

```

# Libraries

#for downloading data from NSE website
!pip install bhavcopy
import bhavcopy

#for several dataframe and other operations in python
import pandas as pd
from datetime import datetime, date
import os
import numpy as np
import math
import numpy as np
import io
import contextlib

#for calculating GARCH volatilities
!pip install arch
from arch import arch_model

#for calculating Black Scholes prices and Implied Volatility
from scipy.stats import norm
from scipy.optimize import newton
from scipy.optimize import fsolve

#for applying ANN, LSTM, GRU
import tensorflow as tf
import sklearn.metrics as metrics
from keras.models import Sequential
from keras.layers import GRU, Dense, Concatenate
from sklearn.preprocessing import MinMaxScaler
from sklearn import metrics
from sklearn.model_selection import train_test_split
from sklearn.metrics import r2_score
from tensorflow.keras.layers import LSTM, Dropout
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import GRU, Dropout, Dense

#for plotting
import matplotlib.pyplot as plt
plt.style.use('ggplot')

#for accessing google drive in google colab
from google.colab import drive
from google.colab import files

Collecting bhavcopy
  Downloading bhavcopy-3.0.tar.gz (4.9 kB)
  Preparing metadata (setup.py) ... ent already satisfied: pandas

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Requirement already satisfied: python-dateutil>=2.8.1 in
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>pandas->bhavcopy) (1.16.0)
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  Building wheel for bhavcopy (setup.py) ... e=bhavcopy-3.0-py3-none-
any.whl size=5314
sha256=d69e81e122b83d9aeed8f135ad248e35f9677bc919c6e2c2fcc3ff31bf8965d
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  Stored in directory:
/root/.cache/pip/wheels/98/6e/ec/dled7817d15c778faccd62848124dac5cb5d6
acb28ef630f75
Successfully built bhavcopy
Installing collected packages: bhavcopy
Successfully installed bhavcopy-3.0
Collecting arch
  Downloading arch-6.3.0-cp310-cp310-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (982 kB)
_____ 983.0/983.0 kB 3.2 MB/s eta
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Installing collected packages: arch
Successfully installed arch-6.3.0
```

*#function defined for calculating GARCH volatilties - same is accessed later in the code*

*#GARCH volatility has been further used as an input to Black Scholes model to find option prices*

```
def garch_vol(returns, forecast_horizon, p, q):
    # Estimate GARCH(p,q) model for volatility
    with io.StringIO() as buf, contextlib.redirect_stdout(buf):
        garch_model = arch_model(returns, vol='Garch', p=p, q=q)
        results = garch_model.fit()

    # Forecast volatility
    forecast = results.forecast(horizon=forecast_horizon)
    vol = forecast.mean.iloc[-1]
    return vol
```

*#function defined for calculating Black Scholes option prices - same is accessed later in the code*

```
def BS(S, K, T, r, sigma, type):
    d1 = (np.log(S / K) + (r + 0.5 * sigma**2) * T) / (sigma *
np.sqrt(T))
    d2 = d1 - sigma * np.sqrt(T)
    if (type=='CE'):
        BS = S * norm.cdf(d1) - K * np.exp(-r * T) * norm.cdf(d2)
    elif (type=='PE'):
        BS = K * np.exp(-r * T) * norm.cdf(-d2) - S * norm.cdf(-d1)
    return BS
```

*#function defined for calculating implied volatilities - same is accessed later in the code*

*#3 different functions have been defined using bisection, fsolve and*

*newton raphson methods of numerical estimation - currently the code later is using fsolver*

```
def iv_bisec(opt_price, S, K, T, r, type):
    tol = 1e-5
    low_vol = 0.001
    high_vol = 5.0
    iterations = 100
    for i in range(iterations):
        mid_vol = (low_vol + high_vol) / 2.0
        price = BS(S, K, T, r, mid_vol, type)
        diff = price - opt_price
        if abs(diff) < tol:
            return mid_vol
        if diff < 0:
            low_vol = mid_vol
        else:
            high_vol = mid_vol
    return None # Return None if no convergence

def iv_fsolve(opt_price, S, K, T, r, type):
    # Define the function to solve for implied volatility
    def function(sigma, *args):
        opt_price, S, K, T, r, type = args
        return BS(S, K, T, r, sigma, type) - opt_price

    # Initial guess for implied volatility
    initial_guess = 0.3 # You can start with any value here

    # Solve for implied volatility
    implied_vol = fsolve(function, initial_guess, args=(opt_price, S,
K, T, r, type))

    return implied_vol[0]

def iv_newton(opt_price, S, K, T, r, type):
    # Define the function to solve for implied volatility
    def function(sigma):
        return BS(S, K, T, r, sigma, type) - opt_price

    # Initial guess for implied volatility
    initial_guess = 0.3 # You can start with any value here

    # Solve for implied volatility
    implied_vol = newton(function, initial_guess)

    return implied_vol
```

*#Getting underlying equity index (NIFTY 50 data) for 2023 using API bhavcopy which fetches historical data from www.nseindia.com*

```

# Mount Google Drive to save data
drive.mount('/content/drive')

# Define start and end dates, and convert them into date format
start_date = date(2023, 1, 1)
end_date = date(2023, 12, 31)

# Define wait time in seconds to avoid multiple fast hits on
www.nseindia.com
wait_time = [1, 2]

# path of the folder in google drive where all input and output files
and plots are getting stored.
folder_path = '/content/drive/My Drive/Capstone_Grp4524/'

# Check if the folder already exists; if not, create it
if not os.path.exists(folder_path):
    os.makedirs(folder_path)
    print(f"Folder '{folder_path}' created successfully!")
else:
    print(f"Folder '{folder_path}' already exists.")

try:
    # Attempt to load the file
    data_nifty = pd.read_csv('/content/drive/My
Drive/Capstone_Grp4524/indices.csv', parse_dates=['TIMESTAMP'])
except FileNotFoundError:

# Instantiate bhavcopy class for equities, indices, and derivatives
nse = bhavcopy.bhavcopy("indices", start_date, end_date,
folder_path, wait_time)
nse.get_data()
if os.path.exists(os.path.join(folder_path, "\\indices.csv")):
    # Rename the file to "indices.csv"
    os.rename(os.path.join(folder_path, "\\indices.csv"),
os.path.join(folder_path, "indices.csv"))
    data_nifty = pd.read_csv('/content/drive/My
Drive/Capstone_Grp4524/indices.csv', parse_dates=['TIMESTAMP'])

data_nifty = data_nifty.loc[data_nifty['Index Name'] == 'Nifty 50']
data_nifty.rename(columns={"Index Name": "Index", "Closing Index
Value": "Close"}, inplace=True)

#creating input columns using the underlying data - returns, squared
returns, historical volatilities with different tenors
data_nifty['rt'] = pd.to_numeric(data_nifty['Change(%)'])
data_nifty['rt2'] = pd.to_numeric(data_nifty['rt'])**2.
data_nifty['sigma2'] = data_nifty['rt'].rolling(2).std()*(252**0.5)
data_nifty['sigma3'] = data_nifty['rt'].rolling(3).std()*(252**0.5)

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data_nifty['sigma5'] = data_nifty['rt'].rolling(5).std()*(252**0.5)
data_nifty['sigma20'] = data_nifty['rt'].rolling(20).std()*(252**0.5)
data_nifty['sigma60'] = data_nifty['rt'].rolling(60).std()*(252**0.5)
data_nifty['sigma110'] =
data_nifty['rt'].rolling(110).std()*(252**0.5)
```

*#saving the processed underlying data file in folder*

```
data_nifty.to_csv('/content/drive/My
Drive/Capstone_Grp4524/data_nifty.csv')
```

Mounted at /content/drive

Folder '/content/drive/My Drive/Capstone\_Grp4524/' created successfully!

Running File Check

The file does not exist. Creating File

Downloading Data for [Timestamp('2023-01-02 00:00:00', freq='D'),  
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2023-05-26 00:00:00:done  
2023-05-29 00:00:00  
2023-05-29 00:00:00:done  
2023-05-30 00:00:00  
2023-05-30 00:00:00:done  
2023-05-31 00:00:00  
2023-05-31 00:00:00:done  
2023-06-01 00:00:00  
2023-06-01 00:00:00:done  
2023-06-02 00:00:00  
2023-06-02 00:00:00:done  
2023-06-05 00:00:00  
2023-06-05 00:00:00:done  
2023-06-06 00:00:00  
2023-06-06 00:00:00:done  
2023-06-07 00:00:00  
2023-06-07 00:00:00:done  
2023-06-08 00:00:00  
2023-06-08 00:00:00:done  
2023-06-09 00:00:00  
2023-06-09 00:00:00:done  
2023-06-12 00:00:00  
2023-06-12 00:00:00:done  
2023-06-13 00:00:00  
2023-06-13 00:00:00:done  
2023-06-14 00:00:00  
2023-06-14 00:00:00:done  
2023-06-15 00:00:00  
2023-06-15 00:00:00:done  
2023-06-16 00:00:00

2023-06-16 00:00:00:done  
2023-06-19 00:00:00  
2023-06-19 00:00:00:done  
2023-06-20 00:00:00  
2023-06-20 00:00:00:done  
2023-06-21 00:00:00  
2023-06-21 00:00:00:done  
2023-06-22 00:00:00  
2023-06-22 00:00:00:done  
2023-06-23 00:00:00  
2023-06-23 00:00:00:done  
2023-06-26 00:00:00  
2023-06-26 00:00:00:done  
2023-06-27 00:00:00  
2023-06-27 00:00:00:done  
2023-06-28 00:00:00  
2023-06-28 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_29062023.csv](https://archives.nseindia.com/content/indices/ind_close_all_29062023.csv)  
sv  
2023-06-29 00:00:00:failed  
2023-06-30 00:00:00  
2023-06-30 00:00:00:done  
2023-07-03 00:00:00  
2023-07-03 00:00:00:done  
2023-07-04 00:00:00  
2023-07-04 00:00:00:done  
2023-07-05 00:00:00  
2023-07-05 00:00:00:done  
2023-07-06 00:00:00  
2023-07-06 00:00:00:done  
2023-07-07 00:00:00  
2023-07-07 00:00:00:done  
2023-07-10 00:00:00  
2023-07-10 00:00:00:done  
2023-07-11 00:00:00  
2023-07-11 00:00:00:done  
2023-07-12 00:00:00  
2023-07-12 00:00:00:done  
2023-07-13 00:00:00  
2023-07-13 00:00:00:done  
2023-07-14 00:00:00  
2023-07-14 00:00:00:done  
2023-07-17 00:00:00  
2023-07-17 00:00:00:done  
2023-07-18 00:00:00  
2023-07-18 00:00:00:done  
2023-07-19 00:00:00  
2023-07-19 00:00:00:done

2023-07-20 00:00:00  
2023-07-20 00:00:00:done  
2023-07-21 00:00:00  
2023-07-21 00:00:00:done  
2023-07-24 00:00:00  
2023-07-24 00:00:00:done  
2023-07-25 00:00:00  
2023-07-25 00:00:00:done  
2023-07-26 00:00:00  
2023-07-26 00:00:00:done  
2023-07-27 00:00:00  
2023-07-27 00:00:00:done  
2023-07-28 00:00:00  
2023-07-28 00:00:00:done  
2023-07-31 00:00:00  
2023-07-31 00:00:00:done  
2023-08-01 00:00:00  
2023-08-01 00:00:00:done  
2023-08-02 00:00:00  
2023-08-02 00:00:00:done  
2023-08-03 00:00:00  
2023-08-03 00:00:00:done  
2023-08-04 00:00:00  
2023-08-04 00:00:00:done  
2023-08-07 00:00:00  
2023-08-07 00:00:00:done  
2023-08-08 00:00:00  
2023-08-08 00:00:00:done  
2023-08-09 00:00:00  
2023-08-09 00:00:00:done  
2023-08-10 00:00:00  
2023-08-10 00:00:00:done  
2023-08-11 00:00:00  
2023-08-11 00:00:00:done  
2023-08-14 00:00:00  
2023-08-14 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_15082023.csv](https://archives.nseindia.com/content/indices/ind_close_all_15082023.csv)  
sv  
2023-08-15 00:00:00:failed  
2023-08-16 00:00:00  
2023-08-16 00:00:00:done  
2023-08-17 00:00:00  
2023-08-17 00:00:00:done  
2023-08-18 00:00:00  
2023-08-18 00:00:00:done  
2023-08-21 00:00:00  
2023-08-21 00:00:00:done  
2023-08-22 00:00:00  
2023-08-22 00:00:00:done



2023-08-23 00:00:00  
2023-08-23 00:00:00:done  
2023-08-24 00:00:00  
2023-08-24 00:00:00:done  
2023-08-25 00:00:00  
2023-08-25 00:00:00:done  
2023-08-28 00:00:00  
2023-08-28 00:00:00:done  
2023-08-29 00:00:00  
2023-08-29 00:00:00:done  
2023-08-30 00:00:00  
2023-08-30 00:00:00:done  
2023-08-31 00:00:00  
2023-08-31 00:00:00:done  
2023-09-01 00:00:00  
2023-09-01 00:00:00:done  
2023-09-04 00:00:00  
2023-09-04 00:00:00:done  
2023-09-05 00:00:00  
2023-09-05 00:00:00:done  
2023-09-06 00:00:00  
2023-09-06 00:00:00:done  
2023-09-07 00:00:00  
2023-09-07 00:00:00:done  
2023-09-08 00:00:00  
2023-09-08 00:00:00:done  
2023-09-11 00:00:00  
2023-09-11 00:00:00:done  
2023-09-12 00:00:00  
2023-09-12 00:00:00:done  
2023-09-13 00:00:00  
2023-09-13 00:00:00:done  
2023-09-14 00:00:00  
2023-09-14 00:00:00:done  
2023-09-15 00:00:00  
2023-09-15 00:00:00:done  
2023-09-18 00:00:00  
2023-09-18 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_19092023.csv](https://archives.nseindia.com/content/indices/ind_close_all_19092023.csv)  
sv  
2023-09-19 00:00:00:failed  
2023-09-20 00:00:00  
2023-09-20 00:00:00:done  
2023-09-21 00:00:00  
2023-09-21 00:00:00:done  
2023-09-22 00:00:00  
2023-09-22 00:00:00:done  
2023-09-25 00:00:00

2023-09-25 00:00:00:done  
2023-09-26 00:00:00  
2023-09-26 00:00:00:done  
2023-09-27 00:00:00  
2023-09-27 00:00:00:done  
2023-09-28 00:00:00  
2023-09-28 00:00:00:done  
2023-09-29 00:00:00  
2023-09-29 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_02102023.csv](https://archives.nseindia.com/content/indices/ind_close_all_02102023.csv)  
2023-10-02 00:00:00:failed  
2023-10-03 00:00:00  
2023-10-03 00:00:00:done  
2023-10-04 00:00:00  
2023-10-04 00:00:00:done  
2023-10-05 00:00:00  
2023-10-05 00:00:00:done  
2023-10-06 00:00:00  
2023-10-06 00:00:00:done  
2023-10-09 00:00:00  
2023-10-09 00:00:00:done  
2023-10-10 00:00:00  
2023-10-10 00:00:00:done  
2023-10-11 00:00:00  
2023-10-11 00:00:00:done  
2023-10-12 00:00:00  
2023-10-12 00:00:00:done  
2023-10-13 00:00:00  
2023-10-13 00:00:00:done  
2023-10-16 00:00:00  
2023-10-16 00:00:00:done  
2023-10-17 00:00:00  
2023-10-17 00:00:00:done  
2023-10-18 00:00:00  
2023-10-18 00:00:00:done  
2023-10-19 00:00:00  
2023-10-19 00:00:00:done  
2023-10-20 00:00:00  
2023-10-20 00:00:00:done  
2023-10-23 00:00:00  
2023-10-23 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_24102023.csv](https://archives.nseindia.com/content/indices/ind_close_all_24102023.csv)  
2023-10-24 00:00:00:failed  
2023-10-25 00:00:00  
2023-10-25 00:00:00:done

2023-10-26 00:00:00  
2023-10-26 00:00:00:done  
2023-10-27 00:00:00  
2023-10-27 00:00:00:done  
2023-10-30 00:00:00  
2023-10-30 00:00:00:done  
2023-10-31 00:00:00  
2023-10-31 00:00:00:done  
2023-11-01 00:00:00  
2023-11-01 00:00:00:done  
2023-11-02 00:00:00  
2023-11-02 00:00:00:done  
2023-11-03 00:00:00  
2023-11-03 00:00:00:done  
2023-11-06 00:00:00  
2023-11-06 00:00:00:done  
2023-11-07 00:00:00  
2023-11-07 00:00:00:done  
2023-11-08 00:00:00  
2023-11-08 00:00:00:done  
2023-11-09 00:00:00  
2023-11-09 00:00:00:done  
2023-11-10 00:00:00  
2023-11-10 00:00:00:done  
2023-11-13 00:00:00  
2023-11-13 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_14112023.csv](https://archives.nseindia.com/content/indices/ind_close_all_14112023.csv)  
2023-11-14 00:00:00:failed  
2023-11-15 00:00:00  
2023-11-15 00:00:00:done  
2023-11-16 00:00:00  
2023-11-16 00:00:00:done  
2023-11-17 00:00:00  
2023-11-17 00:00:00:done  
2023-11-20 00:00:00  
2023-11-20 00:00:00:done  
2023-11-21 00:00:00  
2023-11-21 00:00:00:done  
2023-11-22 00:00:00  
2023-11-22 00:00:00:done  
2023-11-23 00:00:00  
2023-11-23 00:00:00:done  
2023-11-24 00:00:00  
2023-11-24 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_27112023.csv](https://archives.nseindia.com/content/indices/ind_close_all_27112023.csv)

2023-11-27 00:00:00:failed  
2023-11-28 00:00:00  
2023-11-28 00:00:00:done  
2023-11-29 00:00:00  
2023-11-29 00:00:00:done  
2023-11-30 00:00:00  
2023-11-30 00:00:00:done  
2023-12-01 00:00:00  
2023-12-01 00:00:00:done  
2023-12-04 00:00:00  
2023-12-04 00:00:00:done  
2023-12-05 00:00:00  
2023-12-05 00:00:00:done  
2023-12-06 00:00:00  
2023-12-06 00:00:00:done  
2023-12-07 00:00:00  
2023-12-07 00:00:00:done  
2023-12-08 00:00:00  
2023-12-08 00:00:00:done  
2023-12-11 00:00:00  
2023-12-11 00:00:00:done  
2023-12-12 00:00:00  
2023-12-12 00:00:00:done  
2023-12-13 00:00:00  
2023-12-13 00:00:00:done  
2023-12-14 00:00:00  
2023-12-14 00:00:00:done  
2023-12-15 00:00:00  
2023-12-15 00:00:00:done  
2023-12-18 00:00:00  
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2023-12-19 00:00:00  
2023-12-19 00:00:00:done  
2023-12-20 00:00:00  
2023-12-20 00:00:00:done  
2023-12-21 00:00:00  
2023-12-21 00:00:00:done  
2023-12-22 00:00:00  
2023-12-22 00:00:00:done  
HTTP Error: 404 Client Error: Not Found for url:  
[https://archives.nseindia.com/content/indices/ind\\_close\\_all\\_25122023.c  
sv](https://archives.nseindia.com/content/indices/ind_close_all_25122023.csv)  
2023-12-25 00:00:00:failed  
2023-12-26 00:00:00  
2023-12-26 00:00:00:done  
2023-12-27 00:00:00  
2023-12-27 00:00:00:done  
2023-12-28 00:00:00  
2023-12-28 00:00:00:done

```
2023-12-29 00:00:00
2023-12-29 00:00:00:done
```

```
#Getting option chain data on NIFTY 50 data fetching historical data
(option chain for each day in 2023) from www.nseindia.com
```

```
dt = pd.date_range(start=start_date, end=end_date, freq='B')
datafno = pd.DataFrame()
try:
    # Attempt to load the file
    datafno = pd.read_csv('/content/drive/My
Drive/Capstone_Grp4524/datafno.csv', parse_dates=['TIMESTAMP'])
    print("File found and loaded successfully!")
except FileNotFoundError:
    for tday in dt:
        try:
            dd = datetime.strptime(tday, '%d')
            MM = datetime.strptime(tday, '%b').upper()
            YYYY = datetime.strptime(tday, '%Y')
            fnoBhavcopyUrl =
'http://archives.nseindia.com/content/historical/DERIVATIVES/' +YYYY+
            '/' +MM+ '/fo' + dd+ MM+ YYYY+'bhav.csv.zip'
            print(fnoBhavcopyUrl)
            datafno1 = pd.read_csv(fnoBhavcopyUrl,
            parse_dates=['EXPIRY_DT', 'TIMESTAMP'])
            datafno = pd.concat([datafno, datafno1], join = 'outer',
            ignore_index=True)
        except:
            print("Error in" + dd + MM + YYYY)

    datafno = datafno.drop(datafno.columns[15:], axis=1)
    datafno.columns = [c.strip() for c in
datafno.columns.values.tolist()]

    #only taking Fn0 data on underlying index and dropping other
indices and stocks to make file of manageable size
    datafno = datafno.loc[datafno['SYMBOL'] == 'NIFTY']

    #saving the processed Nifty50 Fn0 data file in folder
    datafno.to_csv('/content/drive/My
Drive/Capstone_Grp4524/datafno.csv')

def check_date_format(date_string, date_format):
    try:
        datetime.strptime(date_string, date_format)
        return True
    except ValueError:
        return False
    except TypeError:
        return False
```

```

def convert_date_format(date_string):
    if check_date_format(date_string, "%d-%b-%Y") == True:
        return datetime.strptime(date_string, "%d-%b-%Y").strftime('%d-%m-%Y')
    else:
        return date_string

datafno['EXPIRY_DT'] =
pd.to_datetime(datafno['EXPIRY_DT'].apply(convert_date_format),
dayfirst=True)

#separating out the Fn0 data into 2 files - one with futures and other with options
datafno_fut = datafno.loc[datafno['INSTRUMENT'] == 'FUTIDX']
datafno_opt = datafno.loc[(datafno['INSTRUMENT'] == 'OPTIDX') & (datafno['CONTRACTS'] > 0)]

http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo02JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo03JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo04JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo05JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo06JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo09JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo10JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo11JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo12JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo13JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo16JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo17JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo18JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo19JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo20JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo23JAN2023bhav.csv.zip

```

<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo24JAN2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo25JAN2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo26JAN2023bhav.csv.zip>  
Error in26JAN2023  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo27JAN2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo30JAN2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/fo31JAN2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo01FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo02FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo03FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo06FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo07FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo08FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo09FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo10FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo13FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo14FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo15FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo16FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo17FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo20FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo21FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo22FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo23FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo24FEB2023bhav.csv.zip>

<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo27FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/fo28FEB2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/MAR/fo01MAR2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/MAR/fo02MAR2023bhav.csv.zip>  
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<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo12DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo13DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo14DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo15DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo18DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo19DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo20DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/fo21DEC2023bhav.csv.zip>  
<http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/>



```
fo22DEC2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/
fo25DEC2023bhav.csv.zip
Error in25DEC2023
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/
fo26DEC2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/
fo27DEC2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/
fo28DEC2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/
fo29DEC2023bhav.csv.zip
```

*#Creating input file for applying Black Scholes, GARCH volatilities, neural networks (ANN, LSTM, GRU)*

```
data_input = pd.merge(datafno_opt, data_nifty, on='TIMESTAMP')
data_input['S'] = data_input['Close']
data_input['K'] = data_input['STRIKE_PR']
data_input['Moneyness'] = data_input['Close']/data_input['STRIKE_PR']
data_input['T'] = pd.to_datetime(data_input['EXPIRY_DT']) -
pd.to_datetime(data_input['TIMESTAMP'])
data_input['T'] = data_input['T'].dt.days
r = 6.9441 #risk free 30day t-bill rate as taken from Reserve Bank of
India website
```

*#implied vol calculation using iv\_fsolve function*

```
data_input['IV'] = list(map(lambda opt_price, S, K, T, type:
iv_fsolve(opt_price, S, K, T, r/100,type), data_input['CLOSE'],
data_input['S'], data_input['K'], data_input['T']/365,
data_input['OPTION_TYP']))
data_input = data_input.dropna()
```

*#saving the processed input data file in folder*

```
data_input.to_csv('/content/drive/My
Drive/Capstone_Grp4524/data_input.csv')
```

*#separating the input data into call options and put options*

*#we have used call options data only for the purpose of this study*

```
data_inputCE = data_input.loc[data_input['OPTION_TYP'] == 'CE']
data_inputPE = data_input.loc[data_input['OPTION_TYP'] == 'PE']
```

```
/usr/local/lib/python3.10/dist-packages/scipy/optimize/
_minpack_py.py:177: RuntimeWarning: The iteration is not making good
progress, as measured by the
improvement from the last ten iterations.
warnings.warn(msg, RuntimeWarning)
<ipython-input-3-79564a4429c2>:4: RuntimeWarning: divide by zero
encountered in divide
```

```

d1 = (np.log(S / K) + (r + 0.5 * sigma**2) * T) / (sigma *
np.sqrt(T))

#forecasting volatilities using GARCH(1,1)

#data taken till 30th Sep 2023 as input in order to forecast
volatility upto 63 days ahead till end Dec 2023
filtered_df = data_nifty[(data_nifty['TIMESTAMP'] <=
pd.to_datetime(date(2023, 9, 30)))]

#forecasting for upto 63 trading days (3 calender month) to cover the
entire year till end of 2023
forecast_horizons = range(1, 63)
forecast_results = {}
filtered_df['Close'] = pd.to_numeric(filtered_df['Close'],
errors='coerce')
filtered_df.dropna(subset=['Close'], inplace=True)
garchvol = pd.DataFrame()
garchvol['T'] = forecast_horizons

for horizon in forecast_horizons:
    # Create a new column for returns with the specified horizon
    returns = filtered_df['Close'].pct_change( periods=horizon)
    filtered_df[f'Return_{horizon}D'] = returns
    rescaled_returns = returns[~np.isnan(returns)] * 100
    forecast_results[horizon] = garch_vol(rescaled_returns, horizon,
1, 1)

#filtered_df.to_csv('/content/drive/My
Drive/Capstone_Grp4524/filtered_df.csv')

for horizon, volatility in forecast_results.items():
    print(f"Forecast horizon: {horizon}, Forecasted volatility:
{volatility[0]*((252/horizon)**0.5):.4f}")
    garchvol.loc[(garchvol['T'] == horizon), 'vol_garch'] =
volatility[0]*((252/horizon)**0.5)

#saving the garchvol file in folder
garchvol.to_csv('/content/drive/My
Drive/Capstone_Grp4524/garchvol.csv')

<ipython-input-7-2dad16f6b0b0>:9: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation:
https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#
returning-a-view-versus-a-copy
    filtered_df['Close'] = pd.to_numeric(filtered_df['Close'],
errors='coerce')

```

```
<ipython-input-7-2dad16f6b0b0>:10: SettingWithCopyWarning:  
A value is trying to be set on a copy of a slice from a DataFrame
```

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```
https://pandas.pydata.org/pandas-docs/stable/user\_guide/indexing.html#  
returning-a-view-versus-a-copy
```

```
    filtered_df.dropna(subset=['Close'], inplace=True)
```

```
<ipython-input-7-2dad16f6b0b0>:17: SettingWithCopyWarning:  
A value is trying to be set on a copy of a slice from a DataFrame.  
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```

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```
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```

```
    filtered_df[f'Return_{horizon}D'] = returns
```

```
<ipython-input-7-2dad16f6b0b0>:17: SettingWithCopyWarning:  
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```
filtered_df['Return_{horizon}D'] = returns
```

```
Forecast horizon: 1, Forecasted volatility: 0.8325
Forecast horizon: 2, Forecasted volatility: 1.4707
Forecast horizon: 3, Forecasted volatility: 1.6403
Forecast horizon: 4, Forecasted volatility: 2.2983
Forecast horizon: 5, Forecasted volatility: 1.4884
Forecast horizon: 6, Forecasted volatility: 2.3636
Forecast horizon: 7, Forecasted volatility: 2.7377
Forecast horizon: 8, Forecasted volatility: 3.8467
Forecast horizon: 9, Forecasted volatility: 4.6214
Forecast horizon: 10, Forecasted volatility: 3.9850
Forecast horizon: 11, Forecasted volatility: 5.0275
Forecast horizon: 12, Forecasted volatility: 4.6150
Forecast horizon: 13, Forecasted volatility: 5.4708
Forecast horizon: 14, Forecasted volatility: 5.7067
Forecast horizon: 15, Forecasted volatility: 5.9593
Forecast horizon: 16, Forecasted volatility: 6.1974
Forecast horizon: 17, Forecasted volatility: 7.8306
Forecast horizon: 18, Forecasted volatility: 6.6829
Forecast horizon: 19, Forecasted volatility: 7.8694
Forecast horizon: 20, Forecasted volatility: 6.9196
Forecast horizon: 21, Forecasted volatility: 6.5902
Forecast horizon: 22, Forecasted volatility: 6.6673
Forecast horizon: 23, Forecasted volatility: 7.2118
Forecast horizon: 24, Forecasted volatility: 7.1300
Forecast horizon: 25, Forecasted volatility: 7.7803
Forecast horizon: 26, Forecasted volatility: 8.4625
Forecast horizon: 27, Forecasted volatility: 8.3170
Forecast horizon: 28, Forecasted volatility: 8.2668
Forecast horizon: 29, Forecasted volatility: 9.0732
Forecast horizon: 30, Forecasted volatility: 3.5076
Forecast horizon: 31, Forecasted volatility: 9.2992
Forecast horizon: 32, Forecasted volatility: 8.3390
Forecast horizon: 33, Forecasted volatility: 10.3251
Forecast horizon: 34, Forecasted volatility: 10.8590
Forecast horizon: 35, Forecasted volatility: 10.9199
Forecast horizon: 36, Forecasted volatility: 11.5187
Forecast horizon: 37, Forecasted volatility: 11.2416
Forecast horizon: 38, Forecasted volatility: 12.1439
Forecast horizon: 39, Forecasted volatility: 12.3020
Forecast horizon: 40, Forecasted volatility: 12.3512
Forecast horizon: 41, Forecasted volatility: 12.7844
Forecast horizon: 42, Forecasted volatility: 13.3027
Forecast horizon: 43, Forecasted volatility: 13.1967
Forecast horizon: 44, Forecasted volatility: 12.4408
Forecast horizon: 45, Forecasted volatility: 8.4885
Forecast horizon: 46, Forecasted volatility: 8.0150
```

```
Forecast horizon: 47, Forecasted volatility: 9.0443
Forecast horizon: 48, Forecasted volatility: 9.3238
Forecast horizon: 49, Forecasted volatility: 9.5283
Forecast horizon: 50, Forecasted volatility: 9.2763
Forecast horizon: 51, Forecasted volatility: 10.8142
Forecast horizon: 52, Forecasted volatility: 9.7649
Forecast horizon: 53, Forecasted volatility: 9.6517
Forecast horizon: 54, Forecasted volatility: 9.6944
Forecast horizon: 55, Forecasted volatility: 9.4483
Forecast horizon: 56, Forecasted volatility: 10.8270
Forecast horizon: 57, Forecasted volatility: 12.5320
Forecast horizon: 58, Forecasted volatility: 12.3640
Forecast horizon: 59, Forecasted volatility: 12.7622
Forecast horizon: 60, Forecasted volatility: 12.7325
Forecast horizon: 61, Forecasted volatility: 12.3508
Forecast horizon: 62, Forecasted volatility: 12.7494
```

*#calculation of option prices using Black Scholes*

```
output_BS = pd.DataFrame()
columns_to_replicate = data_inputCE.iloc[:, 2:6]
output_BS[columns_to_replicate.columns] = columns_to_replicate
output_BS['Close'] = pd.to_numeric(data_inputCE['CLOSE'])
output_BS['q'] = pd.to_numeric(data_inputCE['Div Yield'])
output_BS['S'] = pd.to_numeric(data_inputCE['S'])
output_BS['K'] = pd.to_numeric(data_inputCE['K'])
output_BS['T'] = pd.to_numeric(data_inputCE['T'])
output_BS['r-q'] = r - output_BS['q']
output_BS['Moneyness'] =
pd.to_numeric(data_inputCE['Moneyness']).round(3)
output_BS = pd.merge(output_BS, garchvol, on='T')
output_BS['BS_price'] = output_BS.apply(lambda row: BS(row['S'],
row['K'], row['T']/365, row['r-q']/100, row['vol_garch']/100, 'CE'),
axis=1)
```

*#saving the Black Scholes option prices output file in folder*

```
output_BS.to_csv('/content/drive/My
Drive/Capstone_Grp4524/output_BS.csv')
```

*#error metrics for BS output vis-a-vis actual market prices of corresponding options*

```
mae = metrics.mean_absolute_error(output_BS['Close'],
output_BS['BS_price'])
mse = metrics.mean_squared_error(output_BS['Close'],
output_BS['BS_price'])
rmse = np.sqrt(mse)
mape = metrics.mean_absolute_percentage_error(output_BS['Close'],
output_BS['BS_price'])
r2 = metrics.r2_score(output_BS['Close'], output_BS['BS_price'])
```

```

print("BS error metrics:")
print("MAE:", "%.2f" %mae)
print("MSE:", "%.2f" %mse)
print("RMSE:", "%.2f" %rmse)
print("MAPE:", "%.2f" %mape)
print("R-Squared:", "%.3f" %r2)

BS error metrics:
MAE: 32.40
MSE: 2559.20
RMSE: 50.59
MAPE: 0.48
R-Squared: 0.996

#Running ANN for call options

#number of input columns are last 14 columns of data_inputCE file
ncol = 14
X = data_inputCE.iloc[:,-ncol:]
X = X.apply(pd.to_numeric, errors='coerce')
y = pd.to_numeric(data_inputCE['CLOSE'])

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.2, random_state=42)
# Create the neural network model
ANN = Sequential()
ANN.add(Dense(64, input_dim=ncol, activation='relu')) # Input layer
ANN.add(Dense(32, activation='relu')) # Hidden layer
ANN.add(Dense(32, activation='relu')) # Hidden layer
ANN.add(Dense(32, activation='relu')) # Hidden layer
ANN.add(Dense(1, activation='linear',
kernel_constraint=tf.keras.constraints.NonNeg())) # Output layer

def custom_loss(y_true, y_pred):
    # Compute the mean squared error loss
    mse_loss = tf.keras.losses.mean_squared_error(y_true, y_pred)
    # Penalize negative predictions by adding their absolute values
    neg_penalty = tf.reduce_mean(tf.abs(tf.minimum(y_pred - y_true,
0)))
    # Total loss with an added penalty for negative predictions
    total_loss = mse_loss + neg_penalty
    return total_loss

# Compile the model
ANN.compile(loss='mean_squared_error', optimizer='adam',
metrics=['mse'])

# Train the model
ANN.fit(X_train, y_train, epochs=50, batch_size=32)

```

```

# Evaluate the model on the test set
loss, mae = ANN.evaluate(X_test, y_test)

# Predict option prices using the trained model
y_pred = ANN.predict(X_test)
output_ANN = pd.DataFrame()
output_ANN['S'] = X_test['S']
output_ANN['K'] = X_test['K']
output_ANN['T'] = X_test['T']
#output_ANN['actual_price'] = y_test
output_ANN['ANN_price'] = y_pred.round(2)

#saving the ANN output to folder
output_ANN.to_csv('/content/drive/My
Drive/Capstone_Grp4524/output_ANN.csv')

#preparing dataframe having comparison of actual prices, BS prices,
ANN prices
comparemodels = pd.merge(output_BS, output_ANN, on=['S','K','T'])

#error metrics for ANN output vis-a-vis actual market prices of
corresponding options
mae = metrics.mean_absolute_error(y_test, y_pred)
mse = metrics.mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mape = metrics.mean_absolute_percentage_error(y_test, y_pred)
r2 = metrics.r2_score(y_test, y_pred)

print("ANN error metrics:")
print("MAE:", "%.2f" %mae)
print("MSE:", "%.2f" %mse)
print("RMSE:", "%.2f" %rmse)
print("MAPE:", "%.2f" %mape)
print("R-Squared:", "%.3f" %r2)

#plotting ANN prices vs. actual prices
plt.figure(figsize=(15,10))
plt.scatter(y_test,y_pred)
plt.xlabel("Real Value")
plt.ylabel("ANN Value")
plt.annotate("r-squared = {:.3f}".format(r2_score(y_test,y_pred)),
(20,1), size=15)
plt.savefig('/content/drive/My Drive/Capstone_Grp4524/plot_ANN.png',
format="png")
plt.show()

Epoch 1/50
1241/1241 [=====] - 5s 3ms/step - loss:
94140.2656 - mse: 94140.2656

```



```
Epoch 2/50
1241/1241 [=====] - 5s 4ms/step - loss:
7556.0332 - mse: 7556.0332
Epoch 3/50
1241/1241 [=====] - 3s 3ms/step - loss:
6127.0562 - mse: 6127.0562
Epoch 4/50
1241/1241 [=====] - 3s 3ms/step - loss:
5293.2666 - mse: 5293.2666
Epoch 5/50
1241/1241 [=====] - 3s 3ms/step - loss:
4877.8413 - mse: 4877.8413
Epoch 6/50
1241/1241 [=====] - 4s 4ms/step - loss:
4558.2515 - mse: 4558.2515
Epoch 7/50
1241/1241 [=====] - 4s 3ms/step - loss:
4407.8501 - mse: 4407.8501
Epoch 8/50
1241/1241 [=====] - 3s 2ms/step - loss:
3987.5369 - mse: 3987.5369
Epoch 9/50
1241/1241 [=====] - 3s 2ms/step - loss:
3658.0020 - mse: 3658.0020
Epoch 10/50
1241/1241 [=====] - 3s 2ms/step - loss:
3590.8052 - mse: 3590.8052
Epoch 11/50
1241/1241 [=====] - 5s 4ms/step - loss:
3493.4504 - mse: 3493.4504
Epoch 12/50
1241/1241 [=====] - 3s 3ms/step - loss:
3164.7061 - mse: 3164.7061
Epoch 13/50
1241/1241 [=====] - 3s 2ms/step - loss:
3673.7622 - mse: 3673.7622
Epoch 14/50
1241/1241 [=====] - 3s 2ms/step - loss:
3290.2817 - mse: 3290.2817
Epoch 15/50
1241/1241 [=====] - 3s 3ms/step - loss:
3422.7271 - mse: 3422.7271
Epoch 16/50
1241/1241 [=====] - 4s 4ms/step - loss:
3095.4229 - mse: 3095.4229
Epoch 17/50
1241/1241 [=====] - 3s 3ms/step - loss:
2889.4124 - mse: 2889.4124
Epoch 18/50
```

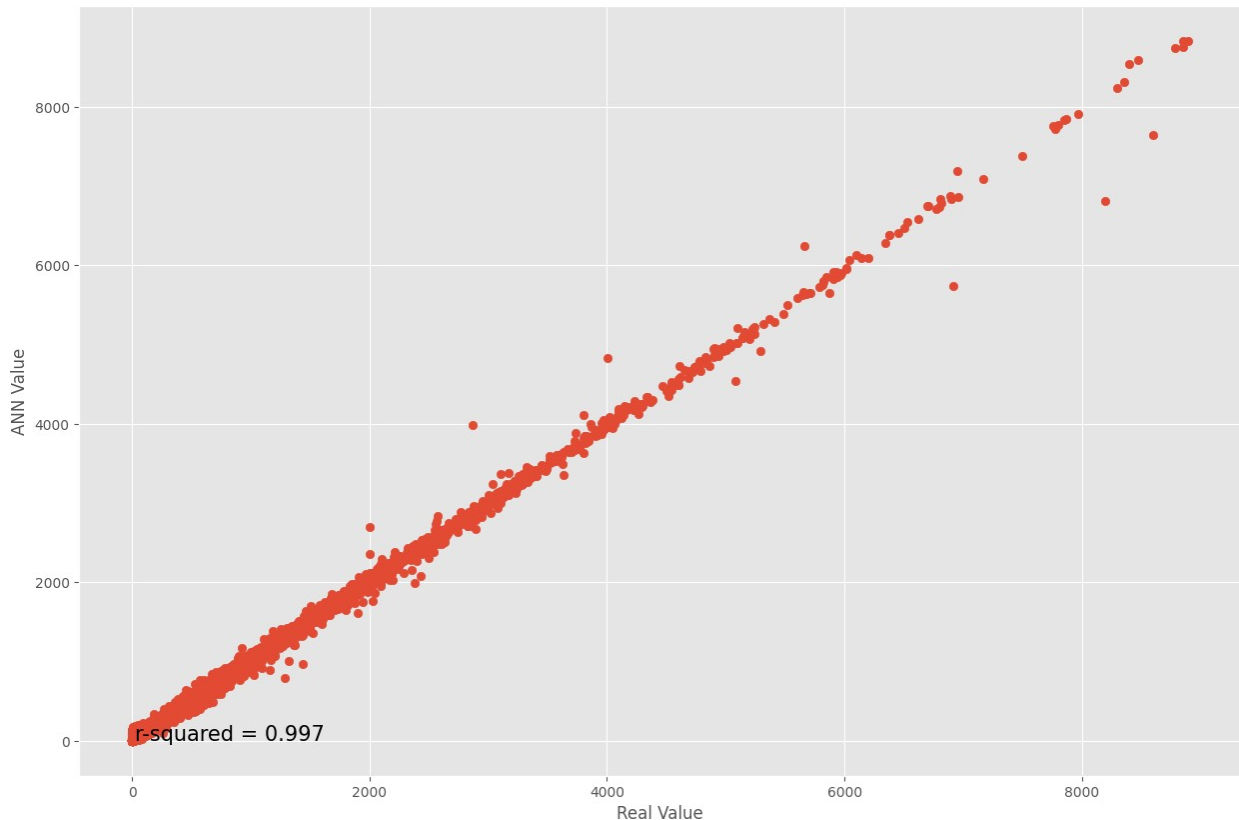
```
1241/1241 [=====] - 3s 2ms/step - loss:
3016.4270 - mse: 3016.4270
Epoch 19/50
1241/1241 [=====] - 3s 2ms/step - loss:
3067.5420 - mse: 3067.5420
Epoch 20/50
1241/1241 [=====] - 4s 3ms/step - loss:
2838.4009 - mse: 2838.4009
Epoch 21/50
1241/1241 [=====] - 5s 4ms/step - loss:
2550.3433 - mse: 2550.3433
Epoch 22/50
1241/1241 [=====] - 3s 2ms/step - loss:
2891.9878 - mse: 2891.9878
Epoch 23/50
1241/1241 [=====] - 3s 2ms/step - loss:
2729.8455 - mse: 2729.8455
Epoch 24/50
1241/1241 [=====] - 3s 2ms/step - loss:
2933.3657 - mse: 2933.3657
Epoch 25/50
1241/1241 [=====] - 4s 3ms/step - loss:
2566.8889 - mse: 2566.8889
Epoch 26/50
1241/1241 [=====] - 4s 3ms/step - loss:
2556.9407 - mse: 2556.9407
Epoch 27/50
1241/1241 [=====] - 3s 2ms/step - loss:
2561.0955 - mse: 2561.0955
Epoch 28/50
1241/1241 [=====] - 3s 2ms/step - loss:
2467.9692 - mse: 2467.9692
Epoch 29/50
1241/1241 [=====] - 3s 3ms/step - loss:
2465.1670 - mse: 2465.1670
Epoch 30/50
1241/1241 [=====] - 5s 4ms/step - loss:
2504.1240 - mse: 2504.1240
Epoch 31/50
1241/1241 [=====] - 3s 3ms/step - loss:
2400.6448 - mse: 2400.6448
Epoch 32/50
1241/1241 [=====] - 3s 2ms/step - loss:
2544.7642 - mse: 2544.7642
Epoch 33/50
1241/1241 [=====] - 3s 2ms/step - loss:
2309.1987 - mse: 2309.1987
Epoch 34/50
1241/1241 [=====] - 4s 3ms/step - loss:
```

```
2476.8210 - mse: 2476.8210
Epoch 35/50
1241/1241 [=====] - 4s 4ms/step - loss:
2317.0808 - mse: 2317.0808
Epoch 36/50
1241/1241 [=====] - 3s 2ms/step - loss:
2376.4875 - mse: 2376.4875
Epoch 37/50
1241/1241 [=====] - 3s 2ms/step - loss:
2344.6968 - mse: 2344.6968
Epoch 38/50
1241/1241 [=====] - 3s 2ms/step - loss:
2173.6528 - mse: 2173.6528
Epoch 39/50
1241/1241 [=====] - 4s 4ms/step - loss:
2243.4939 - mse: 2243.4939
Epoch 40/50
1241/1241 [=====] - 4s 3ms/step - loss:
2206.1978 - mse: 2206.1978
Epoch 41/50
1241/1241 [=====] - 3s 2ms/step - loss:
2207.0679 - mse: 2207.0679
Epoch 42/50
1241/1241 [=====] - 3s 2ms/step - loss:
2306.4785 - mse: 2306.4785
Epoch 43/50
1241/1241 [=====] - 3s 2ms/step - loss:
2217.8735 - mse: 2217.8735
Epoch 44/50
1241/1241 [=====] - 5s 4ms/step - loss:
2122.7461 - mse: 2122.7461
Epoch 45/50
1241/1241 [=====] - 3s 3ms/step - loss:
2214.6301 - mse: 2214.6301
Epoch 46/50
1241/1241 [=====] - 3s 2ms/step - loss:
2142.0198 - mse: 2142.0198
Epoch 47/50
1241/1241 [=====] - 3s 3ms/step - loss:
2046.8136 - mse: 2046.8136
Epoch 48/50
1241/1241 [=====] - 4s 4ms/step - loss:
2210.4626 - mse: 2210.4626
Epoch 49/50
1241/1241 [=====] - 4s 4ms/step - loss:
2037.1615 - mse: 2037.1615
Epoch 50/50
1241/1241 [=====] - 4s 3ms/step - loss:
2121.2598 - mse: 2121.2598
```

```

311/311 [=====] - 1s 2ms/step - loss:
2671.3481 - mse: 2671.3481
311/311 [=====] - 1s 2ms/step
ANN error metrics:
MAE: 32.23
MSE: 2671.35
RMSE: 51.69
MAPE: 4.19
R-Squared: 0.997

```



```

#Running LSTM for call options
# Assuming data and ncol are defined similarly to the previous code
# Preprocessing
data = data_inputCE.iloc[:, -ncol:]
data = data.apply(pd.to_numeric, errors='coerce')
data['opt_price'] = pd.to_numeric(data_inputCE['CLOSE'])
# Normalizing the data
scaler = MinMaxScaler()
scaled_data = scaler.fit_transform(data)

# Splitting data into features and target
X = scaled_data[:, :-1] # Features (all columns except the last one)
y = scaled_data[:, -1]  # Target (last column - option_price)
X = X.reshape(X.shape[0], 1, X.shape[1])

```

```

# Reshaping the data for LSTM (samples, time steps, features)

# Splitting the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.2, random_state=42)

# Build LSTM model
model = Sequential()
model.add(LSTM(units=200, return_sequences=True,
input_shape=(X_train.shape[1], X_train.shape[2])))
model.add(Dropout(0.2))
model.add(LSTM(units=200))
model.add(Dropout(0.2))
model.add(Dense(units=64, activation='relu'))
model.add(Dense(units=1,
kernel_constraint=tf.keras.constraints.NonNeg()))

# Compile the model
model.compile(optimizer='adam', loss='mean_squared_error',
metrics=['mse'])

# Train the model
model.fit(X_train, y_train, epochs=30, batch_size=32,
validation_data=(X_test, y_test))

# Predictions
predicted_values = model.predict(X_test)

# You can inverse_transform the predicted values to get the actual
option prices if needed
predicted_values =
scaler.inverse_transform(np.concatenate((X_test.reshape(X_test.shape[0]
], X_test.shape[2]), predicted_values), axis=1))
actual_prices =
scaler.inverse_transform(np.concatenate((X_test.reshape(X_test.shape[0]
], X_test.shape[2]), y_test.reshape(len(y_test), 1)), axis=1))
actual_prices = pd.DataFrame(actual_prices)
predicted_values = pd.DataFrame(predicted_values)
actual_prices.columns = data.columns
predicted_values.columns = data.columns
y_test = actual_prices.iloc[:, -1:]
y_pred = predicted_values.iloc[:, -1:]
output_LSTM = pd.DataFrame()
output_LSTM['S'] = actual_prices['S']
output_LSTM['K'] = actual_prices['K']
output_LSTM['T'] = actual_prices['T']
output_LSTM['LSTM_price'] = y_pred.round(2)

#saving the LSTM output to folder
output_LSTM.to_csv('/content/drive/My

```

```
Drive/Capstone_Grp4524/output_LSTM.csv')
```

```
#comparison of actual prices, BS prices, ANN prices, LSTM prices  
comparemodels = pd.merge(comparemodels, output_LSTM, on=['S','K','T'])
```

```
#error metrics for LSTM output vis-a-vis actual market prices of  
corresponding options
```

```
mae = metrics.mean_absolute_error(y_test, y_pred)  
mse = metrics.mean_squared_error(y_test, y_pred)  
rmse = np.sqrt(mse)  
mape = metrics.mean_absolute_percentage_error(y_test, y_pred)  
r2 = metrics.r2_score(y_test, y_pred)
```

```
print("LSTM error metrics:")  
print("MAE:", "%.2f" %mae)  
print("MSE:", "%.2f" %mse)  
print("RMSE:", "%.2f" %rmse)  
print("MAPE:", "%.2f" %mape)  
print("R-Squared:", "%.3f" %r2)
```

```
#plotting LSTM prices vs. actual prices
```

```
plt.figure(figsize=(10,6))  
plt.scatter(y_test,y_pred)  
plt.xlabel("Real Value")  
plt.ylabel("LSTM Value")  
plt.annotate("r-squared = {:.3f}".format(r2_score(y_test,y_pred)),  
(20,1), size=15)  
plt.savefig('/content/drive/My Drive/Capstone_Grp4524/plot_LSTM.png',  
format="png")  
plt.show()
```

```
Epoch 1/30
```

```
1241/1241 [=====] - 32s 20ms/step - loss:  
6.1344e-04 - mse: 6.1344e-04 - val_loss: 1.0114e-04 - val_mse:  
1.0114e-04
```

```
Epoch 2/30
```

```
1241/1241 [=====] - 27s 22ms/step - loss:  
1.0730e-04 - mse: 1.0730e-04 - val_loss: 4.4139e-05 - val_mse:  
4.4139e-05
```

```
Epoch 3/30
```

```
1241/1241 [=====] - 23s 18ms/step - loss:  
8.1970e-05 - mse: 8.1970e-05 - val_loss: 3.3330e-05 - val_mse:  
3.3330e-05
```

```
Epoch 4/30
```

```
1241/1241 [=====] - 25s 20ms/step - loss:  
7.8934e-05 - mse: 7.8934e-05 - val_loss: 4.6074e-05 - val_mse:  
4.6074e-05
```

```
Epoch 5/30
```

```
1241/1241 [=====] - 23s 19ms/step - loss:  
7.3462e-05 - mse: 7.3462e-05 - val_loss: 3.8761e-05 - val_mse:
```

```
3.8761e-05
Epoch 6/30
1241/1241 [=====] - 26s 21ms/step - loss:
6.6005e-05 - mse: 6.6005e-05 - val_loss: 3.0423e-05 - val_mse:
3.0423e-05
Epoch 7/30
1241/1241 [=====] - 23s 19ms/step - loss:
5.9771e-05 - mse: 5.9771e-05 - val_loss: 3.9716e-05 - val_mse:
3.9716e-05
Epoch 8/30
1241/1241 [=====] - 28s 22ms/step - loss:
6.2453e-05 - mse: 6.2453e-05 - val_loss: 2.1395e-05 - val_mse:
2.1395e-05
Epoch 9/30
1241/1241 [=====] - 23s 19ms/step - loss:
5.9136e-05 - mse: 5.9136e-05 - val_loss: 2.1941e-05 - val_mse:
2.1941e-05
Epoch 10/30
1241/1241 [=====] - 25s 20ms/step - loss:
5.7829e-05 - mse: 5.7829e-05 - val_loss: 2.1794e-05 - val_mse:
2.1794e-05
Epoch 11/30
1241/1241 [=====] - 23s 19ms/step - loss:
4.8685e-05 - mse: 4.8685e-05 - val_loss: 2.7644e-05 - val_mse:
2.7644e-05
Epoch 12/30
1241/1241 [=====] - 25s 20ms/step - loss:
6.0030e-05 - mse: 6.0030e-05 - val_loss: 5.9353e-05 - val_mse:
5.9353e-05
Epoch 13/30
1241/1241 [=====] - 23s 18ms/step - loss:
5.4028e-05 - mse: 5.4028e-05 - val_loss: 5.0789e-05 - val_mse:
5.0789e-05
Epoch 14/30
1241/1241 [=====] - 26s 21ms/step - loss:
5.0380e-05 - mse: 5.0380e-05 - val_loss: 3.6871e-05 - val_mse:
3.6871e-05
Epoch 15/30
1241/1241 [=====] - 23s 18ms/step - loss:
4.9871e-05 - mse: 4.9871e-05 - val_loss: 2.8845e-05 - val_mse:
2.8845e-05
Epoch 16/30
1241/1241 [=====] - 22s 18ms/step - loss:
4.9196e-05 - mse: 4.9196e-05 - val_loss: 3.0194e-05 - val_mse:
3.0194e-05
Epoch 17/30
1241/1241 [=====] - 24s 19ms/step - loss:
4.6243e-05 - mse: 4.6243e-05 - val_loss: 1.8201e-05 - val_mse:
1.8201e-05
```

```
Epoch 18/30
1241/1241 [=====] - 22s 18ms/step - loss:
4.4936e-05 - mse: 4.4936e-05 - val_loss: 2.3531e-05 - val_mse:
2.3531e-05
Epoch 19/30
1241/1241 [=====] - 26s 21ms/step - loss:
4.6771e-05 - mse: 4.6771e-05 - val_loss: 5.7681e-05 - val_mse:
5.7681e-05
Epoch 20/30
1241/1241 [=====] - 24s 19ms/step - loss:
4.4050e-05 - mse: 4.4050e-05 - val_loss: 4.0185e-05 - val_mse:
4.0185e-05
Epoch 21/30
1241/1241 [=====] - 24s 19ms/step - loss:
4.8875e-05 - mse: 4.8875e-05 - val_loss: 2.2152e-05 - val_mse:
2.2152e-05
Epoch 22/30
1241/1241 [=====] - 24s 19ms/step - loss:
4.1999e-05 - mse: 4.1999e-05 - val_loss: 1.9345e-05 - val_mse:
1.9345e-05
Epoch 23/30
1241/1241 [=====] - 24s 19ms/step - loss:
4.7411e-05 - mse: 4.7411e-05 - val_loss: 2.9056e-05 - val_mse:
2.9056e-05
Epoch 24/30
1241/1241 [=====] - 22s 18ms/step - loss:
5.0517e-05 - mse: 5.0517e-05 - val_loss: 2.2619e-05 - val_mse:
2.2619e-05
Epoch 25/30
1241/1241 [=====] - 23s 19ms/step - loss:
4.4259e-05 - mse: 4.4259e-05 - val_loss: 3.6324e-05 - val_mse:
3.6324e-05
Epoch 26/30
1241/1241 [=====] - 23s 19ms/step - loss:
4.2901e-05 - mse: 4.2901e-05 - val_loss: 2.1653e-05 - val_mse:
2.1653e-05
Epoch 27/30
1241/1241 [=====] - 24s 20ms/step - loss:
4.1290e-05 - mse: 4.1290e-05 - val_loss: 2.1404e-05 - val_mse:
2.1404e-05
Epoch 28/30
1241/1241 [=====] - 25s 20ms/step - loss:
4.8705e-05 - mse: 4.8705e-05 - val_loss: 3.4418e-05 - val_mse:
3.4418e-05
Epoch 29/30
1241/1241 [=====] - 25s 20ms/step - loss:
4.1360e-05 - mse: 4.1360e-05 - val_loss: 3.2715e-05 - val_mse:
3.2715e-05
Epoch 30/30
```



```
1241/1241 [=====] - 24s 20ms/step - loss:
3.9962e-05 - mse: 3.9962e-05 - val_loss: 3.1864e-05 - val_mse:
3.1864e-05
311/311 [=====] - 3s 6ms/step
```

```
<ipython-input-10-5fcdcdade597f>:57: UserWarning: You are merging on
int and float columns where the float values are not equal to their
int representation.
```

```
comparemodels = pd.merge(comparemodels, output_LSTM,
on=['S', 'K', 'T'])
```

LSTM error metrics:

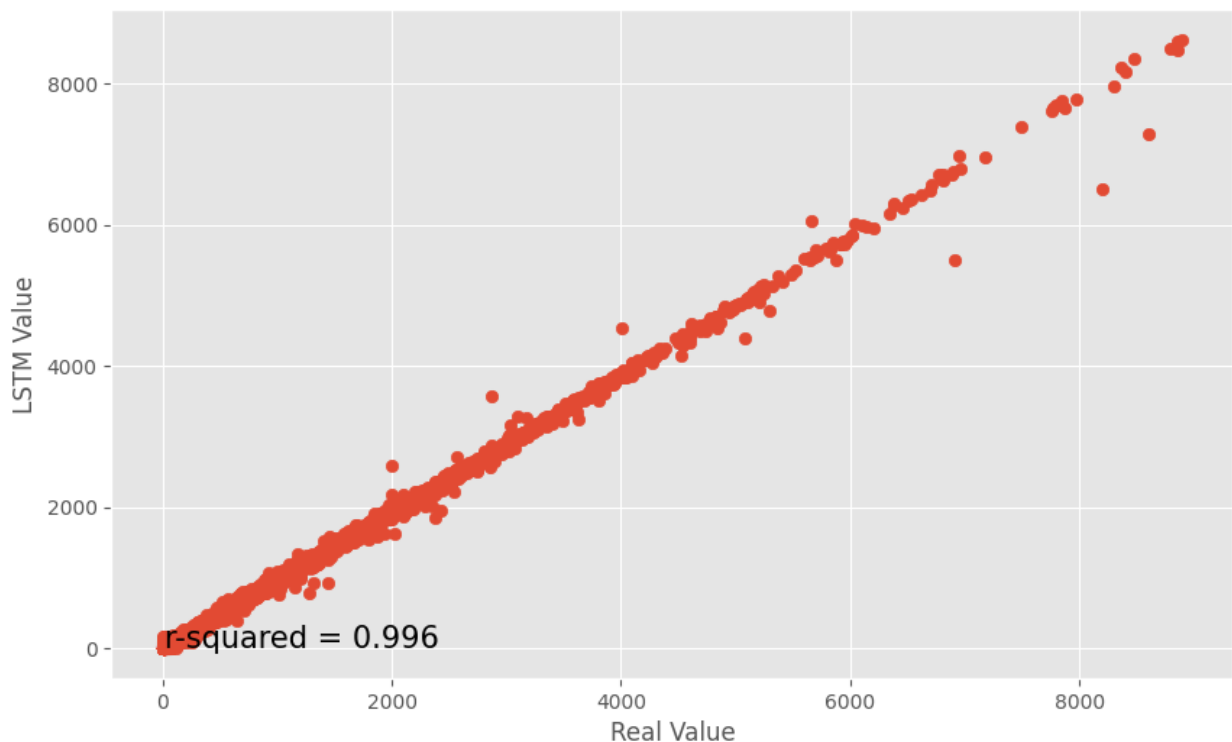
MAE: 32.70

MSE: 3687.77

RMSE: 60.73

MAPE: 3.14

R-Squared: 0.996



```
#Running GRU for call options
# Assuming data and ncol are defined similarly to the previous code
# Preprocessing
data = data_inputCE.iloc[:, -ncol:]
data = data.apply(pd.to_numeric, errors='coerce')
data['opt_price'] = pd.to_numeric(data_inputCE['CLOSE'])

scaler = MinMaxScaler()
```

```

scaled_data = scaler.fit_transform(data)

X = scaled_data[:, :-1]
y = scaled_data[:, -1]
X = X.reshape(X.shape[0], 1, X.shape[1])

# Train-test split
X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.2, random_state=42)

# Build GRU model
model = Sequential()
model.add(GRU(units=200, return_sequences=True,
input_shape=(X_train.shape[1], X_train.shape[2])))
model.add(Dropout(0.2))
model.add(GRU(units=200))
model.add(Dropout(0.2))
model.add(Dense(units=64, activation='relu'))
model.add(Dense(units=1,
kernel_constraint=tf.keras.constraints.NonNeg()))

# Compile the model
model.compile(optimizer='adam', loss='mean_squared_error',
metrics=['mse'])

# Train the model
model.fit(X_train, y_train, epochs=30, batch_size=32,
validation_data=(X_test, y_test))

# Predictions
predicted_values = model.predict(X_test)

# Inverse transform for original scale
predicted_values =
scaler.inverse_transform(np.concatenate((X_test.reshape(X_test.shape[0]
], X_test.shape[2]), predicted_values), axis=1))
actual_prices =
scaler.inverse_transform(np.concatenate((X_test.reshape(X_test.shape[0]
], X_test.shape[2]), y_test.reshape(len(y_test), 1)), axis=1))
actual_prices = pd.DataFrame(actual_prices)
predicted_values = pd.DataFrame(predicted_values)
actual_prices.columns = data.columns
predicted_values.columns = data.columns
y_test = actual_prices.iloc[:, -1:]
y_pred = predicted_values.iloc[:, -1:]
output_GRU = pd.DataFrame()
output_GRU['S'] = actual_prices['S']
output_GRU['K'] = actual_prices['K']
output_GRU['T'] = actual_prices['T']
output_GRU['GRU_price'] = y_pred.round(2)

```

```

#saving the GRU output to folder
output_GRU.to_csv('/content/drive/My
Drive/Capstone_Grp4524/output_GRU.csv')
comparemodels = pd.merge(comparemodels, output_GRU, on=['S','K','T'])

#saving the final comparison of option prices from all models
comparemodels.to_csv('/content/drive/My
Drive/Capstone_Grp4524/comparemodels.csv')

#error metrics for GRU output vis-a-vis actual market prices of
corresponding options
mae = metrics.mean_absolute_error(y_test, y_pred)
mse = metrics.mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mape = metrics.mean_absolute_percentage_error(y_test, y_pred)
r2 = metrics.r2_score(y_test, y_pred)

print("GRU error metrics:")
print("MAE:", "%.2f" %mae)
print("MSE:", "%.2f" %mse)
print("RMSE:", "%.2f" %rmse)
print("MAPE:", "%.2f" %mape)
print("R-Squared:", "%.3f" %r2)

#plotting GRU prices vs. actual prices
plt.figure(figsize=(10,6))
plt.scatter(y_test, y_pred)
plt.xlabel("Real Value")
plt.ylabel("GRU Value")
plt.annotate("r-squared = {:.3f}".format(r2_score(y_test, y_pred)),
(20,1), size=15)
plt.savefig('/content/drive/My Drive/Capstone_Grp4524/plot_GRU.png',
format="png")
plt.show()

Epoch 1/30
1241/1241 [=====] - 30s 20ms/step - loss:
5.2503e-04 - mse: 5.2503e-04 - val_loss: 5.2289e-05 - val_mse:
5.2289e-05
Epoch 2/30
1241/1241 [=====] - 24s 19ms/step - loss:
1.2964e-04 - mse: 1.2964e-04 - val_loss: 4.8683e-05 - val_mse:
4.8683e-05
Epoch 3/30
1241/1241 [=====] - 23s 19ms/step - loss:
1.0898e-04 - mse: 1.0898e-04 - val_loss: 3.0718e-05 - val_mse:
3.0718e-05
Epoch 4/30
1241/1241 [=====] - 25s 20ms/step - loss:

```

```
9.0422e-05 - mse: 9.0422e-05 - val_loss: 2.8683e-05 - val_mse:
2.8683e-05
Epoch 5/30
1241/1241 [=====] - 23s 18ms/step - loss:
7.7664e-05 - mse: 7.7664e-05 - val_loss: 4.9625e-05 - val_mse:
4.9625e-05
Epoch 6/30
1241/1241 [=====] - 25s 20ms/step - loss:
7.9242e-05 - mse: 7.9242e-05 - val_loss: 3.0336e-05 - val_mse:
3.0336e-05
Epoch 7/30
1241/1241 [=====] - 22s 18ms/step - loss:
7.7148e-05 - mse: 7.7148e-05 - val_loss: 5.3366e-05 - val_mse:
5.3366e-05
Epoch 8/30
1241/1241 [=====] - 25s 20ms/step - loss:
7.3127e-05 - mse: 7.3127e-05 - val_loss: 2.7523e-05 - val_mse:
2.7523e-05
Epoch 9/30
1241/1241 [=====] - 23s 18ms/step - loss:
7.2026e-05 - mse: 7.2026e-05 - val_loss: 5.3777e-05 - val_mse:
5.3777e-05
Epoch 10/30
1241/1241 [=====] - 25s 20ms/step - loss:
6.8343e-05 - mse: 6.8343e-05 - val_loss: 2.8514e-05 - val_mse:
2.8514e-05
Epoch 11/30
1241/1241 [=====] - 22s 18ms/step - loss:
6.8645e-05 - mse: 6.8645e-05 - val_loss: 2.4989e-05 - val_mse:
2.4989e-05
Epoch 12/30
1241/1241 [=====] - 24s 19ms/step - loss:
6.0109e-05 - mse: 6.0109e-05 - val_loss: 3.5075e-05 - val_mse:
3.5075e-05
Epoch 13/30
1241/1241 [=====] - 26s 21ms/step - loss:
5.6702e-05 - mse: 5.6702e-05 - val_loss: 7.7640e-05 - val_mse:
7.7640e-05
Epoch 14/30
1241/1241 [=====] - 25s 20ms/step - loss:
5.7935e-05 - mse: 5.7935e-05 - val_loss: 3.8291e-05 - val_mse:
3.8291e-05
Epoch 15/30
1241/1241 [=====] - 23s 18ms/step - loss:
5.5605e-05 - mse: 5.5605e-05 - val_loss: 2.9548e-05 - val_mse:
2.9548e-05
Epoch 16/30
1241/1241 [=====] - 28s 23ms/step - loss:
5.6563e-05 - mse: 5.6563e-05 - val_loss: 2.5907e-05 - val_mse:
```

```
2.5907e-05
Epoch 17/30
1241/1241 [=====] - 35s 28ms/step - loss:
5.4799e-05 - mse: 5.4799e-05 - val_loss: 2.7663e-05 - val_mse:
2.7663e-05
Epoch 18/30
1241/1241 [=====] - 23s 18ms/step - loss:
5.2372e-05 - mse: 5.2372e-05 - val_loss: 3.5919e-05 - val_mse:
3.5919e-05
Epoch 19/30
1241/1241 [=====] - 25s 20ms/step - loss:
5.0982e-05 - mse: 5.0982e-05 - val_loss: 3.3232e-05 - val_mse:
3.3232e-05
Epoch 20/30
1241/1241 [=====] - 23s 18ms/step - loss:
4.8832e-05 - mse: 4.8832e-05 - val_loss: 3.6331e-05 - val_mse:
3.6331e-05
Epoch 21/30
1241/1241 [=====] - 25s 20ms/step - loss:
4.5865e-05 - mse: 4.5865e-05 - val_loss: 3.3046e-05 - val_mse:
3.3046e-05
Epoch 22/30
1241/1241 [=====] - 23s 18ms/step - loss:
4.9122e-05 - mse: 4.9122e-05 - val_loss: 2.5846e-05 - val_mse:
2.5846e-05
Epoch 23/30
1241/1241 [=====] - 25s 21ms/step - loss:
5.0052e-05 - mse: 5.0052e-05 - val_loss: 4.5729e-05 - val_mse:
4.5729e-05
Epoch 24/30
1241/1241 [=====] - 23s 19ms/step - loss:
4.9123e-05 - mse: 4.9123e-05 - val_loss: 8.3072e-05 - val_mse:
8.3072e-05
Epoch 25/30
1241/1241 [=====] - 26s 21ms/step - loss:
4.8771e-05 - mse: 4.8771e-05 - val_loss: 2.5661e-05 - val_mse:
2.5661e-05
Epoch 26/30
1241/1241 [=====] - 22s 18ms/step - loss:
4.8975e-05 - mse: 4.8975e-05 - val_loss: 4.5546e-05 - val_mse:
4.5546e-05
Epoch 27/30
1241/1241 [=====] - 23s 19ms/step - loss:
4.8156e-05 - mse: 4.8156e-05 - val_loss: 2.7972e-05 - val_mse:
2.7972e-05
Epoch 28/30
1241/1241 [=====] - 24s 19ms/step - loss:
4.7245e-05 - mse: 4.7245e-05 - val_loss: 2.2839e-05 - val_mse:
2.2839e-05
```

```
Epoch 29/30
1241/1241 [=====] - 22s 18ms/step - loss:
4.4727e-05 - mse: 4.4727e-05 - val_loss: 5.0474e-05 - val_mse:
5.0474e-05
Epoch 30/30
1241/1241 [=====] - 25s 20ms/step - loss:
4.4718e-05 - mse: 4.4718e-05 - val_loss: 3.2208e-05 - val_mse:
3.2208e-05
311/311 [=====] - 2s 4ms/step
```

```
<ipython-input-11-66e7567e7041>:53: UserWarning: You are merging on
int and float columns where the float values are not equal to their
int representation.
```

```
comparemodels = pd.merge(comparemodels, output_GRU,
on=['S', 'K', 'T'])
```

GRU error metrics:

MAE: 39.11

MSE: 3727.55

RMSE: 61.05

MAPE: 3.10

R-Squared: 0.996

