```
# 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
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  Downloading bhavcopy-3.0.tar.gz (4.9 kB)
  Preparing metadata (setup.py) ... ent already satisfied: pandas
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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)
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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 volatilites - same is
accessed later in the code
#3 different functions have been defined using bissection, 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 volatilies 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')
```

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Mounted at /content/drive
Folder '/content/drive/My Drive/Capstone_Grp4524/' created
successfully!
Running File Check
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00:00:00', freq='D'), Timestamp('2023-10-31 00:00:00', freq='D'),
Timestamp('2023-11-01 00:00:00', freq='D'), Timestamp('2023-11-02
00:00:00', freq='D'), Timestamp('2023-11-03 00:00:00', freq='D'),
Timestamp('2023-11-06 00:00:00', freq='D'), Timestamp('2023-11-07
00:00:00', freq='D'), Timestamp('2023-11-08 00:00:00', freq='D'),
Timestamp('2023-11-09 00:00:00', freq='D'), Timestamp('2023-11-10
00:00:00', freq='D'), Timestamp('2023-11-13 00:00:00', freq='D'),
Timestamp('2023-11-14 00:00:00', freq='D'), Timestamp('2023-11-15
00:00:00', freq='D'), Timestamp('2023-11-16 00:00:00', freq='D'),
Timestamp('2023-11-17 00:00:00', freq='D'), Timestamp('2023-11-20
00:00:00', freq='D'), Timestamp('2023-11-21 00:00:00', freq='D'),
Timestamp('2023-11-22 00:00:00', freq='D'), Timestamp('2023-11-23
00:00:00', freq='D'), Timestamp('2023-11-24 00:00:00', freq='D'),
Timestamp('2023-11-27 00:00:00', freq='D'), Timestamp('2023-11-28
00:00:00', freq='D'), Timestamp('2023-11-29 00:00:00', freq='D'),
Timestamp('2023-11-30 00:00:00', freq='D'), Timestamp('2023-12-01
00:00:00', freq='D'), Timestamp('2023-12-04 00:00:00', freq='D'),
Timestamp('2023-12-05 00:00:00', freq='D'), Timestamp('2023-12-06
00:00:00', freq='D'), Timestamp('2023-12-07 00:00:00', freq='D'),
Timestamp('2023-12-08 00:00:00', freq='D'), Timestamp('2023-12-11
00:00:00', freq='D'), Timestamp('2023-12-12 00:00:00', freq='D'),
Timestamp('2023-12-13 00:00:00', freq='D'), Timestamp('2023-12-14
00:00:00', freq='D'), Timestamp('2023-12-15 00:00:00', freq='D'),
Timestamp('2023-12-18 00:00:00', freq='D'), Timestamp('2023-12-19
00:00:00', freq='D'), Timestamp('2023-12-20 00:00:00', freq='D'),
Timestamp('2023-12-21 00:00:00', freq='D'), Timestamp('2023-12-22
00:00:00', freq='D'), Timestamp('2023-12-25 00:00:00', freq='D'),
Timestamp('2023-12-26 00:00:00', freq='D'), Timestamp('2023-12-27
00:00:00', freq='D'), Timestamp('2023-12-28 00:00:00', freq='D'),
Timestamp('2023-12-29 00:00:00', freq='D')]
2023-01-02 00:00:00
2023-01-02 00:00:00:done
2023-01-03 00:00:00
2023-01-03 00:00:00:done
2023-01-04 00:00:00
2023-01-04 00:00:00:done
2023-01-05 00:00:00
2023-01-05 00:00:00:done
```

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2023-01-06 00:00:00
2023-01-06 00:00:00:done
2023-01-09 00:00:00
2023-01-09 00:00:00:done
2023-01-10 00:00:00
2023-01-10 00:00:00:done
2023-01-11 00:00:00
2023-01-11 00:00:00:done
2023-01-12 00:00:00
2023-01-12 00:00:00:done
2023-01-13 00:00:00
2023-01-13 00:00:00:done
2023-01-16 00:00:00
2023-01-16 00:00:00:done
2023-01-17 00:00:00
2023-01-17 00:00:00:done
2023-01-18 00:00:00
2023-01-18 00:00:00:done
2023-01-19 00:00:00
2023-01-19 00:00:00:done
2023-01-20 00:00:00
2023-01-20 00:00:00:done
2023-01-23 00:00:00
2023-01-23 00:00:00:done
2023-01-24 00:00:00
2023-01-24 00:00:00:done
2023-01-25 00:00:00
2023-01-25 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_26012023.c
sv
2023-01-26 00:00:00:failed
2023-01-27 00:00:00
2023-01-27 00:00:00:done
2023-01-30 00:00:00
2023-01-30 00:00:00:done
2023-01-31 00:00:00
2023-01-31 00:00:00:done
2023-02-01 00:00:00
2023-02-01 00:00:00:done
2023-02-02 00:00:00
2023-02-02 00:00:00:done
2023-02-03 00:00:00
2023-02-03 00:00:00:done
2023-02-06 00:00:00
2023-02-06 00:00:00:done
2023-02-07 00:00:00
2023-02-07 00:00:00:done
2023-02-08 00:00:00
```

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2023-02-08 00:00:00:done
2023-02-09 00:00:00
2023-02-09 00:00:00:done
2023-02-10 00:00:00
2023-02-10 00:00:00:done
2023-02-13 00:00:00
2023-02-13 00:00:00:done
2023-02-14 00:00:00
2023-02-14 00:00:00:done
2023-02-15 00:00:00
2023-02-15 00:00:00:done
2023-02-16 00:00:00
2023-02-16 00:00:00:done
2023-02-17 00:00:00
2023-02-17 00:00:00:done
2023-02-20 00:00:00
2023-02-20 00:00:00:done
2023-02-21 00:00:00
2023-02-21 00:00:00:done
2023-02-22 00:00:00
2023-02-22 00:00:00:done
2023-02-23 00:00:00
2023-02-23 00:00:00:done
2023-02-24 00:00:00
2023-02-24 00:00:00:done
2023-02-27 00:00:00
2023-02-27 00:00:00:done
2023-02-28 00:00:00
2023-02-28 00:00:00:done
2023-03-01 00:00:00
2023-03-01 00:00:00:done
2023-03-02 00:00:00
2023-03-02 00:00:00:done
2023-03-03 00:00:00
2023-03-03 00:00:00:done
2023-03-06 00:00:00
2023-03-06 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_07032023.c
sv
2023-03-07 00:00:00:failed
2023-03-08 00:00:00
2023-03-08 00:00:00:done
2023-03-09 00:00:00
2023-03-09 00:00:00:done
2023-03-10 00:00:00
2023-03-10 00:00:00:done
2023-03-13 00:00:00
2023-03-13 00:00:00:done
```

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2023-03-14 00:00:00
2023-03-14 00:00:00:done
2023-03-15 00:00:00
2023-03-15 00:00:00:done
2023-03-16 00:00:00
2023-03-16 00:00:00:done
2023-03-17 00:00:00
2023-03-17 00:00:00:done
2023-03-20 00:00:00
2023-03-20 00:00:00:done
2023-03-21 00:00:00
2023-03-21 00:00:00:done
2023-03-22 00:00:00
2023-03-22 00:00:00:done
2023-03-23 00:00:00
2023-03-23 00:00:00:done
2023-03-24 00:00:00
2023-03-24 00:00:00:done
2023-03-27 00:00:00
2023-03-27 00:00:00:done
2023-03-28 00:00:00
2023-03-28 00:00:00:done
2023-03-29 00:00:00
2023-03-29 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_30032023.c
sv
2023-03-30 00:00:00:failed
2023-03-31 00:00:00
2023-03-31 00:00:00:done
2023-04-03 00:00:00
2023-04-03 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_04042023.c
sv
2023-04-04 00:00:00:failed
2023-04-05 00:00:00
2023-04-05 00:00:00:done
2023-04-06 00:00:00
2023-04-06 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_07042023.c
sv
2023-04-07 00:00:00:failed
2023-04-10 00:00:00
2023-04-10 00:00:00:done
2023-04-11 00:00:00
2023-04-11 00:00:00:done
2023-04-12 00:00:00
```

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2023-04-12 00:00:00:done
2023-04-13 00:00:00
2023-04-13 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_14042023.c
sv
2023-04-14 00:00:00:failed
2023-04-17 00:00:00
2023-04-17 00:00:00:done
2023-04-18 00:00:00
2023-04-18 00:00:00:done
2023-04-19 00:00:00
2023-04-19 00:00:00:done
2023-04-20 00:00:00
2023-04-20 00:00:00:done
2023-04-21 00:00:00
2023-04-21 00:00:00:done
2023-04-24 00:00:00
2023-04-24 00:00:00:done
2023-04-25 00:00:00
2023-04-25 00:00:00:done
2023-04-26 00:00:00
2023-04-26 00:00:00:done
2023-04-27 00:00:00
2023-04-27 00:00:00:done
2023-04-28 00:00:00
2023-04-28 00:00:00:done
HTTP Error: 404 Client Error: Not Found for url:
https://archives.nseindia.com/content/indices/ind_close_all_01052023.c
sv
2023-05-01 00:00:00:failed
2023-05-02 00:00:00
2023-05-02 00:00:00:done
2023-05-03 00:00:00
2023-05-03 00:00:00:done
2023-05-04 00:00:00
2023-05-04 00:00:00:done
2023-05-05 00:00:00
2023-05-05 00:00:00:done
2023-05-08 00:00:00
2023-05-08 00:00:00:done
2023-05-09 00:00:00
2023-05-09 00:00:00:done
2023-05-10 00:00:00
2023-05-10 00:00:00:done
2023-05-11 00:00:00
2023-05-11 00:00:00:done
2023-05-12 00:00:00
2023-05-12 00:00:00:done
```

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2023-05-15 00:00:00
2023-05-15 00:00:00:done
2023-05-16 00:00:00
2023-05-16 00:00:00:done
2023-05-17 00:00:00
2023-05-17 00:00:00:done
2023-05-18 00:00:00
2023-05-18 00:00:00:done
2023-05-19 00:00:00
2023-05-19 00:00:00:done
2023-05-22 00:00:00
2023-05-22 00:00:00:done
2023-05-23 00:00:00
2023-05-23 00:00:00:done
2023-05-24 00:00:00
2023-05-24 00:00:00:done
2023-05-25 00:00:00
2023-05-25 00:00:00:done
2023-05-26 00:00:00
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
```

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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.c
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
```

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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.c
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
```

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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.c
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
```

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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.c
sv
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.c
sv
2023-10-24 00:00:00:failed
2023-10-25 00:00:00
2023-10-25 00:00:00:done
```

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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.c
sv
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.c
sv
```

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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
2023-12-18 00:00:00:done
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
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.strftime(tday, '%d')
            MM = datetime.strftime(tday, '%b').upper()
            YYYY = datetime.strftime(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 FnO 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 FnO 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 FnO 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/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JAN/
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fo20JAN2023bhav.csv.zip
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fo23JAN2023bhav.csv.zip
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fo26JAN2023bhav.csv.zip
Error in26JAN2023
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fo27JAN2023bhav.csv.zip
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fo31JAN2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/FEB/
fo24FEB2023bhav.csv.zip
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Error in29JUN2023
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fo24JUL2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/JUL/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/AUG/
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fo10AUG2023bhav.csv.zip
```

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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/AUG/
fo14AUG2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/AUG/
fo15AUG2023bhav.csv.zip
Error in15AUG2023
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/AUG/
fo16AUG2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/AUG/
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/AUG/
fo18AUG2023bhav.csv.zip
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fo13SEP2023bhav.csv.zip
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/SEP/
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fo27SEP2023bhav.csv.zip
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Error in02OCT2023
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Error in24OCT2023
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fo30OCT2023bhav.csv.zip
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/NOV/
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fo08NOV2023bhav.csv.zip
http://archives.nseindia.com/content/historical/DERIVATIVES/2023/NOV/
fo09NOV2023bhav.csv.zip
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/NOV/
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fo19DEC2023bhav.csv.zip
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http://archives.nseindia.com/content/historical/DERIVATIVES/2023/DEC/
```

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

```
#Creating input file for applying Black Scholes, GARCH volatilites,
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

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

```
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<ipython-input-7-2dad16f6b0b0>:17: SettingWithCopyWarning:
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returning-a-view-versus-a-copy
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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

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

```
#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'])
```

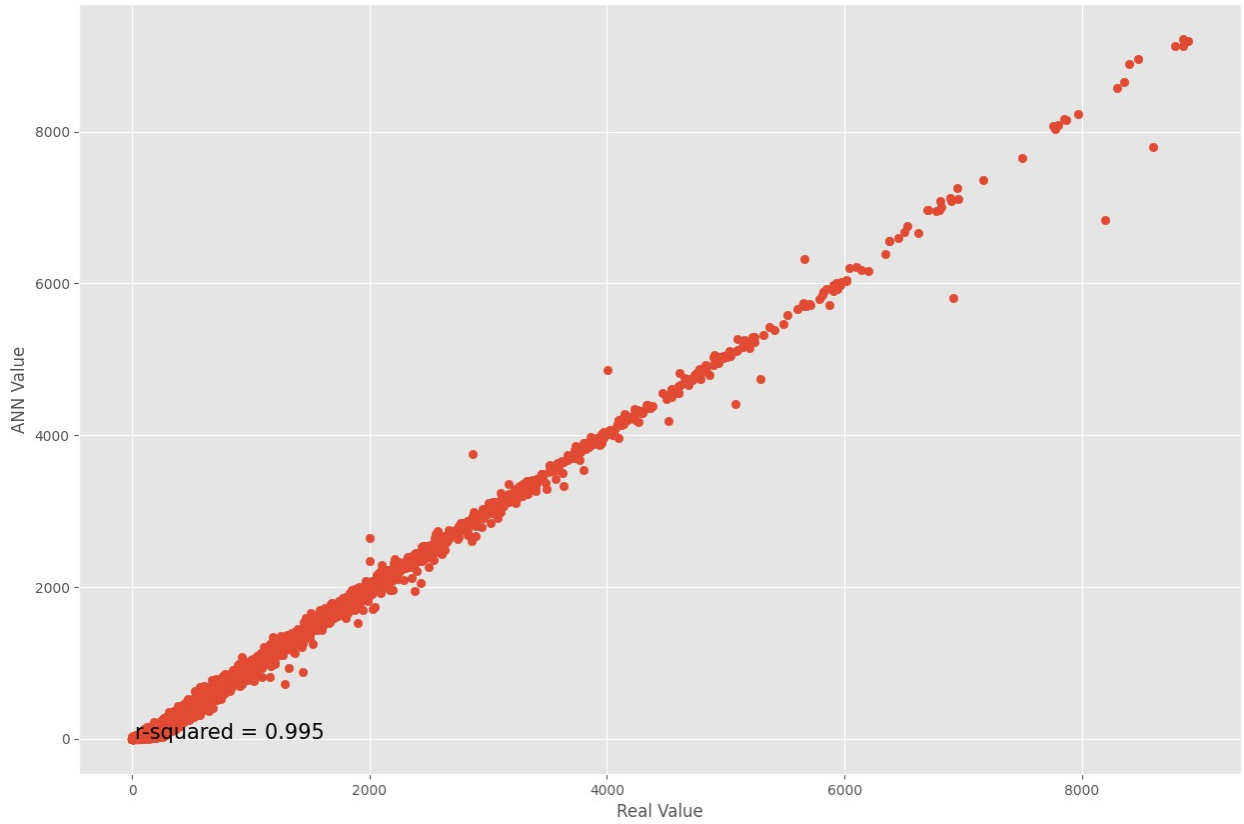
```
# Train the model
ANN.fit(X_train, y_train, epochs=50, batch_size=32)

# 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 [==============================] - 4s 2ms/step - loss:
144781.2969 - mse: 144781.2969
Epoch 2/50
1241/1241 [==============================] - 3s 2ms/step - loss:
7906.4863 - mse: 7906.4863
Epoch 3/50
1241/1241 [==============================] - 3s 2ms/step - loss:
6776.4287 - mse: 6776.4287
Epoch 4/50
1241/1241 [==============================] - 3s 3ms/step - loss:
5475.5352 - mse: 5475.5352
Epoch 5/50
1241/1241 [==============================] - 4s 3ms/step - loss:
4432.7817 - mse: 4432.7817
Epoch 6/50
1241/1241 [==============================] - 3s 2ms/step - loss:
4236.1099 - mse: 4236.1099
Epoch 7/50
1241/1241 [==============================] - 2s 2ms/step - loss:
3975.5215 - mse: 3975.5215
Epoch 8/50
1241/1241 [==============================] - 2s 2ms/step - loss:
3576.4885 - mse: 3576.4885
Epoch 9/50
1241/1241 [==============================] - 3s 2ms/step - loss:
3546.0688 - mse: 3546.0688
Epoch 10/50
1241/1241 [==============================] - 4s 3ms/step - loss:
3483.1362 - mse: 3483.1362
Epoch 11/50
1241/1241 [==============================] - 3s 2ms/step - loss:
3334.3669 - mse: 3334.3669
Epoch 12/50
1241/1241 [==============================] - 2s 2ms/step - loss:
3457.6003 - mse: 3457.6003
Epoch 13/50
1241/1241 [==============================] - 2s 2ms/step - loss:
3135.5156 - mse: 3135.5156
Epoch 14/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2885.4504 - mse: 2885.4504
Epoch 15/50
1241/1241 [==============================] - 4s 3ms/step - loss:
3063.0063 - mse: 3063.0063
Epoch 16/50
1241/1241 [==============================] - 3s 3ms/step - loss:
3003.0862 - mse: 3003.0862
Epoch 17/50
1241/1241 [==============================] - 2s 2ms/step - loss:
```

```
2750.9651 - mse: 2750.9651
Epoch 18/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2879.9500 - mse: 2879.9500
Epoch 19/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2816.8606 - mse: 2816.8606
Epoch 20/50
1241/1241 [==============================] - 4s 4ms/step - loss:
2610.3115 - mse: 2610.3115
Epoch 21/50
1241/1241 [==============================] - 4s 3ms/step - loss:
2598.1348 - mse: 2598.1348
Epoch 22/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2490.6470 - mse: 2490.6470
Epoch 23/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2726.6311 - mse: 2726.6311
Epoch 24/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2431.5034 - mse: 2431.5034
Epoch 25/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2546.2883 - mse: 2546.2883
Epoch 26/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2581.6243 - mse: 2581.6243
Epoch 27/50
1241/1241 [==============================] - 3s 3ms/step - loss:
2529.4570 - mse: 2529.4570
Epoch 28/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2327.4424 - mse: 2327.4424
Epoch 29/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2547.2139 - mse: 2547.2139
Epoch 30/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2319.7302 - mse: 2319.7302
Epoch 31/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2259.2371 - mse: 2259.2371
Epoch 32/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2296.0889 - mse: 2296.0889
Epoch 33/50
1241/1241 [==============================] - 4s 3ms/step - loss:
2398.8154 - mse: 2398.8154
Epoch 34/50
```

```
1241/1241 [==============================] - 2s 2ms/step - loss:
2336.4641 - mse: 2336.4641
Epoch 35/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2179.1396 - mse: 2179.1396
Epoch 36/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2320.0266 - mse: 2320.0266
Epoch 37/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2257.3125 - mse: 2257.3125
Epoch 38/50
1241/1241 [==============================] - 4s 3ms/step - loss:
2298.7383 - mse: 2298.7383
Epoch 39/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2278.4988 - mse: 2278.4988
Epoch 40/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2123.5815 - mse: 2123.5815
Epoch 41/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2173.8113 - mse: 2173.8113
Epoch 42/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2069.1729 - mse: 2069.1729
Epoch 43/50
1241/1241 [==============================] - 3s 3ms/step - loss:
2158.8083 - mse: 2158.8083
Epoch 44/50
1241/1241 [==============================] - 4s 3ms/step - loss:
2066.9453 - mse: 2066.9453
Epoch 45/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2256.9741 - mse: 2256.9741
Epoch 46/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2157.9756 - mse: 2157.9756
Epoch 47/50
1241/1241 [==============================] - 3s 2ms/step - loss:
2058.1738 - mse: 2058.1738
Epoch 48/50
1241/1241 [==============================] - 2s 2ms/step - loss:
2097.9417 - mse: 2097.9417
Epoch 49/50
1241/1241 [==============================] - 4s 3ms/step - loss:
1996.5444 - mse: 1996.5444
Epoch 50/50
1241/1241 [==============================] - 3s 3ms/step - loss:
2154.3831 - mse: 2154.3831
```

```
311/311 [==============================] - 1s 1ms/step - loss:
4614.8315 - mse: 4614.8315
311/311 [==============================] - 0s 1ms/step
ANN error metrics:
MAE: 43.62
MSE: 4614.83
RMSE: 67.93
MAPE: 0.91
R-Squared: 0.995
```




```python
#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 [==============================] - 25s 15ms/step - loss:
5.8890e-04 - mse: 5.8890e-04 - val_loss: 1.1567e-04 - val_mse:
1.1567e-04
Epoch 2/30
1241/1241 [==============================] - 18s 14ms/step - loss:
1.0289e-04 - mse: 1.0289e-04 - val_loss: 2.7959e-05 - val_mse:
2.7959e-05
Epoch 3/30
1241/1241 [==============================] - 18s 14ms/step - loss:
7.8801e-05 - mse: 7.8801e-05 - val_loss: 4.9654e-05 - val_mse:
4.9654e-05
Epoch 4/30
1241/1241 [==============================] - 20s 16ms/step - loss:
7.7961e-05 - mse: 7.7961e-05 - val_loss: 5.0527e-05 - val_mse:
5.0527e-05
Epoch 5/30
1241/1241 [==============================] - 21s 17ms/step - loss:
6.5645e-05 - mse: 6.5645e-05 - val_loss: 5.0134e-05 - val_mse:
```

```
5.0134e-05
Epoch 6/30
 181/1241 [===>..........................] - ETA: 12s - loss: 6.8948e-
05 - mse: 6.8948e-05
```

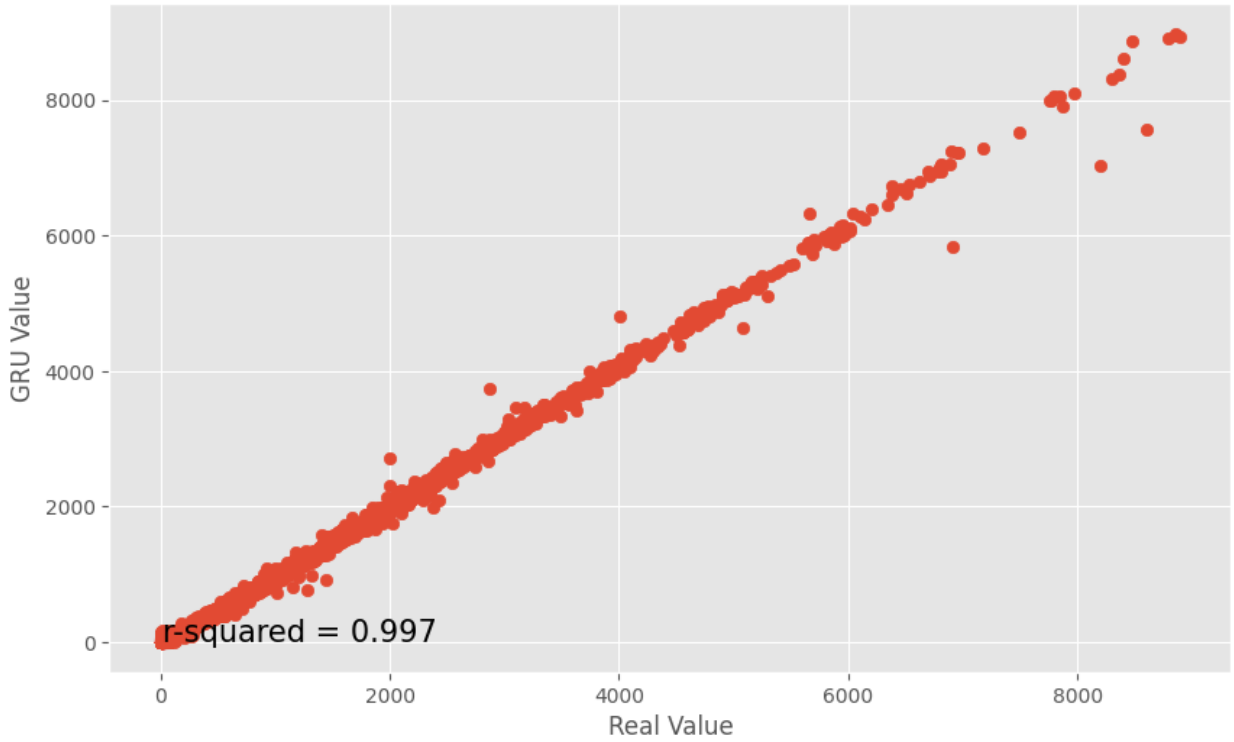
```
#Running GRU for call options
# Assuming data and ncol are defined similarly to the previous code
# Preprocessing
data = data_inputCE.iloc[:, -ncol:]
data = data.apply(pd.to_numeric, errors='coerce')
data['opt_price'] = pd.to_numeric(data_inputCE['CLOSE'])

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 [==============================] - 24s 15ms/step - loss:
5.5978e-04 - mse: 5.5978e-04 - val_loss: 6.6636e-05 - val_mse:
6.6636e-05
Epoch 2/30
1241/1241 [==============================] - 17s 14ms/step - loss:
1.1078e-04 - mse: 1.1078e-04 - val_loss: 4.6209e-05 - val_mse:
4.6209e-05
Epoch 3/30
1241/1241 [==============================] - 18s 14ms/step - loss:
1.0440e-04 - mse: 1.0440e-04 - val_loss: 4.5870e-05 - val_mse:
4.5870e-05
Epoch 4/30
1241/1241 [==============================] - 19s 15ms/step - loss:
8.7960e-05 - mse: 8.7960e-05 - val_loss: 5.0620e-05 - val_mse:
5.0620e-05
Epoch 5/30
1241/1241 [==============================] - 18s 14ms/step - loss:
8.2930e-05 - mse: 8.2930e-05 - val_loss: 1.2369e-04 - val_mse:
1.2369e-04
Epoch 6/30
1241/1241 [==============================] - 18s 14ms/step - loss:
8.7804e-05 - mse: 8.7804e-05 - val_loss: 6.0330e-05 - val_mse:
6.0330e-05
Epoch 7/30
1241/1241 [==============================] - 18s 14ms/step - loss:
6.8593e-05 - mse: 6.8593e-05 - val_loss: 4.8830e-05 - val_mse:
4.8830e-05
Epoch 8/30
1241/1241 [==============================] - 19s 15ms/step - loss:
7.5509e-05 - mse: 7.5509e-05 - val_loss: 2.8503e-05 - val_mse:
2.8503e-05
Epoch 9/30
1241/1241 [==============================] - 17s 14ms/step - loss:
6.7650e-05 - mse: 6.7650e-05 - val_loss: 3.1896e-05 - val_mse:
3.1896e-05
Epoch 10/30
1241/1241 [==============================] - 18s 14ms/step - loss:
5.9045e-05 - mse: 5.9045e-05 - val_loss: 7.9621e-05 - val_mse:
7.9621e-05
Epoch 11/30
1241/1241 [==============================] - 19s 16ms/step - loss:
5.7511e-05 - mse: 5.7511e-05 - val_loss: 2.5577e-05 - val_mse:
2.5577e-05
Epoch 12/30
1241/1241 [==============================] - 19s 16ms/step - loss:
6.0421e-05 - mse: 6.0421e-05 - val_loss: 2.4044e-05 - val_mse:
2.4044e-05
Epoch 13/30
1241/1241 [==============================] - 18s 14ms/step - loss:
```

```
5.8252e-05 - mse: 5.8252e-05 - val_loss: 5.3296e-05 - val_mse:
5.3296e-05
Epoch 14/30
1241/1241 [==============================] - 18s 14ms/step - loss:
5.9297e-05 - mse: 5.9297e-05 - val_loss: 6.2106e-05 - val_mse:
6.2106e-05
Epoch 15/30
1241/1241 [==============================] - 17s 14ms/step - loss:
5.4472e-05 - mse: 5.4472e-05 - val_loss: 3.1356e-05 - val_mse:
3.1356e-05
Epoch 16/30
1241/1241 [==============================] - 20s 16ms/step - loss:
5.4632e-05 - mse: 5.4632e-05 - val_loss: 3.0760e-05 - val_mse:
3.0760e-05
Epoch 17/30
1241/1241 [==============================] - 17s 14ms/step - loss:
5.0410e-05 - mse: 5.0410e-05 - val_loss: 3.6320e-05 - val_mse:
3.6320e-05
Epoch 18/30
1241/1241 [==============================] - 18s 14ms/step - loss:
5.0387e-05 - mse: 5.0387e-05 - val_loss: 4.6122e-05 - val_mse:
4.6122e-05
Epoch 19/30
1241/1241 [==============================] - 17s 14ms/step - loss:
5.0609e-05 - mse: 5.0609e-05 - val_loss: 2.1785e-05 - val_mse:
2.1785e-05
Epoch 20/30
1241/1241 [==============================] - 20s 16ms/step - loss:
5.0334e-05 - mse: 5.0334e-05 - val_loss: 2.1497e-05 - val_mse:
2.1497e-05
Epoch 21/30
1241/1241 [==============================] - 18s 14ms/step - loss:
4.7895e-05 - mse: 4.7895e-05 - val_loss: 8.7425e-05 - val_mse:
8.7425e-05
Epoch 22/30
1241/1241 [==============================] - 17s 14ms/step - loss:
4.6695e-05 - mse: 4.6695e-05 - val_loss: 2.6744e-05 - val_mse:
2.6744e-05
Epoch 23/30
1241/1241 [==============================] - 18s 14ms/step - loss:
4.8980e-05 - mse: 4.8980e-05 - val_loss: 2.3341e-05 - val_mse:
2.3341e-05
Epoch 24/30
1241/1241 [==============================] - 21s 17ms/step - loss:
4.8630e-05 - mse: 4.8630e-05 - val_loss: 2.0370e-05 - val_mse:
2.0370e-05
Epoch 25/30
1241/1241 [==============================] - 17s 14ms/step - loss:
4.9657e-05 - mse: 4.9657e-05 - val_loss: 3.4589e-05 - val_mse:
3.4589e-05
```

```
Epoch 26/30
1241/1241 [==============================] - 17s 14ms/step - loss:
4.3400e-05 - mse: 4.3400e-05 - val_loss: 1.8843e-05 - val_mse:
1.8843e-05
Epoch 27/30
1241/1241 [==============================] - 17s 14ms/step - loss:
4.5345e-05 - mse: 4.5345e-05 - val_loss: 1.8057e-05 - val_mse:
1.8057e-05
Epoch 28/30
1241/1241 [==============================] - 19s 16ms/step - loss:
4.2609e-05 - mse: 4.2609e-05 - val_loss: 2.5223e-05 - val_mse:
2.5223e-05
Epoch 29/30
1241/1241 [==============================] - 18s 14ms/step - loss:
4.5052e-05 - mse: 4.5052e-05 - val_loss: 2.8021e-05 - val_mse:
2.8021e-05
Epoch 30/30
1241/1241 [==============================] - 17s 14ms/step - loss:
4.3035e-05 - mse: 4.3035e-05 - val_loss: 2.9022e-05 - val_mse:
2.9022e-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: 36.59
MSE: 3358.85
RMSE: 57.96
MAPE: 2.09
R-Squared: 0.997
```




```
# Define ranges for moneyness - OTM, ATM & ITM
#compare the error metrics of 4 models in each of the range
ranges = [(0.5, 0.9), (0.9, 1.1), (1.1, 1.5)]

# Iterate through the ranges
def calculate_errors(filter_df, model):
    mse = round(metrics.mean_squared_error(filter['Close'],
filter[f'{model}_price']), 3)
    rmse = round(np.sqrt(mse), 3)
    mae = round(metrics.mean_absolute_error(filter['Close'],
filter[f'{model}_price']), 3)
    mape =
round(metrics.mean_absolute_percentage_error(filter['Close'],
filter[f'{model}_price']), 3)
    return {'MSE': mse, 'RMSE': rmse, 'MAE': mae, 'MAPE': mape}

# Initialize dictionaries to store error metrics for each range and
model
error_metrics = {r: {model: [] for model in ['BS', 'ANN', 'LSTM',
'GRU']} for r in ranges}

# Iterate through the ranges
for r in ranges:
    # Filter the DataFrame based on moneyness range
    filter = comparemodels[(comparemodels['Moneyness'] >= r[0]) &
(comparemodels['Moneyness'] < r[1])]
```

```
    # Calculate errors for each model and store in the respective
dictionary
    for model in ['BS', 'ANN', 'LSTM', 'GRU']:
        error_metrics[r][model] = calculate_errors(filter, model)

# Create DataFrames for each range and model
dfs = {r: {model: pd.DataFrame([error_metrics[r][model]]) for model in
error_metrics[r]} for r in ranges}

# Combine OTM error metrics for each model into a single DataFrame
combined_dfs = {r: pd.concat([dfs[r][model] for model in ['BS', 'ANN',
'LSTM', 'GRU']],
                             keys=['BS', 'ANN', 'LSTM',
'GRU']).reset_index(level=0).rename(
    columns={'level_0': 'Model'}) for r in ranges}

# Display the combined DataFrames for each range
for r in ranges:
    print(f"Range {r} Error Metrics:")
    print(combined_dfs[r])
    print("\n")
```

```
Range (0.5, 0.9) Error Metrics:
  Model     MSE   RMSE    MAE   MAPE
0    BS  18.875  4.345  3.822  0.994
0   ANN  10.230  3.198  2.567  0.662
0  LSTM  12.992  3.604  3.115  1.945
0   GRU   6.472  2.544  2.039  0.687


Range (0.9, 1.1) Error Metrics:
  Model       MSE    RMSE     MAE   MAPE
0    BS  2601.458  51.004  32.167  0.510
0   ANN  3633.252  60.276  42.222  0.610
0  LSTM  1530.226  39.118  24.990  1.409
0   GRU  2235.351  47.279  32.340  0.496


Range (1.1, 1.5) Error Metrics:
  Model       MSE    RMSE     MAE   MAPE
0    BS  2980.945  54.598  40.701  0.016
0   ANN  1863.100  43.164  31.565  0.013
0  LSTM  6330.835  79.567  69.199  0.028
0   GRU  3523.744  59.361  45.440  0.017
```