In [3]:
```
import findspark
findspark.init()
findspark.find()

import pyspark
from pyspark import SparkContext, SparkConf, SQLContext
from pyspark.sql import SparkSession

from pyspark.sql import SparkSession

spark = SparkSession.builder \
    .master("local[*]") \
    .appName("GenericAppName") \
    .getOrCreate()
sc=spark.sparkContext
sqlContext = SQLContext(sc)
```

Task I

In [4]:
```
# Ingest data 2015-2022
from pyspark import SparkFiles

players_15 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_16 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_17 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_18 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_19 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_20 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_21 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
players_22 = spark.read.csv('gs://dataproc-staging-us-west1-682917987486-wdaku6r5/FIFA_
```

In [5]:
```
print(players_15.columns[55])
```

```
movement_agility
```

In [6]:
```
#Add new column for the year
from pyspark.sql.functions import lit

players_15 = players_15.withColumn('Year', lit(2015))
players_16 = players_16.withColumn('Year', lit(2016))
players_17 = players_17.withColumn('Year', lit(2017))
players_18 = players_18.withColumn('Year', lit(2018))
players_19 = players_19.withColumn('Year', lit(2019))
players_20 = players_20.withColumn('Year', lit(2020))
players_21 = players_21.withColumn('Year', lit(2021))
players_22 = players_22.withColumn('Year', lit(2022))
```

In [7]:
```
#Ensure every record can be uniquely identified
#combine fifa id and year as index
from pyspark.sql import functions as sf
```

```
players_15 = players_15.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_16 = players_16.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_17 = players_17.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_18 = players_18.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_19 = players_19.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_20 = players_20.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_21 = players_21.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
players_22 = players_22.withColumn('data_ID', sf.concat(sf.col('sofifa_id'),sf.lit('_')
```

In [8]:

```
# union the data to one dataset
data = players_15.union(players_16)
data = data.union(players_17)
data = data.union(players_18)
data = data.union(players_19)
data = data.union(players_20)
data = data.union(players_21)
data = data.union(players_22)
```

In [9]:

```
# db_properties={}
# #update your db username
# db_properties['username']="postgres"
# #update your db password
# db_properties['password']="psql"
# #make sure you got the right port number here
# db_properties['url']= "jdbc:postgresql://localhost:5432/postgres"
# #make sure you had the Postgres JAR file in the right location
# db_properties['driver']="org.postgresql.Driver"
# db_properties['table']= "fifa.data"



# data.write.format("jdbc")\
# .mode("overwrite")\
# .option("url", db_properties['url'])\
# .option("dbtable", db_properties['table'])\
# .option("user", db_properties['username'])\
# .option("password", db_properties['password'])\
# .option("Driver", db_properties['driver'])\
# .save()
```

In [10]:

```
data.printSchema()
```

```
root
 |-- sofifa_id: integer (nullable = true)
 |-- player_url: string (nullable = true)
 |-- short_name: string (nullable = true)
 |-- long_name: string (nullable = true)
 |-- player_positions: string (nullable = true)
 |-- overall: integer (nullable = true)
 |-- potential: integer (nullable = true)
 |-- value_eur: double (nullable = true)
 |-- wage_eur: double (nullable = true)
 |-- age: integer (nullable = true)
 |-- dob: string (nullable = true)
 |-- height_cm: integer (nullable = true)
 |-- weight_kg: integer (nullable = true)
```

```
|-- club_team_id: double (nullable = true)
|-- club_name: string (nullable = true)
|-- league_name: string (nullable = true)
|-- league_level: integer (nullable = true)
|-- club_position: string (nullable = true)
|-- club_jersey_number: integer (nullable = true)
|-- club_loaned_from: string (nullable = true)
|-- club_joined: string (nullable = true)
|-- club_contract_valid_until: integer (nullable = true)
|-- nationality_id: integer (nullable = true)
|-- nationality_name: string (nullable = true)
|-- nation_team_id: double (nullable = true)
|-- nation_position: string (nullable = true)
|-- nation_jersey_number: integer (nullable = true)
|-- preferred_foot: string (nullable = true)
|-- weak_foot: integer (nullable = true)
|-- skill_moves: integer (nullable = true)
|-- international_reputation: integer (nullable = true)
|-- work_rate: string (nullable = true)
|-- body_type: string (nullable = true)
|-- real_face: string (nullable = true)
|-- release_clause_eur: string (nullable = true)
|-- player_tags: string (nullable = true)
|-- player_traits: string (nullable = true)
|-- pace: integer (nullable = true)
|-- shooting: integer (nullable = true)
|-- passing: integer (nullable = true)
|-- dribbling: integer (nullable = true)
|-- defending: integer (nullable = true)
|-- physic: integer (nullable = true)
|-- attacking_crossing: integer (nullable = true)
|-- attacking_finishing: integer (nullable = true)
|-- attacking_heading_accuracy: integer (nullable = true)
|-- attacking_short_passing: integer (nullable = true)
|-- attacking_volleys: integer (nullable = true)
|-- skill_dribbling: integer (nullable = true)
|-- skill_curve: integer (nullable = true)
|-- skill_fk_accuracy: integer (nullable = true)
|-- skill_long_passing: integer (nullable = true)
|-- skill_ball_control: integer (nullable = true)
|-- movement_acceleration: integer (nullable = true)
|-- movement_sprint_speed: integer (nullable = true)
|-- movement_agility: integer (nullable = true)
|-- movement_reactions: integer (nullable = true)
|-- movement_balance: integer (nullable = true)
|-- power_shot_power: integer (nullable = true)
|-- power_jumping: integer (nullable = true)
|-- power_stamina: integer (nullable = true)
|-- power_strength: integer (nullable = true)
|-- power_long_shots: integer (nullable = true)
|-- mentality_aggression: integer (nullable = true)
|-- mentality_interceptions: integer (nullable = true)
|-- mentality_positioning: integer (nullable = true)
|-- mentality_vision: integer (nullable = true)
|-- mentality_penalties: integer (nullable = true)
|-- mentality_composure: string (nullable = true)
|-- defending_marking_awareness: integer (nullable = true)
|-- defending_standing_tackle: integer (nullable = true)
|-- defending_sliding_tackle: integer (nullable = true)
|-- goalkeeping_diving: integer (nullable = true)
|-- goalkeeping_handling: integer (nullable = true)
|-- goalkeeping_kicking: integer (nullable = true)
|-- goalkeeping_positioning: integer (nullable = true)
|-- goalkeeping_reflexes: integer (nullable = true)
|-- goalkeeping_speed: integer (nullable = true)
```

```
|-- ls: string (nullable = true)
|-- st: string (nullable = true)
|-- rs: string (nullable = true)
|-- lw: string (nullable = true)
|-- lf: string (nullable = true)
|-- cf: string (nullable = true)
|-- rf: string (nullable = true)
|-- rw: string (nullable = true)
|-- lam: string (nullable = true)
|-- cam: string (nullable = true)
|-- ram: string (nullable = true)
|-- lm: string (nullable = true)
|-- lcm: string (nullable = true)
|-- cm: string (nullable = true)
|-- rcm: string (nullable = true)
|-- rm: string (nullable = true)
|-- lwb: string (nullable = true)
|-- ldm: string (nullable = true)
|-- cdm: string (nullable = true)
|-- rdm: string (nullable = true)
|-- rwb: string (nullable = true)
|-- lb: string (nullable = true)
|-- lcb: string (nullable = true)
|-- cb: string (nullable = true)
|-- rcb: string (nullable = true)
|-- rb: string (nullable = true)
|-- gk: string (nullable = true)
|-- player_face_url: string (nullable = true)
|-- club_logo_url: string (nullable = true)
|-- club_flag_url: string (nullable = true)
|-- nation_logo_url: string (nullable = true)
|-- nation_flag_url: string (nullable = true)
|-- Year: integer (nullable = false)
|-- data_ID: string (nullable = true)
```

In [11]:

```
# data_read = sqlContext.read.format("jdbc")\
#     .option("url", db_properties['url'])\
#     .option("dbtable", db_properties['table'])\
#     .option("user", db_properties['username'])\
#     .option("password", db_properties['password'])\
#     .option("Driver", db_properties['driver'])\
#     .load()

# data_read.show(1, vertical=True)
```

In [13]:

```
data_read = data
```

Task II

Find X

In [33]:

```
#In order to find the club with highest numbers of players
#use where to find the data in 2022
#use .agg to Compute aggregates when(data_read["club_contract_valid_until"]=='2023' and
#group the data by club name and sort them by the count of data
from pyspark.sql import functions as F
def findX(x):
```

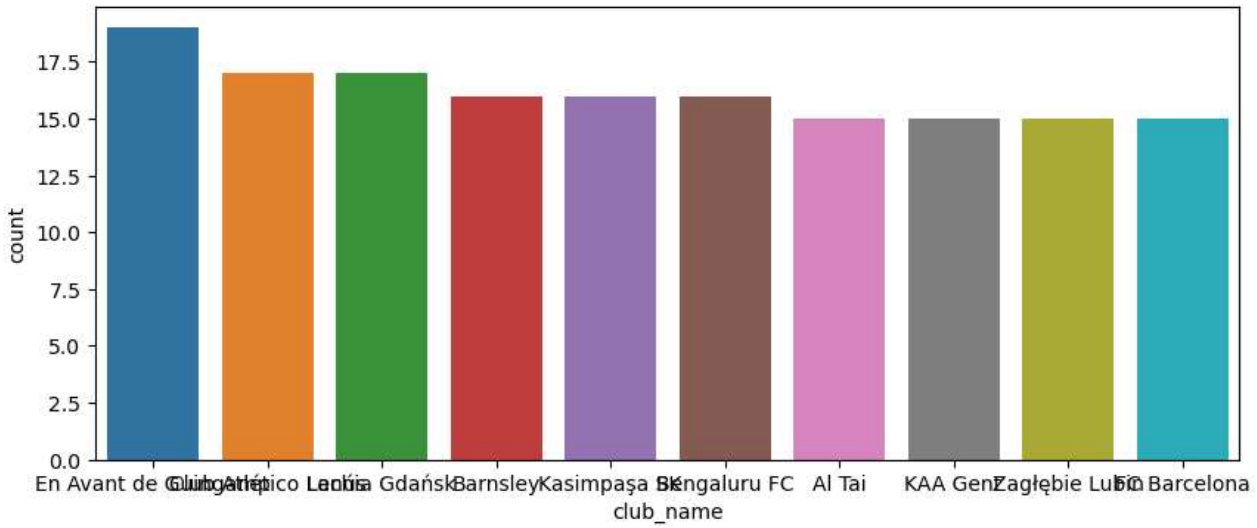
```
    SORT_club = data_read.where(data_read['Year']=='2022').groupBy("club_name")
    highest_number_club = SORT_club.agg(F.count(F.when(data_read["club_contract_valid_u
    highest_number_club.show(x,vertical = True)
findX(5)
```

```
-RECORD 0-------------------------
 club_name | En Avant de Guingamp
 count     | 19
-RECORD 1-------------------------
 club_name | Lechia Gdańsk
 count     | 17
-RECORD 2-------------------------
 club_name | Club Atlético Lanús
 count     | 17
-RECORD 3-------------------------
 club_name | Barnsley
 count     | 16
-RECORD 4-------------------------
 club_name | Kasimpaşa SK
 count     | 16
only showing top 5 rows
```

In [34]:

```
# we drew the barplot of the count to give a direct interpretation
import seaborn as sns
from IPython import display
import matplotlib.pyplot as plt

SORT_club = data_read.where(data_read['Year']=='2022').groupBy("club_name")
highest_number_club = SORT_club.agg(F.count(F.when(data_read["club_contract_valid_until
plt.figure( figsize = ( 10, 4 ) )
sns.barplot( x="club_name", y="count", data=highest_number_club[:10])
plt.show()
```



FindY

In [35]:

```
# the number of players older than 27 years oldfor each club
# we used where to find the players who are older than 27 and group the data by club_na
# to find the club who has the highest number
# we sum the age for each club

import numpy as np
```

```
highest_number_over27_count = data_read.where(data_read['age']>27).groupBy("club_name")
highest_number_over27_sum = data_read.where(data_read['age']>27).groupBy("club_name").s
print(highest_number_over27_count)
print(highest_number_over27_sum)
average_over27 = highest_number_over27_sum['sum(age)'].values/highest_number_over27_cou
print(type(average_over27),average_over27)
```

```
[Stage 38:================================================>       (25 + 4) / 29]
                  club_name  count
0                      None    874
1     İstanbul Başakşehir FK    133
2     Jeonbuk Hyundai Motors    118
3        FC Lokomotiv Moscow    108
4             Crystal Palace    106
...                      ...    ...
1007     Caracas Fútbol Club      3
1008          SC Freiburg II      2
1009            FC Helsingør      2
1010            FC Dordrecht      1
1011    Borussia Dortmund II      1

[1012 rows x 2 columns]
                        club_name  sum(age)
0                         Palermo      1105
1              Santiago Wanderers       749
2              1. FC Union Berlin      2215
3                           Carpi       554
4     Club Independiente Santa Fe      2119
...                           ...       ...
1007                    Gefle IF       614
1008                        Bury      1731
1009           Accrington Stanley      1020
1010                 Bohemian FC      1269
1011                        Como       219

[1012 rows x 2 columns]
<class 'numpy.ndarray'> [1.26430206e+00 5.63157895e+00 1.87711864e+01 ... 5.10000000e+02
 1.26900000e+03 2.19000000e+02]
```

In [36]:

```
# we calculated the average and found the highest average
def findY(y):
    highest_number_over27_avg = data_read.where(data_read['age']>27).groupBy("club_name
    highest_number_over27_avg.show(y,vertical =True)
findY(5)
```

```
[Stage 41:=============================================>          (23 + 4) / 29]
-RECORD 0------------------------
 club_name | Yokohama FC
 avg(age)  | 34.7037037037037
-RECORD 1------------------------
 club_name | Wexford Youths
 avg(age)  | 34.0
-RECORD 2------------------------
 club_name | Zamora Fútbol Club
 avg(age)  | 33.857142857142854
-RECORD 3------------------------
 club_name | Centro Atlético F...
 avg(age)  | 33.6
-RECORD 4------------------------
 club_name | CF Fuenlabrada
 avg(age)  | 33.54545454545455
```

```
only showing top 5 rows
```

In [37]:
```
top1_highest_number_over27_avg = data_read.where(data_read['age']>27).groupBy("club_nam
print("club with highest numbers over 27:",top1_highest_number_over27_avg['club_name'].
findY(1)
```

```
club with highest numbers over 27: ['Yokohama FC']
[Stage 48:=============================================>           (23 + 4) / 29]
-RECORD 0--------------------
 club_name | Yokohama FC
 avg(age)  | 34.7037037037037
only showing top 1 row
```

In [38]:
```
# most frequent nation_positions for each year
# we also used where to filter the year, and group them by nation_position, count the n
# them to search the highest one.
most_frequent_nation_2015 = data_read.where(data_read['Year']==2015).groupBy("nation_po
print("Most frequent nation position 2015:",most_frequent_nation_2015['nation_position'
most_frequent_nation_2016 = data_read.where(data_read['Year']==2016).groupBy("nation_po
print("Most frequent nation position 2016:",most_frequent_nation_2016['nation_position'
most_frequent_nation_2017 = data_read.where(data_read['Year']==2017).groupBy("nation_po
print("Most frequent nation position 2017:",most_frequent_nation_2017['nation_position'
most_frequent_nation_2018 = data_read.where(data_read['Year']==2018).groupBy("nation_po
print("Most frequent nation position 2018:",most_frequent_nation_2018['nation_position'
most_frequent_nation_2019 = data_read.where(data_read['Year']==2019).groupBy("nation_po
print("Most frequent nation position 2019:",most_frequent_nation_2019['nation_position'
most_frequent_nation_2020 = data_read.where(data_read['Year']==2020).groupBy("nation_po
print("Most frequent nation position 2020:",most_frequent_nation_2020['nation_position'
most_frequent_nation_2021 = data_read.where(data_read['Year']==2021).groupBy("nation_po
print("Most frequent nation position 2021:",most_frequent_nation_2021['nation_position'
most_frequent_nation_2022 = data_read.where(data_read['Year']==2022).groupBy("nation_po
print("Most frequent nation position 2022:",most_frequent_nation_2022['nation_position'
```

```
Most frequent nation position 2015: ['SUB']
Most frequent nation position 2016: ['SUB']
Most frequent nation position 2017: ['SUB']
Most frequent nation position 2018: ['SUB']
Most frequent nation position 2019: ['SUB']
Most frequent nation position 2020: ['SUB']
Most frequent nation position 2021: ['SUB']
Most frequent nation position 2022: ['SUB']
```

In [39]:
```
# most_frequent_nation_2015 = data_read.where(data_read['Year']==2015).groupBy("nation_
# print(most_frequent_nation_2015)
```

Task III

Data Engineering and cleaning

In [40]:

```
# Since we only use the skillsets of the players, we dropped all the unneccessary colum
drop_list = ['player_position',' nationality_name','work_rate','body_type','real_face',
                              'club_loaned_from','club_joined','club_contract_valid_until
                              'nationality_id','nation_team_id','nation_position','nation
                              'release_clause_eur','player_tags','player_traits','player_
                              'club_logo_url','club_flag_url','nation_logo_url','nation_f
                              'player_url','mentality_composure','goalkeeping_speed','clu
```

In [41]:
```
print(len(drop_list))
```

```
33
```

In [42]:
```
df_read = data_read.drop('player_positions','nationality_name','work_rate','body_type',
                              'club_loaned_from','club_joined','club_contract_valid_until
                              'nationality_id','nation_team_id','nation_position','nation
                              'release_clause_eur','player_tags','player_traits','player_
                              'club_logo_url','club_flag_url','nation_logo_url','nation_f
                              'player_url','mentality_composure','goalkeeping_speed','clu
```

In [43]:
```
print(len(data_read.columns))
print(len(df_read.columns))
```

```
112
79
```

In [44]:
```
df_read.printSchema()
```

```
root
 |-- sofifa_id: integer (nullable = true)
 |-- overall: integer (nullable = true)
 |-- potential: integer (nullable = true)
 |-- value_eur: double (nullable = true)
 |-- wage_eur: double (nullable = true)
 |-- age: integer (nullable = true)
 |-- height_cm: integer (nullable = true)
 |-- weight_kg: integer (nullable = true)
 |-- preferred_foot: string (nullable = true)
 |-- weak_foot: integer (nullable = true)
 |-- skill_moves: integer (nullable = true)
 |-- international_reputation: integer (nullable = true)
 |-- pace: integer (nullable = true)
 |-- shooting: integer (nullable = true)
 |-- passing: integer (nullable = true)
 |-- dribbling: integer (nullable = true)
 |-- defending: integer (nullable = true)
 |-- physic: integer (nullable = true)
 |-- attacking_crossing: integer (nullable = true)
 |-- attacking_finishing: integer (nullable = true)
 |-- attacking_heading_accuracy: integer (nullable = true)
 |-- attacking_short_passing: integer (nullable = true)
 |-- attacking_volleys: integer (nullable = true)
 |-- skill_dribbling: integer (nullable = true)
 |-- skill_curve: integer (nullable = true)
 |-- skill_fk_accuracy: integer (nullable = true)
 |-- skill_long_passing: integer (nullable = true)
 |-- skill_ball_control: integer (nullable = true)
 |-- movement_acceleration: integer (nullable = true)
 |-- movement_sprint_speed: integer (nullable = true)
```

```
|-- movement_agility: integer (nullable = true)
|-- movement_reactions: integer (nullable = true)
|-- movement_balance: integer (nullable = true)
|-- power_shot_power: integer (nullable = true)
|-- power_jumping: integer (nullable = true)
|-- power_stamina: integer (nullable = true)
|-- power_strength: integer (nullable = true)
|-- power_long_shots: integer (nullable = true)
|-- mentality_aggression: integer (nullable = true)
|-- mentality_interceptions: integer (nullable = true)
|-- mentality_positioning: integer (nullable = true)
|-- mentality_vision: integer (nullable = true)
|-- mentality_penalties: integer (nullable = true)
|-- defending_marking_awareness: integer (nullable = true)
|-- defending_standing_tackle: integer (nullable = true)
|-- defending_sliding_tackle: integer (nullable = true)
|-- goalkeeping_diving: integer (nullable = true)
|-- goalkeeping_handling: integer (nullable = true)
|-- goalkeeping_kicking: integer (nullable = true)
|-- goalkeeping_positioning: integer (nullable = true)
|-- goalkeeping_reflexes: integer (nullable = true)
|-- ls: string (nullable = true)
|-- st: string (nullable = true)
|-- rs: string (nullable = true)
|-- lw: string (nullable = true)
|-- lf: string (nullable = true)
|-- cf: string (nullable = true)
|-- rf: string (nullable = true)
|-- rw: string (nullable = true)
|-- lam: string (nullable = true)
|-- cam: string (nullable = true)
|-- ram: string (nullable = true)
|-- lm: string (nullable = true)
|-- lcm: string (nullable = true)
|-- cm: string (nullable = true)
|-- rcm: string (nullable = true)
|-- rm: string (nullable = true)
|-- lwb: string (nullable = true)
|-- ldm: string (nullable = true)
|-- cdm: string (nullable = true)
|-- rdm: string (nullable = true)
|-- rwb: string (nullable = true)
|-- lb: string (nullable = true)
|-- lcb: string (nullable = true)
|-- cb: string (nullable = true)
|-- rcb: string (nullable = true)
|-- rb: string (nullable = true)
|-- gk: string (nullable = true)
|-- Year: integer (nullable = false)
```

In [45]:

```
# from pyspark.sql.functions import *

# # Notice I dropped isPenalty and isSTPlay
# null_counts_plays_df = df_read.select([count(when(isnan(c) | col(c).isNull(), c)).ali
#                         for c in df_read.columns])

# null_counts_plays_df.show(truncate=False, vertical=True)
```

impute 'pace','shooting','passing','dribbling','defending','physic'

In [46]:

```
# we checked the missing values of the whole dataset and we found out that the columns
```

```
# larger amoungt of missing value: 'pace','shooting','passing','dribbling','defending',
# Because there were many missing value in the data, we want to impute the missing valu
```

In [47]:

```
from pyspark.ml.feature import Imputer
columns_to_be_imputed = ['pace']
value_not_in_dataset = -200

# Replace None/Missing Value with a value that can't be present in the dataset.
df_with_filled_na = df_read.fillna(-200, columns_to_be_imputed)

#Create new columns with imputed values. New columns will be suffixed with "_imputed"
imputer = Imputer (
            inputCols=columns_to_be_imputed,
            outputCols=["{}_imputed".format(c) for c in columns_to_be_imputed])\
            .setStrategy("median").setMissingValue(value_not_in_dataset)

df_imputed = imputer.fit(df_with_filled_na).transform(df_with_filled_na)
# we will drop the old column without imputation. We have only one column to be imputed
df_imputed_enhanced = df_imputed.drop(columns_to_be_imputed[0])

# We will rename our newly imputed column with the correct name
df_fully_imputed = df_imputed_enhanced.withColumnRenamed("pace_imputed","pace")
```

In [48]:

```
from pyspark.ml.feature import Imputer
columns_to_be_imputed = ['shooting']
value_not_in_dataset = -200

# Replace None/Missing Value with a value that can't be present in the dataset.
df_with_filled_na2 = df_fully_imputed.fillna(-200, columns_to_be_imputed)

#Create new columns with imputed values. New columns will be suffixed with "_imputed"
imputer = Imputer (
            inputCols=columns_to_be_imputed,
            outputCols=["{}_imputed".format(c) for c in columns_to_be_imputed])\
            .setStrategy("median").setMissingValue(value_not_in_dataset)

df_imputed2 = imputer.fit(df_with_filled_na2).transform(df_with_filled_na2)
# we will drop the old column without imputation. We have only one column to be imputed
df_imputed_enhanced2 = df_imputed2.drop(columns_to_be_imputed[0])

# We will rename our newly imputed column with the correct name
df_fully_imputed2 = df_imputed_enhanced2.withColumnRenamed("shooting_imputed","shooting
```

In [49]:

```
from pyspark.ml.feature import Imputer
columns_to_be_imputed = ['passing']
value_not_in_dataset = -200

# Replace None/Missing Value with a value that can't be present in the dataset.
df_with_filled_na3 = df_fully_imputed2.fillna(-200, columns_to_be_imputed)

#Create new columns with imputed values. New columns will be suffixed with "_imputed"
imputer = Imputer (
            inputCols=columns_to_be_imputed,
```

```
            outputCols=["{}_imputed".format(c) for c in columns_to_be_imputed])\
            .setStrategy("median").setMissingValue(value_not_in_dataset)

df_imputed3 = imputer.fit(df_with_filled_na3).transform(df_with_filled_na3)
# we will drop the old column without imputation. We have only one column to be imputed
df_imputed_enhanced3 = df_imputed3.drop(columns_to_be_imputed[0])

# We will rename our newly imputed column with the correct name
df_fully_imputed3 = df_imputed_enhanced3.withColumnRenamed("passing_imputed","passing")
```

In [50]:

```
from pyspark.ml.feature import Imputer
columns_to_be_imputed = ['dribbling']
value_not_in_dataset = -200

# Replace None/Missing Value with a value that can't be present in the dataset.
df_with_filled_na4 = df_fully_imputed3.fillna(-200, columns_to_be_imputed)

#Create new columns with imputed values. New columns will be suffixed with "_imputed"
imputer = Imputer (
            inputCols=columns_to_be_imputed,
            outputCols=["{}_imputed".format(c) for c in columns_to_be_imputed])\
            .setStrategy("median").setMissingValue(value_not_in_dataset)

df_imputed4 = imputer.fit(df_with_filled_na4).transform(df_with_filled_na4)
# we will drop the old column without imputation. We have only one column to be imputed
df_imputed_enhanced4 = df_imputed4.drop(columns_to_be_imputed[0])

# We will rename our newly imputed column with the correct name
df_fully_imputed4 = df_imputed_enhanced4.withColumnRenamed("dribbling_imputed","dribbli
```

In [51]:

```
from pyspark.ml.feature import Imputer
columns_to_be_imputed = ['defending']
value_not_in_dataset = -200

# Replace None/Missing Value with a value that can't be present in the dataset.
df_with_filled_na5 = df_fully_imputed4.fillna(-200, columns_to_be_imputed)

#Create new columns with imputed values. New columns will be suffixed with "_imputed"
imputer = Imputer (
            inputCols=columns_to_be_imputed,
            outputCols=["{}_imputed".format(c) for c in columns_to_be_imputed])\
            .setStrategy("median").setMissingValue(value_not_in_dataset)

df_imputed5 = imputer.fit(df_with_filled_na5).transform(df_with_filled_na5)
# we will drop the old column without imputation. We have only one column to be imputed
df_imputed_enhanced5 = df_imputed5.drop(columns_to_be_imputed[0])

# We will rename our newly imputed column with the correct name
df_fully_imputed5 = df_imputed_enhanced5.withColumnRenamed("defending_imputed","defendi
```

In [52]:

```
from pyspark.ml.feature import Imputer
```

```
columns_to_be_imputed = ['physic']
value_not_in_dataset = -200

# Replace None/Missing Value with a value that can't be present in the dataset.
df_with_filled_na6 = df_fully_imputed5.fillna(-200, columns_to_be_imputed)

#Create new columns with imputed values. New columns will be suffixed with "_imputed"
imputer = Imputer (
            inputCols=columns_to_be_imputed,
            outputCols=["{}_imputed".format(c) for c in columns_to_be_imputed])\
            .setStrategy("median").setMissingValue(value_not_in_dataset)

df_imputed6 = imputer.fit(df_with_filled_na6).transform(df_with_filled_na6)
# we will drop the old column without imputation. We have only one column to be imputed
df_imputed_enhanced6 = df_imputed6.drop(columns_to_be_imputed[0])

# We will rename our newly imputed column with the correct name
df_fully_imputed6 = df_imputed_enhanced6.withColumnRenamed("physic_imputed","physic")
```

In [53]:

```
from pyspark.sql.functions import *

# # Notice I dropped isPenalty and isSTPlay
# null_counts_plays_df = df_fully_imputed6.select([count(when(isnan(c) | col(c).isNull(
#                         for c in df_read.columns])

# null_counts_plays_df.show(truncate=False, vertical=True)
```

drop null

In [54]:

```
# we chaecked the missing value again and found out the rows with missing value
# Then we drop the rows
# Reason: The number of row was small compared to the entire dataset, so we just drop t
```

In [55]:

```
df_read = df_fully_imputed6.dropna()
```

In [56]:

```
null_counts_plays_df = df_read.select([count(when(isnan(c) | col(c).isNull(), c)).alias
                        for c in df_read.columns])

null_counts_plays_df.show(truncate=False, vertical=True)
```

```
22/11/29 06:14:00 WARN org.apache.spark.sql.catalyst.util.package: Truncated the string
representation of a plan since it was too large. This behavior can be adjusted by settin
g 'spark.sql.debug.maxToStringFields'.

-RECORD 0--------------------------
 sofifa_id                    | 0
 overall                      | 0
 potential                    | 0
 value_eur                    | 0
 wage_eur                     | 0
 age                          | 0
 height_cm                    | 0
 weight_kg                    | 0
```

preferred_foot	0
weak_foot	0
skill_moves	0
international_reputation	0
attacking_crossing	0
attacking_finishing	0
attacking_heading_accuracy	0
attacking_short_passing	0
attacking_volleys	0
skill_dribbling	0
skill_curve	0
skill_fk_accuracy	0
skill_long_passing	0
skill_ball_control	0
movement_acceleration	0
movement_sprint_speed	0
movement_agility	0
movement_reactions	0
movement_balance	0
power_shot_power	0
power_jumping	0
power_stamina	0
power_strength	0
power_long_shots	0
mentality_aggression	0
mentality_interceptions	0
mentality_positioning	0
mentality_vision	0
mentality_penalties	0
defending_marking_awareness	0
defending_standing_tackle	0
defending_sliding_tackle	0
goalkeeping_diving	0
goalkeeping_handling	0
goalkeeping_kicking	0
goalkeeping_positioning	0
goalkeeping_reflexes	0
ls	0
st	0
rs	0
lw	0
lf	0
cf	0
rf	0
rw	0
lam	0
cam	0
ram	0
lm	0
lcm	0
cm	0
rcm	0
rm	0
lwb	0
ldm	0
cdm	0
rdm	0
rwb	0
lb	0
lcb	0
cb	0
rcb	0
rb	0
gk	0
Year	0

```
pace                | 0
shooting            | 0
passing             | 0
dribbling           | 0
defending           | 0
physic              | 0
```

Data preprocessing

label to binary

In [57]:
```
# Because there are only two values in the 'preferred_foot' column, we convert the valu
label_to_binary = udf(lambda name: 0.0 if name == 'Left' else 1.0)
df_read_bi = df_read.withColumn('preferred_foot', label_to_binary(col('preferred_foot')
```

In [58]:
```
# df_read_bi.show(vertical = True)
```

string to int

In [59]:
```
# We found the format "XX+X" in some columns and we calculated them and converted them
def addall(string):
    if len(string)== 4:
        string = int(string[0:2])+int(string[-1])
    elif len(string) ==2:
        string = int(string)
    elif len(string)== 6:
        string = int(string[-2:])
    return string
```

In [60]:
```
from pyspark.sql.functions import udf
from pyspark.sql.types import IntegerType
```

In [61]:
```
addallUDF = udf(lambda i:addall(i), IntegerType())
```

In [62]:
```
str_to_int_list = ['ls','st','rs','lw','lf','cf','rf','rw','lam','cam','ram','lm','lcm'
                   'ldm','cdm','rdm','rwb','lb','lcb','cb','rcb','rb','gk']
```

In [63]:
```
df_read_int = df_read_bi.withColumn('ls', addallUDF(col('ls')))
df_read_int = df_read_int.withColumn('st', addallUDF(col('st')))
df_read_int = df_read_int.withColumn('rs', addallUDF(col('rs')))
df_read_int = df_read_int.withColumn('lw', addallUDF(col('lw')))
df_read_int = df_read_int.withColumn('lf', addallUDF(col('lf')))
df_read_int = df_read_int.withColumn('cf', addallUDF(col('cf')))
df_read_int = df_read_int.withColumn('rf', addallUDF(col('rf')))
df_read_int = df_read_int.withColumn('rw', addallUDF(col('rw')))
df_read_int = df_read_int.withColumn('lam', addallUDF(col('lam')))
df_read_int = df_read_int.withColumn('cam', addallUDF(col('cam')))
df_read_int = df_read_int.withColumn('ram', addallUDF(col('ram')))
df_read_int = df_read_int.withColumn('lm', addallUDF(col('lm')))
df_read_int = df_read_int.withColumn('lcm', addallUDF(col('lcm')))
```

```
df_read_int = df_read_int.withColumn('cm', addallUDF(col('cm')))
df_read_int = df_read_int.withColumn('rcm', addallUDF(col('rcm')))
df_read_int = df_read_int.withColumn('rm', addallUDF(col('rm')))
df_read_int = df_read_int.withColumn('lwb', addallUDF(col('lwb')))
df_read_int = df_read_int.withColumn('ldm', addallUDF(col('ldm')))
df_read_int = df_read_int.withColumn('cdm', addallUDF(col('cdm')))
df_read_int = df_read_int.withColumn('rdm', addallUDF(col('rdm')))
df_read_int = df_read_int.withColumn('rwb', addallUDF(col('rwb')))
df_read_int = df_read_int.withColumn('lb', addallUDF(col('lb')))
df_read_int = df_read_int.withColumn('lcb', addallUDF(col('lcb')))
df_read_int = df_read_int.withColumn('cb', addallUDF(col('cb')))
df_read_int = df_read_int.withColumn('rcb', addallUDF(col('rcb')))
df_read_int = df_read_int.withColumn('rb', addallUDF(col('rb')))
df_read_int = df_read_int.withColumn('gk', addallUDF(col('gk')))
```

cast data type

In [64]:
```
print(df_read_int.columns)
```

```
['sofifa_id', 'overall', 'potential', 'value_eur', 'wage_eur', 'age', 'height_cm', 'weig
ht_kg', 'preferred_foot', 'weak_foot', 'skill_moves', 'international_reputation', 'attac
king_crossing', 'attacking_finishing', 'attacking_heading_accuracy', 'attacking_short_pa
ssing', 'attacking_volleys', 'skill_dribbling', 'skill_curve', 'skill_fk_accuracy', 'ski
ll_long_passing', 'skill_ball_control', 'movement_acceleration', 'movement_sprint_spee
d', 'movement_agility', 'movement_reactions', 'movement_balance', 'power_shot_power', 'p
ower_jumping', 'power_stamina', 'power_strength', 'power_long_shots', 'mentality_aggress
ion', 'mentality_interceptions', 'mentality_positioning', 'mentality_vision', 'mentality
_penalties', 'defending_marking_awareness', 'defending_standing_tackle', 'defending_slid
ing_tackle', 'goalkeeping_diving', 'goalkeeping_handling', 'goalkeeping_kicking', 'goalk
eeping_positioning', 'goalkeeping_reflexes', 'ls', 'st', 'rs', 'lw', 'lf', 'cf', 'rf',
'rw', 'lam', 'cam', 'ram', 'lm', 'lcm', 'cm', 'rcm', 'rm', 'lwb', 'ldm', 'cdm', 'rdm',
'rwb', 'lb', 'lcb', 'cb', 'rcb', 'rb', 'gk', 'Year', 'pace', 'shooting', 'passing', 'dri
bbling', 'defending', 'physic']
```

In [65]:
```
# we changed the type of data to DoubleType
```

In [66]:
```
from pyspark.sql.types import DoubleType
for i in df_read_int.columns:
    df_read_int = df_read_int.withColumn(i, df_read_int[i].cast(DoubleType()))
```

In [67]:
```
df_read_int.printSchema()
```

```
root
 |-- sofifa_id: double (nullable = true)
 |-- overall: double (nullable = true)
 |-- potential: double (nullable = true)
 |-- value_eur: double (nullable = true)
 |-- wage_eur: double (nullable = true)
 |-- age: double (nullable = true)
 |-- height_cm: double (nullable = true)
 |-- weight_kg: double (nullable = true)
 |-- preferred_foot: double (nullable = true)
 |-- weak_foot: double (nullable = true)
 |-- skill_moves: double (nullable = true)
 |-- international_reputation: double (nullable = true)
 |-- attacking_crossing: double (nullable = true)
 |-- attacking_finishing: double (nullable = true)
```

```
|-- attacking_heading_accuracy: double (nullable = true)
|-- attacking_short_passing: double (nullable = true)
|-- attacking_volleys: double (nullable = true)
|-- skill_dribbling: double (nullable = true)
|-- skill_curve: double (nullable = true)
|-- skill_fk_accuracy: double (nullable = true)
|-- skill_long_passing: double (nullable = true)
|-- skill_ball_control: double (nullable = true)
|-- movement_acceleration: double (nullable = true)
|-- movement_sprint_speed: double (nullable = true)
|-- movement_agility: double (nullable = true)
|-- movement_reactions: double (nullable = true)
|-- movement_balance: double (nullable = true)
|-- power_shot_power: double (nullable = true)
|-- power_jumping: double (nullable = true)
|-- power_stamina: double (nullable = true)
|-- power_strength: double (nullable = true)
|-- power_long_shots: double (nullable = true)
|-- mentality_aggression: double (nullable = true)
|-- mentality_interceptions: double (nullable = true)
|-- mentality_positioning: double (nullable = true)
|-- mentality_vision: double (nullable = true)
|-- mentality_penalties: double (nullable = true)
|-- defending_marking_awareness: double (nullable = true)
|-- defending_standing_tackle: double (nullable = true)
|-- defending_sliding_tackle: double (nullable = true)
|-- goalkeeping_diving: double (nullable = true)
|-- goalkeeping_handling: double (nullable = true)
|-- goalkeeping_kicking: double (nullable = true)
|-- goalkeeping_positioning: double (nullable = true)
|-- goalkeeping_reflexes: double (nullable = true)
|-- ls: double (nullable = true)
|-- st: double (nullable = true)
|-- rs: double (nullable = true)
|-- lw: double (nullable = true)
|-- lf: double (nullable = true)
|-- cf: double (nullable = true)
|-- rf: double (nullable = true)
|-- rw: double (nullable = true)
|-- lam: double (nullable = true)
|-- cam: double (nullable = true)
|-- ram: double (nullable = true)
|-- lm: double (nullable = true)
|-- lcm: double (nullable = true)
|-- cm: double (nullable = true)
|-- rcm: double (nullable = true)
|-- rm: double (nullable = true)
|-- lwb: double (nullable = true)
|-- ldm: double (nullable = true)
|-- cdm: double (nullable = true)
|-- rdm: double (nullable = true)
|-- rwb: double (nullable = true)
|-- lb: double (nullable = true)
|-- lcb: double (nullable = true)
|-- cb: double (nullable = true)
|-- rcb: double (nullable = true)
|-- rb: double (nullable = true)
|-- gk: double (nullable = true)
|-- Year: double (nullable = false)
|-- pace: double (nullable = true)
|-- shooting: double (nullable = true)
|-- passing: double (nullable = true)
|-- dribbling: double (nullable = true)
|-- defending: double (nullable = true)
```

```
 |-- physic: double (nullable = true)
```

In [68]:
```
df_read_features = df_read_int.withColumn('overall_new',col('overall')).drop('overall')
```

In [69]:
```
df_read_int.show(5,vertical = True)
```

```
[Stage 110:>                                                        (0 + 1) / 1]
-RECORD 0------------------------------
 sofifa_id                     | 158023.0
 overall                       | 93.0
 potential                     | 95.0
 value_eur                     | 1.005E8
 wage_eur                      | 550000.0
 age                           | 27.0
 height_cm                     | 169.0
 weight_kg                     | 67.0
 preferred_foot                | 0.0
 weak_foot                     | 3.0
 skill_moves                   | 4.0
 international_reputation      | 5.0
 attacking_crossing            | 84.0
 attacking_finishing           | 94.0
 attacking_heading_accuracy    | 71.0
 attacking_short_passing       | 89.0
 attacking_volleys             | 85.0
 skill_dribbling               | 96.0
 skill_curve                   | 89.0
 skill_fk_accuracy             | 90.0
 skill_long_passing            | 76.0
 skill_ball_control            | 96.0
 movement_acceleration         | 96.0
 movement_sprint_speed         | 90.0
 movement_agility              | 94.0
 movement_reactions            | 94.0
 movement_balance              | 95.0
 power_shot_power              | 80.0
 power_jumping                 | 73.0
 power_stamina                 | 77.0
 power_strength                | 60.0
 power_long_shots              | 88.0
 mentality_aggression          | 48.0
 mentality_interceptions       | 22.0
 mentality_positioning         | 92.0
 mentality_vision              | 90.0
 mentality_penalties           | 76.0
 defending_marking_awareness   | 25.0
 defending_standing_tackle     | 21.0
 defending_sliding_tackle      | 20.0
 goalkeeping_diving            | 6.0
 goalkeeping_handling          | 11.0
 goalkeeping_kicking           | 15.0
 goalkeeping_positioning       | 14.0
 goalkeeping_reflexes          | 8.0
 ls                            | 92.0
 st                            | 92.0
 rs                            | 92.0
 lw                            | 95.0
 lf                            | 93.0
 cf                            | 93.0
 rf                            | 93.0
 rw                            | 95.0
```

```
lam                          | 95.0
cam                          | 95.0
ram                          | 95.0
lm                           | 93.0
lcm                          | 82.0
cm                           | 82.0
rcm                          | 82.0
rm                           | 93.0
lwb                          | 65.0
ldm                          | 65.0
cdm                          | 65.0
rdm                          | 65.0
rwb                          | 65.0
lb                           | 57.0
lcb                          | 48.0
cb                           | 48.0
rcb                          | 48.0
rb                           | 57.0
gk                           | 18.0
Year                         | 2015.0
pace                         | 93.0
shooting                     | 89.0
passing                      | 86.0
dribbling                    | 96.0
defending                    | 27.0
physic                       | 63.0
-RECORD 1-------------------------------
sofifa_id                    | 20801.0
overall                      | 92.0
potential                    | 92.0
value_eur                    | 7.9E7
wage_eur                     | 375000.0
age                          | 29.0
height_cm                    | 185.0
weight_kg                    | 80.0
preferred_foot               | 1.0
weak_foot                    | 4.0
skill_moves                  | 5.0
international_reputation     | 5.0
attacking_crossing           | 83.0
attacking_finishing          | 95.0
attacking_heading_accuracy   | 86.0
attacking_short_passing      | 82.0
attacking_volleys            | 87.0
skill_dribbling              | 93.0
skill_curve                  | 88.0
skill_fk_accuracy            | 79.0
skill_long_passing           | 72.0
skill_ball_control           | 92.0
movement_acceleration        | 91.0
movement_sprint_speed        | 94.0
movement_agility             | 93.0
movement_reactions           | 90.0
movement_balance             | 63.0
power_shot_power             | 94.0
power_jumping                | 94.0
power_stamina                | 89.0
power_strength               | 79.0
power_long_shots             | 93.0
mentality_aggression         | 63.0
mentality_interceptions      | 24.0
mentality_positioning        | 91.0
mentality_vision             | 81.0
mentality_penalties          | 85.0
defending_marking_awareness  | 22.0
```

```
defending_standing_tackle   | 31.0
defending_sliding_tackle    | 23.0
goalkeeping_diving          | 7.0
goalkeeping_handling        | 11.0
goalkeeping_kicking         | 15.0
goalkeeping_positioning     | 14.0
goalkeeping_reflexes        | 11.0
ls                          | 92.0
st                          | 92.0
rs                          | 92.0
lw                          | 92.0
lf                          | 92.0
cf                          | 92.0
rf                          | 92.0
rw                          | 92.0
lam                         | 92.0
cam                         | 92.0
ram                         | 92.0
lm                          | 90.0
lcm                         | 80.0
cm                          | 80.0
rcm                         | 80.0
rm                          | 90.0
lwb                         | 66.0
ldm                         | 66.0
cdm                         | 66.0
rdm                         | 66.0
rwb                         | 66.0
lb                          | 60.0
lcb                         | 55.0
cb                          | 55.0
rcb                         | 55.0
rb                          | 60.0
gk                          | 19.0
Year                        | 2015.0
pace                        | 93.0
shooting                    | 93.0
passing                     | 81.0
dribbling                   | 91.0
defending                   | 32.0
physic                      | 79.0
-RECORD 2-------------------------------
sofifa_id                   | 9014.0
overall                     | 90.0
potential                   | 90.0
value_eur                   | 5.45E7
wage_eur                    | 275000.0
age                         | 30.0
height_cm                   | 180.0
weight_kg                   | 80.0
preferred_foot              | 0.0
weak_foot                   | 2.0
skill_moves                 | 4.0
international_reputation    | 5.0
attacking_crossing          | 80.0
attacking_finishing         | 85.0
attacking_heading_accuracy  | 50.0
attacking_short_passing     | 86.0
attacking_volleys           | 86.0
skill_dribbling             | 93.0
skill_curve                 | 85.0
skill_fk_accuracy           | 83.0
skill_long_passing          | 76.0
skill_ball_control          | 90.0
movement_acceleration       | 93.0
```

```
movement_sprint_speed       | 93.0
movement_agility            | 93.0
movement_reactions          | 89.0
movement_balance            | 91.0
power_shot_power            | 86.0
power_jumping               | 61.0
power_stamina               | 78.0
power_strength              | 65.0
power_long_shots            | 90.0
mentality_aggression        | 47.0
mentality_interceptions     | 39.0
mentality_positioning       | 89.0
mentality_vision            | 84.0
mentality_penalties         | 80.0
defending_marking_awareness | 29.0
defending_standing_tackle   | 26.0
defending_sliding_tackle    | 26.0
goalkeeping_diving          | 10.0
goalkeeping_handling        | 8.0
goalkeeping_kicking         | 11.0
goalkeeping_positioning     | 5.0
goalkeeping_reflexes        | 15.0
ls                          | 87.0
st                          | 87.0
rs                          | 87.0
lw                          | 90.0
lf                          | 90.0
cf                          | 90.0
rf                          | 90.0
rw                          | 90.0
lam                         | 90.0
cam                         | 90.0
ram                         | 90.0
lm                          | 90.0
lcm                         | 81.0
cm                          | 81.0
rcm                         | 81.0
rm                          | 90.0
lwb                         | 67.0
ldm                         | 67.0
cdm                         | 67.0
rdm                         | 67.0
rwb                         | 67.0
lb                          | 58.0
lcb                         | 49.0
cb                          | 49.0
rcb                         | 49.0
rb                          | 58.0
gk                          | 17.0
Year                        | 2015.0
pace                        | 93.0
shooting                    | 86.0
passing                     | 83.0
dribbling                   | 92.0
defending                   | 32.0
physic                      | 64.0
-RECORD 3-------------------------------
sofifa_id                   | 41236.0
overall                     | 90.0
potential                   | 90.0
value_eur                   | 5.25E7
wage_eur                    | 275000.0
age                         | 32.0
height_cm                   | 195.0
weight_kg                   | 95.0
```

preferred_foot	1.0
weak_foot	4.0
skill_moves	4.0
international_reputation	5.0
attacking_crossing	76.0
attacking_finishing	91.0
attacking_heading_accuracy	76.0
attacking_short_passing	84.0
attacking_volleys	92.0
skill_dribbling	88.0
skill_curve	80.0
skill_fk_accuracy	80.0
skill_long_passing	76.0
skill_ball_control	90.0
movement_acceleration	74.0
movement_sprint_speed	77.0
movement_agility	86.0
movement_reactions	85.0
movement_balance	41.0
power_shot_power	93.0
power_jumping	72.0
power_stamina	78.0
power_strength	93.0
power_long_shots	88.0
mentality_aggression	84.0
mentality_interceptions	20.0
mentality_positioning	86.0
mentality_vision	83.0
mentality_penalties	91.0
defending_marking_awareness	25.0
defending_standing_tackle	41.0
defending_sliding_tackle	27.0
goalkeeping_diving	13.0
goalkeeping_handling	15.0
goalkeeping_kicking	10.0
goalkeeping_positioning	9.0
goalkeeping_reflexes	12.0
ls	90.0
st	90.0
rs	90.0
lw	87.0
lf	89.0
cf	89.0
rf	89.0
rw	87.0
lam	89.0
cam	89.0
ram	89.0
lm	86.0
lcm	79.0
cm	79.0
rcm	79.0
rm	86.0
lwb	64.0
ldm	68.0
cdm	68.0
rdm	68.0
rwb	64.0
lb	59.0
lcb	58.0
cb	58.0
rcb	58.0
rb	59.0
gk	20.0
Year	2015.0

```
pace                        | 76.0
shooting                    | 91.0
passing                     | 81.0
dribbling                   | 86.0
defending                   | 34.0
physic                      | 86.0
-RECORD 4-------------------------------
sofifa_id                   | 167495.0
overall                     | 90.0
potential                   | 90.0
value_eur                   | 6.35E7
wage_eur                    | 300000.0
age                         | 28.0
height_cm                   | 193.0
weight_kg                   | 92.0
preferred_foot              | 1.0
weak_foot                   | 4.0
skill_moves                 | 1.0
international_reputation    | 5.0
attacking_crossing          | 25.0
attacking_finishing         | 25.0
attacking_heading_accuracy  | 25.0
attacking_short_passing     | 42.0
attacking_volleys           | 25.0
skill_dribbling             | 25.0
skill_curve                 | 25.0
skill_fk_accuracy           | 25.0
skill_long_passing          | 41.0
skill_ball_control          | 31.0
movement_acceleration       | 58.0
movement_sprint_speed       | 61.0
movement_agility            | 43.0
movement_reactions          | 89.0
movement_balance            | 35.0
power_shot_power            | 42.0
power_jumping               | 78.0
power_stamina               | 44.0
power_strength              | 83.0
power_long_shots            | 25.0
mentality_aggression        | 29.0
mentality_interceptions     | 30.0
mentality_positioning       | 25.0
mentality_vision            | 20.0
mentality_penalties         | 37.0
defending_marking_awareness | 25.0
defending_standing_tackle   | 25.0
defending_sliding_tackle    | 25.0
goalkeeping_diving          | 87.0
goalkeeping_handling        | 85.0
goalkeeping_kicking         | 92.0
goalkeeping_positioning     | 90.0
goalkeeping_reflexes        | 86.0
ls                          | 41.0
st                          | 41.0
rs                          | 41.0
lw                          | 39.0
lf                          | 40.0
cf                          | 40.0
rf                          | 40.0
rw                          | 39.0
lam                         | 39.0
cam                         | 39.0
ram                         | 39.0
lm                          | 41.0
lcm                         | 39.0
```

```
 cm                        | 39.0
 rcm                       | 39.0
 rm                        | 41.0
 lwb                       | 39.0
 ldm                       | 43.0
 cdm                       | 43.0
 rdm                       | 43.0
 rwb                       | 39.0
 lb                        | 39.0
 lcb                       | 41.0
 cb                        | 41.0
 rcb                       | 41.0
 rb                        | 39.0
 gk                        | 90.0
 Year                      | 2015.0
 pace                      | 69.0
 shooting                  | 54.0
 passing                   | 58.0
 dribbling                 | 63.0
 defending                 | 55.0
 physic                    | 66.0
only showing top 5 rows

Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/daemon.py", line 186, in manager
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/daemon.py", line 74, in worker
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/worker.py", line 643, in main
    if read_int(infile) == SpecialLengths.END_OF_STREAM:
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/serializers.py", line 564, in read
_int
    raise EOFError
EOFError
```

In [70]:
```
feature_cols = df_read_int.columns
del feature_cols[2]
```

In [71]:
```
from pyspark.sql import Row
from pyspark.ml.linalg import Vectors
```

In [72]:
```
len(df_read_features.columns)
```

Out[72]: 79

In [73]:
```
null_counts_plays_df_2 = df_read_features.select([count(when(isnan(c) | col(c).isNull()
                        for c in df_read_features.columns])

null_counts_plays_df_2.show(truncate=False, vertical=True)
```

```
[Stage 111:=====================================================> (28 + 1) / 29]
-RECORD 0-------------------------
 sofifa_id                 | 0
 potential                 | 0
 value_eur                 | 0
 wage_eur                  | 0
 age                       | 0
 height_cm                 | 0
 weight_kg                 | 0
```

preferred_foot	0
weak_foot	0
skill_moves	0
international_reputation	0
attacking_crossing	0
attacking_finishing	0
attacking_heading_accuracy	0
attacking_short_passing	0
attacking_volleys	0
skill_dribbling	0
skill_curve	0
skill_fk_accuracy	0
skill_long_passing	0
skill_ball_control	0
movement_acceleration	0
movement_sprint_speed	0
movement_agility	0
movement_reactions	0
movement_balance	0
power_shot_power	0
power_jumping	0
power_stamina	0
power_strength	0
power_long_shots	0
mentality_aggression	0
mentality_interceptions	0
mentality_positioning	0
mentality_vision	0
mentality_penalties	0
defending_marking_awareness	0
defending_standing_tackle	0
defending_sliding_tackle	0
goalkeeping_diving	0
goalkeeping_handling	0
goalkeeping_kicking	0
goalkeeping_positioning	0
goalkeeping_reflexes	0
ls	0
st	0
rs	0
lw	0
lf	0
cf	0
rf	0
rw	0
lam	0
cam	0
ram	0
lm	0
lcm	0
cm	0
rcm	0
rm	0
lwb	0
ldm	0
cdm	0
rdm	0
rwb	0
lb	0
lcb	1
cb	1
rcb	1
rb	0
gk	451
Year	0

```
pace                        | 0
shooting                    | 0
passing                     | 0
dribbling                   | 0
defending                   | 0
physic                      | 0
overall_new                 | 0
```

In [74]:
```
df_read_features = df_read_features.dropna()
```

In [75]:
```
# we checked the data again to ensure there is no missing value in the dataset
null_counts_plays_df_2 = df_read_features.select([count(when(isnan(c) | col(c).isNull()
                         for c in df_read_features.columns])

null_counts_plays_df_2.show(truncate=False, vertical=True)
```

```
[Stage 114:=====================================================> (28 + 1) / 29]
-RECORD 0-------------------------
 sofifa_id                   | 0
 potential                   | 0
 value_eur                   | 0
 wage_eur                    | 0
 age                         | 0
 height_cm                   | 0
 weight_kg                   | 0
 preferred_foot              | 0
 weak_foot                   | 0
 skill_moves                 | 0
 international_reputation    | 0
 attacking_crossing          | 0
 attacking_finishing         | 0
 attacking_heading_accuracy  | 0
 attacking_short_passing     | 0
 attacking_volleys           | 0
 skill_dribbling             | 0
 skill_curve                 | 0
 skill_fk_accuracy           | 0
 skill_long_passing          | 0
 skill_ball_control          | 0
 movement_acceleration       | 0
 movement_sprint_speed       | 0
 movement_agility            | 0
 movement_reactions          | 0
 movement_balance            | 0
 power_shot_power            | 0
 power_jumping               | 0
 power_stamina               | 0
 power_strength              | 0
 power_long_shots            | 0
 mentality_aggression        | 0
 mentality_interceptions     | 0
 mentality_positioning       | 0
 mentality_vision            | 0
 mentality_penalties         | 0
 defending_marking_awareness | 0
 defending_standing_tackle   | 0
 defending_sliding_tackle    | 0
 goalkeeping_diving          | 0
 goalkeeping_handling        | 0
```

```
goalkeeping_kicking         | 0
goalkeeping_positioning     | 0
goalkeeping_reflexes        | 0
ls                          | 0
st                          | 0
rs                          | 0
lw                          | 0
lf                          | 0
cf                          | 0
rf                          | 0
rw                          | 0
lam                         | 0
cam                         | 0
ram                         | 0
lm                          | 0
lcm                         | 0
cm                          | 0
rcm                         | 0
rm                          | 0
lwb                         | 0
ldm                         | 0
cdm                         | 0
rdm                         | 0
rwb                         | 0
lb                          | 0
lcb                         | 0
cb                          | 0
rcb                         | 0
rb                          | 0
gk                          | 0
Year                        | 0
pace                        | 0
shooting                    | 0
passing                     | 0
dribbling                   | 0
defending                   | 0
physic                      | 0
overall_new                 | 0
```

In [76]:

```
# we assembled the features in the data to a vector so that it can be recognized by pys
```

In [77]:

```
def transData(data):
    return data.rdd.map(lambda r: [r[-1], Vectors.dense(r[:-1])]).\
           toDF(['output','features'])

data= transData(df_read_features)
data.show()
```

```
[Stage 118:>                                                        (0 + 1) / 1]
+------+--------------------+
|output|            features|
+------+--------------------+
|  93.0|[158023.0,95.0,1....|
|  92.0|[20801.0,92.0,7.9...|
|  90.0|[9014.0,90.0,5.45...|
|  90.0|[41236.0,90.0,5.2...|
|  90.0|[167495.0,90.0,6....|
|  89.0|[41.0,89.0,3.6E7,...|
|  89.0|[176580.0,91.0,4....|
```

```
|  88.0|[7826.0,88.0,4.05...|
|  88.0|[121944.0,88.0,3....|
|  88.0|[156616.0,88.0,3....|
|  88.0|[167397.0,88.0,4....|
|  88.0|[183277.0,90.0,4....|
|  87.0|[121939.0,87.0,2....|
|  87.0|[155862.0,87.0,3....|
|  87.0|[164240.0,87.0,2....|
|  87.0|[168542.0,87.0,3....|
|  87.0|[173731.0,91.0,3....|
|  87.0|[177003.0,87.0,3....|
|  87.0|[188545.0,89.0,4....|
|  86.0|[10535.0,86.0,1.5...|
+------+--------------------+
only showing top 20 rows

Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/daemon.py", line 186, in manager
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/daemon.py", line 74, in worker
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/worker.py", line 643, in main
    if read_int(infile) == SpecialLengths.END_OF_STREAM:
  File "/usr/lib/spark/python/lib/pyspark.zip/pyspark/serializers.py", line 564, in read
_int
    raise EOFError
EOFError
```

In [78]:
```
# we normalized the features by using StandardScaler
```

In [79]:
```
from pyspark.ml.feature import StandardScaler
Scalerizer=StandardScaler().setInputCol("features").setOutputCol("norm_features")
data_norm = Scalerizer.fit(data).transform(data)
```

In [80]:
```
data_norm = data_norm.drop('features')
data_norm = data_norm.withColumn('features',col('norm_features')).drop('norm_features')
```

In [81]:
```
# data_norm.select('features').show(vertical = False)
```

In [82]:
```
# (trainingData, testData) = data_norm.randomSplit([0.8, 0.2])

# then we splited the data in to training and test dataset

(trainingData, testData) = data_norm.randomSplit([0.8, 0.2])
```

In [83]:
```
trainingData.describe().show()
```

```
[Stage 122:================================================>     (26 + 3) / 29]
+-------+-----------------+
|summary|           output|
+-------+-----------------+
|  count|           111655|
|   mean|65.65939725045901|
| stddev|7.060391706034455|
|    min|             40.0|
```

```
|    max|             94.0|
+-------+------------------+
```

In [84]:
```
print("Training Dataset Count: " + str(trainingData.count()))
print("Test Dataset Count: " + str(testData.count()))
```

```
Training Dataset Count: 111655
[Stage 128:=====================================================>   (27 + 2) / 29]
Test Dataset Count: 28075
```

Pyspark

Random Forest

In [ ]:
```
from pyspark.ml.regression import RandomForestRegressor
from pyspark.ml.feature import VectorIndexer
from pyspark.ml.evaluation import RegressionEvaluator
from pyspark.ml.tuning import ParamGridBuilder, CrossValidator

rf = RandomForestRegressor(featuresCol = 'features', labelCol = 'output')

# Create ParamGrid for Cross Validation
rf_paramGrid = (ParamGridBuilder()
             .addGrid(rf.numTrees, [50,100,150])
             .addGrid(rf.maxDepth, [3,4,5])
             .build())

evaluator = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")

rf_cv = CrossValidator(estimator=rf, estimatorParamMaps=rf_paramGrid,
                    evaluator=evaluator, numFolds=5)

# Train model.  This also runs the indexer.
model_rf = rf_cv.fit(trainingData)

# Make predictions.
predictions_rf = model_rf.transform(testData)
predictions_rf.show(5)
```

```
22/11/29 06:17:08 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1064.3 KiB
22/11/29 06:17:32 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:17:47 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:17:52 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1370.1 KiB
22/11/29 06:18:30 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:18:53 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
```

```
22/11/29 06:19:00 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1675.7 KiB
22/11/29 06:20:05 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1064.2 KiB
22/11/29 06:20:29 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:20:44 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:20:49 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1370.1 KiB
22/11/29 06:21:27 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:21:49 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:21:57 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1675.6 KiB
22/11/29 06:23:00 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1064.3 KiB
22/11/29 06:23:24 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.6 KiB
22/11/29 06:23:39 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.6 KiB
22/11/29 06:23:43 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1370.3 KiB
22/11/29 06:24:22 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.8 KiB
22/11/29 06:24:45 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.8 KiB
22/11/29 06:24:53 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1675.7 KiB
22/11/29 06:25:57 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1064.2 KiB
22/11/29 06:26:21 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:26:36 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:26:41 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1370.2 KiB
22/11/29 06:27:20 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:27:43 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:27:51 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1675.8 KiB
22/11/29 06:28:55 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1064.2 KiB
22/11/29 06:29:18 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:29:33 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1054.5 KiB
22/11/29 06:29:38 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1370.1 KiB
22/11/29 06:30:16 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:30:38 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1202.7 KiB
22/11/29 06:30:45 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1675.8 KiB
22/11/29 06:31:56 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1188.9 KiB
22/11/29 06:32:05 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1662.0 KiB
[Stage 775:>                                                        (0 + 1) / 1]
+------+--------------------+-----------------+
|output|            features|       prediction|
```

```
+------+--------------------+-----------------+
|  66.0|[0.09244059313201...|65.04024140795268|
|  66.0|[0.23534812657222...| 63.7360731340364|
|  66.0|[0.91849251614329...|64.46272326892581|
|  66.0|[0.99638146996760...|64.93970138084205|
|  66.0|[1.39127585699721...|62.96560003701531|
+------+--------------------+-----------------+
only showing top 5 rows
```

In [99]:

```
evaluator = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse = evaluator.evaluate(predictions_rf)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse)
```

```
[Stage 1210:=============================================>       (25 + 4) / 29]
Root Mean Squared Error (RMSE) on test data = 1.5497
```

Tune the parameters one by one and see the impact of each parameter

In [ ]:

```
from pyspark.ml.regression import RandomForestRegressor
from pyspark.ml.feature import VectorIndexer
from pyspark.ml.evaluation import RegressionEvaluator

rf3 = RandomForestRegressor(featuresCol = 'features', labelCol = 'output',numTrees=100,

# Train model.  This also runs the indexer.
model3 = rf3.fit(trainingData)

# Make predictions.
predictions3 = model3.transform(testData)

predictions3.show(5)

evaluator3 = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse3 = evaluator3.evaluate(predictions3)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse3)
```

```
22/11/29 06:33:22 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1040.6 KiB
22/11/29 06:33:28 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1356.3 KiB

+------+--------------------+-----------------+
|output|            features|       prediction|
+------+--------------------+-----------------+
|  66.0|[0.09244059313201...| 65.06673200137273|
|  66.0|[0.23534812657222...|63.546544155074045|
|  66.0|[0.91849251614329...| 64.71979246753254|
|  66.0|[0.99638146996760...| 65.16721502433619|
|  66.0|[1.39127585699721...| 63.38429258440907|
+------+--------------------+-----------------+
only showing top 5 rows

[Stage 793:=====================================================> (28 + 1) / 29]
```

```
Root Mean Squared Error (RMSE) on test data = 1.5739
```

In [ ]:

```
trainingData.show(5)
```

```
+------+--------------------+
|output|            features|
+------+--------------------+
|  66.0|[0.03820530001504...|
|  66.0|[0.06238073264976...|
|  66.0|[0.28265544798691...|
|  66.0|[0.45799980291182...|
|  66.0|[0.52388800240667...|
+------+--------------------+
only showing top 5 rows
```

In [ ]:

```
from pyspark.ml.regression import RandomForestRegressor
from pyspark.ml.feature import VectorIndexer
from pyspark.ml.evaluation import RegressionEvaluator

rf_1 = RandomForestRegressor(featuresCol = 'features', labelCol = 'output',numTrees=100

# Train model.  This also runs the indexer.
model_1 = rf_1.fit(trainingData)

# Make predictions.
predictions_1 = model_1.transform(testData)

predictions_1.show(5)

evaluator_1 = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse_1 = evaluator_1.evaluate(predictions_1)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse_1)
```

```
22/11/29 06:34:40 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1040.6 KiB
22/11/29 06:34:45 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1356.3 KiB
22/11/29 06:34:53 WARN org.apache.spark.scheduler.DAGScheduler: Broadcasting large task
binary with size 1987.1 KiB

+------+--------------------+-----------------+
|output|            features|       prediction|
+------+--------------------+-----------------+
|  66.0|[0.09244059313201...|65.25258903230538|
|  66.0|[0.23534812657222...|63.96400077567084|
|  66.0|[0.91849251614329...|65.41231420039252|
|  66.0|[0.99638146996760...| 65.1097204509944|
|  66.0|[1.39127585699721...|64.18709968896937|
+------+--------------------+-----------------+
only showing top 5 rows

[Stage 813:================================================>     (26 + 3) / 29]
Root Mean Squared Error (RMSE) on test data = 1.31114
```

Linear Regression

In [119…

```
from pyspark.ml.classification import LogisticRegression
from pyspark.ml.tuning import ParamGridBuilder, CrossValidator
from pyspark.ml.evaluation import BinaryClassificationEvaluator

from sklearn.metrics import roc_curve
import pyspark.sql.functions as F
import pyspark.sql.types as T
import numpy
from matplotlib import pyplot as plt

from pyspark.ml.regression import RandomForestRegressor
from pyspark.ml.feature import VectorIndexer
from pyspark.ml.evaluation import RegressionEvaluator

from pyspark.sql.types import Row
from pyspark.ml.linalg import Vectors
from pyspark.ml.classification import MultilayerPerceptronClassifier
```

In [125…

```
from pyspark.ml.regression import LinearRegression

lrg2 = LinearRegression(featuresCol = 'features', labelCol = 'output')

# Create ParamGrid for Cross Validation
lrg_paramGrid2 = ParamGridBuilder() \
    .addGrid(lrg.maxIter, [10, 30,200,1000]) \
    .addGrid(lrg.regParam, [0.1, 1, 2]) \
    .build()

evaluator = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")

lrg_cv2 = CrossValidator(estimator=lrg2, estimatorParamMaps=lrg_paramGrid2,
                    evaluator=evaluator, numFolds=5)

model_lrg = lrg_cv2.fit(trainingData)

predictions_lrg = model_lrg.transform(testData)
predictions_lrg.show(5)
```

```
22/11/29 11:54:07 WARN org.apache.spark.ml.util.Instrumentation: [ae96b0f4] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:20 WARN org.apache.spark.ml.util.Instrumentation: [ae96b0f4] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:33 WARN org.apache.spark.ml.util.Instrumentation: [3f24f4bd] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:33 WARN org.apache.spark.ml.util.Instrumentation: [3f24f4bd] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:34 WARN org.apache.spark.ml.util.Instrumentation: [1654152a] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:34 WARN org.apache.spark.ml.util.Instrumentation: [1654152a] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:35 WARN org.apache.spark.ml.util.Instrumentation: [718ff6e9] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:36 WARN org.apache.spark.ml.util.Instrumentation: [718ff6e9] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:36 WARN org.apache.spark.ml.util.Instrumentation: [329c4de6] regParam is
```

```
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:37 WARN org.apache.spark.ml.util.Instrumentation: [329c4de6] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:37 WARN org.apache.spark.ml.util.Instrumentation: [e92c7adf] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:38 WARN org.apache.spark.ml.util.Instrumentation: [e92c7adf] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:38 WARN org.apache.spark.ml.util.Instrumentation: [04914b5f] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:39 WARN org.apache.spark.ml.util.Instrumentation: [04914b5f] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:40 WARN org.apache.spark.ml.util.Instrumentation: [d535f33c] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:40 WARN org.apache.spark.ml.util.Instrumentation: [d535f33c] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:41 WARN org.apache.spark.ml.util.Instrumentation: [7ace6f68] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:41 WARN org.apache.spark.ml.util.Instrumentation: [7ace6f68] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:42 WARN org.apache.spark.ml.util.Instrumentation: [9bb09a55] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:42 WARN org.apache.spark.ml.util.Instrumentation: [9bb09a55] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:43 WARN org.apache.spark.ml.util.Instrumentation: [9b8aec3b] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:44 WARN org.apache.spark.ml.util.Instrumentation: [9b8aec3b] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:44 WARN org.apache.spark.ml.util.Instrumentation: [35d892cf] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:45 WARN org.apache.spark.ml.util.Instrumentation: [35d892cf] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:54:45 WARN org.apache.spark.ml.util.Instrumentation: [0b7df616] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:54:58 WARN org.apache.spark.ml.util.Instrumentation: [0b7df616] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:11 WARN org.apache.spark.ml.util.Instrumentation: [aee3c835] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:12 WARN org.apache.spark.ml.util.Instrumentation: [aee3c835] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:12 WARN org.apache.spark.ml.util.Instrumentation: [ccf7be39] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:13 WARN org.apache.spark.ml.util.Instrumentation: [ccf7be39] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:13 WARN org.apache.spark.ml.util.Instrumentation: [c8e4e269] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:14 WARN org.apache.spark.ml.util.Instrumentation: [c8e4e269] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:15 WARN org.apache.spark.ml.util.Instrumentation: [aac627e8] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:15 WARN org.apache.spark.ml.util.Instrumentation: [aac627e8] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:16 WARN org.apache.spark.ml.util.Instrumentation: [c4736313] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:16 WARN org.apache.spark.ml.util.Instrumentation: [c4736313] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:17 WARN org.apache.spark.ml.util.Instrumentation: [b4f565b7] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:17 WARN org.apache.spark.ml.util.Instrumentation: [b4f565b7] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:18 WARN org.apache.spark.ml.util.Instrumentation: [4945eaec] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:18 WARN org.apache.spark.ml.util.Instrumentation: [4945eaec] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:19 WARN org.apache.spark.ml.util.Instrumentation: [7b064382] regParam is
zero, which might cause numerical instability and overfitting.
```

```
22/11/29 11:55:20 WARN org.apache.spark.ml.util.Instrumentation: [7b064382] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:20 WARN org.apache.spark.ml.util.Instrumentation: [953c1c2a] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:21 WARN org.apache.spark.ml.util.Instrumentation: [953c1c2a] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:21 WARN org.apache.spark.ml.util.Instrumentation: [b7a153f7] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:22 WARN org.apache.spark.ml.util.Instrumentation: [b7a153f7] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:23 WARN org.apache.spark.ml.util.Instrumentation: [c7677890] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:23 WARN org.apache.spark.ml.util.Instrumentation: [c7677890] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:24 WARN org.apache.spark.sql.execution.CacheManager: Asked to cache alrea
dy cached data.
22/11/29 11:55:24 WARN org.apache.spark.sql.execution.CacheManager: Asked to cache alrea
dy cached data.
22/11/29 11:55:24 WARN org.apache.spark.ml.util.Instrumentation: [55ff3405] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:24 WARN org.apache.spark.ml.util.Instrumentation: [55ff3405] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:25 WARN org.apache.spark.ml.util.Instrumentation: [67a17cb4] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:25 WARN org.apache.spark.ml.util.Instrumentation: [67a17cb4] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:26 WARN org.apache.spark.ml.util.Instrumentation: [9d191e0c] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:26 WARN org.apache.spark.ml.util.Instrumentation: [9d191e0c] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:27 WARN org.apache.spark.ml.util.Instrumentation: [7b1d8a59] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:27 WARN org.apache.spark.ml.util.Instrumentation: [7b1d8a59] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:28 WARN org.apache.spark.ml.util.Instrumentation: [a1270fd8] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:29 WARN org.apache.spark.ml.util.Instrumentation: [a1270fd8] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:29 WARN org.apache.spark.ml.util.Instrumentation: [62ff0962] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:30 WARN org.apache.spark.ml.util.Instrumentation: [62ff0962] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:30 WARN org.apache.spark.ml.util.Instrumentation: [20f17d7d] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:31 WARN org.apache.spark.ml.util.Instrumentation: [20f17d7d] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:31 WARN org.apache.spark.ml.util.Instrumentation: [811ee0ac] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:32 WARN org.apache.spark.ml.util.Instrumentation: [811ee0ac] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:33 WARN org.apache.spark.ml.util.Instrumentation: [dfa70524] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:33 WARN org.apache.spark.ml.util.Instrumentation: [dfa70524] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:34 WARN org.apache.spark.ml.util.Instrumentation: [686aa0ea] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:34 WARN org.apache.spark.ml.util.Instrumentation: [686aa0ea] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:35 WARN org.apache.spark.ml.util.Instrumentation: [b2435f03] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:35 WARN org.apache.spark.ml.util.Instrumentation: [b2435f03] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:36 WARN org.apache.spark.ml.util.Instrumentation: [d9dea629] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:36 WARN org.apache.spark.ml.util.Instrumentation: [d9dea629] Cholesky sol
```

```
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:55:37 WARN org.apache.spark.ml.util.Instrumentation: [1bb738f9] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:55:50 WARN org.apache.spark.ml.util.Instrumentation: [1bb738f9] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:03 WARN org.apache.spark.ml.util.Instrumentation: [1367c02f] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:04 WARN org.apache.spark.ml.util.Instrumentation: [1367c02f] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:04 WARN org.apache.spark.ml.util.Instrumentation: [bbc3a494] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:05 WARN org.apache.spark.ml.util.Instrumentation: [bbc3a494] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:06 WARN org.apache.spark.ml.util.Instrumentation: [bc6b28f5] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:06 WARN org.apache.spark.ml.util.Instrumentation: [bc6b28f5] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:07 WARN org.apache.spark.ml.util.Instrumentation: [5c1ca465] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:07 WARN org.apache.spark.ml.util.Instrumentation: [5c1ca465] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:08 WARN org.apache.spark.ml.util.Instrumentation: [ed6a9b93] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:08 WARN org.apache.spark.ml.util.Instrumentation: [ed6a9b93] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:09 WARN org.apache.spark.ml.util.Instrumentation: [1ad68398] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:10 WARN org.apache.spark.ml.util.Instrumentation: [1ad68398] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:10 WARN org.apache.spark.ml.util.Instrumentation: [d61e1fce] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:11 WARN org.apache.spark.ml.util.Instrumentation: [d61e1fce] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:12 WARN org.apache.spark.ml.util.Instrumentation: [715d06ee] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:12 WARN org.apache.spark.ml.util.Instrumentation: [715d06ee] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:13 WARN org.apache.spark.ml.util.Instrumentation: [076c7866] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:13 WARN org.apache.spark.ml.util.Instrumentation: [076c7866] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:14 WARN org.apache.spark.ml.util.Instrumentation: [ba934c91] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:14 WARN org.apache.spark.ml.util.Instrumentation: [ba934c91] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:15 WARN org.apache.spark.ml.util.Instrumentation: [833bcfa3] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:16 WARN org.apache.spark.ml.util.Instrumentation: [833bcfa3] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:16 WARN org.apache.spark.sql.execution.CacheManager: Asked to cache alrea
dy cached data.
22/11/29 11:56:16 WARN org.apache.spark.sql.execution.CacheManager: Asked to cache alrea
dy cached data.
22/11/29 11:56:16 WARN org.apache.spark.ml.util.Instrumentation: [d3e08da0] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:17 WARN org.apache.spark.ml.util.Instrumentation: [d3e08da0] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:17 WARN org.apache.spark.ml.util.Instrumentation: [3de2946e] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:18 WARN org.apache.spark.ml.util.Instrumentation: [3de2946e] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:19 WARN org.apache.spark.ml.util.Instrumentation: [03ff76a7] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:19 WARN org.apache.spark.ml.util.Instrumentation: [03ff76a7] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
```

```
22/11/29 11:56:20 WARN org.apache.spark.ml.util.Instrumentation: [8e5f2c07] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:20 WARN org.apache.spark.ml.util.Instrumentation: [8e5f2c07] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:21 WARN org.apache.spark.ml.util.Instrumentation: [1a865988] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:22 WARN org.apache.spark.ml.util.Instrumentation: [1a865988] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:22 WARN org.apache.spark.ml.util.Instrumentation: [e05899ef] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:23 WARN org.apache.spark.ml.util.Instrumentation: [e05899ef] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:24 WARN org.apache.spark.ml.util.Instrumentation: [06335ac7] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:24 WARN org.apache.spark.ml.util.Instrumentation: [06335ac7] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:25 WARN org.apache.spark.ml.util.Instrumentation: [ce80406e] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:25 WARN org.apache.spark.ml.util.Instrumentation: [ce80406e] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:26 WARN org.apache.spark.ml.util.Instrumentation: [7cda66d2] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:26 WARN org.apache.spark.ml.util.Instrumentation: [7cda66d2] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:27 WARN org.apache.spark.ml.util.Instrumentation: [58ddc4ef] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:28 WARN org.apache.spark.ml.util.Instrumentation: [58ddc4ef] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:28 WARN org.apache.spark.ml.util.Instrumentation: [6555c766] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:29 WARN org.apache.spark.ml.util.Instrumentation: [6555c766] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:30 WARN org.apache.spark.ml.util.Instrumentation: [9ad041a2] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:30 WARN org.apache.spark.ml.util.Instrumentation: [9ad041a2] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
22/11/29 11:56:31 WARN org.apache.spark.ml.util.Instrumentation: [5b74f2da] regParam is
zero, which might cause numerical instability and overfitting.
22/11/29 11:56:44 WARN org.apache.spark.ml.util.Instrumentation: [5b74f2da] Cholesky sol
ver failed due to singular covariance matrix. Retrying with Quasi-Newton solver.
[Stage 2443:>                                                       (0 + 1) / 1]
+------+--------------------+-----------------+
|output|            features|       prediction|
+------+--------------------+-----------------+
|  66.0|[0.09244059313201...|69.11041060954167|
|  66.0|[0.23534812657222...|67.63196245212879|
|  66.0|[0.91849251614329...|66.25163843597272|
|  66.0|[0.99638146996760...|67.14784185470705|
|  66.0|[1.39127585699721...|70.64487733468064|
+------+--------------------+-----------------+
only showing top 5 rows
```

In [126…

```
evaluator = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse5 = evaluator.evaluate(predictions_lrg)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse5)
```

```
[Stage 2444:=============================================>       (25 + 4) / 29]
Root Mean Squared Error (RMSE) on test data = 1.81377
```

Tune one by one to find the impact for each hyperparameter

In [135…

```
from pyspark.ml.regression import LinearRegression

# Define LinearRegression algorithm
lrg_1 = LinearRegression(featuresCol = 'features', labelCol = 'output',regParam=2.0)
# maxIter: int = 100
model_1 = lrg_1.fit(trainingData)
predictions_1 = model_1.transform(testData)

predictions_1.show(5)

evaluator_1 = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse_1 = evaluator_1.evaluate(predictions_1)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse_1)
```

```
ERROR:py4j.java_gateway:An error occurred while trying to connect to the Java server (12
7.0.0.1:35431)
Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 977, i
n _get_connection
    connection = self.deque.pop()
IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 1115,
in start
    self.socket.connect((self.address, self.port))
ConnectionRefusedError: [Errno 111] Connection refused
---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:977, in GatewayC
lient._get_connection(self)
    976 try:
--> 977     connection = self.deque.pop()
    978 except IndexError:

IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

ConnectionRefusedError                    Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1115, in Gatewa
yConnection.start(self)
   1114 try:
-> 1115     self.socket.connect((self.address, self.port))
   1116     self.stream = self.socket.makefile("rb")

ConnectionRefusedError: [Errno 111] Connection refused

During handling of the above exception, another exception occurred:

Py4JNetworkError                          Traceback (most recent call last)
Cell In [135], line 4
      1 from pyspark.ml.regression import LinearRegression
      3 # Define LinearRegression algorithm
----> 4 lrg_1 = LinearRegression(featuresCol = 'features', labelCol = 'output',regParam
=2.0)
      5 # maxIter: int = 100
```

```
      6 model_1 = lrg_1.fit(trainingData)

File /usr/lib/spark/python/pyspark/__init__.py:114, in keyword_only.<locals>.wrapper(self, *args, **kwargs)
    112     raise TypeError("Method %s forces keyword arguments." % func.__name__)
    113 self._input_kwargs = kwargs
--> 114 return func(self, **kwargs)

File /usr/lib/spark/python/pyspark/ml/regression.py:216, in LinearRegression.__init__(self, featuresCol, labelCol, predictionCol, maxIter, regParam, elasticNetParam, tol, fitIntercept, standardization, solver, weightCol, aggregationDepth, loss, epsilon, maxBlockSizeInMB)
    209 """
    210 __init__(self, \\*, featuresCol="features", labelCol="label", predictionCol="prediction", \
    211          maxIter=100, regParam=0.0, elasticNetParam=0.0, tol=1e-6, fitIntercept=True, \
    212          standardization=True, solver="auto", weightCol=None, aggregationDepth=2, \
    213          loss="squaredError", epsilon=1.35, maxBlockSizeInMB=0.0)
    214 """
    215 super(LinearRegression, self).__init__()
--> 216 self._java_obj = self._new_java_obj(
    217     "org.apache.spark.ml.regression.LinearRegression", self.uid)
    218 kwargs = self._input_kwargs
    219 self.setParams(**kwargs)

File /usr/lib/spark/python/pyspark/ml/wrapper.py:64, in JavaWrapper._new_java_obj(java_class, *args)
     62 java_obj = _jvm()
     63 for name in java_class.split("."):
---> 64     java_obj = getattr(java_obj, name)
     65 java_args = [_py2java(sc, arg) for arg in args]
     66 return java_obj(*java_args)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1692, in JVMView.__getattr__(self, name)
   1689 if name == UserHelpAutoCompletion.KEY:
   1690     return UserHelpAutoCompletion()
-> 1692 answer = self._gateway_client.send_command(
   1693     proto.REFLECTION_COMMAND_NAME +
   1694     proto.REFL_GET_UNKNOWN_SUB_COMMAND_NAME + name + "\n" + self._id +
   1695     "\n" + proto.END_COMMAND_PART)
   1696 if answer == proto.SUCCESS_PACKAGE:
   1697     return JavaPackage(name, self._gateway_client, jvm_id=self._id)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1031, in GatewayClient.send_command(self, command, retry, binary)
   1010 def send_command(self, command, retry=True, binary=False):
   1011     """Sends a command to the JVM. This method is not intended to be
   1012        called directly by Py4J users. It is usually called by
   1013        :class:`JavaMember` instances.
   (...)
   1029      if `binary` is `True`.
   1030     """
-> 1031     connection = self._get_connection()
   1032     try:
   1033         response = connection.send_command(command)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:979, in GatewayClient._get_connection(self)
    977     connection = self.deque.pop()
    978 except IndexError:
--> 979     connection = self._create_connection()
    980 return connection
```

```
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:985, in GatewayC
lient._create_connection(self)
    982 def _create_connection(self):
    983     connection = GatewayConnection(
    984         self.gateway_parameters, self.gateway_property)
--> 985     connection.start()
    986     return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1127, in Gatewa
yConnection.start(self)
   1124 msg = "An error occurred while trying to connect to the Java "\
   1125     "server ({0}:{1})".format(self.address, self.port)
   1126 logger.exception(msg)
-> 1127 raise Py4JNetworkError(msg, e)

Py4JNetworkError: An error occurred while trying to connect to the Java server (127.0.0.
1:35431)
```

In [132…

```
from pyspark.ml.regression import LinearRegression

# Define LinearRegression algorithm
lrg_2 = LinearRegression(featuresCol = 'features', labelCol = 'output',maxIter=10)
model_2 = lrg_2.fit(trainingData)
predictions_2 = model_2.transform(testData)

predictions_2.show(5)

evaluator_2 = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse_2 = evaluator_2.evaluate(predictions_2)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse_2)
```

```
ERROR:py4j.java_gateway:An error occurred while trying to connect to the Java server (12
7.0.0.1:35431)
Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 977, i
n _get_connection
    connection = self.deque.pop()
IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 1115,
in start
    self.socket.connect((self.address, self.port))
ConnectionRefusedError: [Errno 111] Connection refused
---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:977, in GatewayC
lient._get_connection(self)
    976 try:
--> 977     connection = self.deque.pop()
    978 except IndexError:

IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

ConnectionRefusedError                    Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1115, in Gatewa
```

```
yConnection.start(self)
   1114 try:
-> 1115     self.socket.connect((self.address, self.port))
   1116     self.stream = self.socket.makefile("rb")

ConnectionRefusedError: [Errno 111] Connection refused

During handling of the above exception, another exception occurred:

Py4JNetworkError                          Traceback (most recent call last)
Cell In [132], line 4
      1 from pyspark.ml.regression import LinearRegression
      3 # Define LinearRegression algorithm
----> 4 lrg_2 = LinearRegression(featuresCol = 'features', labelCol = 'output',maxIter=
10)
      5 model_2 = lrg_2.fit(trainingData)
      6 predictions_2 = model_2.transform(testData)

File /usr/lib/spark/python/pyspark/__init__.py:114, in keyword_only.<locals>.wrapper(sel
f, *args, **kwargs)
    112     raise TypeError("Method %s forces keyword arguments." % func.__name__)
    113 self._input_kwargs = kwargs
--> 114 return func(self, **kwargs)

File /usr/lib/spark/python/pyspark/ml/regression.py:216, in LinearRegression.__init__(se
lf, featuresCol, labelCol, predictionCol, maxIter, regParam, elasticNetParam, tol, fitIn
tercept, standardization, solver, weightCol, aggregationDepth, loss, epsilon, maxBlockSi
zeInMB)
    209 """
    210 __init__(self, \\*, featuresCol="features", labelCol="label", predictionCol="pre
diction", \
    211          maxIter=100, regParam=0.0, elasticNetParam=0.0, tol=1e-6, fitIntercept=
True, \
    212          standardization=True, solver="auto", weightCol=None, aggregationDepth=
2, \
    213          loss="squaredError", epsilon=1.35, maxBlockSizeInMB=0.0)
    214 """
    215 super(LinearRegression, self).__init__()
--> 216 self._java_obj = self._new_java_obj(
    217     "org.apache.spark.ml.regression.LinearRegression", self.uid)
    218 kwargs = self._input_kwargs
    219 self.setParams(**kwargs)

File /usr/lib/spark/python/pyspark/ml/wrapper.py:64, in JavaWrapper._new_java_obj(java_
class, *args)
     62 java_obj = _jvm()
     63 for name in java_class.split("."):
---> 64     java_obj = getattr(java_obj, name)
     65 java_args = [_py2java(sc, arg) for arg in args]
     66 return java_obj(*java_args)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1692, in JVMVie
w.__getattr__(self, name)
   1689 if name == UserHelpAutoCompletion.KEY:
   1690     return UserHelpAutoCompletion()
-> 1692 answer = self._gateway_client.send_command(
   1693     proto.REFLECTION_COMMAND_NAME +
   1694     proto.REFL_GET_UNKNOWN_SUB_COMMAND_NAME + name + "\n" + self._id +
   1695     "\n" + proto.END_COMMAND_PART)
   1696 if answer == proto.SUCCESS_PACKAGE:
   1697     return JavaPackage(name, self._gateway_client, jvm_id=self._id)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1031, in Gatewa
yClient.send_command(self, command, retry, binary)
   1010 def send_command(self, command, retry=True, binary=False):
```

```
   1011     """Sends a command to the JVM. This method is not intended to be
   1012        called directly by Py4J users. It is usually called by
   1013        :class:`JavaMember` instances.
   (...)
   1029      if `binary` is `True`.
   1030     """
-> 1031     connection = self._get_connection()
   1032     try:
   1033         response = connection.send_command(command)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:979, in GatewayC
lient._get_connection(self)
    977     connection = self.deque.pop()
    978 except IndexError:
--> 979     connection = self._create_connection()
    980 return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:985, in GatewayC
lient._create_connection(self)
    982 def _create_connection(self):
    983     connection = GatewayConnection(
    984         self.gateway_parameters, self.gateway_property)
--> 985     connection.start()
    986     return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1127, in Gatewa
yConnection.start(self)
   1124 msg = "An error occurred while trying to connect to the Java "\
   1125     "server ({0}:{1})".format(self.address, self.port)
   1126 logger.exception(msg)
-> 1127 raise Py4JNetworkError(msg, e)

Py4JNetworkError: An error occurred while trying to connect to the Java server (127.0.0.
1:35431)
```

In [133…

```
from pyspark.ml.regression import LinearRegression

# Define LinearRegression algorithm
lrg_3 = LinearRegression(featuresCol = 'features', labelCol = 'output',maxIter=30)
model_3 = lrg_3.fit(trainingData)
predictions_3 = model_3.transform(testData)

predictions_3.show(5)

evaluator_3 = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
rmse_3 = evaluator_3.evaluate(predictions_3)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse_3)
```

```
ERROR:py4j.java_gateway:An error occurred while trying to connect to the Java server (12
7.0.0.1:35431)
Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 977, i
n _get_connection
    connection = self.deque.pop()
IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 1115,
in start
```

```
    self.socket.connect((self.address, self.port))
ConnectionRefusedError: [Errno 111] Connection refused

---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:977, in GatewayC
lient._get_connection(self)
    976 try:
--> 977     connection = self.deque.pop()
    978 except IndexError:

IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

ConnectionRefusedError                    Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1115, in Gatewa
yConnection.start(self)
   1114 try:
-> 1115     self.socket.connect((self.address, self.port))
   1116     self.stream = self.socket.makefile("rb")

ConnectionRefusedError: [Errno 111] Connection refused

During handling of the above exception, another exception occurred:

Py4JNetworkError                          Traceback (most recent call last)
Cell In [133], line 4
      1 from pyspark.ml.regression import LinearRegression
      3 # Define LinearRegression algorithm
----> 4 lrg_3 = LinearRegression(featuresCol = 'features', labelCol = 'output',maxIter=
30)
      5 model_3 = lrg_3.fit(trainingData)
      6 predictions_3 = model_3.transform(testData)

File /usr/lib/spark/python/pyspark/__init__.py:114, in keyword_only.<locals>.wrapper(sel
f, *args, **kwargs)
    112     raise TypeError("Method %s forces keyword arguments." % func.__name__)
    113 self._input_kwargs = kwargs
--> 114 return func(self, **kwargs)

File /usr/lib/spark/python/pyspark/ml/regression.py:216, in LinearRegression.__init__(se
lf, featuresCol, labelCol, predictionCol, maxIter, regParam, elasticNetParam, tol, fitIn
tercept, standardization, solver, weightCol, aggregationDepth, loss, epsilon, maxBlockSi
zeInMB)
    209 """
    210 __init__(self, \\*, featuresCol="features", labelCol="label", predictionCol="pre
diction", \
    211          maxIter=100, regParam=0.0, elasticNetParam=0.0, tol=1e-6, fitIntercept=
True, \
    212          standardization=True, solver="auto", weightCol=None, aggregationDepth=
2, \
    213          loss="squaredError", epsilon=1.35, maxBlockSizeInMB=0.0)
    214 """
    215 super(LinearRegression, self).__init__()
--> 216 self._java_obj = self._new_java_obj(
    217     "org.apache.spark.ml.regression.LinearRegression", self.uid)
    218 kwargs = self._input_kwargs
    219 self.setParams(**kwargs)

File /usr/lib/spark/python/pyspark/ml/wrapper.py:64, in JavaWrapper._new_java_obj(java_
class, *args)
     62 java_obj = _jvm()
     63 for name in java_class.split("."):
---> 64     java_obj = getattr(java_obj, name)
     65 java_args = [_py2java(sc, arg) for arg in args]
```

```
     66 return java_obj(*java_args)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1692, in JVMVie
w.__getattr__(self, name)
   1689 if name == UserHelpAutoCompletion.KEY:
   1690     return UserHelpAutoCompletion()
-> 1692 answer = self._gateway_client.send_command(
   1693     proto.REFLECTION_COMMAND_NAME +
   1694     proto.REFL_GET_UNKNOWN_SUB_COMMAND_NAME + name + "\n" + self._id +
   1695     "\n" + proto.END_COMMAND_PART)
   1696 if answer == proto.SUCCESS_PACKAGE:
   1697     return JavaPackage(name, self._gateway_client, jvm_id=self._id)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1031, in Gatewa
yClient.send_command(self, command, retry, binary)
   1010 def send_command(self, command, retry=True, binary=False):
   1011     """Sends a command to the JVM. This method is not intended to be
   1012        called directly by Py4J users. It is usually called by
   1013        :class:`JavaMember` instances.
   (...)
   1029      if `binary` is `True`.
   1030     """
-> 1031     connection = self._get_connection()
   1032     try:
   1033         response = connection.send_command(command)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:979, in GatewayC
lient._get_connection(self)
    977     connection = self.deque.pop()
    978 except IndexError:
--> 979     connection = self._create_connection()
    980 return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:985, in GatewayC
lient._create_connection(self)
    982 def _create_connection(self):
    983     connection = GatewayConnection(
    984         self.gateway_parameters, self.gateway_property)
--> 985     connection.start()
    986     return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1127, in Gatewa
yConnection.start(self)
   1124 msg = "An error occurred while trying to connect to the Java "\
   1125     "server ({0}:{1})".format(self.address, self.port)
   1126 logger.exception(msg)
-> 1127 raise Py4JNetworkError(msg, e)

Py4JNetworkError: An error occurred while trying to connect to the Java server (127.0.0.
1:35431)
```

In [134…

```
from pyspark.ml.regression import LinearRegression

# Define LinearRegression algorithm
lrg_4 = LinearRegression(featuresCol = 'features', labelCol = 'output',maxIter=200)
model_4 = lrg_4.fit(trainingData)
predictions_4 = model_4.transform(testData)

predictions_4.show(5)

evaluator_4 = RegressionEvaluator(
    labelCol="output", predictionCol="prediction", metricName="rmse")
```

```
rmse_4 = evaluator_4.evaluate(predictions_4)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse_4)
```

```
ERROR:py4j.java_gateway:An error occurred while trying to connect to the Java server (12
7.0.0.1:35431)
Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 977, i
n _get_connection
    connection = self.deque.pop()
IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "/usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py", line 1115,
in start
    self.socket.connect((self.address, self.port))
ConnectionRefusedError: [Errno 111] Connection refused
---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:977, in GatewayC
lient._get_connection(self)
    976 try:
--> 977     connection = self.deque.pop()
    978 except IndexError:

IndexError: pop from an empty deque

During handling of the above exception, another exception occurred:

ConnectionRefusedError                    Traceback (most recent call last)
File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1115, in Gatewa
yConnection.start(self)
   1114 try:
-> 1115     self.socket.connect((self.address, self.port))
   1116     self.stream = self.socket.makefile("rb")

ConnectionRefusedError: [Errno 111] Connection refused

During handling of the above exception, another exception occurred:

Py4JNetworkError                          Traceback (most recent call last)
Cell In [134], line 4
      1 from pyspark.ml.regression import LinearRegression
      3 # Define LinearRegression algorithm
----> 4 lrg_4 = LinearRegression(featuresCol = 'features', labelCol = 'output',maxIter=
200)
      5 model_4 = lrg_4.fit(trainingData)
      6 predictions_4 = model_4.transform(testData)

File /usr/lib/spark/python/pyspark/__init__.py:114, in keyword_only.<locals>.wrapper(sel
f, *args, **kwargs)
    112     raise TypeError("Method %s forces keyword arguments." % func.__name__)
    113 self._input_kwargs = kwargs
--> 114 return func(self, **kwargs)

File /usr/lib/spark/python/pyspark/ml/regression.py:216, in LinearRegression.__init__(se
lf, featuresCol, labelCol, predictionCol, maxIter, regParam, elasticNetParam, tol, fitIn
tercept, standardization, solver, weightCol, aggregationDepth, loss, epsilon, maxBlockSi
zeInMB)
    209 """
    210 __init__(self, \\*, featuresCol="features", labelCol="label", predictionCol="pre
diction", \
    211          maxIter=100, regParam=0.0, elasticNetParam=0.0, tol=1e-6, fitIntercept=
```

```
True, \
    212         standardization=True, solver="auto", weightCol=None, aggregationDepth=
2, \
    213         loss="squaredError", epsilon=1.35, maxBlockSizeInMB=0.0)
    214 """
    215 super(LinearRegression, self).__init__()
--> 216 self._java_obj = self._new_java_obj(
    217     "org.apache.spark.ml.regression.LinearRegression", self.uid)
    218 kwargs = self._input_kwargs
    219 self.setParams(**kwargs)

File /usr/lib/spark/python/pyspark/ml/wrapper.py:64, in JavaWrapper._new_java_obj(java_
class, *args)
     62 java_obj = _jvm()
     63 for name in java_class.split("."):
---> 64     java_obj = getattr(java_obj, name)
     65 java_args = [_py2java(sc, arg) for arg in args]
     66 return java_obj(*java_args)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1692, in JVMVie
w.__getattr__(self, name)
   1689 if name == UserHelpAutoCompletion.KEY:
   1690     return UserHelpAutoCompletion()
-> 1692 answer = self._gateway_client.send_command(
   1693     proto.REFLECTION_COMMAND_NAME +
   1694     proto.REFL_GET_UNKNOWN_SUB_COMMAND_NAME + name + "\n" + self._id +
   1695     "\n" + proto.END_COMMAND_PART)
   1696 if answer == proto.SUCCESS_PACKAGE:
   1697     return JavaPackage(name, self._gateway_client, jvm_id=self._id)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1031, in Gatewa
yClient.send_command(self, command, retry, binary)
   1010 def send_command(self, command, retry=True, binary=False):
   1011     """Sends a command to the JVM. This method is not intended to be
   1012        called directly by Py4J users. It is usually called by
   1013        :class:`JavaMember` instances.
   (...)
   1029      if `binary` is `True`.
   1030     """
-> 1031     connection = self._get_connection()
   1032     try:
   1033         response = connection.send_command(command)

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:979, in GatewayC
lient._get_connection(self)
    977     connection = self.deque.pop()
    978 except IndexError:
--> 979     connection = self._create_connection()
    980 return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:985, in GatewayC
lient._create_connection(self)
    982 def _create_connection(self):
    983     connection = GatewayConnection(
    984         self.gateway_parameters, self.gateway_property)
--> 985     connection.start()
    986     return connection

File /usr/lib/spark/python/lib/py4j-0.10.9-src.zip/py4j/java_gateway.py:1127, in Gatewa
yConnection.start(self)
   1124 msg = "An error occurred while trying to connect to the Java "\
   1125     "server ({0}:{1})".format(self.address, self.port)
   1126 logger.exception(msg)
-> 1127 raise Py4JNetworkError(msg, e)
```

```
Py4JNetworkError: An error occurred while trying to connect to the Java server (127.0.0.
1:35431)
```

Tensorflow

In [100…

```
from pyspark.sql.types import *
```

In [101…

```
to_array = udf(lambda v: v.toArray().tolist(), ArrayType(FloatType()))

df_test = testData
df_validate,df_train = trainingData.randomSplit([0.5,0.5])

df_train_pandas = df_train.withColumn('features', to_array('features')).toPandas()
df_validate_pandas = df_validate.withColumn('features', to_array('features')).toPandas(
df_test_pandas = df_test.withColumn('features', to_array('features')).toPandas()
```

In [104…

```
import tensorflow as tf
from tensorflow import keras

x_train = tf.constant(np.array(df_train_pandas['features'].values.tolist()))
y_train = tf.constant(np.array(df_train_pandas['output'].values.tolist()))

x_validate = tf.constant(np.array(df_validate_pandas['features'].values.tolist()))
y_validate = tf.constant(np.array(df_validate_pandas['output'].values.tolist()))


x_test = tf.constant(np.array(df_test_pandas['features'].values.tolist()))
y_test = tf.constant(np.array(df_test_pandas['output'].values.tolist()))
```

In [105…

```
print(x_train)
print(y_train)
```

```
tf.Tensor(
[[6.23807311e-02 1.05221472e+01 1.08017780e-01 ... 8.06517029e+00
  1.64716005e+00 5.66285610e+00]
 [2.82655448e-01 1.05221472e+01 2.07394138e-02 ... 6.43171787e+00
  3.48437715e+00 7.18747139e+00]
 [4.57999796e-01 1.05221472e+01 1.72828455e-04 ... 6.22753620e+00
  3.99119544e+00 7.62307549e+00]
 ...
 [7.66767025e+00 1.11598530e+01 2.59242672e-02 ... 5.30871964e+00
  2.47074008e+00 5.22725201e+00]
 [7.66796017e+00 9.88444138e+00 3.11091207e-02 ... 5.92126417e+00
  1.45710313e+00 5.55395508e+00]
 [7.66801834e+00 9.40616226e+00 2.76525524e-02 ... 5.00244713e+00
  1.33039856e+00 5.44505405e+00]], shape=(56194, 78), dtype=float64)
tf.Tensor([66. 66. 66. ... 51. 52. 52.], shape=(56194,), dtype=float64)
```

Neural networks

In [106…

```
model_nn = keras.Sequential( [keras.layers.Dense(78,activation='relu'),
                              keras.layers.Dense(10,activation='relu'),
```

```
                                keras.layers.Dense(10,activation='relu'),
                                keras.layers.Dense(10,activation='relu') ,
                                keras.layers.Dense(1)] )
```

In [107…

```
y_pred = model_nn(x_train)
model_nn.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense (Dense)               (56194, 78)               6162

 dense_1 (Dense)             (56194, 10)               790

 dense_2 (Dense)             (56194, 10)               110

 dense_3 (Dense)             (56194, 10)               110

 dense_4 (Dense)             (56194, 1)                11

=================================================================
Total params: 7,183
Trainable params: 7,183
Non-trainable params: 0
_________________________________________________________________
```

In [108…

```
print(y_pred)
print(y_train)
```

```
tf.Tensor(
[[-1.3078046 ]
 [-2.1032403 ]
 [-0.68787897]
 ...
 [-1.8970299 ]
 [-2.3687515 ]
 [-2.0279553 ]], shape=(56194, 1), dtype=float32)
tf.Tensor([66. 66. 66. ... 51. 52. 52.], shape=(56194,), dtype=float64)
```

In [110…

```
mse = keras.losses.MeanSquaredError()

model_nn.compile(optimizer = 'adam',
    loss=mse,
    metrics=[mse])
model_nn.fit(x_train,y_train, epochs = 20,validation_data=(x_validate,y_validate),verbo

loss = mse(y_train, y_pred).numpy()
print(loss)
```

```
Epoch 1/20
1757/1757 - 6s - loss: 1.6969 - mean_squared_error: 1.6961 - val_loss: 1.4290 - val_mean
_squared_error: 1.4325 - 6s/epoch - 3ms/step
Epoch 2/20
1757/1757 - 4s - loss: 1.6463 - mean_squared_error: 1.6463 - val_loss: 1.8893 - val_mean
_squared_error: 1.8931 - 4s/epoch - 3ms/step
Epoch 3/20
1757/1757 - 4s - loss: 1.6520 - mean_squared_error: 1.6520 - val_loss: 1.5368 - val_mean
_squared_error: 1.5380 - 4s/epoch - 3ms/step
Epoch 4/20
```

```
1757/1757 - 5s - loss: 1.5949 - mean_squared_error: 1.5946 - val_loss: 1.3962 - val_mean
_squared_error: 1.3969 - 5s/epoch - 3ms/step
Epoch 5/20
1757/1757 - 4s - loss: 1.5436 - mean_squared_error: 1.5428 - val_loss: 2.2757 - val_mean
_squared_error: 2.2804 - 4s/epoch - 3ms/step
Epoch 6/20
1757/1757 - 4s - loss: 1.4928 - mean_squared_error: 1.4973 - val_loss: 2.5179 - val_mean
_squared_error: 2.5171 - 4s/epoch - 3ms/step
Epoch 7/20
1757/1757 - 4s - loss: 1.4376 - mean_squared_error: 1.4377 - val_loss: 4.1597 - val_mean
_squared_error: 4.1581 - 4s/epoch - 3ms/step
Epoch 8/20
1757/1757 - 4s - loss: 1.3820 - mean_squared_error: 1.3818 - val_loss: 2.2020 - val_mean
_squared_error: 2.2015 - 4s/epoch - 2ms/step
Epoch 9/20
1757/1757 - 4s - loss: 1.3582 - mean_squared_error: 1.3575 - val_loss: 1.0783 - val_mean
_squared_error: 1.0799 - 4s/epoch - 2ms/step
Epoch 10/20
1757/1757 - 4s - loss: 1.3500 - mean_squared_error: 1.3497 - val_loss: 1.3291 - val_mean
_squared_error: 1.3298 - 4s/epoch - 3ms/step
Epoch 11/20
1757/1757 - 4s - loss: 1.2423 - mean_squared_error: 1.2431 - val_loss: 3.1723 - val_mean
_squared_error: 3.1713 - 4s/epoch - 3ms/step
Epoch 12/20
1757/1757 - 4s - loss: 1.2329 - mean_squared_error: 1.2326 - val_loss: 2.0219 - val_mean
_squared_error: 2.0276 - 4s/epoch - 2ms/step
Epoch 13/20
1757/1757 - 4s - loss: 1.1417 - mean_squared_error: 1.1417 - val_loss: 2.9505 - val_mean
_squared_error: 2.9495 - 4s/epoch - 2ms/step
Epoch 14/20
1757/1757 - 4s - loss: 1.1635 - mean_squared_error: 1.1639 - val_loss: 1.0200 - val_mean
_squared_error: 1.0214 - 4s/epoch - 2ms/step
Epoch 15/20
1757/1757 - 4s - loss: 1.1085 - mean_squared_error: 1.1081 - val_loss: 1.2490 - val_mean
_squared_error: 1.2507 - 4s/epoch - 2ms/step
Epoch 16/20
1757/1757 - 4s - loss: 1.0944 - mean_squared_error: 1.0942 - val_loss: 1.1478 - val_mean
_squared_error: 1.1491 - 4s/epoch - 2ms/step
Epoch 17/20
1757/1757 - 4s - loss: 1.0823 - mean_squared_error: 1.0819 - val_loss: 0.9469 - val_mean
_squared_error: 0.9475 - 4s/epoch - 2ms/step
Epoch 18/20
1757/1757 - 4s - loss: 1.0775 - mean_squared_error: 1.0772 - val_loss: 1.7955 - val_mean
_squared_error: 1.7984 - 4s/epoch - 2ms/step
Epoch 19/20
1757/1757 - 4s - loss: 1.0429 - mean_squared_error: 1.0426 - val_loss: 1.9373 - val_mean
_squared_error: 1.9425 - 4s/epoch - 2ms/step
Epoch 20/20
1757/1757 - 4s - loss: 1.0872 - mean_squared_error: 1.0877 - val_loss: 0.9661 - val_mean
_squared_error: 0.9673 - 4s/epoch - 3ms/step
4547.805
```

In [111…

```
model_nn.evaluate(x_test,y_test, verbose = 2)
```

```
878/878 - 1s - loss: 0.9305 - mean_squared_error: 0.9319 - 970ms/epoch - 1ms/step
```

Out[111… `[0.9305020570755005, 0.931940495967865]`

In [112…

```
def cross_valiation(hyper,k,s_r,x,y,logdir):

    def data_split():
        for i in range(k):
            idx=tf.range(df_train_pandas.shape[0])
```

```
            splt_idx = int(s_r*df_train_pandas.shape[0])
            idx = tf.random.shuffle(idx)
            x_train, y_train = tf.gather(x, idx[:splt_idx]), tf.gather(y, idx[:splt_idx
            x_valid, y_valid = tf.gather(x, idx[splt_idx:]), tf.gather(y, idx[splt_idx:
            return x_train,y_train,x_valid,y_valid

    model = keras.Sequential()
    for _ in range(hparams[HP_DEPTH]):
        model.add(keras.layers.Dense(hparams[HP_WIDTH],activation='relu'))
        model.add(keras.layers.Dense(1))
        model.compile(optimizer = 'adam',
            loss=keras.losses.MeanSquaredError(),
            metrics=[keras.losses.MeanSquaredError(name = 'MSE')])
        x_train,y_train,x_valid,y_valid = data_split()
        history = model.fit(x_train, y_train, epochs=5, verbose = 2,validation_data = (
                  callbacks=[tf.keras.callbacks.TensorBoard(log_dir=logdir, histogram_f
        accuracy = np.mean(history.history["MSE"])
        model.summary()
    return accuracy
```

In [113…

```
from tensorboard.plugins.hparams import api as hp

HP_WIDTH = hp.HParam('NN_width', hp.Discrete([10,20,30]))
HP_DEPTH = hp.HParam('NN_depth', hp.Discrete([3,4,5]))


with tf.summary.create_file_writer('logs14813/hparam_tuning').as_default():
    hp.hparams_config(
    hparams=[HP_WIDTH, HP_DEPTH],
    metrics=[hp.Metric('MSE')],
  )
```

In [114…

```
import datetime
for hp_width in HP_WIDTH.domain.values:
    for hp_depth in (HP_DEPTH.domain.values):
        hparams = {
            HP_WIDTH: hp_width,
            HP_DEPTH: hp_depth,
        }
        run_name = f"run-WIDTH{int(hparams[HP_WIDTH])}-DEPTH{hparams[HP_DEPTH]}"
        print('--- Starting trial: %s' % run_name)
        print({h.name: hparams[h] for h in hparams})

        run_dir = 'logs14813/hparam_tuning/' + datetime.datetime.now().strftime("%Y%m%d
        accuracy = cross_valiation(hparams,10,0.7,x_train, y_train,run_dir)

        with tf.summary.create_file_writer(run_dir).as_default():
          hp.hparams(hparams)  # record the values used in this trial
          tf.summary.scalar("MSE", accuracy, step=1)
```

```
--- Starting trial: run-WIDTH10-DEPTH3
{'NN_width': 10, 'NN_depth': 3}
Epoch 1/5
1230/1230 - 3s - loss: 27.5363 - MSE: 27.5224 - val_loss: 10.1622 - val_MSE: 10.1631 - 3
s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 8.5006 - MSE: 8.4959 - val_loss: 7.3856 - val_MSE: 7.3862 - 2s/ep
och - 2ms/step
```

```
Epoch 3/5
1230/1230 - 2s - loss: 6.5537 - MSE: 6.5549 - val_loss: 5.5198 - val_MSE: 5.5202 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.3720 - MSE: 5.3752 - val_loss: 4.5673 - val_MSE: 4.5676 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.6772 - MSE: 4.6787 - val_loss: 5.0986 - val_MSE: 5.0985 - 2s/ep
och - 2ms/step
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_5 (Dense)             (None, 10)                790

 dense_6 (Dense)             (None, 1)                 11

=================================================================
Total params: 801
Trainable params: 801
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 110.4980 - MSE: 110.4329 - val_loss: 17.8756 - val_MSE: 17.8762 -
3s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 12.1077 - MSE: 12.1199 - val_loss: 8.5591 - val_MSE: 8.5604 - 2s/
epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 7.8804 - MSE: 7.8823 - val_loss: 7.2856 - val_MSE: 7.2865 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 7.0528 - MSE: 7.0514 - val_loss: 6.3664 - val_MSE: 6.3672 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 6.3207 - MSE: 6.3176 - val_loss: 5.6708 - val_MSE: 5.6717 - 2s/ep
och - 2ms/step
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_5 (Dense)             (None, 10)                790

 dense_6 (Dense)             (None, 1)                 11

 dense_7 (Dense)             (None, 10)                20

 dense_8 (Dense)             (None, 1)                 11

=================================================================
Total params: 832
Trainable params: 832
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 32.7926 - MSE: 32.7749 - val_loss: 7.0933 - val_MSE: 7.0923 - 4s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 6.5409 - MSE: 6.5398 - val_loss: 6.6526 - val_MSE: 6.6515 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.7437 - MSE: 5.7446 - val_loss: 5.3633 - val_MSE: 5.3625 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.0309 - MSE: 5.0302 - val_loss: 5.7998 - val_MSE: 5.7992 - 2s/ep
```

```
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.6131 - MSE: 4.6149 - val_loss: 4.2171 - val_MSE: 4.2165 - 2s/ep
och - 2ms/step
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_5 (Dense)             (None, 10)                790

 dense_6 (Dense)             (None, 1)                 11

 dense_7 (Dense)             (None, 10)                20

 dense_8 (Dense)             (None, 1)                 11

 dense_9 (Dense)             (None, 10)                20

 dense_10 (Dense)            (None, 1)                 11

=================================================================
Total params: 863
Trainable params: 863
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH10-DEPTH4
{'NN_width': 10, 'NN_depth': 4}
Epoch 1/5
1230/1230 - 3s - loss: 403.5477 - MSE: 403.3085 - val_loss: 38.5559 - val_MSE: 38.5548 -
3s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 25.1463 - MSE: 25.1331 - val_loss: 17.4940 - val_MSE: 17.4935 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 13.7679 - MSE: 13.7667 - val_loss: 12.2865 - val_MSE: 12.2861 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 9.9609 - MSE: 9.9558 - val_loss: 9.2169 - val_MSE: 9.2165 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 8.1566 - MSE: 8.1550 - val_loss: 7.6003 - val_MSE: 7.5998 - 2s/ep
och - 2ms/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_11 (Dense)            (None, 10)                790

 dense_12 (Dense)            (None, 1)                 11

=================================================================
Total params: 801
Trainable params: 801
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 52.7300 - MSE: 52.6986 - val_loss: 10.3107 - val_MSE: 10.3113 - 3
s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 8.6681 - MSE: 8.6640 - val_loss: 7.4981 - val_MSE: 7.4988 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 7.0971 - MSE: 7.0951 - val_loss: 6.4978 - val_MSE: 6.4981 - 2s/ep
och - 2ms/step
Epoch 4/5
```

```
1230/1230 - 2s - loss: 6.0469 - MSE: 6.0444 - val_loss: 5.7743 - val_MSE: 5.7746 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 5.1471 - MSE: 5.1458 - val_loss: 4.7953 - val_MSE: 4.7959 - 2s/ep
och - 2ms/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_11 (Dense)            (None, 10)                790

 dense_12 (Dense)            (None, 1)                 11

 dense_13 (Dense)            (None, 10)                20

 dense_14 (Dense)            (None, 1)                 11

=================================================================
Total params: 832
Trainable params: 832
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 40.3829 - MSE: 40.3594 - val_loss: 5.6454 - val_MSE: 5.6460 - 4s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 4.9623 - MSE: 4.9602 - val_loss: 4.8772 - val_MSE: 4.8778 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 4.4289 - MSE: 4.4284 - val_loss: 4.0982 - val_MSE: 4.0986 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 4.0473 - MSE: 4.0466 - val_loss: 4.1046 - val_MSE: 4.1050 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 3.7665 - MSE: 3.7661 - val_loss: 3.6047 - val_MSE: 3.6049 - 2s/ep
och - 2ms/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_11 (Dense)            (None, 10)                790

 dense_12 (Dense)            (None, 1)                 11

 dense_13 (Dense)            (None, 10)                20

 dense_14 (Dense)            (None, 1)                 11

 dense_15 (Dense)            (None, 10)                20

 dense_16 (Dense)            (None, 1)                 11

=================================================================
Total params: 863
Trainable params: 863
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 143.8477 - MSE: 143.7587 - val_loss: 4.9488 - val_MSE: 4.9489 - 4
s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 4.4289 - MSE: 4.4269 - val_loss: 4.1446 - val_MSE: 4.1444 - 2s/ep
och - 2ms/step
Epoch 3/5
```

```
1230/1230 - 2s - loss: 3.8955 - MSE: 3.8963 - val_loss: 3.5726 - val_MSE: 3.5723 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 3.6309 - MSE: 3.6303 - val_loss: 3.3257 - val_MSE: 3.3256 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 3.4136 - MSE: 3.4129 - val_loss: 4.4667 - val_MSE: 4.4665 - 2s/ep
och - 2ms/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_11 (Dense)            (None, 10)                790

 dense_12 (Dense)            (None, 1)                 11

 dense_13 (Dense)            (None, 10)                20

 dense_14 (Dense)            (None, 1)                 11

 dense_15 (Dense)            (None, 10)                20

 dense_16 (Dense)            (None, 1)                 11

 dense_17 (Dense)            (None, 10)                20

 dense_18 (Dense)            (None, 1)                 11

=================================================================
Total params: 894
Trainable params: 894
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH10-DEPTH5
{'NN_width': 10, 'NN_depth': 5}
Epoch 1/5
1230/1230 - 3s - loss: 30.4516 - MSE: 30.4347 - val_loss: 12.4071 - val_MSE: 12.4064 - 3
s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 10.5812 - MSE: 10.5853 - val_loss: 8.9311 - val_MSE: 8.9305 - 2s/
epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 8.5596 - MSE: 8.5563 - val_loss: 9.2008 - val_MSE: 9.2015 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 7.3962 - MSE: 7.4024 - val_loss: 8.4267 - val_MSE: 8.4257 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 6.5788 - MSE: 6.5812 - val_loss: 6.2370 - val_MSE: 6.2364 - 2s/ep
och - 2ms/step
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_19 (Dense)            (None, 10)                790

 dense_20 (Dense)            (None, 1)                 11

=================================================================
Total params: 801
Trainable params: 801
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 1059.6027 - MSE: 1058.9749 - val_loss: 54.2037 - val_MSE: 54.2054
```

```
- 3s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 49.7873 - MSE: 49.7825 - val_loss: 45.6439 - val_MSE: 45.6456 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 41.5399 - MSE: 41.5486 - val_loss: 37.2489 - val_MSE: 37.2505 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 32.6633 - MSE: 32.6567 - val_loss: 26.9428 - val_MSE: 26.9442 - 2
s/epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 21.1371 - MSE: 21.1334 - val_loss: 15.1663 - val_MSE: 15.1665 - 2
s/epoch - 2ms/step
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_19 (Dense)            (None, 10)                790

 dense_20 (Dense)            (None, 1)                 11

 dense_21 (Dense)            (None, 10)                20

 dense_22 (Dense)            (None, 1)                 11

=================================================================
Total params: 832
Trainable params: 832
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 457.4865 - MSE: 457.2085 - val_loss: 24.5646 - val_MSE: 24.5660 -
4s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 16.6311 - MSE: 16.6263 - val_loss: 11.0462 - val_MSE: 11.0464 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 9.8203 - MSE: 9.8177 - val_loss: 8.5023 - val_MSE: 8.5026 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 8.0256 - MSE: 8.0260 - val_loss: 7.3165 - val_MSE: 7.3168 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 6.9216 - MSE: 6.9203 - val_loss: 6.5625 - val_MSE: 6.5622 - 2s/ep
och - 2ms/step
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_19 (Dense)            (None, 10)                790

 dense_20 (Dense)            (None, 1)                 11

 dense_21 (Dense)            (None, 10)                20

 dense_22 (Dense)            (None, 1)                 11

 dense_23 (Dense)            (None, 10)                20

 dense_24 (Dense)            (None, 1)                 11

=================================================================
Total params: 863
Trainable params: 863
Non-trainable params: 0
```

```
Epoch 1/5
1230/1230 - 4s - loss: 426.6310 - MSE: 426.3643 - val_loss: 6.6005 - val_MSE: 6.5995 - 4
s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 6.2008 - MSE: 6.1996 - val_loss: 6.1520 - val_MSE: 6.1513 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.7126 - MSE: 5.7112 - val_loss: 5.4181 - val_MSE: 5.4176 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.2663 - MSE: 5.2667 - val_loss: 5.0948 - val_MSE: 5.0944 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.8600 - MSE: 4.8589 - val_loss: 4.5223 - val_MSE: 4.5218 - 2s/ep
och - 2ms/step
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_19 (Dense)            (None, 10)                790

 dense_20 (Dense)            (None, 1)                 11

 dense_21 (Dense)            (None, 10)                20

 dense_22 (Dense)            (None, 1)                 11

 dense_23 (Dense)            (None, 10)                20

 dense_24 (Dense)            (None, 1)                 11

 dense_25 (Dense)            (None, 10)                20

 dense_26 (Dense)            (None, 1)                 11

=================================================================
Total params: 894
Trainable params: 894
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 839.0534 - MSE: 838.5250 - val_loss: 4.6685 - val_MSE: 4.6687 - 4
s/epoch - 4ms/step
Epoch 2/5
1230/1230 - 3s - loss: 4.6721 - MSE: 4.6725 - val_loss: 4.5150 - val_MSE: 4.5153 - 3s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 3s - loss: 4.4820 - MSE: 4.4840 - val_loss: 4.2303 - val_MSE: 4.2304 - 3s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 3s - loss: 4.3314 - MSE: 4.3290 - val_loss: 5.2856 - val_MSE: 5.2855 - 3s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 3s - loss: 4.2046 - MSE: 4.2048 - val_loss: 4.0692 - val_MSE: 4.0692 - 3s/ep
och - 2ms/step
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_19 (Dense)            (None, 10)                790

 dense_20 (Dense)            (None, 1)                 11

 dense_21 (Dense)            (None, 10)                20
```

```
 dense_22 (Dense)            (None, 1)                 11

 dense_23 (Dense)            (None, 10)                20

 dense_24 (Dense)            (None, 1)                 11

 dense_25 (Dense)            (None, 10)                20

 dense_26 (Dense)            (None, 1)                 11

 dense_27 (Dense)            (None, 10)                20

 dense_28 (Dense)            (None, 1)                 11

=================================================================
Total params: 925
Trainable params: 925
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH20-DEPTH3
{'NN_width': 20, 'NN_depth': 3}
Epoch 1/5
1230/1230 - 3s - loss: 644.2581 - MSE: 643.8654 - val_loss: 25.2803 - val_MSE: 25.2775 -
3s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 20.8063 - MSE: 20.7960 - val_loss: 16.5602 - val_MSE: 16.5587 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 13.3278 - MSE: 13.3281 - val_loss: 11.1926 - val_MSE: 11.1921 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 10.2049 - MSE: 10.2064 - val_loss: 10.6150 - val_MSE: 10.6147 - 2
s/epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 8.7590 - MSE: 8.7564 - val_loss: 7.8629 - val_MSE: 7.8626 - 2s/ep
och - 2ms/step
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_29 (Dense)            (None, 20)                1580

 dense_30 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,601
Trainable params: 1,601
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 205.3304 - MSE: 205.2190 - val_loss: 35.0859 - val_MSE: 35.0827 -
3s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 20.6651 - MSE: 20.6582 - val_loss: 11.2234 - val_MSE: 11.2220 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 10.3665 - MSE: 10.3707 - val_loss: 9.4567 - val_MSE: 9.4554 - 2s/
epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 8.9934 - MSE: 8.9931 - val_loss: 8.5887 - val_MSE: 8.5881 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 7.6704 - MSE: 7.6758 - val_loss: 6.8214 - val_MSE: 6.8206 - 2s/ep
och - 2ms/step
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_29 (Dense)            (None, 20)                1580

 dense_30 (Dense)            (None, 1)                 21

 dense_31 (Dense)            (None, 20)                40

 dense_32 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,662
Trainable params: 1,662
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 21.5383 - MSE: 21.5262 - val_loss: 7.1054 - val_MSE: 7.1065 - 4s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 7.0655 - MSE: 7.0633 - val_loss: 7.5264 - val_MSE: 7.5275 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 6.4025 - MSE: 6.4040 - val_loss: 7.0139 - val_MSE: 7.0146 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.8621 - MSE: 5.8600 - val_loss: 5.2268 - val_MSE: 5.2275 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 5.3507 - MSE: 5.3503 - val_loss: 5.0162 - val_MSE: 5.0169 - 2s/ep
och - 2ms/step
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_29 (Dense)            (None, 20)                1580

 dense_30 (Dense)            (None, 1)                 21

 dense_31 (Dense)            (None, 20)                40

 dense_32 (Dense)            (None, 1)                 21

 dense_33 (Dense)            (None, 20)                40

 dense_34 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,723
Trainable params: 1,723
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH20-DEPTH4
{'NN_width': 20, 'NN_depth': 4}
Epoch 1/5
1230/1230 - 3s - loss: 717.5007 - MSE: 717.0616 - val_loss: 19.7234 - val_MSE: 19.7215 -
3s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 16.0023 - MSE: 15.9970 - val_loss: 13.3775 - val_MSE: 13.3764 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 11.6068 - MSE: 11.6154 - val_loss: 10.6554 - val_MSE: 10.6545 - 2
s/epoch - 2ms/step
Epoch 4/5
```

```
1230/1230 - 2s - loss: 9.8098 - MSE: 9.8076 - val_loss: 10.2646 - val_MSE: 10.2648 - 2s/
epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 8.6767 - MSE: 8.6784 - val_loss: 8.1003 - val_MSE: 8.1001 - 2s/ep
och - 2ms/step
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_35 (Dense)            (None, 20)                1580

 dense_36 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,601
Trainable params: 1,601
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 26.1606 - MSE: 26.1498 - val_loss: 8.8660 - val_MSE: 8.8675 - 3s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 8.0701 - MSE: 8.0684 - val_loss: 7.7788 - val_MSE: 7.7804 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 6.7551 - MSE: 6.7526 - val_loss: 6.2460 - val_MSE: 6.2482 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.7753 - MSE: 5.7770 - val_loss: 5.2117 - val_MSE: 5.2137 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.8395 - MSE: 4.8413 - val_loss: 4.2593 - val_MSE: 4.2609 - 2s/ep
och - 2ms/step
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_35 (Dense)            (None, 20)                1580

 dense_36 (Dense)            (None, 1)                 21

 dense_37 (Dense)            (None, 20)                40

 dense_38 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,662
Trainable params: 1,662
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 6.3936 - MSE: 6.3924 - val_loss: 4.1517 - val_MSE: 4.1513 - 4s/ep
och - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 4.0897 - MSE: 4.0882 - val_loss: 3.7186 - val_MSE: 3.7181 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 3.9035 - MSE: 3.9029 - val_loss: 3.4625 - val_MSE: 3.4621 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 3.6561 - MSE: 3.6589 - val_loss: 3.7643 - val_MSE: 3.7638 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 3.5068 - MSE: 3.5073 - val_loss: 3.1743 - val_MSE: 3.1739 - 2s/ep
och - 2ms/step
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_35 (Dense)            (None, 20)                1580

 dense_36 (Dense)            (None, 1)                 21

 dense_37 (Dense)            (None, 20)                40

 dense_38 (Dense)            (None, 1)                 21

 dense_39 (Dense)            (None, 20)                40

 dense_40 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,723
Trainable params: 1,723
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 5.5433 - MSE: 5.5423 - val_loss: 3.3183 - val_MSE: 3.3185 - 4s/ep
och - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 3.4029 - MSE: 3.4033 - val_loss: 3.2433 - val_MSE: 3.2434 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 3.3677 - MSE: 3.3673 - val_loss: 3.0802 - val_MSE: 3.0803 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 3s - loss: 3.2777 - MSE: 3.2784 - val_loss: 2.8628 - val_MSE: 2.8630 - 3s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 3.1991 - MSE: 3.1981 - val_loss: 2.8016 - val_MSE: 2.8019 - 2s/ep
och - 2ms/step
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_35 (Dense)            (None, 20)                1580

 dense_36 (Dense)            (None, 1)                 21

 dense_37 (Dense)            (None, 20)                40

 dense_38 (Dense)            (None, 1)                 21

 dense_39 (Dense)            (None, 20)                40

 dense_40 (Dense)            (None, 1)                 21

 dense_41 (Dense)            (None, 20)                40

 dense_42 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,784
Trainable params: 1,784
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH20-DEPTH5
{'NN_width': 20, 'NN_depth': 5}
Epoch 1/5
1230/1230 - 3s - loss: 305.7193 - MSE: 305.5336 - val_loss: 14.9410 - val_MSE: 14.9445 -
```

```
3s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 12.4871 - MSE: 12.4852 - val_loss: 11.2185 - val_MSE: 11.2211 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 10.1936 - MSE: 10.1903 - val_loss: 9.4809 - val_MSE: 9.4834 - 2s/
epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 8.7776 - MSE: 8.7740 - val_loss: 9.5288 - val_MSE: 9.5310 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 7.5693 - MSE: 7.5680 - val_loss: 6.8149 - val_MSE: 6.8167 - 2s/ep
och - 2ms/step
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_43 (Dense)            (None, 20)                1580

 dense_44 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,601
Trainable params: 1,601
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 397.5793 - MSE: 397.3423 - val_loss: 35.7416 - val_MSE: 35.7391 -
3s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 24.2156 - MSE: 24.2100 - val_loss: 17.6551 - val_MSE: 17.6558 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 13.2130 - MSE: 13.2071 - val_loss: 12.0210 - val_MSE: 12.0218 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 10.1065 - MSE: 10.1107 - val_loss: 9.4646 - val_MSE: 9.4655 - 2s/
epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 7.9367 - MSE: 7.9421 - val_loss: 6.5900 - val_MSE: 6.5906 - 2s/ep
och - 2ms/step
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_43 (Dense)            (None, 20)                1580

 dense_44 (Dense)            (None, 1)                 21

 dense_45 (Dense)            (None, 20)                40

 dense_46 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,662
Trainable params: 1,662
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 164.2424 - MSE: 164.1433 - val_loss: 9.6107 - val_MSE: 9.6107 - 4
s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 8.2497 - MSE: 8.2505 - val_loss: 7.1277 - val_MSE: 7.1275 - 2s/ep
och - 2ms/step
Epoch 3/5
```

```
1230/1230 - 2s - loss: 7.0309 - MSE: 7.0299 - val_loss: 7.3175 - val_MSE: 7.3172 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 6.0536 - MSE: 6.0526 - val_loss: 5.0928 - val_MSE: 5.0927 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 5.2075 - MSE: 5.2049 - val_loss: 4.3759 - val_MSE: 4.3758 - 2s/ep
och - 2ms/step
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_43 (Dense)            (None, 20)                1580

 dense_44 (Dense)            (None, 1)                 21

 dense_45 (Dense)            (None, 20)                40

 dense_46 (Dense)            (None, 1)                 21

 dense_47 (Dense)            (None, 20)                40

 dense_48 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,723
Trainable params: 1,723
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 575.6024 - MSE: 575.2567 - val_loss: 46.6009 - val_MSE: 46.5973 -
4s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 37.2452 - MSE: 37.2328 - val_loss: 25.1273 - val_MSE: 25.1256 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 18.0672 - MSE: 18.0654 - val_loss: 13.6806 - val_MSE: 13.6812 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 12.5254 - MSE: 12.5225 - val_loss: 12.1792 - val_MSE: 12.1804 - 2
s/epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 9.9247 - MSE: 9.9239 - val_loss: 8.4520 - val_MSE: 8.4529 - 2s/ep
och - 2ms/step
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_43 (Dense)            (None, 20)                1580

 dense_44 (Dense)            (None, 1)                 21

 dense_45 (Dense)            (None, 20)                40

 dense_46 (Dense)            (None, 1)                 21

 dense_47 (Dense)            (None, 20)                40

 dense_48 (Dense)            (None, 1)                 21

 dense_49 (Dense)            (None, 20)                40

 dense_50 (Dense)            (None, 1)                 21

=================================================================
```

```
Total params: 1,784
Trainable params: 1,784
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 741.7123 - MSE: 741.2446 - val_loss: 9.5885 - val_MSE: 9.5885 - 4
s/epoch - 4ms/step
Epoch 2/5
1230/1230 - 3s - loss: 8.4226 - MSE: 8.4283 - val_loss: 9.1449 - val_MSE: 9.1450 - 3s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 3s - loss: 7.6350 - MSE: 7.6360 - val_loss: 7.0578 - val_MSE: 7.0582 - 3s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 3s - loss: 6.7978 - MSE: 6.7969 - val_loss: 6.0846 - val_MSE: 6.0855 - 3s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 3s - loss: 5.9809 - MSE: 5.9821 - val_loss: 6.1859 - val_MSE: 6.1860 - 3s/ep
och - 2ms/step
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_43 (Dense)            (None, 20)                1580

 dense_44 (Dense)            (None, 1)                 21

 dense_45 (Dense)            (None, 20)                40

 dense_46 (Dense)            (None, 1)                 21

 dense_47 (Dense)            (None, 20)                40

 dense_48 (Dense)            (None, 1)                 21

 dense_49 (Dense)            (None, 20)                40

 dense_50 (Dense)            (None, 1)                 21

 dense_51 (Dense)            (None, 20)                40

 dense_52 (Dense)            (None, 1)                 21

=================================================================
Total params: 1,845
Trainable params: 1,845
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH30-DEPTH3
{'NN_width': 30, 'NN_depth': 3}
Epoch 1/5
1230/1230 - 3s - loss: 27.1980 - MSE: 27.1877 - val_loss: 11.3945 - val_MSE: 11.3953 - 3
s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 8.9502 - MSE: 8.9511 - val_loss: 9.2056 - val_MSE: 9.2048 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 7.0411 - MSE: 7.0427 - val_loss: 7.0978 - val_MSE: 7.0980 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.9376 - MSE: 5.9366 - val_loss: 5.0592 - val_MSE: 5.0586 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 5.3300 - MSE: 5.3296 - val_loss: 5.2413 - val_MSE: 5.2406 - 2s/ep
och - 2ms/step
```

```
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_53 (Dense)            (None, 30)                2370

 dense_54 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,401
Trainable params: 2,401
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 31.3136 - MSE: 31.3002 - val_loss: 6.9564 - val_MSE: 6.9556 - 4s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 6.4826 - MSE: 6.4852 - val_loss: 7.4719 - val_MSE: 7.4714 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.6057 - MSE: 5.6080 - val_loss: 5.2941 - val_MSE: 5.2935 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.1059 - MSE: 5.1056 - val_loss: 5.2356 - val_MSE: 5.2352 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.7299 - MSE: 4.7307 - val_loss: 4.1585 - val_MSE: 4.1580 - 2s/ep
och - 2ms/step
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_53 (Dense)            (None, 30)                2370

 dense_54 (Dense)            (None, 1)                 31

 dense_55 (Dense)            (None, 30)                60

 dense_56 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,492
Trainable params: 2,492
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 229.3527 - MSE: 229.2248 - val_loss: 35.4937 - val_MSE: 35.4973 -
4s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 26.4487 - MSE: 26.4362 - val_loss: 21.1871 - val_MSE: 21.1907 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 15.3382 - MSE: 15.3406 - val_loss: 12.8007 - val_MSE: 12.8023 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 12.1164 - MSE: 12.1143 - val_loss: 11.3335 - val_MSE: 11.3343 - 2
s/epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 9.8173 - MSE: 9.8197 - val_loss: 8.4830 - val_MSE: 8.4836 - 2s/ep
och - 2ms/step
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_53 (Dense)            (None, 30)                2370
```

```
 dense_54 (Dense)            (None, 1)                 31

 dense_55 (Dense)            (None, 30)                60

 dense_56 (Dense)            (None, 1)                 31

 dense_57 (Dense)            (None, 30)                60

 dense_58 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,583
Trainable params: 2,583
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH30-DEPTH4
{'NN_width': 30, 'NN_depth': 4}
Epoch 1/5
1230/1230 - 3s - loss: 100.6722 - MSE: 100.6149 - val_loss: 17.4545 - val_MSE: 17.4529 -
3s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 13.6322 - MSE: 13.6271 - val_loss: 11.0005 - val_MSE: 11.0001 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 9.6612 - MSE: 9.6561 - val_loss: 9.4774 - val_MSE: 9.4774 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 7.8166 - MSE: 7.8170 - val_loss: 9.3424 - val_MSE: 9.3421 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 6.3764 - MSE: 6.3757 - val_loss: 5.3646 - val_MSE: 5.3645 - 2s/ep
och - 2ms/step
Model: "sequential_8"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_59 (Dense)            (None, 30)                2370

 dense_60 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,401
Trainable params: 2,401
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 73.9634 - MSE: 73.9199 - val_loss: 8.0130 - val_MSE: 8.0125 - 3s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 6.5753 - MSE: 6.5747 - val_loss: 5.9241 - val_MSE: 5.9239 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.2285 - MSE: 5.2277 - val_loss: 4.6799 - val_MSE: 4.6794 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 4.3727 - MSE: 4.3751 - val_loss: 4.1015 - val_MSE: 4.1010 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 3.9036 - MSE: 3.9026 - val_loss: 3.7064 - val_MSE: 3.7062 - 2s/ep
och - 2ms/step
Model: "sequential_8"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
```

```
 dense_59 (Dense)            (None, 30)                2370

 dense_60 (Dense)            (None, 1)                 31

 dense_61 (Dense)            (None, 30)                60

 dense_62 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,492
Trainable params: 2,492
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 69.9265 - MSE: 69.8850 - val_loss: 8.3880 - val_MSE: 8.3881 - 4s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 6.8763 - MSE: 6.8776 - val_loss: 5.8745 - val_MSE: 5.8741 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.6854 - MSE: 5.6835 - val_loss: 5.2165 - val_MSE: 5.2160 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 5.0387 - MSE: 5.0380 - val_loss: 4.6810 - val_MSE: 4.6810 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.6998 - MSE: 4.7039 - val_loss: 4.1841 - val_MSE: 4.1839 - 2s/ep
och - 2ms/step
Model: "sequential_8"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_59 (Dense)            (None, 30)                2370

 dense_60 (Dense)            (None, 1)                 31

 dense_61 (Dense)            (None, 30)                60

 dense_62 (Dense)            (None, 1)                 31

 dense_63 (Dense)            (None, 30)                60

 dense_64 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,583
Trainable params: 2,583
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 200.3524 - MSE: 200.2280 - val_loss: 4.2014 - val_MSE: 4.2022 - 4
s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 4.2256 - MSE: 4.2246 - val_loss: 3.6896 - val_MSE: 3.6901 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 3s - loss: 3.9260 - MSE: 3.9267 - val_loss: 4.0227 - val_MSE: 4.0230 - 3s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 3.8445 - MSE: 3.8429 - val_loss: 4.8189 - val_MSE: 4.8191 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 3.6829 - MSE: 3.6826 - val_loss: 3.1282 - val_MSE: 3.1284 - 2s/ep
och - 2ms/step
Model: "sequential_8"
```

```
 Layer (type)                Output Shape              Param #
=================================================================
 dense_59 (Dense)            (None, 30)                2370

 dense_60 (Dense)            (None, 1)                 31

 dense_61 (Dense)            (None, 30)                60

 dense_62 (Dense)            (None, 1)                 31

 dense_63 (Dense)            (None, 30)                60

 dense_64 (Dense)            (None, 1)                 31

 dense_65 (Dense)            (None, 30)                60

 dense_66 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,674
Trainable params: 2,674
Non-trainable params: 0
_________________________________________________________________
--- Starting trial: run-WIDTH30-DEPTH5
{'NN_width': 30, 'NN_depth': 5}
Epoch 1/5
1230/1230 - 3s - loss: 1189.3732 - MSE: 1188.6248 - val_loss: 18.8719 - val_MSE: 18.8726
- 3s/epoch - 2ms/step
Epoch 2/5
1230/1230 - 2s - loss: 15.8420 - MSE: 15.8451 - val_loss: 13.4293 - val_MSE: 13.4302 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 11.7802 - MSE: 11.7810 - val_loss: 10.7474 - val_MSE: 10.7489 - 2
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 9.9969 - MSE: 9.9942 - val_loss: 9.2234 - val_MSE: 9.2246 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 8.7088 - MSE: 8.7080 - val_loss: 8.0971 - val_MSE: 8.0981 - 2s/ep
och - 2ms/step
Model: "sequential_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_67 (Dense)            (None, 30)                2370

 dense_68 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,401
Trainable params: 2,401
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 3s - loss: 14.7645 - MSE: 14.7584 - val_loss: 9.1442 - val_MSE: 9.1448 - 3s/
epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 7.2408 - MSE: 7.2434 - val_loss: 6.6456 - val_MSE: 6.6456 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.6680 - MSE: 5.6683 - val_loss: 5.8395 - val_MSE: 5.8399 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 4.6656 - MSE: 4.6638 - val_loss: 4.3125 - val_MSE: 4.3126 - 2s/ep
```

```
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.0859 - MSE: 4.0877 - val_loss: 3.6541 - val_MSE: 3.6542 - 2s/ep
och - 2ms/step
Model: "sequential_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_67 (Dense)            (None, 30)                2370

 dense_68 (Dense)            (None, 1)                 31

 dense_69 (Dense)            (None, 30)                60

 dense_70 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,492
Trainable params: 2,492
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 186.5122 - MSE: 186.3997 - val_loss: 8.0163 - val_MSE: 8.0171 - 4
s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 6.5935 - MSE: 6.5910 - val_loss: 5.3848 - val_MSE: 5.3846 - 2s/ep
och - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 5.2439 - MSE: 5.2424 - val_loss: 4.8342 - val_MSE: 4.8342 - 2s/ep
och - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 4.5819 - MSE: 4.5817 - val_loss: 3.9100 - val_MSE: 3.9099 - 2s/ep
och - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 4.1279 - MSE: 4.1268 - val_loss: 4.8574 - val_MSE: 4.8570 - 2s/ep
och - 2ms/step
Model: "sequential_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_67 (Dense)            (None, 30)                2370

 dense_68 (Dense)            (None, 1)                 31

 dense_69 (Dense)            (None, 30)                60

 dense_70 (Dense)            (None, 1)                 31

 dense_71 (Dense)            (None, 30)                60

 dense_72 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,583
Trainable params: 2,583
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 289.8218 - MSE: 289.6737 - val_loss: 46.1233 - val_MSE: 46.1221 -
4s/epoch - 3ms/step
Epoch 2/5
1230/1230 - 2s - loss: 38.9493 - MSE: 38.9523 - val_loss: 29.5118 - val_MSE: 29.5099 - 2
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 2s - loss: 23.6450 - MSE: 23.6408 - val_loss: 16.8819 - val_MSE: 16.8804 - 2
```

```
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 2s - loss: 15.5076 - MSE: 15.4991 - val_loss: 13.7689 - val_MSE: 13.7677 - 2
s/epoch - 2ms/step
Epoch 5/5
1230/1230 - 2s - loss: 12.8180 - MSE: 12.8122 - val_loss: 11.3904 - val_MSE: 11.3894 - 2
s/epoch - 2ms/step
Model: "sequential_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_67 (Dense)            (None, 30)                2370

 dense_68 (Dense)            (None, 1)                 31

 dense_69 (Dense)            (None, 30)                60

 dense_70 (Dense)            (None, 1)                 31

 dense_71 (Dense)            (None, 30)                60

 dense_72 (Dense)            (None, 1)                 31

 dense_73 (Dense)            (None, 30)                60

 dense_74 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,674
Trainable params: 2,674
Non-trainable params: 0
_________________________________________________________________
Epoch 1/5
1230/1230 - 4s - loss: 1042.2133 - MSE: 1041.5867 - val_loss: 56.2574 - val_MSE: 56.2618
- 4s/epoch - 4ms/step
Epoch 2/5
1230/1230 - 3s - loss: 47.4016 - MSE: 47.3957 - val_loss: 41.7383 - val_MSE: 41.7424 - 3
s/epoch - 2ms/step
Epoch 3/5
1230/1230 - 3s - loss: 34.3585 - MSE: 34.3424 - val_loss: 33.2297 - val_MSE: 33.2329 - 3
s/epoch - 2ms/step
Epoch 4/5
1230/1230 - 3s - loss: 20.5470 - MSE: 20.5457 - val_loss: 10.9391 - val_MSE: 10.9387 - 3
s/epoch - 2ms/step
Epoch 5/5
1230/1230 - 3s - loss: 9.0988 - MSE: 9.1018 - val_loss: 7.7555 - val_MSE: 7.7550 - 3s/ep
och - 2ms/step
Model: "sequential_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_67 (Dense)            (None, 30)                2370

 dense_68 (Dense)            (None, 1)                 31

 dense_69 (Dense)            (None, 30)                60

 dense_70 (Dense)            (None, 1)                 31

 dense_71 (Dense)            (None, 30)                60

 dense_72 (Dense)            (None, 1)                 31

 dense_73 (Dense)            (None, 30)                60
```

```
dense_74 (Dense)            (None, 1)                 31

dense_75 (Dense)            (None, 30)                60

dense_76 (Dense)            (None, 1)                 31

=================================================================
Total params: 2,765
Trainable params: 2,765
Non-trainable params: 0
_________________________________________________________________
```

Linear Regression

In [115…

```
tf.compat.v1.disable_eager_execution()
# tf.compat.v1.enable_eager_execution()
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np

from sklearn.datasets import load_boston

def append_bias_reshape(x_train,y_train):
    n_training_samples = x_train.shape[0]
    n_dim = x_train.shape[1]
    f = np.reshape(np.c_[np.ones(n_training_samples),x_train],[n_training_samples,n_dim
    l = np.reshape(y_train,[n_training_samples,1])

    return f,l

if __name__ == '__main__':


#     x,y = read_boston_data()
#     norm_features = feature_normalize(x)
    f,l = append_bias_reshape(x_train,y_train)
    n_dim = f.shape[1]

    rnd_indices = np.random.rand(len(f)) < 0.80

    x_train = f[rnd_indices]
    y_train = l[rnd_indices]
    x_test = f[~rnd_indices]
    y_test = l[~rnd_indices]



    learning_rate = 0.0001
    training_epochs = 30
    cost_history = []
    test_history = []

    X = tf.compat.v1.placeholder(tf.float32,[None,n_dim])
    Y = tf.compat.v1.placeholder(tf.float32,[None,1])
    W = tf.Variable(tf.ones([n_dim,1]))

    init = tf.compat.v1.initialize_all_variables()

    y_ = tf.matmul(X,W)
```

```
    cost = tf.reduce_mean(tf.abs(y_-Y))
    training_step = tf.compat.v1.train.GradientDescentOptimizer(learning_rate).minimize

    sess = tf.compat.v1.Session()
    sess.run(init)

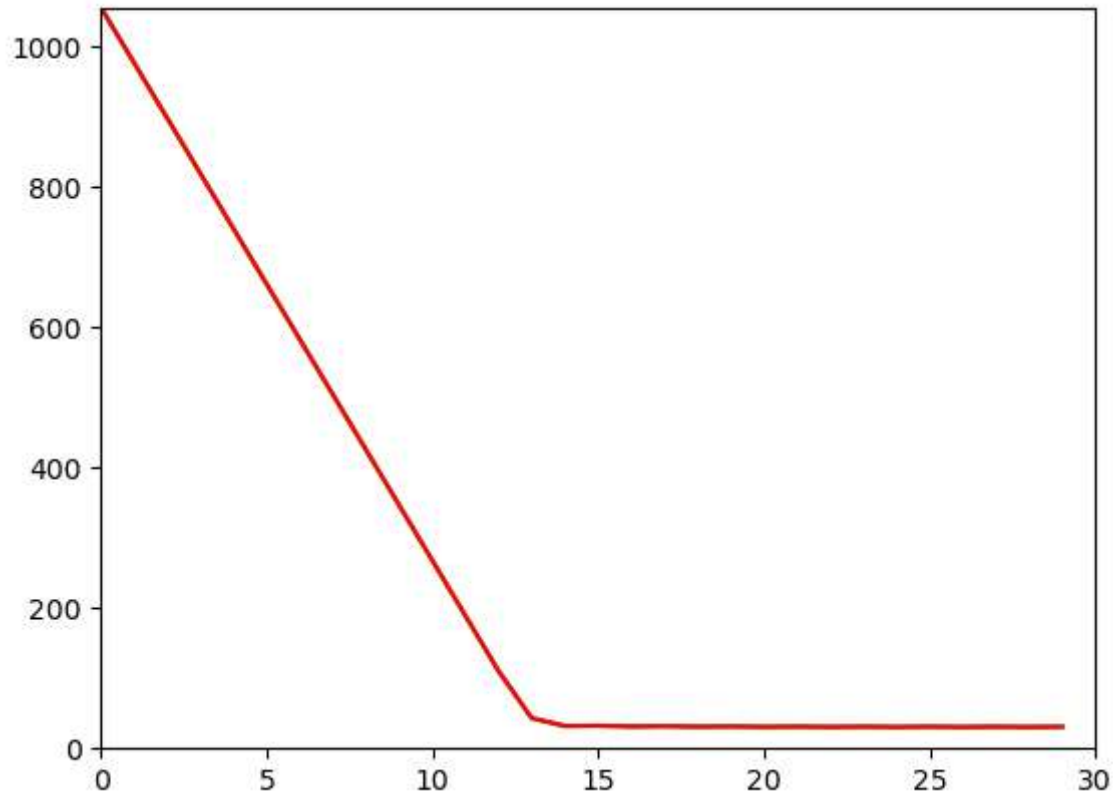
    for epoch in range(training_epochs):
        sess.run(training_step,feed_dict={X:x_train,Y:y_train})
        c = sess.run(cost,feed_dict={X:x_train,Y:y_train})
        print(c)
        t = sess.run(cost,feed_dict={X:x_test,Y:y_test})
        print(t)
        cost_history.append(c)
        test_history.append(t)

    plt.plot(range(len(test_history)),test_history,color = 'green')
    plt.plot(range(len(cost_history)),cost_history,color = 'red')

    plt.axis([0,training_epochs,0,np.max(cost_history)])
    plt.show()
```

```
WARNING:tensorflow:From /opt/conda/miniconda3/lib/python3.8/site-packages/tensorflow/pyt
hon/util/tf_should_use.py:243: initialize_all_variables (from tensorflow.python.ops.vari
ables) is deprecated and will be removed after 2017-03-02.
Instructions for updating:
Use `tf.global_variables_initializer` instead.
2022-11-29 11:34:55.200035: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:3
57] MLIR V1 optimization pass is not enabled
1056.6455
1057.1296
977.7627
978.2464
898.8799
899.363
819.9971
820.4797
741.11426
741.5963
662.2315
662.713
583.34863
583.8297
504.4659
504.94635
425.58313
426.06305
346.70035
347.17975
267.81757
268.29642
188.93477
189.41312
110.05222
110.53048
43.02768
43.156796
32.090935
31.787062
32.337605
32.33992
31.340061
31.056177
31.619144
```

```
31.607231
30.997797
30.721834
31.266632
31.245726
30.745256
30.47669
31.014843
30.987577
30.649391
30.384268
30.936522
30.907791
30.612192
30.3485
30.90662
30.877464
30.584766
30.322075
30.868538
30.838861
30.559853
30.298079
30.843607
30.813633
```



In [116…

```
# tf.compat.v1.disable_eager_execution()
# tf.compat.v1.enable_eager_execution()
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np

from sklearn.datasets import load_boston

def append_bias_reshape(x_train,y_train):
    n_training_samples = x_train.shape[0]
```

```
    n_dim = x_train.shape[1]
    f = np.reshape(np.c_[np.ones(n_training_samples),x_train],[n_training_samples,n_dim
    l = np.reshape(y_train,[n_training_samples,1])

    return f,l

if __name__ == '__main__':


#     x,y = read_boston_data()
#     norm_features = feature_normalize(x)
    f,l = append_bias_reshape(x_train,y_train)
    n_dim = f.shape[1]

    rnd_indices = np.random.rand(len(f)) < 0.80

    x_train = f[rnd_indices]
    y_train = l[rnd_indices]
    x_test = f[~rnd_indices]
    y_test = l[~rnd_indices]



    learning_rate = 0.001
    training_epochs = 30
    cost_history = []
    test_history = []

    X = tf.compat.v1.placeholder(tf.float32,[None,n_dim])
    Y = tf.compat.v1.placeholder(tf.float32,[None,1])
    W = tf.Variable(tf.ones([n_dim,1]))

    init = tf.compat.v1.initialize_all_variables()

    y_ = tf.matmul(X,W)
    cost = tf.reduce_mean(tf.abs(y_-Y))
    training_step = tf.compat.v1.train.GradientDescentOptimizer(learning_rate).minimize

    sess = tf.compat.v1.Session()
    sess.run(init)

    for epoch in range(training_epochs):
        sess.run(training_step,feed_dict={X:x_train,Y:y_train})
        c = sess.run(cost,feed_dict={X:x_train,Y:y_train})
        print(c)
        t = sess.run(cost,feed_dict={X:x_test,Y:y_test})
        print(t)
        cost_history.append(c)
        test_history.append(t)

    plt.plot(range(len(test_history)),test_history,color = 'green')
    plt.plot(range(len(cost_history)),cost_history,color = 'red')

    plt.axis([0,training_epochs,0,np.max(cost_history)])
    plt.show()
```

```
347.64478
347.93274
441.17865
440.90033
```

```
347.64478
347.93274
441.17865
440.90033
347.64478
347.93274
441.17865
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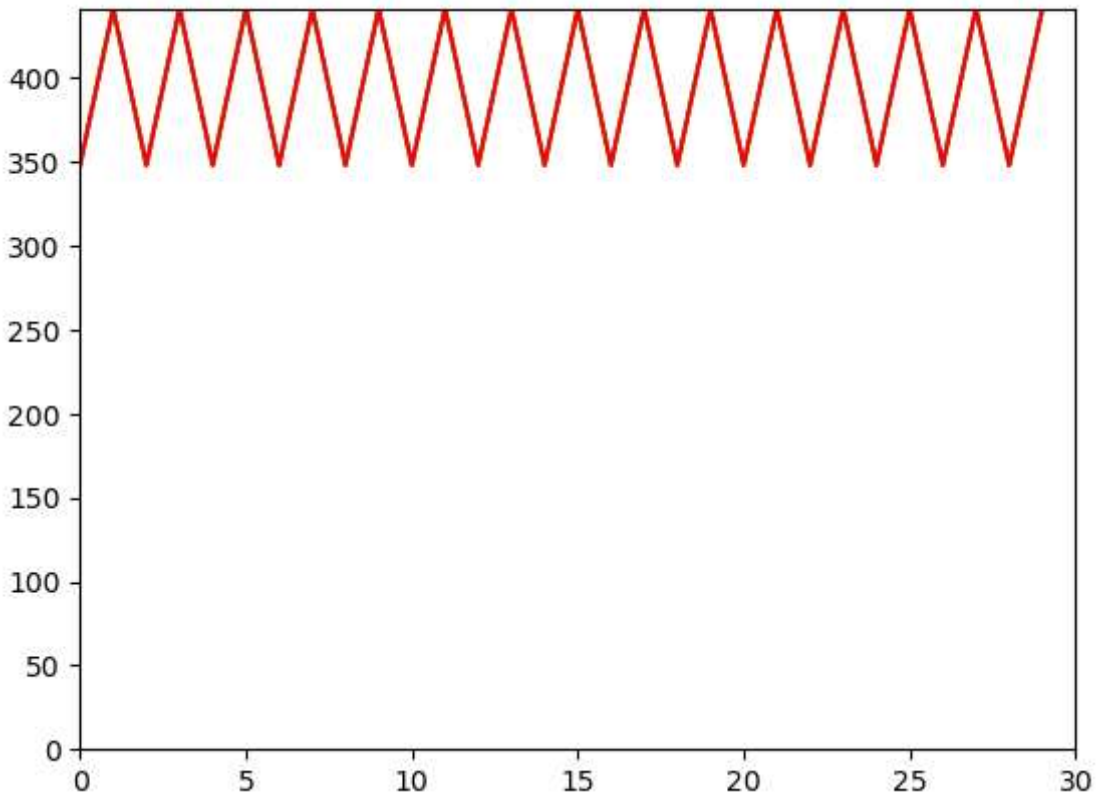
441.17865
440.90033
347.64478
347.93274
441.17865
440.90033
347.64478
347.93274
441.17865
440.90033
```



In [117…

```
# tf.compat.v1.disable_eager_execution()
# tf.compat.v1.enable_eager_execution()
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np

from sklearn.datasets import load_boston

def append_bias_reshape(x_train,y_train):
    n_training_samples = x_train.shape[0]
    n_dim = x_train.shape[1]
    f = np.reshape(np.c_[np.ones(n_training_samples),x_train],[n_training_samples,n_dim
    l = np.reshape(y_train,[n_training_samples,1])

    return f,l

if __name__ == '__main__':


#     x,y = read_boston_data()
#     norm_features = feature_normalize(x)
    f,l = append_bias_reshape(x_train,y_train)
    n_dim = f.shape[1]

    rnd_indices = np.random.rand(len(f)) < 0.80

    x_train = f[rnd_indices]
    y_train = l[rnd_indices]
    x_test = f[~rnd_indices]
    y_test = l[~rnd_indices]
```

```
learning_rate = 0.00001
training_epochs = 300
cost_history = []
test_history = []

X = tf.compat.v1.placeholder(tf.float32,[None,n_dim])
Y = tf.compat.v1.placeholder(tf.float32,[None,1])
W = tf.Variable(tf.ones([n_dim,1]))

init = tf.compat.v1.initialize_all_variables()

y_ = tf.matmul(X,W)
cost = tf.reduce_mean(tf.abs(y_-Y))
training_step = tf.compat.v1.train.GradientDescentOptimizer(learning_rate).minimize

sess = tf.compat.v1.Session()
sess.run(init)

for epoch in range(training_epochs):
    sess.run(training_step,feed_dict={X:x_train,Y:y_train})
    c = sess.run(cost,feed_dict={X:x_train,Y:y_train})
    print(c)
    t = sess.run(cost,feed_dict={X:x_test,Y:y_test})
    print(t)
    cost_history.append(c)
    test_history.append(t)

plt.plot(range(len(test_history)),test_history,color = 'green')
plt.plot(range(len(cost_history)),cost_history,color = 'red')

plt.axis([0,training_epochs,0,np.max(cost_history)])
plt.show()
```

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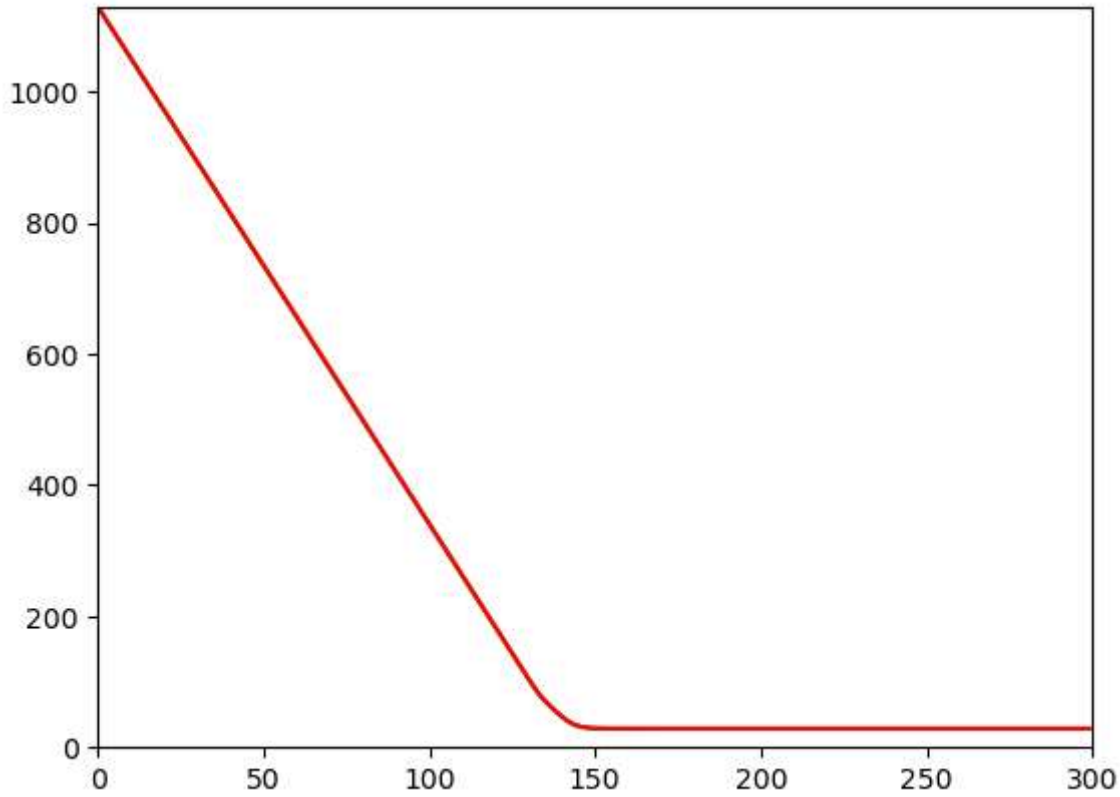

In [118…

```
# tf.compat.v1.disable_eager_execution()
# tf.compat.v1.enable_eager_execution()
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np

from sklearn.datasets import load_boston

def append_bias_reshape(x_train,y_train):
    n_training_samples = x_train.shape[0]
    n_dim = x_train.shape[1]
    f = np.reshape(np.c_[np.ones(n_training_samples),x_train],[n_training_samples,n_dim
    l = np.reshape(y_train,[n_training_samples,1])

    return f,l

if __name__ == '__main__':


#     x,y = read_boston_data()
#     norm_features = feature_normalize(x)
    f,l = append_bias_reshape(x_train,y_train)
    n_dim = f.shape[1]

    rnd_indices = np.random.rand(len(f)) < 0.80

    x_train = f[rnd_indices]
    y_train = l[rnd_indices]
    x_test = f[~rnd_indices]
    y_test = l[~rnd_indices]
```

```
learning_rate = 0.000001
training_epochs = 3000
cost_history = []
test_history = []

X = tf.compat.v1.placeholder(tf.float32,[None,n_dim])
Y = tf.compat.v1.placeholder(tf.float32,[None,1])
W = tf.Variable(tf.ones([n_dim,1]))

init = tf.compat.v1.initialize_all_variables()

y_ = tf.matmul(X,W)
cost = tf.reduce_mean(tf.abs(y_-Y))
training_step = tf.compat.v1.train.GradientDescentOptimizer(learning_rate).minimize

sess = tf.compat.v1.Session()
sess.run(init)

for epoch in range(training_epochs):
    sess.run(training_step,feed_dict={X:x_train,Y:y_train})
    c = sess.run(cost,feed_dict={X:x_train,Y:y_train})
    print(c)
    t = sess.run(cost,feed_dict={X:x_test,Y:y_test})
    print(t)
    cost_history.append(c)
    test_history.append(t)

plt.plot(range(len(test_history)),test_history,color = 'green')
plt.plot(range(len(cost_history)),cost_history,color = 'red')

plt.axis([0,training_epochs,0,np.max(cost_history)])
plt.show()
```

```
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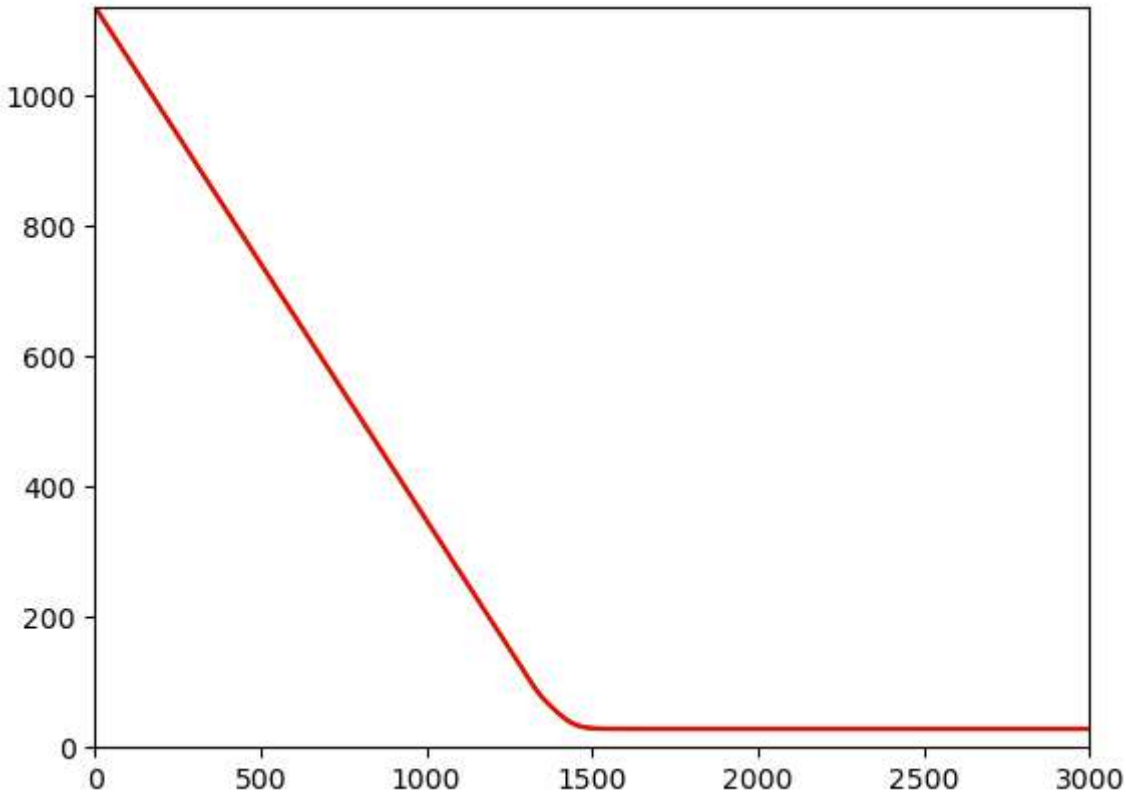

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