```
!sudo apt update
!apt-get install openjdk-8-jdk-headless -qq > /dev/null
!wget -q https://dlcdn.apache.org/spark/spark-3.3.1/spark-3.3.1-bin-hadoop3.tgz
```

```
    Get:1 https://cloud.r-project.org/bin/linux/ubuntu focal-cran40/ InRelease [3,622 B]
    Ign:2 https://developer.download.nvidia.com/compute/machine-learning/repos/ubuntu2004/x86_64  InRelease
    Hit:3 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2004/x86_64  InRelease
    Hit:4 https://developer.download.nvidia.com/compute/machine-learning/repos/ubuntu2004/x86_64  Release
    Get:5 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu focal InRelease [18.1 kB]
    Get:6 http://security.ubuntu.com/ubuntu focal-security InRelease [114 kB]
    Hit:7 http://archive.ubuntu.com/ubuntu focal InRelease
    Get:8 http://archive.ubuntu.com/ubuntu focal-updates InRelease [114 kB]
    Hit:9 http://ppa.launchpad.net/cran/libgit2/ubuntu focal InRelease
    Get:10 https://cloud.r-project.org/bin/linux/ubuntu focal-cran40/ Packages [71.1 kB]
    Hit:11 http://ppa.launchpad.net/deadsnakes/ppa/ubuntu focal InRelease
    Get:12 http://archive.ubuntu.com/ubuntu focal-backports InRelease [108 kB]
    Hit:14 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu focal InRelease
    Get:15 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu focal/main Sources [2,381 kB]
    Get:16 http://archive.ubuntu.com/ubuntu focal-updates/universe amd64 Packages [1,291 kB]
    Get:17 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 Packages [2,921 kB]
    Get:18 http://ppa.launchpad.net/c2d4u.team/c2d4u4.0+/ubuntu focal/main amd64 Packages [1,128 kB]
    Fetched 8,150 kB in 4s (2,270 kB/s)
    Reading package lists... Done
    Building dependency tree
    Reading state information... Done
    29 packages can be upgraded. Run 'apt list --upgradable' to see them.
```

```
!tar xf spark-3.3.1-bin-hadoop3.tgz
!pip install -q findspark
!pip install pyspark
```

```
    Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
    Collecting pyspark
      Downloading pyspark-3.3.1.tar.gz (281.4 MB)
         ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 281.4/281.4 MB 4.6 MB/s eta 0:00:00
      Preparing metadata (setup.py) ... done
    Collecting py4j==0.10.9.5
      Downloading py4j-0.10.9.5-py2.py3-none-any.whl (199 kB)
         ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 199.7/199.7 KB 20.0 MB/s eta 0:00:00
    Building wheels for collected packages: pyspark
      Building wheel for pyspark (setup.py) ... done
      Created wheel for pyspark: filename=pyspark-3.3.1-py2.py3-none-any.whl size=281845512 sha256=76036277844fabfd3e340fdc62515232b0da
      Stored in directory: /root/.cache/pip/wheels/43/dc/11/ec201cd671da62fa9c5cc77078235e40722170ceba231d7598
    Successfully built pyspark
    Installing collected packages: py4j, pyspark
    Successfully installed py4j-0.10.9.5 pyspark-3.3.1
```

```
import os
os.environ["JAVA_HOME"] = "/usr/lib/jvm/java-8-openjdk-amd64"
os.environ["SPARK_HOME"] = "/content/spark-3.3.1-bin-hadoop3"
```

```
import findspark
findspark.init()
findspark.find()
```

```
    '/content/spark-3.3.1-bin-hadoop3'
```

```
from pyspark.sql import DataFrame, SparkSession
from typing import List
import pyspark.sql.types as T
import pyspark.sql.functions as F
from pyspark.sql.functions import isnull, when, count, col, isnan
from pyspark import SparkFiles
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd

spark = SparkSession.builder \
        .master('local') \
        .appName("NY Parking Violation") \
        .config("spark.sql.adaptive.enabled","true") \
        .config("spark.executor.memory","10g") \
        .config("spark.driver.memory","10g") \
        .getOrCreate()
spark
```

SparkSession - in-memory

SparkContext

Spark UI

Version
    v3.3.1
Master

```
from google.colab import files
uploaded = files.upload()
```

Choose Files No file chosen Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable.
Saving PV.00002.csv to PV.00002.csv

```
## ensure to use the link of the raw file of the csv
# url = "https://data.cityofnewyork.us/api/views/pvqr-7yc4/rows.csv"


# spark.sparkContext.addFile(url)


# df = spark.read.csv(SparkFiles.get("rows.csv"),inferSchema=True, header= True)


df = spark.read.csv("/content/PV.00001.csv",inferSchema=True, header=True)


df.count(),len(df.columns)
```

```
(100000, 51)
```

```
df.printSchema()
```

```
root
 |-- Summons Number: long (nullable = true)
 |-- Plate ID: string (nullable = true)
 |-- Registration State: string (nullable = true)
 |-- Plate Type: string (nullable = true)
 |-- Issue Date: string (nullable = true)
 |-- Violation Code: integer (nullable = true)
 |-- Vehicle Body Type: string (nullable = true)
 |-- Vehicle Make: string (nullable = true)
 |-- Issuing Agency: string (nullable = true)
 |-- Street Code1: integer (nullable = true)
 |-- Street Code2: integer (nullable = true)
 |-- Street Code3: integer (nullable = true)
 |-- Vehicle Expiration Date: integer (nullable = true)
 |-- Violation Location: integer (nullable = true)
 |-- Violation Precinct: integer (nullable = true)
 |-- Issuer Precinct: integer (nullable = true)
 |-- Issuer Code: integer (nullable = true)
 |-- Issuer Command: string (nullable = true)
 |-- Issuer Squad: string (nullable = true)
 |-- Violation Time: string (nullable = true)
 |-- Time First Observed: string (nullable = true)
 |-- Violation County: string (nullable = true)
 |-- Violation In Front Of Or Opposite: string (nullable = true)
 |-- House Number: string (nullable = true)
 |-- Street Name: string (nullable = true)
 |-- Intersecting Street: string (nullable = true)
 |-- Date First Observed: integer (nullable = true)
 |-- Law Section: integer (nullable = true)
 |-- Sub Division: string (nullable = true)
 |-- Violation Legal Code: string (nullable = true)
 |-- Days Parking In Effect    : string (nullable = true)
 |-- From Hours In Effect: string (nullable = true)
 |-- To Hours In Effect: string (nullable = true)
 |-- Vehicle Color: string (nullable = true)
 |-- Unregistered Vehicle?: integer (nullable = true)
 |-- Vehicle Year: integer (nullable = true)
 |-- Meter Number: string (nullable = true)
 |-- Feet From Curb: integer (nullable = true)
 |-- Violation Post Code: string (nullable = true)
 |-- Violation Description: string (nullable = true)
 |-- No Standing or Stopping Violation: string (nullable = true)
 |-- Hydrant Violation: string (nullable = true)
 |-- Double Parking Violation: string (nullable = true)
 |-- Latitude: string (nullable = true)
 |-- Longitude: string (nullable = true)
 |-- Community Board: string (nullable = true)
 |-- Community Council : string (nullable = true)
 |-- Census Tract: string (nullable = true)
 |-- BIN: string (nullable = true)
 |-- BBL: string (nullable = true)
 |-- NTA: string (nullable = true)
```

Analyze and preprocess the data

```
# Remove all columns which have more than 70% null values

null_threshold = 0.70
columns_valid = [x for x in df.columns if df.filter(F.col(x).isNull()).count()/df.count() < null_threshold]
df = df.select(*columns_valid)
df.count(), len(df.columns)
```

```
(100000, 37)
```

```
df.printSchema()
```

```
root
 |-- Summons Number: long (nullable = true)
 |-- Plate ID: string (nullable = true)
 |-- Registration State: string (nullable = true)
 |-- Plate Type: string (nullable = true)
 |-- Issue Date: string (nullable = true)
 |-- Violation Code: integer (nullable = true)
 |-- Vehicle Body Type: string (nullable = true)
 |-- Vehicle Make: string (nullable = true)
 |-- Issuing Agency: string (nullable = true)
 |-- Street Code1: integer (nullable = true)
 |-- Street Code2: integer (nullable = true)
 |-- Street Code3: integer (nullable = true)
 |-- Vehicle Expiration Date: integer (nullable = true)
 |-- Violation Location: integer (nullable = true)
 |-- Violation Precinct: integer (nullable = true)
 |-- Issuer Precinct: integer (nullable = true)
 |-- Issuer Code: integer (nullable = true)
 |-- Issuer Command: string (nullable = true)
 |-- Issuer Squad: string (nullable = true)
 |-- Violation Time: string (nullable = true)
 |-- Violation County: string (nullable = true)
 |-- Violation In Front Of Or Opposite: string (nullable = true)
 |-- House Number: string (nullable = true)
 |-- Street Name: string (nullable = true)
 |-- Intersecting Street: string (nullable = true)
 |-- Date First Observed: integer (nullable = true)
 |-- Law Section: integer (nullable = true)
 |-- Sub Division: string (nullable = true)
 |-- Days Parking In Effect    : string (nullable = true)
 |-- From Hours In Effect: string (nullable = true)
 |-- To Hours In Effect: string (nullable = true)
 |-- Vehicle Color: string (nullable = true)
 |-- Unregistered Vehicle?: integer (nullable = true)
 |-- Vehicle Year: integer (nullable = true)
 |-- Meter Number: string (nullable = true)
 |-- Feet From Curb: integer (nullable = true)
 |-- Violation Description: string (nullable = true)
```

```
columns_selected = ["Registration State","Plate Type",\
                "Violation Code", "Vehicle Body Type","Vehicle Make","Issuing Agency", "Street Code1", \
               "Street Code2","Street Code3","Violation Location","Violation Precinct", \
               "Issuer Precinct","Issuer Code","Issuer Command",\
               "Violation County","Law Section","Sub Division","Vehicle Color"]
```

```
# removed the Violation_Legal_Code, summons_number , plate_id as it has same values
df = df.select(columns_selected)
```

```
# clean up the data as many have incorrect values.
df = df[(df['Registration State'] != "99") & (df['Plate Type'] != "999") \
        & (df['Violation Code'] != 0)]
```

```
# Check if the null value still exist
df.select([count(when(isnull(c), c)).alias(c) for c in df.columns]).show()
```

```
+------------------+----------+--------------+-----------------+------------+--------------+------------+------------+------------+
|Registration State|Plate Type|Violation Code|Vehicle Body Type|Vehicle Make|Issuing Agency|Street Code1|Street Code2|Street Code3|
+------------------+----------+--------------+-----------------+------------+--------------+------------+------------+------------+
|                 0|         0|             0|             4928|        3237|             0|           0|           0|           0|
+------------------+----------+--------------+-----------------+------------+--------------+------------+------------+------------+
```

```
df.toPandas().nunique()
```

```
Registration State      60
Plate Type              46
Violation Code          90
Vehicle Body Type      336
Vehicle Make           731
Issuing Agency          12
Street Code1          3422
Street Code2          3719
Street Code3          3648
Violation Location     135
Violation Precinct     136
Issuer Precinct        277
Issuer Code          10952
Issuer Command         602
Violation County         7
Law Section              2
Sub Division           122
Vehicle Color          489
dtype: int64
```

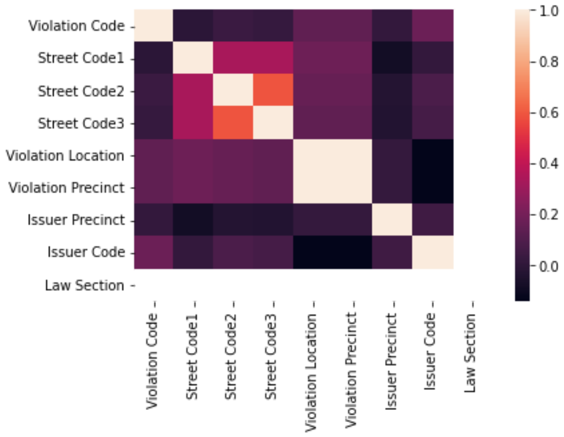
```
df = df.na.drop()
```

```
df.dropDuplicates()
```

```
DataFrame[Registration State: string, Plate Type: string, Violation Code: int, Vehicle Body Type: string, Vehicle Make: string,
Issuing Agency: string, Street Code1: int, Street Code2: int, Street Code3: int, Violation Location: int, Violation Precinct: int,
Issuer Precinct: int, Issuer Code: int, Issuer Command: string, Violation County: string, Law Section: int, Sub Division: string,
Vehicle Color: string]
```

```
sns.heatmap(df.toPandas().corr())
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f4e466aa550>
```

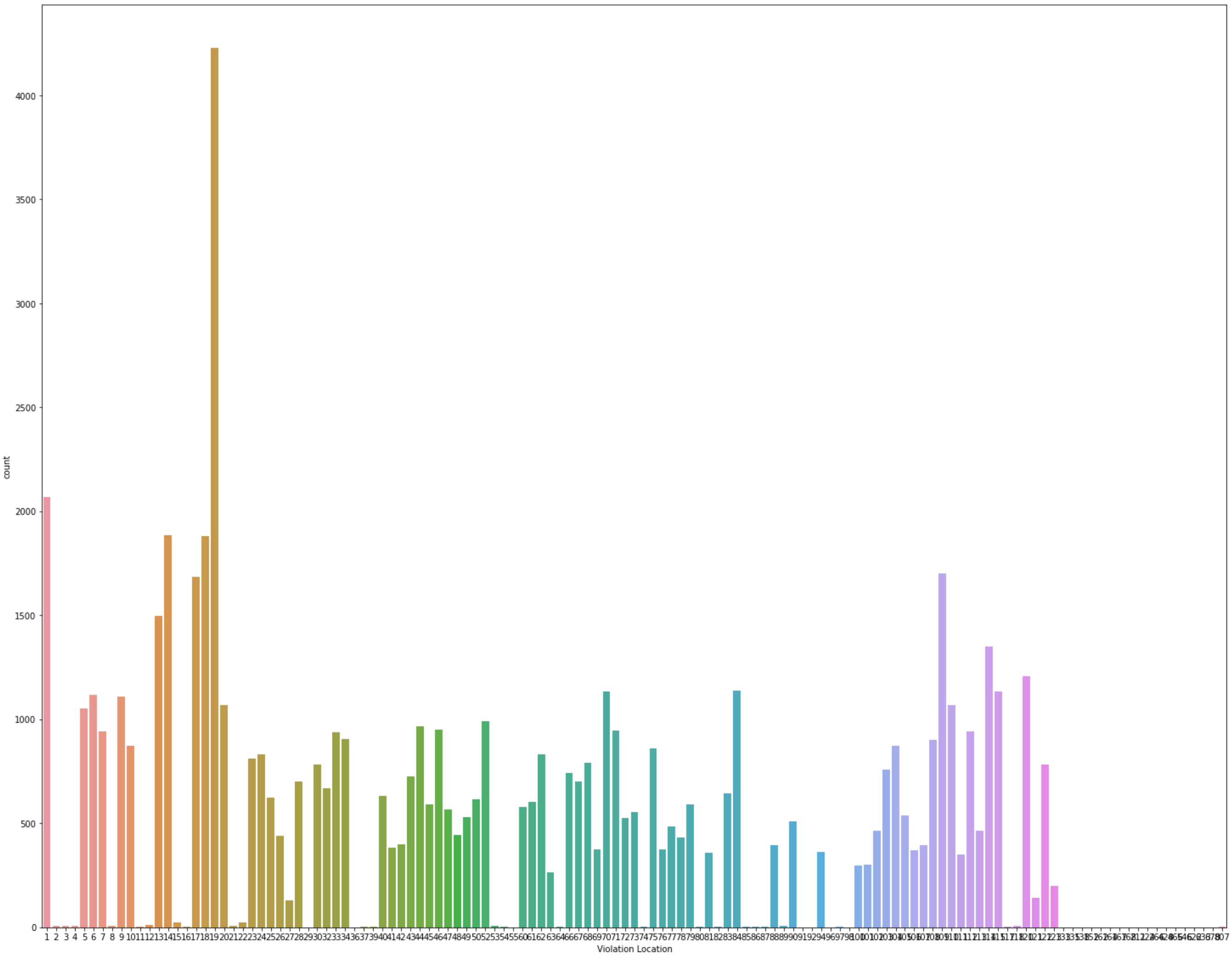


```
# check how labels are ditributed
df.toPandas()['Violation Location'].value_counts()
```

```
19     4227
1      2070
14     1884
18     1883
109    1700
       ...
678       1
92        1
152       1
138       1
162       1
Name: Violation Location, Length: 127, dtype: int64
```

```
df.createOrReplaceTempView("nyc")
```

```
violation_table = df.groupBy('Violation Location').count()
fig = plt.figure(figsize =(25, 20))
sns.barplot(x='Violation Location',y='count',data=violation_table.toPandas())
plt.show()
```



```
# from pyspark.sql.functions import *
# df=df.withColumn("IssueDate", to_timestamp(col("Issue_Date")))
# type(df)


from pyspark.sql.types import StringType,DoubleType

cols = [F.col(field[0]).cast('double') if (field[1] == 'int') else F.col(field[0]) for field in df.dtypes]
df = df.select(cols)
df.printSchema()
```

```
root
 |-- Registration State: string (nullable = true)
 |-- Plate Type: string (nullable = true)
 |-- Violation Code: double (nullable = true)
 |-- Vehicle Body Type: string (nullable = true)
 |-- Vehicle Make: string (nullable = true)
 |-- Issuing Agency: string (nullable = true)
 |-- Street Code1: double (nullable = true)
 |-- Street Code2: double (nullable = true)
 |-- Street Code3: double (nullable = true)
 |-- Violation Location: double (nullable = true)
 |-- Violation Precinct: double (nullable = true)
 |-- Issuer Precinct: double (nullable = true)
 |-- Issuer Code: double (nullable = true)
 |-- Issuer Command: string (nullable = true)
 |-- Violation County: string (nullable = true)
 |-- Law Section: double (nullable = true)
 |-- Sub Division: string (nullable = true)
 |-- Vehicle Color: string (nullable = true)
```

```
label_count=len(df.select('Violation Location').distinct().collect())
print(label_count)
```

```
127
```

Convert categorical data to numerical then to vector assemle the data for ML lib

```
# Split the data into categorical and continuos to use it pipeline
cat_columns = [x for (x, dataType) in df.dtypes if dataType == 'string']
num_columns = [x for (x, dataType) in df.dtypes if ((dataType != 'string') & (x != 'Violation_Location'))]
```

```
# convert categorical to string indexer then to one hot encoder using pipeline
from pyspark.ml.feature import StringIndexer
from pyspark.ml.feature import OneHotEncoder
from pyspark.ml.feature import VectorAssembler
from pyspark.ml.feature import MinMaxScaler
from pyspark.ml import Pipeline
from pyspark.ml import PipelineModel

#1. Convert to string indexer
indexers = [ StringIndexer(inputCol=c,  handleInvalid="skip",outputCol="{0}_indexed".format(c)) for c in cat_columns ]


#2. Convert to OnehotEncoder
encoders = [ OneHotEncoder(
                inputCol=indexer.getOutputCol(),
                outputCol="{0}_encoded".format(indexer.getOutputCol()))
             for indexer in indexers ]


#3. Assembler
assembler = VectorAssembler(inputCols=[encoder.getOutputCol() for encoder in encoders]
                            + num_columns, outputCol="features_vect")
## MinMax Scalar
scaler = MinMaxScaler(inputCol="features_vect", outputCol="features_scaled")

pipeline = Pipeline(stages=indexers + encoders+ [assembler]+[scaler])

pipeline_model = pipeline.fit(df)
# save the model for fitting the data for prediction
pipeline_model.save("va_model")

df = pipeline_model.transform(df)
```

Note that above data transformation pipeline is saved as model to transform the new data for prediction

```
# There are more labels than standard multi label classifier support to predict. So lets index the label.
label_indexer = StringIndexer(inputCol="Violation Location", outputCol="VL_indexed")
label_indexers_model = label_indexer.fit(df)
df= label_indexers_model.transform(df)
```

+ Code + Text

```
# Display the features column to check whether its dense or sparse vector
df.select("features_scaled","VL_indexed").show(3)
```

```
+--------------------+----------+
|     features_scaled|VL_indexed|
+--------------------+----------+
|(1926,[0,60,99,30...|      23.0|
|(1926,[0,60,99,30...|      23.0|
|(1926,[0,60,104,3...|      23.0|
+--------------------+----------+
only showing top 3 rows
```

```
# from pyspark.ml.linalg import Vectors, VectorUDT

# # define function to convert parse to dense vector
# sparseToDense = F.udf(lambda v : Vectors.dense(v), VectorUDT())

# densefeatureDF = df.withColumn('dense_features', sparseToDense('features_scaled'))

# densefeatureDF.select("features_scaled", "dense_features").show(1)


data = df.select(F.col("features_scaled").alias("features"),
                          F.col("VL indexed").alias("label"))
```

```
# cache and persist
from pyspark import StorageLevel

# persist the dataframe in both memo
persist_data = data.persist(StorageLevel.MEMORY_AND_DISK)


trainDF, testDF =  persist_data.randomSplit([0.7,0.3], seed = 2642)


from pyspark.ml.classification import RandomForestClassifier
from pyspark.ml.evaluation import MulticlassClassificationEvaluator
from pyspark.ml.tuning import ParamGridBuilder, TrainValidationSplit

# rf_model = RandomForestClassifier(featuresCol='features', labelCol='label',
#                       predictionCol='prediction',maxDepth=30,
#                       impurity='gini', subsamplingRate= .5).fit(trainDF)
# pred = rf_model.transform(testDF)
# pred.show(3)

rf = RandomForestClassifier(featuresCol='features', labelCol='label',
                    predictionCol='prediction', impurity='gini')

paramGrid = ParamGridBuilder()\
    .addGrid(rf.maxDepth, [30]) \
    .addGrid(rf.subsamplingRate, [0.1, 0.5])\
    .addGrid(rf.numTrees, [20,40])\
    .build()

evaluator=MulticlassClassificationEvaluator(predictionCol="prediction")

rf_tvs = TrainValidationSplit(estimator=rf,
                           estimatorParamMaps=paramGrid,
                           evaluator=evaluator,
                           # 80% of the data will be used for training, 20% for validation.
                           trainRatio=0.8)
rf_tvs_model = rf_tvs.fit(trainDF)
rf_predictonDF = rf_tvs_model.transform(testDF)
acc = evaluator.evaluate(rf_predictonDF)
print("Prediction Accuracy: ", acc)
rf_predictonDF.select("features","label", "prediction").show(5)
```

```
Prediction Accuracy:  0.8608196539256541
+--------------------+-----+----------+
|            features|label|prediction|
+--------------------+-----+----------+
|(1926,[0,59,98,30...|  0.0|       0.0|
|(1926,[0,59,98,30...| 24.0|      24.0|
|(1926,[0,59,98,30...| 34.0|      40.0|
|(1926,[0,59,98,30...| 23.0|      24.0|
|(1926,[0,59,98,30...| 24.0|      23.0|
+--------------------+-----+----------+
only showing top 5 rows
```

```
from pyspark.ml.feature import IndexToString
from pyspark.sql.types import DoubleType
from pyspark.ml import PipelineModel
import os

dirname = os.getcwd()
print('path=',dirname)
# get the best model and save it
lr_model = rf_tvs_model.bestModel
filename = "rf_model"
model_path= os.path.join(dirname, filename)
print(model_path)
# Index to String converter to get the location
label_conv = IndexToString(inputCol="prediction", outputCol="Violation_Location", labels=label_indexers_model.labels)
# save the Randomforest regression model as pipeline model
pm = PipelineModel(stages=[lr_model,label_conv])
# Write the model
pm.save(filename)
```

```
path= /content
/content/rf_model
```

***Best model from TrainValidationSplit is stored along with converion for prediction to violation location using index to string. ***

```
from google.colab import files
!zip -r 'rf_model.zip' 'rf_model'
!zip -r 'va_model.zip' 'va_model'

files.download('/content/rf_model.zip')
files.download('/content/va_model.zip')
```

```
from sklearn.metrics import confusion_matrix
from pyspark.ml.feature import IndexToString
from pyspark.sql.types import DoubleType

label_conv = IndexToString(inputCol="prediction", outputCol="Violation_Location", labels=label_indexers_model.labels)
pred_label = label_conv.transform(rf_predictonDF)
```

```
# convert Violation_Location to DoubleType for accuracy calulation.
pred_label = pred_label.withColumn("Violation_Location", col("Violation_Location").cast(DoubleType()))
evaluator=MulticlassClassificationEvaluator(predictionCol="prediction")
acc = evaluator.evaluate(pred_label)
print("Prediction Accuracy: ", acc)
```

```
# import PipelineModel from pyspark.ml package
from pyspark.ml import PipelineModel
import os
import zipfile
dirname = os.getcwd()
print('path=',dirname)

rf_filename = "rf_model"
model_path= os.path.join(dirname, rf_filename)

print(model_path)
# load the model from the location it is stored
# The loaded model acts as PipelineModel
pipeline = PipelineModel.load(model_path)

# use the PipelineModel object to perform prediciton on test data.
# Use .transform() to perfrom prediction
prediction = pipeline.transform(testDF)

# print the results
# prediction.select('label','prediction','Violation_Location').show(5)
prediction.select('prediction','Violation_Location').show(5)
```

```
spark.stop()
```

Fit the model and check the accuracy