.
 ↪write('TrackID,Predictor\n')
```

[88]:
```
18
```

[89]:
```
last_user_id = -1
track_id_out_vec = [0] * 6
```

[90]:
```
for line in gradient_boosted_tree_classifier_predictions_file:
    arr_out = line.strip().split(',')
    user_id_out = arr_out[0]
    track_id_out = arr_out[1]

    if user_id_out != last_user_id:
        i = 0

    track_id_out_vec[i] = track_id_out

    i = i + 1
    last_user_id = user_id_out

    if i == 6:
        predictions = np.ones(shape=(6))
        for index in range(0, 3):
            predictions[index] = 0

        for ii in range(0, 6):
            out_str = str(user_id_out) + '_' + str(track_id_out_vec[ii]) + ','␣
↪+ str(int(predictions[ii]))
            final_gradient_boosted_tree_classifier_predictions_file.
↪write(out_str + '\n')
```

[91]:
```
gradient_boosted_tree_classifier_predictions_file.close()
final_gradient_boosted_tree_classifier_predictions_file.close()
```