Project Name: Spotify 2017-2021 Daily Global Top 200 Analysis

Project Scope: Exploring Spotify 2017-2021 Daily Global Top 200 Data to Unearth Trends, Insights, and Business Value.

Data Source: https://www.kaggle.com/c0lydxmas/spotify-top-200-daily-global-2017-2021 (https://www.kaggle.com/c0lydxmas/spotify-top-200-daily-global-2017-2021)

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The following cells outline the Model Definition section of the project. The 2017, 2019, and 2021 datasets were used to generate an initial baseline model using the Support Vector Machine algorithm. Following that, both datasets were used to define the code for the final machine learning algorithm choice for this project - Random Forest. As a side note, the Gradient Boosted Trees algorithm was also tested during the model definition stage as well, but unfortunately the file containing the code and output of that model was overwritten. For that reason, I have excluded it from the final report and presentation. An 80-20 train-test split was used for the model definition stage, and a 70-30 train-test split was used for the model training and evaluation stage.

The chosen performance metric was "Area Under the ROC Curve" because it looks at a model's ability to discriminate between two classes while also taking into consideration any imbalance in the dataset itself. The datasets that were used for this project (2017,2018,2019,2020,2021 Daily Global Top 200 Data) are not perfectly balanced when it comes to label distribution. For these reasons, I thought AUC (AUROC) would be a good choice for this project.

- The threshold for acceptable performance was set at 80% AUC as per common online community consensus (ex: https://www.sciencedirect.com/science/article/pii/S1556086415306043#:~:text=In%20general%2C%20an%20AUC%20of,than%200.9%20is%20considered%20outstanding. (https://www.sciencedirect.com/science/article/pii/S1556086415306043#:~:text=In%20general%2C%20an%20AUC%20of,than%200.9%20is%20considered%20outstanding.))
- From article above: "...In general, an AUC of 0.5 suggests no discrimination (i.e., ability to diagnose patients with and without the disease or condition based on the test), 0.7 to 0.8 is considered acceptable, **0.8 to 0.9 is considered excellent**, and more than 0.9 is considered outstanding..."

The 2017, 2019, and 2021 datasets were used during model definition to ensure compatability across all years of the data (i.e. 2017 all the way to 2021).

Step 1: Initializing Spark Environment (IBM Cloud Deprecated Python 3.7)

- Spark Environment Initialized

In [1]:
```python
# Local Spark Environment - IBM Cloud

from IPython.display import Markdown, display
def printmd(string):
    display(Markdown('# <span style="color:red">'+string+'</span>'))


if ('sc' in locals() or 'sc' in globals()):
    printmd('<<<<<!!!!! It seems that you are running in a IBM Watson Studio Apache Spark Notebook. Please run it in an IBM Watson Studio Default Runtime (without Apache Spark) !!!!!>>>>>')

!pip install pyspark==2.4.5

try:
    from pyspark import SparkContext, SparkConf
    from pyspark.sql import SparkSession
except ImportError as e:
    printmd('<<<<<!!!!! Please restart your kernel after installing Apache Spark !!!!!>>>>>')

sc = SparkContext.getOrCreate(SparkConf().setMaster("local[*]"))

spark = SparkSession \
    .builder \
    .getOrCreate()

spark.conf.set("spark.debug.maxToStringFields","true")
```

```
/opt/conda/envs/Python-3.7-OpenCE/lib/python3.7/site-packages/secretstorage/dhcrypto.py:16: CryptographyDeprecationWarning: int_from_bytes is deprecated, use int.from_bytes instead
  from cryptography.utils import int_from_bytes
/opt/conda/envs/Python-3.7-OpenCE/lib/python3.7/site-packages/secretstorage/util.py:25: CryptographyDeprecationWarning: int_from_bytes is deprecated, use int.from_bytes instead
  from cryptography.utils import int_from_bytes
Collecting pyspark==2.4.5
  Downloading pyspark-2.4.5.tar.gz (217.8 MB)
     |████████████████████████████████| 217.8 MB 10 kB/s s eta 0:00:01    |███                             | 20.9 MB 15.0 MB/s eta 0:00:14      | 78.6 MB 40.6 MB/s eta 0:00:04��█            | 136.4 MB 10.0 MB/s eta 0:00:09 | 179.2 MB 9.7 MB/s eta 0:00:05
Collecting py4j==0.10.7
  Downloading py4j-0.10.7-py2.py3-none-any.whl (197 kB)
     |████████████████████████████████| 197 kB 39.9 MB/s eta 0:00:01
Building wheels for collected packages: pyspark
  Building wheel for pyspark (setup.py) ... done
  Created wheel for pyspark: filename=pyspark-2.4.5-py2.py3-none-any.whl size=218257928 sha256=716e4d3249888ef93c8058e75e08b0b4e3419200f06a97f8c2cd58cbb21d76a2
  Stored in directory: /tmp/wsuser/.cache/pip/wheels/01/c0/03/1c241c9c482b647d4d99412a98a5c7f87472728ad41ae55e1e
Successfully built pyspark
Installing collected packages: py4j, pyspark
Successfully installed py4j-0.10.7 pyspark-2.4.5

22/04/04 10:09:23 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
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).
```

Step 2: Loading In 2017, 2019, and 2021 Data for Model Definition (Baselines)

- Credentials Removed for Privacy and Security
- 2017, 2019, and 2021 datasets loaded and prepped for further steps

In [2]:
```python
# Read Data

import os, types
import pandas as pd
from botocore.client import Config
import ibm_boto3

pd.set_option('display.max_columns', None)
pd.set_option('display.max_colwidth',1000)

def __iter__(self): return 0

# @hidden_cell
# The following code accesses a file in your IBM Cloud Object Storage. It includes your credentials.
# You might want to remove those credentials before you share the notebook.
client_ffa959d2c80941dba05e8ff594f32acd = ibm_boto3.client(service_name='',
    ibm_api_key_id='',
    ibm_auth_endpoint="",
    config=Config(signature_version='),
    endpoint_url='')

body = client_ffa959d2c80941dba05e8ff594f32acd.get_object(Bucket='',Key='2017_full_2.csv')['Body']
# add missing __iter__ method, so pandas accepts body as file-like object
if not hasattr(body, "__iter__"): body.__iter__ = types.MethodType( __iter__, body )

df_data_1 = pd.read_csv(body)

body = client_ffa959d2c80941dba05e8ff594f32acd.get_object(Bucket='',Key='2019_full_2.csv')['Body']
# add missing __iter__ method, so pandas accepts body as file-like object
if not hasattr(body, "__iter__"): body.__iter__ = types.MethodType( __iter__, body )

df_data_2 = pd.read_csv(body)

body = client_ffa959d2c80941dba05e8ff594f32acd.get_object(Bucket='',Key='2021_full_2.csv')['Body']
# add missing __iter__ method, so pandas accepts body as file-like object
if not hasattr(body, "__iter__"): body.__iter__ = types.MethodType( __iter__, body )

df_data_3 = pd.read_csv(body)

df_data_1 = df_data_1.drop(columns=['Unnamed: 0'])
df_data_2 = df_data_2.drop(columns=['Unnamed: 0'])
df_data_3 = df_data_3.drop(columns=['Unnamed: 0'])

df_data_1 = df_data_1.rename(columns={"album.album_type": "albumtype", "album.name": "albumname", "album.release_date_precision": "albumdateprecision" })
df_data_2 = df_data_2.rename(columns={"album.album_type": "albumtype", "album.name": "albumname", "album.release_date_precision": "albumdateprecision" })
df_data_3 = df_data_3.rename(columns={"album.album_type": "albumtype", "album.name": "albumname", "album.release_date_precision": "albumdateprecision" })

df_data_1[['artistname','featuredartist','featuredartist2','featuredartist3','primary_genre','secondary_genre','genre3','genre4','genre5','genre6','genre7','genre8','genre9','genre10','genre11','genre12','binary_performance_bin','albumname']] = df_data_1[['artistn
df_data_2[['artistname','featuredartist','featuredartist2','featuredartist3','primary_genre','secondary_genre','genre3','genre4','genre5','genre6','genre7','genre8','genre9','genre10','genre11','genre12','binary_performance_bin','albumname']] = df_data_2[['artistn
df_data_3[['artistname','featuredartist','featuredartist2','featuredartist3','primary_genre','secondary_genre','genre3','genre4','genre5','genre6','genre7','genre8','genre9','genre10','genre11','genre12','binary_performance_bin','albumname']] = df_data_3[['artistn

df_data_1[['explicit', 'has_feature','duration_ms']] = df_data_1[['explicit', 'has_feature','duration_ms']].astype(int)
df_data_2[['explicit', 'has_feature','duration_ms']] = df_data_2[['explicit', 'has_feature','duration_ms']].astype(int)
df_data_3[['explicit', 'has_feature','duration_ms']] = df_data_3[['explicit', 'has_feature','duration_ms']].astype(int)

df_data_1[['tempo']] = df_data_1[['tempo']].astype(float)
df_data_2[['tempo']] = df_data_2[['tempo']].astype(float)
df_data_3[['tempo']] = df_data_3[['tempo']].astype(float)
```

Step 3A: Initial Baseline Model Using SVM and Only Numerical Features

Using only numerical features, three separate pipelines were defined for the three datasets chosen for baseline modeling (2017,2019,2021). It was determined from subject matter expertise that two of these numerical features behaved more like low-cardinality categorical variables instead, so they were indexed and one-hot encoded (Key and Time Signature). As mentioned, the algorithm chosen for this initial baseline was the Spark implementation of Support Vector Machine (SVM).

We can see the performance of the initial baseline SVM models below:
2017 Train: 57.0%
2017 Test: 56.7%
2019 Train: 56.9%
2019 Test: 56.8%
2021 Train: 55.4%
2021 Test: 53.8%

As we can see, there is no overfitting.

In [31]:
```
# SVM - Baseline

# Imports

from pyspark.ml.feature import VectorAssembler
from pyspark.ml.feature import StringIndexer, VectorIndexer, OneHotEncoder, MinMaxScaler
from pyspark.ml import Pipeline
from pyspark.ml.evaluation import BinaryClassificationEvaluator
from pyspark.ml.classification import LinearSVC

# Label Choice

labelchoice = 'binary_performance_bin'

# Data Split

df1 = df_data_1[['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre','key','time_signature',labelchoice]]
df2 = df_data_2[['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre','key','time_signature',labelchoice]]
df3 = df_data_3[['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre','key','time_signature',labelchoice]]

df_spark_1 = spark.createDataFrame(df1)
df_spark_2 = spark.createDataFrame(df2)
df_spark_3 = spark.createDataFrame(df3)

train1, test1 = df_spark_1.randomSplit([0.8, 0.2])
train2, test2 = df_spark_2.randomSplit([0.8, 0.2])
train3, test3 = df_spark_3.randomSplit([0.8, 0.2])

# Pipeline Definitions

indexer = StringIndexer(inputCol=labelchoice, outputCol="label", stringOrderType="frequencyDesc")

indexer1 = StringIndexer(inputCol='key', outputCol="key_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
indexer2 = StringIndexer(inputCol='time_signature', outputCol="timesig_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')

keyencode = OneHotEncoder(inputCol="key_indexed", outputCol="keycoded")

timeencode = OneHotEncoder(inputCol="timesig_indexed", outputCol="timecoded")

numVectorAssembler = VectorAssembler(inputCols=['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre'], outputCol="num_features")

normalizer = MinMaxScaler(inputCol="num_features", outputCol="scaled_num_features")

finalVectorAssembler = VectorAssembler(inputCols=['keycoded','timecoded','scaled_num_features'], outputCol="features")

# Create SVM models

lsvc1 = LinearSVC(maxIter=20, regParam=0.1)
lsvc2 = LinearSVC(maxIter=20, regParam=0.1)
lsvc3 = LinearSVC(maxIter=20, regParam=0.1)

# Create Pipelines
pipeline1 = Pipeline(stages=[indexer,indexer1,indexer2,keyencode,timeencode,numVectorAssembler,normalizer,finalVectorAssembler,lsvc1])
pipeline2 = Pipeline(stages=[indexer,indexer1,indexer2,keyencode,timeencode,numVectorAssembler,normalizer,finalVectorAssembler,lsvc2])
pipeline3 = Pipeline(stages=[indexer,indexer1,indexer2,keyencode,timeencode,numVectorAssembler,normalizer,finalVectorAssembler,lsvc3])

# Fit Pipelines
model1 = pipeline1.fit(train1)
print(model1.stages[-1])

model2 = pipeline2.fit(train2)
print(model2.stages[-1])

model3 = pipeline3.fit(train3)
print(model3.stages[-1])

# Run Models

prediction1 = model1.transform(train1)
prediction2 = model2.transform(train2)
prediction3 = model3.transform(train3)

# BINARY EVALUATION - TRAIN SET - 2017
# Evaluating 2017 Model on Training Set

evaluator = BinaryClassificationEvaluator(rawPredictionCol="rawPrediction")
evaluator.evaluate(prediction1)
```

```
22/04/03 21:51:47 WARN TaskSetManager: Stage 550 contains a task of very large size (5405 KB). The maximum recommended task size is 100 KB.
22/04/03 21:51:48 WARN TaskSetManager: Stage 552 contains a task of very large size (5405 KB). The maximum recommended task size is 100 KB.
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22/04/03 21:53:36 WARN TaskSetManager: Stage 645 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:37 WARN TaskSetManager: Stage 647 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:38 WARN TaskSetManager: Stage 649 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
```

```
22/04/03 21:53:39 WARN TaskSetManager: Stage 651 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:41 WARN TaskSetManager: Stage 652 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:42 WARN TaskSetManager: Stage 653 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:45 WARN TaskSetManager: Stage 654 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:47 WARN TaskSetManager: Stage 655 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:47 WARN TaskSetManager: Stage 656 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:48 WARN TaskSetManager: Stage 657 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:49 WARN TaskSetManager: Stage 658 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:50 WARN TaskSetManager: Stage 659 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:51 WARN TaskSetManager: Stage 660 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:52 WARN TaskSetManager: Stage 661 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:53 WARN TaskSetManager: Stage 662 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:54 WARN TaskSetManager: Stage 663 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:55 WARN TaskSetManager: Stage 664 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:57 WARN TaskSetManager: Stage 665 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:58 WARN TaskSetManager: Stage 666 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:53:59 WARN TaskSetManager: Stage 667 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:00 WARN TaskSetManager: Stage 668 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:00 WARN TaskSetManager: Stage 669 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:02 WARN TaskSetManager: Stage 670 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:03 WARN TaskSetManager: Stage 671 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:04 WARN TaskSetManager: Stage 672 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:05 WARN TaskSetManager: Stage 673 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:06 WARN TaskSetManager: Stage 674 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:07 WARN TaskSetManager: Stage 675 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:08 WARN TaskSetManager: Stage 676 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:09 WARN TaskSetManager: Stage 677 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:10 WARN TaskSetManager: Stage 678 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:11 WARN TaskSetManager: Stage 679 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:12 WARN TaskSetManager: Stage 680 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:13 WARN TaskSetManager: Stage 681 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:14 WARN TaskSetManager: Stage 682 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:15 WARN TaskSetManager: Stage 683 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:16 WARN TaskSetManager: Stage 684 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:16 WARN TaskSetManager: Stage 685 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:17 WARN TaskSetManager: Stage 686 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:19 WARN TaskSetManager: Stage 687 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:20 WARN TaskSetManager: Stage 688 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:21 WARN TaskSetManager: Stage 689 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:22 WARN TaskSetManager: Stage 690 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:23 WARN TaskSetManager: Stage 691 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:24 WARN TaskSetManager: Stage 692 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:25 WARN TaskSetManager: Stage 693 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:26 WARN TaskSetManager: Stage 694 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:27 WARN TaskSetManager: Stage 695 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:28 WARN TaskSetManager: Stage 696 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:29 WARN TaskSetManager: Stage 697 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:29 WARN TaskSetManager: Stage 698 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:32 WARN TaskSetManager: Stage 699 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:33 WARN TaskSetManager: Stage 700 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:34 WARN TaskSetManager: Stage 701 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:35 WARN TaskSetManager: Stage 702 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:36 WARN TaskSetManager: Stage 703 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:37 WARN TaskSetManager: Stage 704 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:38 WARN TaskSetManager: Stage 705 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:39 WARN TaskSetManager: Stage 706 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:40 WARN TaskSetManager: Stage 707 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:41 WARN TaskSetManager: Stage 708 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:42 WARN TaskSetManager: Stage 709 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:43 WARN TaskSetManager: Stage 710 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:44 WARN TaskSetManager: Stage 711 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:45 WARN TaskSetManager: Stage 712 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:46 WARN TaskSetManager: Stage 713 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:47 WARN TaskSetManager: Stage 714 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:48 WARN TaskSetManager: Stage 715 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:49 WARN TaskSetManager: Stage 716 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:50 WARN TaskSetManager: Stage 717 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:51 WARN TaskSetManager: Stage 718 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:52 WARN TaskSetManager: Stage 719 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:53 WARN TaskSetManager: Stage 720 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:54 WARN TaskSetManager: Stage 721 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:55 WARN TaskSetManager: Stage 722 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:56 WARN TaskSetManager: Stage 723 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:57 WARN TaskSetManager: Stage 724 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:58 WARN TaskSetManager: Stage 725 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:54:59 WARN TaskSetManager: Stage 726 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:00 WARN TaskSetManager: Stage 727 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:01 WARN TaskSetManager: Stage 728 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:02 WARN TaskSetManager: Stage 729 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:03 WARN TaskSetManager: Stage 730 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.

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22/04/03 21:55:05 WARN TaskSetManager: Stage 732 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:07 WARN TaskSetManager: Stage 734 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:07 WARN TaskSetManager: Stage 736 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:09 WARN TaskSetManager: Stage 737 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:11 WARN TaskSetManager: Stage 738 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:15 WARN TaskSetManager: Stage 739 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:18 WARN TaskSetManager: Stage 740 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:18 WARN TaskSetManager: Stage 741 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:19 WARN TaskSetManager: Stage 742 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:20 WARN TaskSetManager: Stage 743 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:21 WARN TaskSetManager: Stage 744 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:22 WARN TaskSetManager: Stage 745 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:22 WARN TaskSetManager: Stage 746 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:23 WARN TaskSetManager: Stage 747 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:24 WARN TaskSetManager: Stage 748 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:25 WARN TaskSetManager: Stage 749 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:25 WARN TaskSetManager: Stage 750 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:26 WARN TaskSetManager: Stage 751 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:27 WARN TaskSetManager: Stage 752 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:28 WARN TaskSetManager: Stage 753 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:28 WARN TaskSetManager: Stage 754 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:29 WARN TaskSetManager: Stage 755 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:30 WARN TaskSetManager: Stage 756 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:31 WARN TaskSetManager: Stage 757 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:32 WARN TaskSetManager: Stage 758 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:32 WARN TaskSetManager: Stage 759 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:33 WARN TaskSetManager: Stage 760 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:34 WARN TaskSetManager: Stage 761 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:35 WARN TaskSetManager: Stage 762 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:36 WARN TaskSetManager: Stage 763 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:37 WARN TaskSetManager: Stage 764 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:37 WARN TaskSetManager: Stage 765 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:38 WARN TaskSetManager: Stage 766 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:39 WARN TaskSetManager: Stage 767 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:40 WARN TaskSetManager: Stage 768 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:40 WARN TaskSetManager: Stage 769 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:41 WARN TaskSetManager: Stage 770 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:42 WARN TaskSetManager: Stage 771 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:43 WARN TaskSetManager: Stage 772 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:44 WARN TaskSetManager: Stage 773 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:44 WARN TaskSetManager: Stage 774 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:45 WARN TaskSetManager: Stage 775 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:46 WARN TaskSetManager: Stage 776 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:47 WARN TaskSetManager: Stage 777 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:47 WARN TaskSetManager: Stage 778 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:48 WARN TaskSetManager: Stage 779 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:49 WARN TaskSetManager: Stage 780 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:50 WARN TaskSetManager: Stage 781 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:51 WARN TaskSetManager: Stage 782 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:51 WARN TaskSetManager: Stage 783 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:52 WARN TaskSetManager: Stage 784 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:53 WARN TaskSetManager: Stage 785 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:54 WARN TaskSetManager: Stage 786 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:55 WARN TaskSetManager: Stage 787 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:55 WARN TaskSetManager: Stage 788 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:56 WARN TaskSetManager: Stage 789 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:57 WARN TaskSetManager: Stage 790 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:58 WARN TaskSetManager: Stage 791 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:59 WARN TaskSetManager: Stage 792 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:55:59 WARN TaskSetManager: Stage 793 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:00 WARN TaskSetManager: Stage 794 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:01 WARN TaskSetManager: Stage 795 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:02 WARN TaskSetManager: Stage 796 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:03 WARN TaskSetManager: Stage 797 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:04 WARN TaskSetManager: Stage 798 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:04 WARN TaskSetManager: Stage 799 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.



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22/04/03 21:56:05 WARN TaskSetManager: Stage 800 contains a task of very large size (5405 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:07 WARN TaskSetManager: Stage 801 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:08 WARN TaskSetManager: Stage 802 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:08 WARN TaskSetManager: Stage 803 contains a task of very large size (5405 KB). The maximum recommended task size is 100 KB.
```

```
Out[31]: 0.570227982451897
```

```
In [32]: # BINARY EVALUATION - TRAIN SET - 2019
         # Evaluating 2019 Model on Training Set

         evaluator.evaluate(prediction2)
```

```
22/04/03 21:56:13 WARN TaskSetManager: Stage 812 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
```

```
Out[32]: 0.5692043124002386
```

```
In [33]: # BINARY EVALUATION - TRAIN SET - 2021
         # Evaluating 2021 Model on Training Set

         evaluator.evaluate(prediction3)
```

```
22/04/03 21:56:17 WARN TaskSetManager: Stage 821 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
```

```
Out[33]: 0.554200234722357
```

Step 3B: Test Set Performance for SVM Baseline Models

Below we can see the SVM Baseline Model performance values on the test sets:
2017 Test: 56.7%
2019 Test: 56.8%
2021 Test: 53.8%

In [34]:
```
# BINARY EVALUATION - TEST SET - 2017,2019,2021

prediction_test1 = model1.transform(test1)
prediction_test2 = model2.transform(test2)
prediction_test3 = model3.transform(test3)

# BINARY EVALUATION - TEST SET - 2017,2019,2021
# Evaluating 2017 Model on Test Set

evaluator = BinaryClassificationEvaluator(rawPredictionCol="rawPrediction")
evaluator.evaluate(prediction_test1)
```

```
22/04/03 21:56:21 WARN TaskSetManager: Stage 830 contains a task of very large size (5405 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:23 WARN TaskSetManager: Stage 831 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:24 WARN TaskSetManager: Stage 832 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
22/04/03 21:56:25 WARN TaskSetManager: Stage 833 contains a task of very large size (5405 KB). The maximum recommended task size is 100 KB.
```

Out[34]:
```
0.5672988566234932
```

In [35]:
```
# BINARY EVALUATION - TEST SET - 2017,2019,2021
# Evaluating 2019 Model on Test Set

evaluator.evaluate(prediction_test2)
```

```
22/04/03 21:56:28 WARN TaskSetManager: Stage 842 contains a task of very large size (4850 KB). The maximum recommended task size is 100 KB.
```

Out[35]:
```
0.5680089480823365
```

In [36]:
```
# BINARY EVALUATION - TEST SET - 2017,2019,2021
# Evaluating 2021 Model on Test Set

evaluator.evaluate(prediction_test3)
```

```
22/04/03 21:56:31 WARN TaskSetManager: Stage 851 contains a task of very large size (3197 KB). The maximum recommended task size is 100 KB.
```

Out[36]:
```
0.5378016180812005
```

Step 4: Final Model Choice - Random Forest Classifier with Categorical and Numerical Features

Finally, using a combination of numerical and categorical features, three pipelines were defined for the 2017, 2019, and 2021 datasets. As mentioned above, the algorithm chosen for this step was the Spark implementation of the Random Forest Classifier using a 80/20 Train-Test split. Gradient Boosted Trees were also tested as part of the model definition step before Random Forest, but because my code and output were overwritten, I chose to exclude them from this report.

In terms of implementation of the RF Models, 33 total features were included as inputs:
danceability,energy,loudness,mode,speechiness,acousticness,instrumentalness,liveness,valence,tempo,duration_ms,explicit,has_feature,multigenre,key,time_signature,artistname,albumtype,featuredartist,featuredartist2,featuredartist3,primary_genre,secondary_genre,genre3,genre4,genre5,genre6,genre7,genre8,genre9,genre10,

The categorical features were passed through "StringIndexers" to make them processable, but they did not need to be subsequently One Hot Encoded because Spark's implementation of Random Forest uses metadata to keep track of categorical variables vs numerical ones.

We can see the performance of the final baseline RF models below:
2017 Train: 86.0%
2017 Test: 85.9%
2019 Train: 83.7%
2019 Test: 83.2%
2021 Train: 84.5%
2021 Test: 84.4%

As we can see once again, there is no overfitting.

```
In [22]: # RF - Final Model Choice for Model Definition - 80/20 Split

         # Imports

         from pyspark.ml.feature import VectorAssembler, StringIndexer, VectorIndexer, MinMaxScaler
         from pyspark.ml import Pipeline
         from pyspark.ml.evaluation import BinaryClassificationEvaluator
         from pyspark.ml.classification import RandomForestClassifier
         from pyspark.ml.linalg import Vectors

         # Label Choice

         labelchoice = 'binary_performance_bin'

         # Data Split

         df1 = df_data_1[['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre','key','time_signature','artistname','albumtype','featuredartist','featuredar
         df2 = df_data_2[['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre','key','time_signature','artistname','albumtype','featuredartist','featuredar
         df3 = df_data_3[['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','tempo','duration_ms','explicit','has_feature','multigenre','key','time_signature','artistname','albumtype','featuredartist','featuredar

         df_spark_1 = spark.createDataFrame(df1)
         df_spark_2 = spark.createDataFrame(df2)
         df_spark_3 = spark.createDataFrame(df3)

         train1, test1 = df_spark_1.randomSplit([0.8, 0.2])
         train2, test2 = df_spark_2.randomSplit([0.8, 0.2])
         train3, test3 = df_spark_3.randomSplit([0.8, 0.2])

         # Pipeline Definitions

         # Indexing Label

         indexer = StringIndexer(inputCol=labelchoice, outputCol="label", stringOrderType="frequencyDesc")

         # Indexing Non-Numerical Features

         indexer1 = StringIndexer(inputCol='key', outputCol="key_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer2 = StringIndexer(inputCol='time_signature', outputCol="timesig_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer3 = StringIndexer(inputCol='artistname', outputCol="artistname_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer4 = StringIndexer(inputCol='albumtype', outputCol="albumtype_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer6 = StringIndexer(inputCol='featuredartist', outputCol="featuredartist_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer7 = StringIndexer(inputCol='featuredartist2', outputCol="featuredartist2_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer8 = StringIndexer(inputCol='featuredartist3', outputCol="featuredartist3_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer9 = StringIndexer(inputCol='primary_genre', outputCol="primary_genre_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer10 = StringIndexer(inputCol='secondary_genre', outputCol="secondary_genre_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer11 = StringIndexer(inputCol='genre3', outputCol="genre3_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer12 = StringIndexer(inputCol='genre4', outputCol="genre4_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer13 = StringIndexer(inputCol='genre5', outputCol="genre5_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer14 = StringIndexer(inputCol='genre6', outputCol="genre6_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer15 = StringIndexer(inputCol='genre7', outputCol="genre7_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer16 = StringIndexer(inputCol='genre8', outputCol="genre8_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer17 = StringIndexer(inputCol='genre9', outputCol="genre9_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer18 = StringIndexer(inputCol='genre10', outputCol="genre10_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer19 = StringIndexer(inputCol='genre11', outputCol="genre11_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')
         indexer20 = StringIndexer(inputCol='genre12', outputCol="genre12_indexed", stringOrderType="frequencyDesc", handleInvalid='keep')

         # Feature Scaling

         vectAssem1 = VectorAssembler(inputCols=['tempo'], outputCol="tempoassem")
         vectAssem2 = VectorAssembler(inputCols=['duration_ms'], outputCol="durationassem")

         normalizer1 = MinMaxScaler(inputCol="tempoassem", outputCol="scaled_tempo")

         normalizer2 = MinMaxScaler(inputCol="durationassem", outputCol="scaled_duration")

         # Final Vector Assembly

         finalVectorAssembler = VectorAssembler(inputCols=['danceability','energy','loudness','mode','speechiness','acousticness','instrumentalness','liveness','valence','scaled_tempo','scaled_duration','explicit','has_feature','multigenre','key_indexed','timesig_indexed',

         # Define Random Forest

         rf1 = RandomForestClassifier(labelCol="label", featuresCol="features", numTrees=400, maxDepth=8,maxBins=1000)
         rf2 = RandomForestClassifier(labelCol="label", featuresCol="features", numTrees=400, maxDepth=8,maxBins=1000)
         rf3 = RandomForestClassifier(labelCol="label", featuresCol="features", numTrees=400, maxDepth=8,maxBins=1000)

         # Create Pipelines
         pipeline1 = Pipeline(stages=[indexer,indexer1,indexer2,indexer3,indexer4,indexer6,indexer7,indexer8,indexer9,indexer10,indexer11,indexer12,indexer13,indexer14,indexer15,indexer16,indexer17,indexer18,indexer19,indexer20,vectAssem1,vectAssem2,normalizer1,normalizer2
         pipeline2 = Pipeline(stages=[indexer,indexer1,indexer2,indexer3,indexer4,indexer6,indexer7,indexer8,indexer9,indexer10,indexer11,indexer12,indexer13,indexer14,indexer15,indexer16,indexer17,indexer18,indexer19,indexer20,vectAssem1,vectAssem2,normalizer1,normalizer2
         pipeline3 = Pipeline(stages=[indexer,indexer1,indexer2,indexer3,indexer4,indexer6,indexer7,indexer8,indexer9,indexer10,indexer11,indexer12,indexer13,indexer14,indexer15,indexer16,indexer17,indexer18,indexer19,indexer20,vectAssem1,vectAssem2,normalizer1,normalizer2

         # Fit Pipelines
         model1 = pipeline1.fit(train1)
         print(model1.stages[-1])

         model2 = pipeline2.fit(train2)
         print(model2.stages[-1])

         model3 = pipeline3.fit(train3)
         print(model3.stages[-1])

         # Run Models

         prediction1 = model1.transform(train1)
         prediction2 = model2.transform(train2)
         prediction3 = model3.transform(train3)

         # Evaluating 2017 Model on Training Set

         evaluator = BinaryClassificationEvaluator(rawPredictionCol="rawPrediction")
         evaluator.evaluate(prediction1)
```

```
22/04/03 21:36:17 WARN TaskSetManager: Stage 288 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:23 WARN TaskSetManager: Stage 290 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:25 WARN TaskSetManager: Stage 292 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:28 WARN TaskSetManager: Stage 294 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:31 WARN TaskSetManager: Stage 296 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:35 WARN TaskSetManager: Stage 298 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:39 WARN TaskSetManager: Stage 300 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:43 WARN TaskSetManager: Stage 302 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:47 WARN TaskSetManager: Stage 304 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:51 WARN TaskSetManager: Stage 306 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:36:56 WARN TaskSetManager: Stage 308 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:00 WARN TaskSetManager: Stage 310 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:05 WARN TaskSetManager: Stage 312 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:09 WARN TaskSetManager: Stage 314 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:14 WARN TaskSetManager: Stage 316 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:17 WARN TaskSetManager: Stage 318 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:21 WARN TaskSetManager: Stage 320 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:24 WARN TaskSetManager: Stage 322 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:27 WARN TaskSetManager: Stage 324 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:28 WARN TaskSetManager: Stage 326 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:30 WARN TaskSetManager: Stage 328 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:32 WARN TaskSetManager: Stage 329 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:35 WARN TaskSetManager: Stage 330 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:40 WARN TaskSetManager: Stage 331 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:42 WARN TaskSetManager: Stage 332 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:49 WARN TaskSetManager: Stage 333 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:37:57 WARN TaskSetManager: Stage 335 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:38:21 WARN TaskSetManager: Stage 337 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:38:30 WARN TaskSetManager: Stage 339 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:38:43 WARN TaskSetManager: Stage 341 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:39:09 WARN TaskSetManager: Stage 343 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:39:37 WARN TaskSetManager: Stage 345 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:40:08 WARN TaskSetManager: Stage 347 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:40:47 WARN TaskSetManager: Stage 349 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:22 WARN TaskSetManager: Stage 351 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:33 WARN TaskSetManager: Stage 353 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.


RandomForestClassificationModel (uid=RandomForestClassifier_5022993e932d) with 400 trees

22/04/03 21:41:34 WARN TaskSetManager: Stage 354 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:36 WARN TaskSetManager: Stage 356 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:37 WARN TaskSetManager: Stage 358 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:41 WARN TaskSetManager: Stage 360 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:43 WARN TaskSetManager: Stage 362 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:44 WARN TaskSetManager: Stage 364 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:46 WARN TaskSetManager: Stage 366 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:48 WARN TaskSetManager: Stage 368 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:50 WARN TaskSetManager: Stage 370 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:51 WARN TaskSetManager: Stage 372 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:53 WARN TaskSetManager: Stage 374 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:54 WARN TaskSetManager: Stage 376 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:56 WARN TaskSetManager: Stage 378 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:58 WARN TaskSetManager: Stage 380 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:41:59 WARN TaskSetManager: Stage 382 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:01 WARN TaskSetManager: Stage 384 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:02 WARN TaskSetManager: Stage 386 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:04 WARN TaskSetManager: Stage 388 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:05 WARN TaskSetManager: Stage 390 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:07 WARN TaskSetManager: Stage 392 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:10 WARN TaskSetManager: Stage 394 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:12 WARN TaskSetManager: Stage 395 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:15 WARN TaskSetManager: Stage 396 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:17 WARN TaskSetManager: Stage 397 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:18 WARN TaskSetManager: Stage 398 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:23 WARN TaskSetManager: Stage 399 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:28 WARN TaskSetManager: Stage 401 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:37 WARN TaskSetManager: Stage 403 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:43 WARN TaskSetManager: Stage 405 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:42:54 WARN TaskSetManager: Stage 407 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:43:10 WARN TaskSetManager: Stage 409 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:43:34 WARN TaskSetManager: Stage 411 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:44:06 WARN TaskSetManager: Stage 413 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:44:43 WARN TaskSetManager: Stage 415 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
[Stage 417:>                                                        (0 + 0) / 1]22/04/03 21:45:22 WARN TaskSetManager: Stage 417 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:45:44 WARN TaskSetManager: Stage 419 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:45:53 WARN TaskSetManager: Stage 421 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.


RandomForestClassificationModel (uid=RandomForestClassifier_1733cada3f4e) with 400 trees
```

```
22/04/03 21:45:55 WARN TaskSetManager: Stage 422 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:03 WARN TaskSetManager: Stage 424 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:04 WARN TaskSetManager: Stage 426 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:06 WARN TaskSetManager: Stage 428 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:07 WARN TaskSetManager: Stage 430 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:09 WARN TaskSetManager: Stage 432 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:10 WARN TaskSetManager: Stage 434 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:12 WARN TaskSetManager: Stage 436 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:13 WARN TaskSetManager: Stage 438 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:15 WARN TaskSetManager: Stage 440 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:17 WARN TaskSetManager: Stage 442 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:18 WARN TaskSetManager: Stage 444 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:20 WARN TaskSetManager: Stage 446 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:21 WARN TaskSetManager: Stage 448 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:23 WARN TaskSetManager: Stage 450 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:25 WARN TaskSetManager: Stage 452 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:26 WARN TaskSetManager: Stage 454 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:27 WARN TaskSetManager: Stage 456 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:28 WARN TaskSetManager: Stage 458 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:29 WARN TaskSetManager: Stage 460 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:31 WARN TaskSetManager: Stage 462 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:32 WARN TaskSetManager: Stage 463 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:34 WARN TaskSetManager: Stage 464 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:37 WARN TaskSetManager: Stage 465 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:38 WARN TaskSetManager: Stage 466 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:42 WARN TaskSetManager: Stage 467 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:46 WARN TaskSetManager: Stage 469 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:46:57 WARN TaskSetManager: Stage 471 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:47:03 WARN TaskSetManager: Stage 473 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:47:11 WARN TaskSetManager: Stage 475 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:47:24 WARN TaskSetManager: Stage 477 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:47:44 WARN TaskSetManager: Stage 479 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:48:12 WARN TaskSetManager: Stage 481 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:48:44 WARN TaskSetManager: Stage 483 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:49:11 WARN TaskSetManager: Stage 485 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:49:37 WARN TaskSetManager: Stage 487 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:49:47 WARN TaskSetManager: Stage 489 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.


RandomForestClassificationModel (uid=RandomForestClassifier_d80f3ec6b342) with 400 trees

22/04/03 21:49:50 WARN TaskSetManager: Stage 490 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:49:54 WARN TaskSetManager: Stage 491 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:49:56 WARN TaskSetManager: Stage 492 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:49:59 WARN TaskSetManager: Stage 493 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
```

```
Out[22]: 0.8600722323435794
```

```
In [23]: # Evaluating 2019 Model on Training Set

         evaluator.evaluate(prediction2)
```

```
22/04/03 21:50:29 WARN TaskSetManager: Stage 502 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
```

```
Out[23]: 0.8365554439586363
```

```
In [24]: # Evaluating 2021 Model on Training Set

         evaluator.evaluate(prediction3)
```

```
22/04/03 21:50:48 WARN TaskSetManager: Stage 511 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
```

```
Out[24]: 0.8450662006472492
```

```
In [25]: # BINARY EVALUATION - 2017,2019,2021 - Test Set
         prediction_test1 = model1.transform(test1)
         prediction_test2 = model2.transform(test2)
         prediction_test3 = model3.transform(test3)

         # Evaluating 2017 Model on Test Set
         evaluator = BinaryClassificationEvaluator(rawPredictionCol="rawPrediction")
         evaluator.evaluate(prediction_test1)
```

```
22/04/03 21:51:03 WARN TaskSetManager: Stage 520 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
22/04/03 21:51:05 WARN TaskSetManager: Stage 521 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
22/04/03 21:51:09 WARN TaskSetManager: Stage 522 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
22/04/03 21:51:12 WARN TaskSetManager: Stage 523 contains a task of very large size (7312 KB). The maximum recommended task size is 100 KB.
```

```
Out[25]: 0.8589977526802675
```

```
In [26]: # Evaluating 2019 Model on Test Set

         evaluator.evaluate(prediction_test2)
```

```
22/04/03 21:51:21 WARN TaskSetManager: Stage 532 contains a task of very large size (6546 KB). The maximum recommended task size is 100 KB.
```

```
Out[26]: 0.8316436378721492
```

```
In [27]: # Evaluating 2021 Model on Test Set

         evaluator.evaluate(prediction_test3)
```

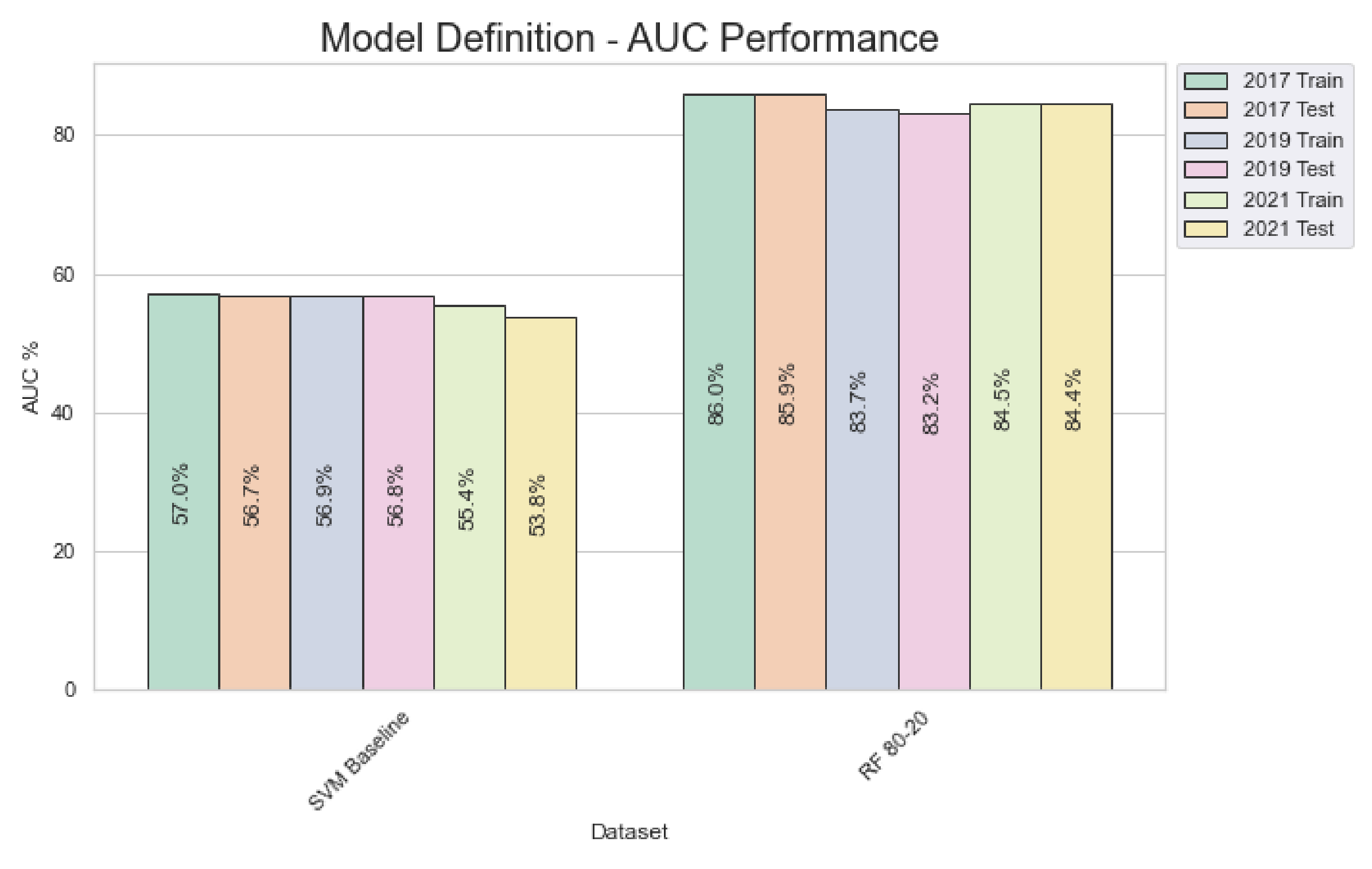
```
22/04/03 21:51:29 WARN TaskSetManager: Stage 541 contains a task of very large size (4506 KB). The maximum recommended task size is 100 KB.
```

```
Out[27]: 0.8443746918954548
```

Visualization of Model Performance at Model Definition Stage

With the Model Definition stage now complete, below we can see a visualization of the relative performances of the SVM and RF (80/20) models across the three datasets (2017,2019,2021).

```
In [3]: # Visualization of Model Definition Performance - 2017,2019,2021

        import pandas as pd
        import seaborn as sns
        import matplotlib.pyplot as plt

        dfvis = pd.DataFrame({'Dataset': ['2017 Train','2017 Test','2017 Train','2017 Test','2019 Train','2019 Test','2019 Train','2019 Test','2021 Train','2021 Test','2021 Train','2021 Test'],
                           'Model': ['SVM Baseline','SVM Baseline','RF 80-20','RF 80-20','SVM Baseline','SVM Baseline','RF 80-20','RF 80-20','SVM Baseline','SVM Baseline','RF 80-20','RF 80-20'],
                           'Score': [57.0,56.7,86.0,85.9,56.9,56.8,83.7,83.2,55.4,53.8,84.5,84.4],
                           })
        # Seaborn Style
        sns.set(style='whitegrid')

        # Grouped Bar Chart
        ax = sns.barplot(x='Model', y='Score', hue='Dataset', data=dfvis, palette='Pastel2', edgecolor='0.2')

        sns.set(rc={"figure.figsize":(10, 6)})

        # Add Chart Title
        plt.title('Model Definition - AUC Performance', fontsize=20)

        # Axis Titles
        plt.xlabel('Dataset')
        plt.ylabel('AUC %')
        plt.legend(bbox_to_anchor=(1.01, 1), loc='upper left', borderaxespad=0)

        # Rotate Axis Labels
        plt.xticks(rotation=45)

        # Bar Labels
        for container in ax.containers:
            ax.bar_label(container, fmt='%.1f%%',label_type='center',rotation=90)
```



Model Definition Stage Complete

In the next and final Jupyter notebook, we will see the final Training and Evaluation steps of the project using the final RF model (70/30 split) and a Neural Network based Perceptron classifier as a deep learning approach.