

# Experiment 1

## AIM

Exploratory data analysis of time series data.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

Month.csv which is a sales and revenue dataset with size 96 rows x 5 columns.

## CODE AND OUTPUT

The screenshot shows a Google Colaboratory notebook titled "Hitesh\_Lab1\_July\_20\_2023.ipynb". The code cell contains the following Python code:

```
[ ] 1 # import numpy as np # linear algebra
2 import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)
3
[ ] 1 #read the csv file using pandas
2 data = pd.read_csv('/content/month.csv')
3
[ ] 1 # preview the data using head or tail command
2
[ ] 1 # check data info
2 data.info
3
<bound method DataFrame.info of
   Period      Revenue  Sales_quantity  Average_cost
0  01.01.2015  1.681007e+07    12729.0       1257.763541
1  01.02.2015  1.681007e+07    11939.0       1358.630086
2  01.03.2015  1.284715e+07    15922.0       1384.697024
3  01.04.2015  1.881458e+07    15227.0       1235.666705
4  01.05.2015  1.402148e+07    8626.0       1626.621765
...
91 01.06.2022        ...          ...          ...
92 01.07.2022        ...          ...          ...
93 01.08.2022        ...          ...          ...
94 01.11.2022        ...          ...          ...
95 01.12.2022        ...          ...          ...
[96 rows x 5 columns]>
4
[ ] 1 data.describe()
5
<table border="1">
|  | Revenue | Sales_quantity | Average_cost | The_average_annual_payroll_of_the_region |
| --- | --- | --- | --- | --- |
| count | 6.400000e+01 | 64.000000 | 64.000000 | 6.400000e+01 |
| mean | 3.236046e+07 | 19197.375000 | 1659.561159 | 2.869083e+07 |
| std | 1.164150e+07 | 6591.287257 | 296.844793 | 1.057191e+06 |
| min | 1.402148e+07 | 8314.000000 | 1110.576805 | 2.740647e+07 |
| 25% | 2.242655e+07 | 15065.500000 | 1499.142841 | 2.782857e+07 |
| 50% | 3.209088e+07 | 18368.000000 | 1654.399798 | 2.819785e+07 |
| 75% | 3.992999e+07 | 22856.250000 | 1916.401096 | 2.987852e+07 |
| max | 5.875647e+07 | 38069.000000 | 2559.328184 | 3.002468e+07 |


6
[ ] 1 # check the number of unique values in the period column
7
8 data.Period.unique()
9
array(['01.01.2015', '01.02.2015', '01.03.2015', '01.04.2015',
       '01.05.2015', '01.06.2015', '01.07.2015', '01.08.2015',
       '01.09.2015', '01.10.2015', '01.11.2015', '01.12.2015',
       '01.01.2016', '01.02.2016', '01.03.2016', '01.04.2016',
       '01.05.2016', '01.06.2016', '01.07.2016', '01.08.2016',
       '01.09.2016', '01.10.2016', '01.11.2016', '01.12.2016',
       '01.01.2017', '01.02.2017', '01.03.2017', '01.04.2017',
       '01.05.2017', '01.06.2017', '01.07.2017', '01.08.2017',
       '01.09.2017', '01.10.2017', '01.11.2017', '01.12.2017',
       '01.01.2018', '01.02.2018', '01.03.2018', '01.04.2018',
       '01.05.2018', '01.06.2018', '01.07.2018', '01.08.2018',
       '01.09.2018', '01.10.2018', '01.11.2018', '01.12.2018',
       '01.01.2019', '01.02.2019', '01.03.2019', '01.04.2019',
       '01.05.2019', '01.06.2019', '01.07.2019', '01.08.2019',
       '01.09.2019', '01.10.2019', '01.11.2019', '01.12.2019',
       '01.01.2020', '01.02.2020', '01.03.2020', '01.04.2020',
       '01.05.2020', '01.06.2020', '01.07.2020', '01.08.2020',
       '01.09.2020', '01.10.2020', '01.11.2020', '01.12.2020',
       '01.01.2021', '01.02.2021', '01.03.2021', '01.04.2021',
       '01.05.2021', '01.06.2021', '01.07.2021', '01.08.2021',
       '01.09.2021', '01.10.2021', '01.11.2021', '01.12.2021',
       '01.01.2022', '01.02.2022', '01.03.2022', '01.04.2022',
       '01.05.2022', '01.06.2022', '01.07.2022', '01.08.2022',
       '01.09.2022', '01.10.2022', '01.11.2022', '01.12.2022'],
      dtype='object')
```

```
[ ] 1 # remove the rows that has those null values  
2  
3 data_dropped
```

Period	Revenue	Sales_quantity	Average_cost	The_average_annual_payroll_of_the_region
0	01.01.2015	1.601007e+07	12729.0	1257.763541
1	02.01.2015	1.580759e+07	11636.0	1358.507000
2	03.01.2015	2.204715e+07	15922.0	1384.697024
3	04.01.2015	1.881458e+07	15227.0	1235.606705
4	05.01.2015	1.402148e+07	8620.0	1626.621765
...	...	...	...	...
59	11.01.2019	5.875564e+07	38069.0	1543.420464
60	01.01.2020	5.628830e+07	27184.0	2070.640650
61	01.02.2020	4.022524e+07	23509.0	1711.057181
62	01.03.2020	5.002217e+07	32569.0	1535.882748
63	01.04.2020	5.232069e+07	26615.0	1965.834790

We have been given revenue values for continuous 64 months, we have to predict for 32 months

```
[ ] 1 #convert dates in a DataFrame to Pandas datetime or Period objects with a specific frequency
2 data[\"Period\"]>pd.to_datetime(data[\"Period\"],format=\"%d.%m.%Y\")
3 data[\"Period\"]>data[\"Period\"].dt.to_period('M')

[ ] 1 # get data info
2 data.info

[ ] <bound method DataFrame.info of      Period          Revenue   Sales_quantity  Average_cost \
0  2015-01  1.68107e+07    12729.0    1257.763541
1  2015-02  1.580759e+07   11636.0    1358.507000
2  2015-03  2.204715e+07   15922.0    1384.869924
3  2015-04  1.588458e+07   15248.0    1235.666705
4  2015-05  1.402148e+07   8628.0    1628.621776
..       ...     ...
91  2022-08  NaN        NaN        NaN
92  2022-09  NaN        NaN        NaN
93  2022-10  NaN        NaN        NaN
94  2022-11  NaN        NaN        NaN
95  2022-12  NaN        NaN        NaN

The_average_annual_payroll_of_the_region
1           30024676.0
2           30024676.0
3           30024676.0
4           30024676.0
..           ...
91          NaN
92          NaN
93          NaN
94          NaN
95          NaN

[ 96 rows x 5 columns]>

[ ] 1 ts>data.loc[0:63,['Period','Revenue','Sales quantity']]
```

<b>0</b>	2015-01	1.601007e+07	12729.0
<b>1</b>	2015-02	1.580759e+07	11636.0
<b>2</b>	2015-03	2.204715e+07	15922.0
<b>3</b>	2015-04	1.881458e+07	15227.0
<b>4</b>	2015-05	1.402148e+07	8620.0
...	...	...	...
<b>59</b>	2019-12	5.785674e+07	38069.0
<b>60</b>	2020-01	5.628830e+07	27184.0
<b>61</b>	2020-02	4.022524e+07	23509.0
<b>62</b>	2020-03	5.002217e+07	32569.0
<b>63</b>	2020-04	5.232069e+07	26615.0

```
[ ] 1 #Extract the month and year from dates in a DataFrame
2 ts['Month']=ts['Period'].dt.month
3 ts['Year']=ts['Period'].dt.year
4 ts.head()
```

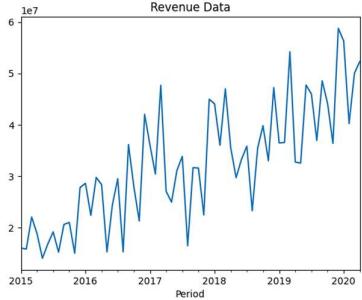
	Period	Revenue	Sales_quantity	Month	Year
0	2015-01	1.601007e+07	12729.0	1	2015
1	2015-02	1.580759e+07	11636.0	2	2015
2	2015-04	2.204715e+07	15922.0	3	2015
3	2015-04	1.881458e+07	15227.0	4	2015
4	2015-05	1.402148e+07	8620.0	5	2015

```
[ ] 1 ts.set_index('Period',inplace=True)
2 ts.head()
```

	Revenue	Sales_quantity	Month	Year
2015-01	1.601007e+07	12729.0	1	2015
2015-02	1.580759e+07	11636.0	2	2015
2015-04	2.204715e+07	15922.0	3	2015
2015-04	1.881458e+07	15227.0	4	2015
2015-05	1.402148e+07	8620.0	5	2015

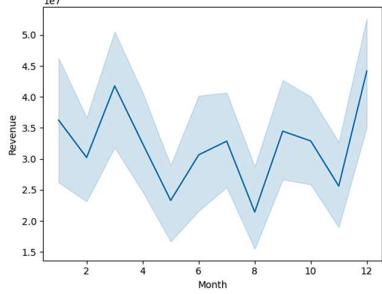
```
[ ] 1 import matplotlib.pyplot as plt
2 import seaborn as sns
3 %matplotlib inline
```

```
[ ] 1 plt.title('Revenue Data')
2 ts['Revenue'].plot()
<Axes: title={'center': 'Revenue Data'}, xlabel='Period'>
```



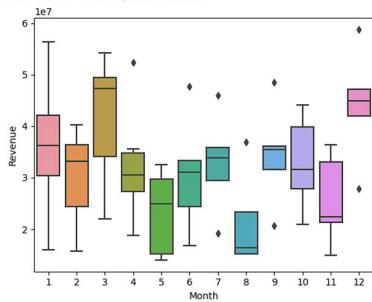
```
[ ] 1 sns.lineplot(x="Month",y="Revenue",data=ts)
```

```
[ ] <Axes: xlabel='Month', ylabel='Revenue'>
```



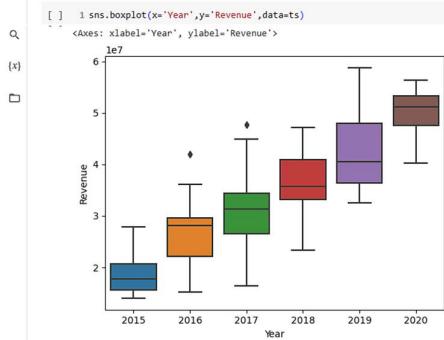
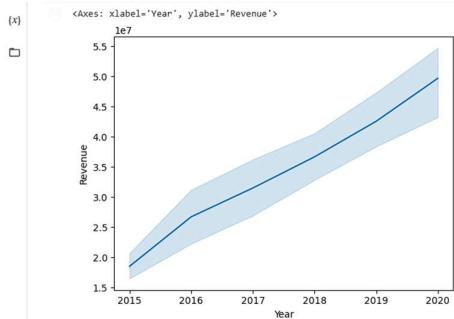
```
[ ] 1 sns.boxplot(x="Month",y="Revenue",data=ts)
```

```
[ ] <Axes: xlabel='Month', ylabel='Revenue'>
```

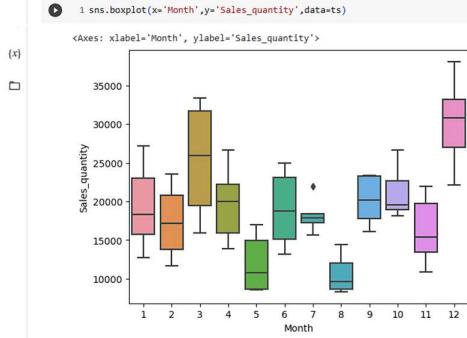
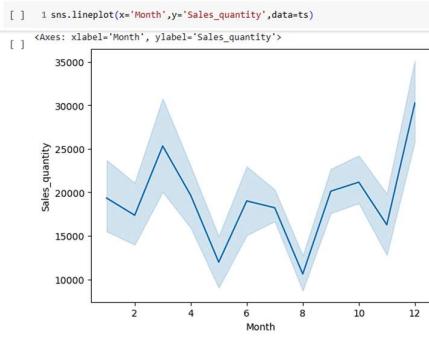
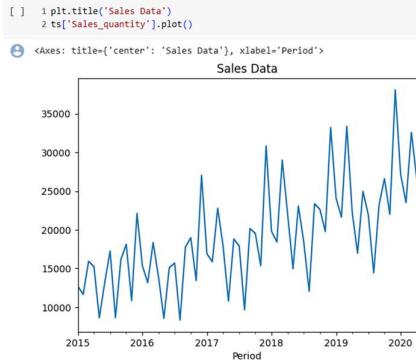


It points toward seasonal pattern

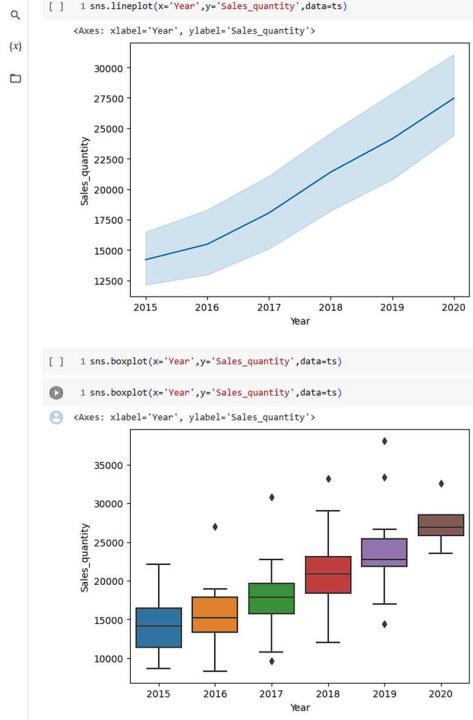
```
[ ] 1 sns.lineplot(x='Year',y='Revenue',data=ts)
```



This shows there is linearly increasing trend



It points toward seasonal pattern



## RESULT

The implementation was successful.

# Experiment 2

## AIM

Handling missing values in data using: Forward fill method (Last observation carried forward), Backward fill method (Next observation carried backwards), Linear interpolation, Spline interpolation, Seasonal decomposition and interpolation.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

AirPassengers.csv which is a flight dataset giving the no. of passengers over time with size (144 x 1).

## CODE AND OUTPUT

The screenshot shows a Google Colaboratory notebook titled "Hitesh\_Lab2\_July\_27\_2023.ipynb". The code cell contains Python code to load the dataset and perform basic operations like renaming columns and checking the shape. The output cell displays the raw data and statistical summary of the dataset.

```
File Edit View Insert Runtime Tools Help Last edited on August 27, 2023
Comment Share Connect ▾
```

+ Code + Text

>About the Dataset

The dataset contains number of air passengers of each month from the year 1949 to 1960.

```
[ ] 1 import pandas, numpy, matplotlib,seaborn as sns
2
3 sns.set(style="whitegrid", color_codes=True, font_scale=1.3)
4
5 import warnings
6 warnings.filterwarnings('ignore')
```

First let's load the dataset and get a general overview.

```
[ ] 1 original = pandas.read_csv("./content/AirPassengers (1).csv", index_col=['Month'], parse_dates=['Month'])
2
3 # read data csv file using pandas and make Month column as index
4 #original = original.set_index('Month')
5 # preview data using head command
6 original.head()
```

Month	#Passengers
1949-01-01	112
1949-02-01	118
1949-03-01	132
1949-04-01	129
1949-05-01	121

```
[ ] 1 original.rename(columns = {'#Passengers' : 'Passengers'}, inplace = True)
```

Passengers

Month	Passengers
1949-01-01	112
1949-02-01	118
1949-03-01	132
1949-04-01	129
1949-05-01	121

```
[ ] 1 # check data shape
2 original.shape
```

(144, 1)

```
[ ] 1 # use describe command to describe your data
2 original.describe()
```

Passengers	
count	144.000000
mean	280.298611
std	119.966317
min	104.000000
25%	180.000000
50%	265.500000
75%	360.500000
max	622.000000

The dataset isn't too complex. We have 2 columns, one for the month and the other column is our target.  
In total we have 144 rows. Not very much, but let's see if we can do something with it.

```
[ ] 1 no_missing_vals = original['Passengers'].isnull().sum()
2 print(f'No of missing observations: {no_missing_vals}')
{x}
No of missing observations: 0
```

if no missing values are in the dataset. We should be happy but for this case we need some missing values to apply the appropriate techniques.  
So let's randomly create some NaNs in our dataset.

```
[ ] 1 import numpy as np
2 data = original.copy()
3 # create a data copy using .copy() command,
4
5
6 # then include some nan values in passengers columns at rows 10:11, 25:29, 40:45, 70:79, 120:125
7
8 data.iloc[10:11, data.columns.get_loc('Passengers')] = np.nan
9 data.iloc[25:29, data.columns.get_loc('Passengers')] = np.nan
10 data.iloc[40:45, data.columns.get_loc('Passengers')] = np.nan
11 data.iloc[70:79, data.columns.get_loc('Passengers')] = np.nan
12 data.iloc[120:125, data.columns.get_loc('Passengers')] = np.nan
```

And check again for missing values.

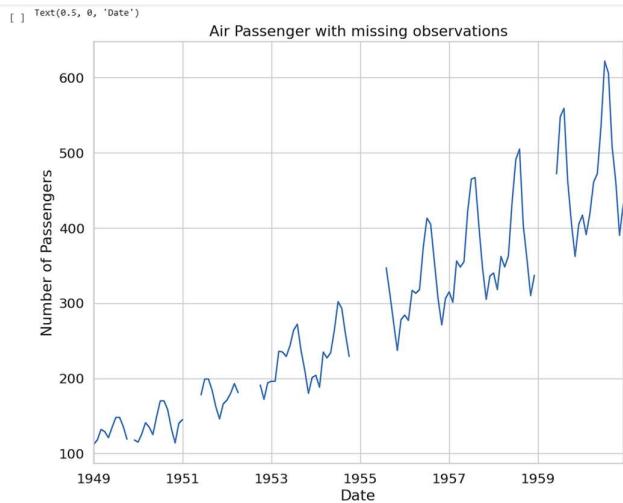
```
[ ] 1 no_missing_vals = data.isnull().sum()
2 # check the sum of null values
3 print(f'No of missing observations: {no_missing_vals}')
4 print(f'% of missing observations: {no_missing_vals / len(data)}')

No of missing observations: Passengers    24
dtype: int64
% of missing observations: Passengers   0.166667
dtype: float64
```

Now 24 observations are missing in our time series. Roughly 17% of our data are affected.

Lets plot our time series data to see the missing values.

```
[ ] 1 ax = data.plot(legend=None, figsize=(10,8))
2 ax.set_title('Air Passenger with missing observations')
3 ax.set_ylabel('Number of Passengers')
4 ax.set_xlabel('Date')
```



#### Missing value handling

I will show 5 techniques for missing value handling.

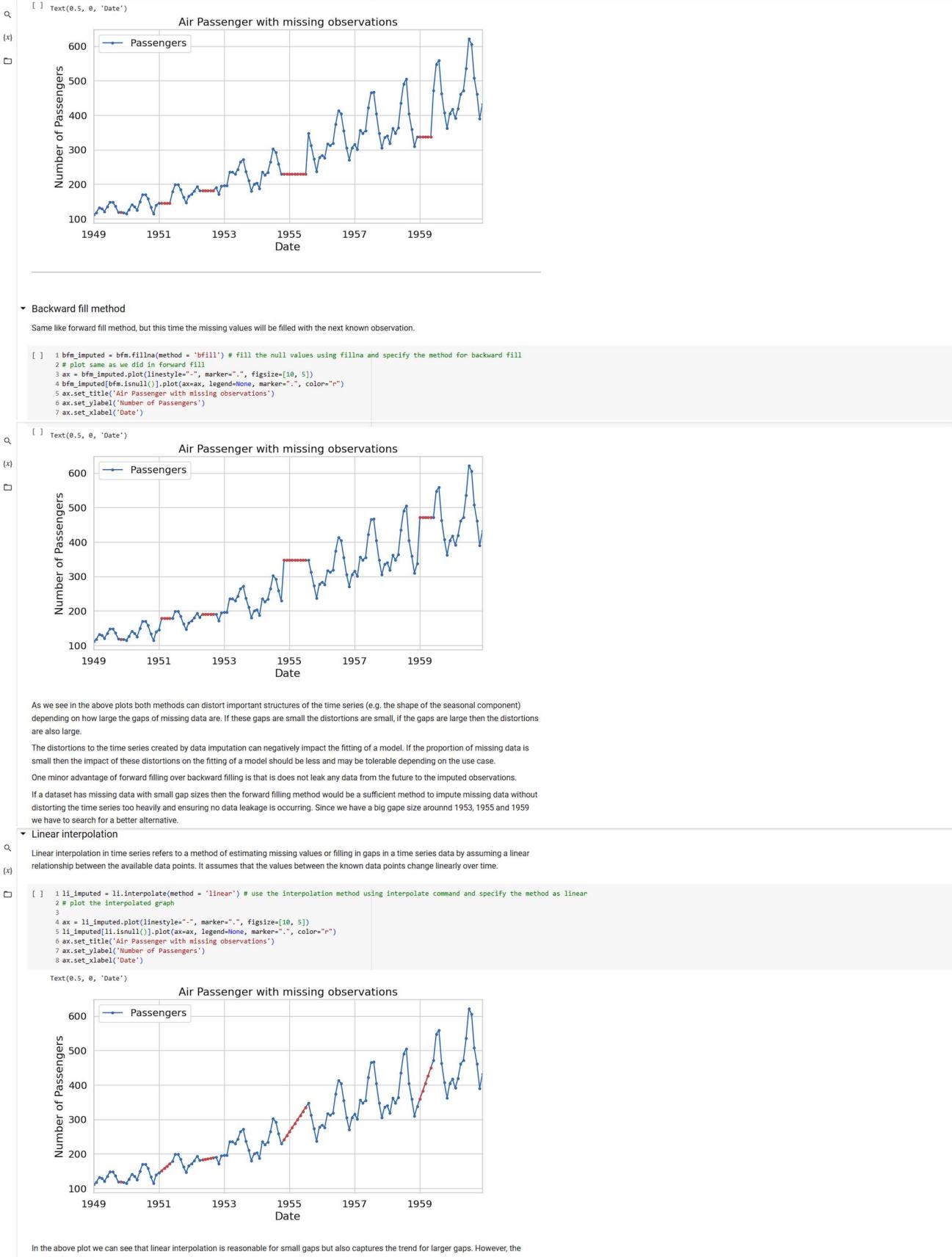
- Forward fill method (Last observation carried forward)
- Backward fill method (Next observation carried backwards)
- Linear interpolation
- Spline interpolation
- Seasonal decomposition and interpolation

```
[ ] 1 ffm = data.copy()
2 bfm = data.copy()
3 li = data.copy()
4 si = data.copy()
5 sdi = data.copy()
```

#### Forward fill method

As the name implies, here the missing data points are filled with the value of the last known data point.

```
[ ] 1 ffm_imputed = ffm.fillna(method='ffill') # fill the null values using fillna and specify the method as 'ffill' for forward fill
2 ax = ffm_imputed.plot(linestyle="--", marker=".", figsize=(10, 5))
3 li = data.copy()
4 si = data.interpolate(method='linear').plot(ax=ax, legend=None, marker=".", color="r")
5 ax.set_title('Air Passenger with missing observations')
6 ax.set_ylabel('Number of Passengers')
7 ax.set_xlabel('Date')
```



#### Spline interpolation

Spline interpolation is used to estimate missing values or fill gaps in a time series data by fitting a smooth curve or spline to the available data points. It aims to capture the underlying pattern of the data more accurately by using a piecewise polynomial function.

Spline interpolation offers several advantages over linear interpolation in time series:

- It can capture more complex and non-linear patterns in the data, as cubic splines can represent a wider range of curves.
- Spline interpolation produces a smoother curve without sharp edges, resulting in a more visually appealing representation.
- It reduces the risk of overfitting compared to higher-degree polynomial interpolation.

However, spline interpolation can be computationally more intensive and may require more data points to achieve accurate estimates.

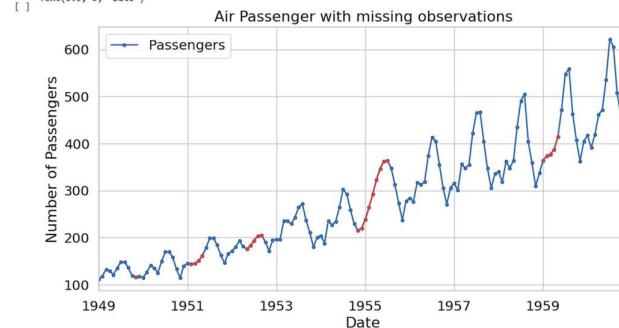
Additionally, the choice of spline interpolation method, such as cubic or higher-degree splines, may depend on the characteristics of the data and the desired smoothness.

Overall, spline interpolation is a flexible and effective technique for estimating missing values or filling gaps in time series data, providing a more accurate representation of the underlying patterns and dynamics.

```
[ ] 1
```

```
[ ] 1 si_imputed = si.interpolate(method='spline', order=3)
2 ax = si_imputed.plot(linestyle='-', marker='.', figsize=(10, 5))
3 si_imputed[si.isnull()].plot(ax=ax, legend=None, marker='.', color='r')
4 ax.set_title('Air Passenger with missing observations')
5 ax.set_ylabel('Number of Passengers')
6 ax.set_xlabel('Date')
```

```
[ ] Text(0.5, 0, 'Date')
```



#### Seasonal decomposition and interpolation

This method involves estimating the seasonal component of a time series. This is then subtracted from the original time series to provide a de-seasoned time series. Any of the prior interpolation methods can then be used on the de-seasoned time series and the seasonal component can be added back to the de-seasoned time series.

There are many different methods to decompose a time series into seasonal and other components. We shall use STL for this notebook. An advantage of STL is that it is able to estimate a seasonal component which can change over time (e.g., if the amplitude or frequency of the seasonal component changes).

*Seasonal-Trend decomposition using LOESS (STL) is a robust method of time series decomposition often used in economic and environmental analyses. The STL method uses locally fitted regression models to decompose a time series into trend, seasonal, and remainder components.*

```
[ ] 1 from statsmodels.tsa.seasonal import STL
```

STL can't handle missing data. A linear interpolation is typically used to fill missing data before decomposing the time series using STL.

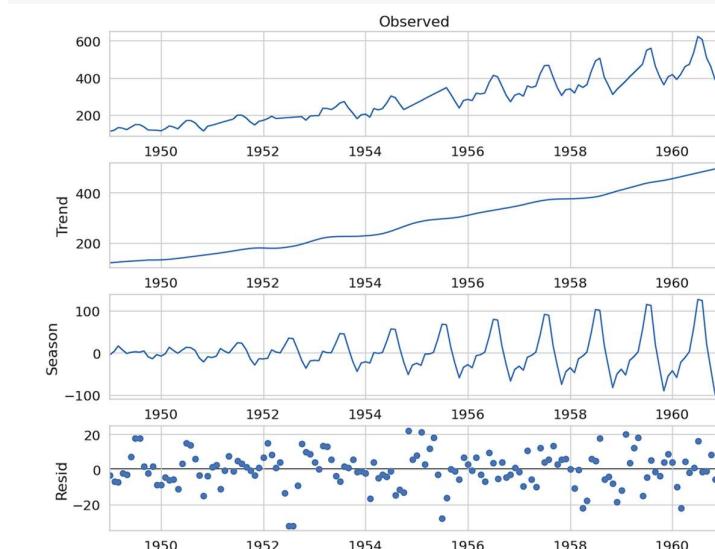
```
[ ] 1 type(sdi)
pandas.core.frame.DataFrame
[ ] 1 # in this place "use linear interpolation here" use the commands for linear interpolation.
2 res = STL(sdi.interpolate(method="linear"), seasonal=3).fit()
```

The seasonal parameter determines how much data is used to infer the seasonality at any given point. If the seasonal component is thought to be fixed throughout time then a large seasonal parameter can be set so that more data is used to determine the seasonal component. Likewise if the seasonal component is thought to change (e.g., the frequency) quickly over time the seasonal parameter can be reduced so that only recent data contributes to determining the seasonal component.

The large missing gap is linearly interpolated. This means that the algorithm sees a region of data with no seasonal component and could distort the estimation of the seasonal component. A large seasonal parameter is set to overcome this. This works because a larger portion of the data is now used to estimate the seasonal component meaning that the local distortion from the interpolation has less effect.

We now plot the decomposition to inspect that it is reasonable.

```
[ ] 1 import matplotlib.pyplot as plt
[ ] 1 plt.rc("figure", figsize=(10, 8))
2 plt.rc("font", size=5)
3 res.plot();
```



We now:

1. extract the seasonal component
2. de-seasonalise the original time series
3. perform linear interpolation on the de-seasonalised data
4. Add the seasonal component back to the imputed de-seasonalised data

```
[ ] 1 seasonal_component = res.seasonal
```

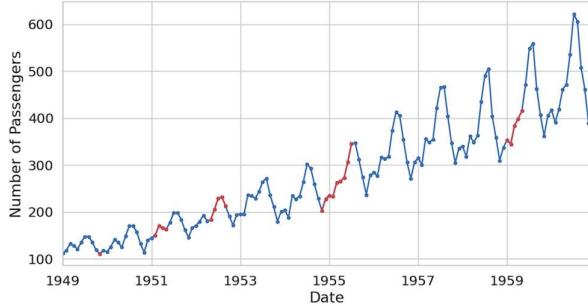
```
2 seasonal_component.head()
```

```
Month
1949-01-01 -4.732242
1949-02-01  3.324781
1949-03-01  15.295959
1949-04-01  6.673724
1949-05-01 -1.617146
Name: season, dtype: float64
```

```
[ ] 1 sdi_desseasonalised = sdi[['Passengers']] + seasonal_component
2 sdi_desseasonalised_imputed = sdi_desseasonalised.interpolate(method='linear')
3 sdi_imputed = sdi_desseasonalised_imputed + seasonal_component
4 ax = sdi_imputed.plot(linestyle="--", marker=".", figsize=[10, 5], legend=None)
5 ax = sdi_imputed[sdi.isnull()].plot(ax=ax, legend=None, marker=".", color="r")
6 ax.set_title('Air Passenger with missing observations')
7 ax.set_ylabel('Number of Passengers')
8 ax.set_xlabel('Date')
```

```
L J Text(0.5, 0, 'Date')
```

Air Passenger with missing observations



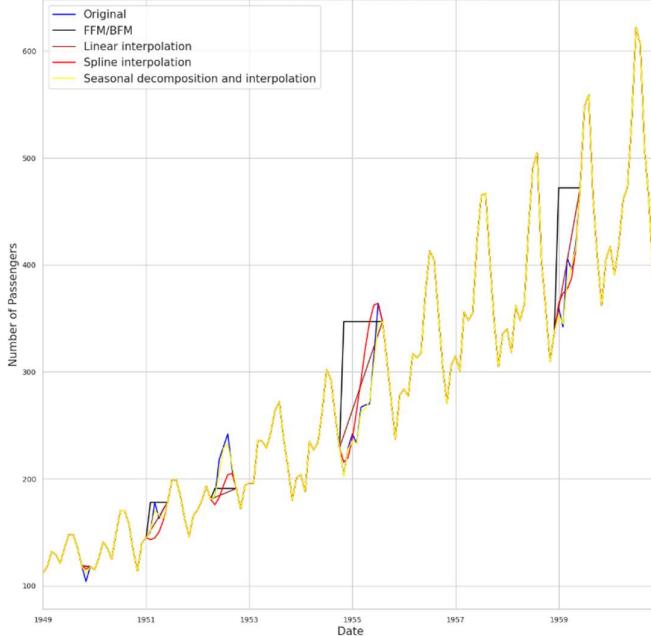
Simpler seasonal decompositions methods exist in Statsmodels such as seasonal\_decompose. However, the simplicity of the seasonal\_decompose method has drawbacks which may or may not be relevant for your use case (e.g., naive seasonal decomposition methods may not capture seasonality which changes over time, may not return values at the start and end of a time series etc.). STL is a more advanced method that is commonly used for data imputation.

#### Wrap up

Now let's wrap up the missing value section and plot the result of each technique in one plot to choose the best fit.

```
[ ] 1 fig, ax = plt.subplots(figsize=(15,15))
2 original.plot(ax=ax, color='blue', label='Original')
3 bfm_imputed.plot(ax=ax, color='black', label='FFM/BFM')
4 li_imputed.plot(ax=ax, color='brown', label='Linear interpolation')
5 sdi_imputed.plot(ax=ax, color='red', label='Spline interpolation')
6 sdi_imputed.plot(ax=ax, color='yellow', label='Seasonal decomposition and interpolation')
7 plt.xlabel('Date', fontsize=15)
8 plt.ylabel('Number of Passengers', fontsize=15)
9 plt.title('Compare different missing values fill techniques', fontsize=15)
10 plt.xticks(fontsize=10)
11 plt.yticks(fontsize=10)
12 plt.legend(fontsize=15)
13 ax.legend(['Original', 'FFM/BFM', 'Linear interpolation', 'Spline interpolation', 'Seasonal decomposition and interpolation'], fontsize=15);
14 plt.show()
```

Compare different missing values fill techniques



## RESULT

The implementation was successful.

# Experiment 3

## AIM

Decompose Time-Series to See Components (Trend, Seasonality, Noise, etc), Dicky-Fuller Test for Stationarity, Remove Trend (Logged Transformation, Power Transformation, Applying Moving Window Functions, Applying Moving Window Function on Log Transformed Time-Series, Applying Moving Window Function on Power Transformed Time-Series, Applying Linear Regression to Remove Trend).

## SOFTWARE USED

Google Colaboratory

## DATASET USED

AirPassengers.csv which is a flight dataset giving the no. of passengers over time with size (144 x 1).

## CODE AND OUTPUT

The screenshot shows a Google Colaboratory notebook titled "Hitesh\_Lab3\_August\_03\_2023.ipynb". The code cell contains the following Python code:

```
[ ] 1 # import pandas, numpy, matplotlib
2 import pandas as pd
3 import numpy as np
4 import matplotlib.pyplot as plt
5
[ ] 1 air_passengers = pd.read_csv("/content/AirPassengers (1).csv", index_col = 0, parse_dates= True)# read the data using pandas include (index_col=0, parse_dates=True)
2
3 air_passengers.rename(columns = {"#Passengers":"Passengers"}, inplace=True)
4 air_passengers.head()# preview data using head command
5
```

The output cell displays the first few rows of the dataset:

Month	Passengers
1949-01-01	112
1949-02-01	118
1949-03-01	132
1949-04-01	129
1949-05-01	121

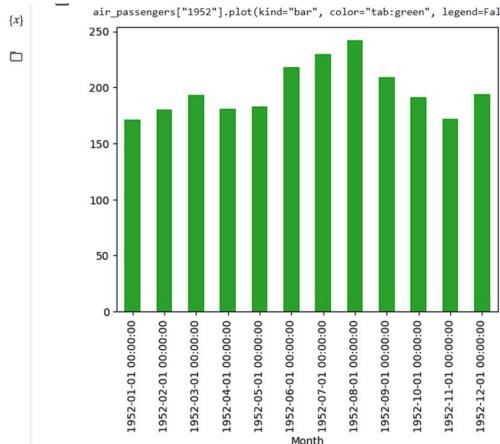
The next cell contains the following code to plot the data:

```
[ ] 1 air_passengers.plot(figsize=(8,4), color="tab:red")
<Axes: xlabel='Month'>
```

The resulting line plot shows the number of passengers over time from 1949 to 1960, with a clear upward trend and seasonal fluctuations.

The final cell contains the following code to plot a bar chart for the year 1952:

```
[ ] 1 air_passengers["1952"].plot(kind="bar", color="tab:green", legend=False);
```



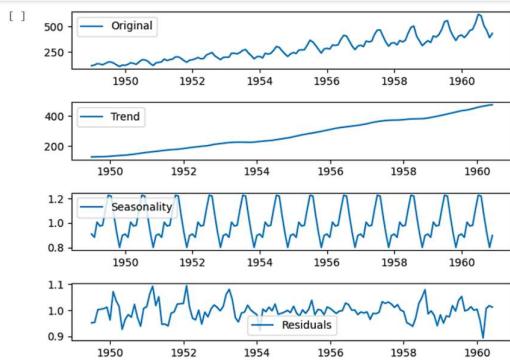
By looking at the above plots we can see that our time-series is multiplicative time-series and has both trend as well as seasonality. We can see the trend as passengers are constantly increasing over time. We can see seasonality with the same variations repeating for 1 year where value peaks somewhere are around August.

#### Decompose Time-Series to See Components (Trend, Seasonality, Noise, etc)

We can decompose time-series to see various components of time-series. Python module named statsmodels provides us with easy to use utility which we can use to get an individual component of time-series and then visualize it.

```
[ ] 1 #import seasonal decomposing using statsmodel and seasonal decompose
2 from statsmodels.tsa.stattools import adfuller
3 from statsmodels.tsa.seasonal import seasonal_decompose
4 from statsmodels.tsa.stattools import acf, pacf
5 from statsmodels.tsa.arima_model import ARIMA

❶ 1 decompose_result = seasonal_decompose(air_passengers, model='multiplicative', filt=None, period=None, two_sided=True, extrapolate_trend=0)
2
3 # perform seasonal decomposing using multiplicative model type
4
5 trend = decompose_result.trend # get trend
6 seasonal = decompose_result.seasonal #get seasonal
7 residual = decompose_result.resid #get residual
8
9 #plot the decompose result
10 # decompose_result.plot("Multiplicative Decomposition")
11
12 plt.subplot(411)
13 plt.plot(air_passengers, label='Original')
14 plt.legend(loc='best')
15
16 plt.subplot(412)
17 plt.plot(trend, label='Trend')
18 plt.legend(loc='best')
19
20 plt.subplot(413)
21 plt.plot(seasonal,label='Seasonality')
22 plt.legend(loc='best')
23
24 plt.subplot(414)
25 plt.plot(residual, label='Residuals')
26 plt.legend(loc='best')
27 plt.tight_layout()
```



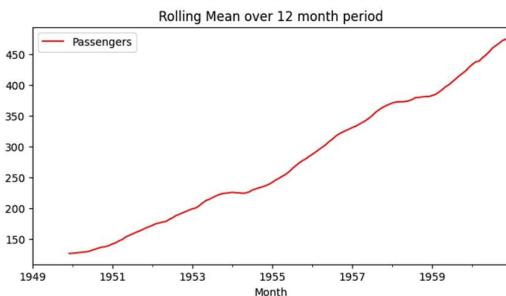
We can notice trend and seasonality components separately as well as residual components. There is a loss of residual in the beginning which is settling later.

#### Checking Whether Time-Series is Stationary or Not

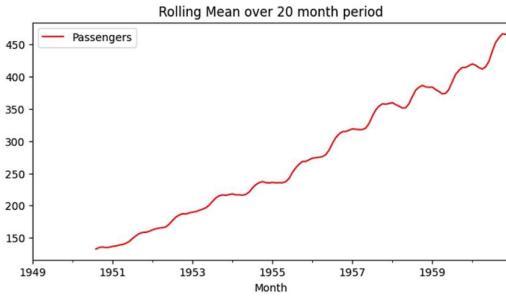
As we declared above time-series is stationary whose mean, variance and auto-covariance are independent of time. We can check mean, variance and auto-covariance using moving window functions available with pandas. We'll also use a dicky-fuller test available with statsmodels to check the stationarity of time-series. If time-series is not stationary then we need to make it stationary.

Below we have taken an average over moving window of 12 samples. We noticed from the above plots that there is the seasonality of 12 months in time-series. We can try different window sizes for testing purposes.

```
[ ] 1 air_passengers.rolling(window = 12).mean().plot(figsize=(8,4), color="tab:red", title="Rolling Mean over 12 month period");
```



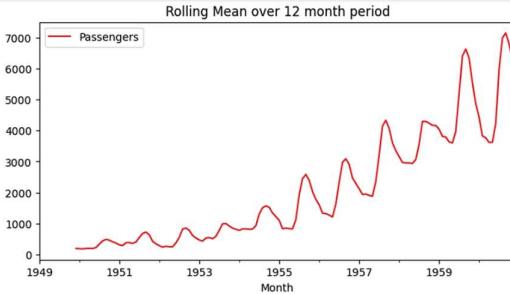
```
[ ] 1 #same as above apply the rolling mean for 20 month period  
2 air_passengers.rolling(window = 20).mean().plot(figsize=(8,4), color="tab:red", title="Rolling Mean over 20 month period");
```



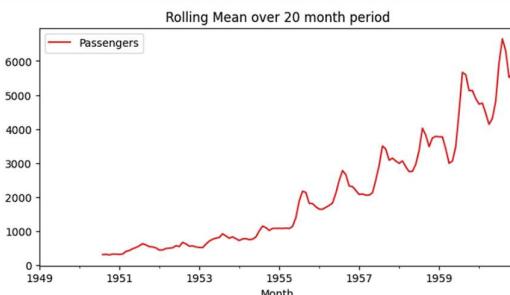
We can clearly see that time-series has a visible upward trend.

Below we have taken variance over the moving window of 12 samples. We noticed from the above plots that there is the seasonality of 12 months in time-series

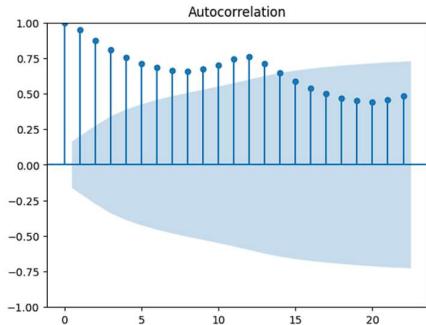
```
[ ] 1 # same as above instead of rolling mean now calculate the variance for 12 months  
2 air_passengers.rolling(window = 12).var().plot(figsize=(8,4), color="tab:red", title="Rolling Mean over 12 month period");
```



```
[ ] 1 # same as above instead of rolling mean now calculate the variance for 20 months  
2 air_passengers.rolling(window = 20).var().plot(figsize=(8,4), color="tab:red", title="Rolling Mean over 20 month period");
```



```
[ ] 1 #using from statsmodels.graphics.tsplots import the autocorrelation function (plot_acf)
2 from statsmodels.graphics.tsplots import plot_acf
3
4 plot_acf(air_passengers);
```



We can notice from the above chart that after 13 lags, the line gets inside confidence interval (light blue area). This can be due to seasonality of 12-13 months in our data.

```
[ ] 1 from statsmodels.tsa.stattools import adfuller
2
3 dfstest = adfuller(air_passengers['Passengers'], autolag = 'AIC')
4
5 print("1. ADF : ",dfstest[0])
6 print("2. P-Value : ", dfstest[1])
7 print("3. Num Of Lags : ", dfstest[2])
8 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
9 print("5. Critical Values :")
10 for key, val in dfstest[4].items():
11     print("\t",key, ":", val)

1. ADF : 0.8153688792060498
2. P-Value : 0.991880243437641
3. Num Of Lags : 13
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 130
5. Critical Values :
    1% : -3.4816817173418295
    5% : -2.8840418343195267
    10% : -2.578770859171598
```

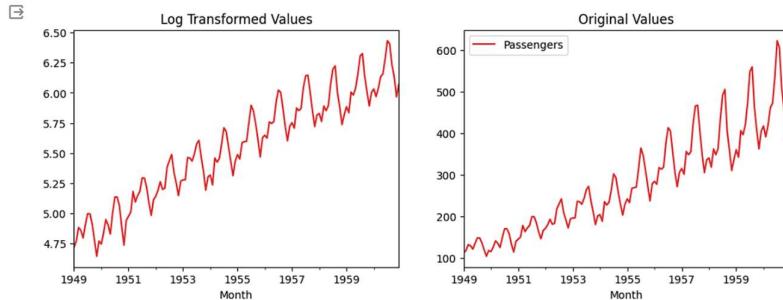
We can interpret above results based on p-values of result.

p-value > 0.05 - This implies that time-series is non-stationary. p-value <=0.05 - This implies that time-series is stationary. We can see from the above results that p-value is greater than 0.05 hence our time-series is not stationary. It still has time-dependent components present which we need to remove.

#### Logged Transformation

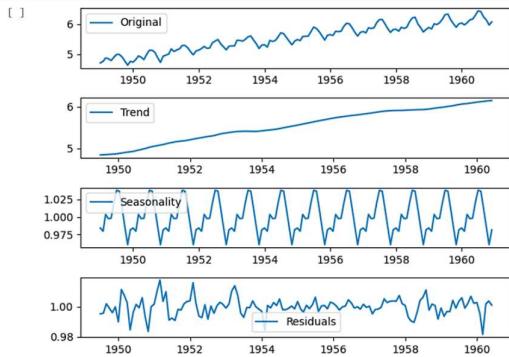
To apply log transformation, we need to take a log of each individual value of time-series data.

```
[ ] 1 logged_passengers = air_passengers["Passengers"].apply(lambda x : np.log(x))
2
3 ax1 = plt.subplot(121)
4 logged_passengers.plot(figsize=(12,4),color="tab:red", title="Log Transformed Values", ax=ax1);
5 ax2 = plt.subplot(122)
6 air_passengers.plot(color="tab:red", title="Original Values", ax=ax2);
```



From the above first chart, we can see that we have reduced the variance of time-series data. We can look at y-values of original time-series data and log-transformed time-series data to conclude that the variance of time-series is reduced.

```
[ ] 1 # perform seasonal decompose on logged transformed
2 decompose_result = seasonal_decompose(logged_passengers, model='multiplicative', filt=None, period=None, two_sided=True, extrapolate_trend=0)
3
4 # perform seasonal decomposing using multiplicative model type
5
6 trend = decompose_result.trend # get trend
7 seasonal = decompose_result.seasonal #get seasonal
8 residual = decompose_result.resid #get residual
9
10 #plot the decompose result
11 # decompose_result.plot("Multiplicative Decomposition")
12
13 plt.subplot(411)
14 plt.plot(logged_passengers, label='Original')
15 plt.legend(loc='best')
16
17 plt.subplot(412)
18 plt.plot(trend, label='Trend')
19 plt.legend(loc='best')
20
21 plt.subplot(413)
22 plt.plot(seasonal,label='Seasonality')
23 plt.legend(loc='best')
24
25 plt.subplot(414)
26 plt.plot(residual, label='Residuals')
27 plt.legend(loc='best')
28 plt.tight_layout()
```

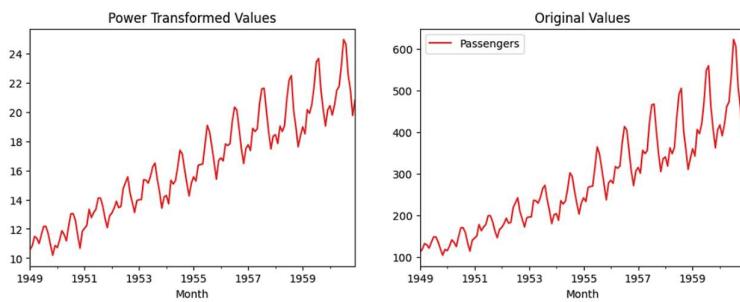


**Power Transformations** We can apply power transformation in data same way as that of log transformation to remove trend.

```

1 # perform power transform using (lambda x : x ** 0.5)
2
3 power_passengers = air_passengers["Passengers"].apply(lambda x : x ** 0.5)
4
5
6 # plot the curve for the same
7
8 ax1 = plt.subplot(121)
9 power_passengers.plot(figsize=(12,4) ,color="tab:red", title="Power Transformed Values", ax=ax1);
10 ax2 = plt.subplot(122)
11 air_passengers.plot(color="tab:red", title="Original Values", ax=ax2);

```

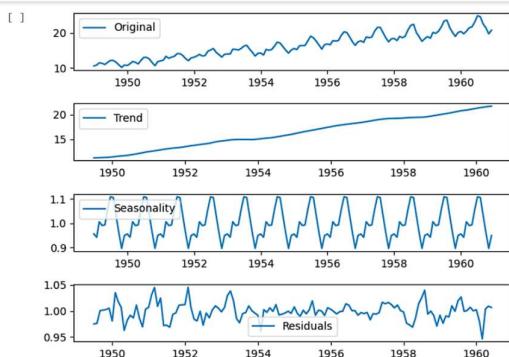


From the above first chart, we can see that we have reduced the variance of time-series data. We can look at y-values of original time-series data and power-transformed time-series data to conclude that the variance of time-series is reduced.

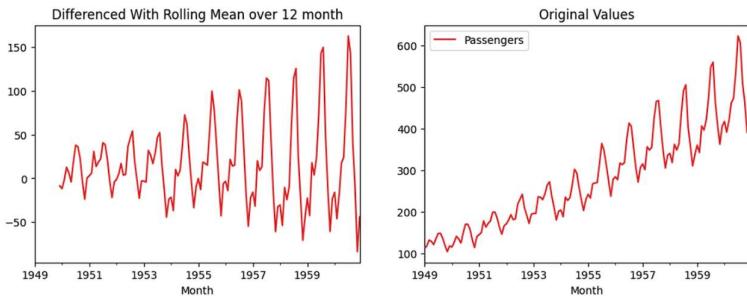
```

1 # perform seasonal decompose on power transformed
2 decompose_result = seasonal_decompose(power_passengers, model='multiplicative', filt=None, period=None, two_sided=True, extrapolate_trend=0)
3
4 # perform seasonal decomposing using multiplicative model type
5
6 trend = decompose_result.trend # get trend
7 seasonal = decompose_result.seasonal #get seasonal
8 residual = decompose_result.resid #get residual
9
10 #plot the decompose result
11 # decompose_result.plot("Multiplicative Decomposition")
12
13 plt.subplot(411)
14 plt.plot(power_passengers, label='Original')
15 plt.legend(loc="best")
16
17 plt.subplot(412)
18 plt.plot(trend, label='Trend')
19 plt.legend(loc="best")
20
21 plt.subplot(413)
22 plt.plot(seasonal,label='Seasonality')
23 plt.legend(loc="best")
24
25 plt.subplot(414)
26 plt.plot(residual, label='Residuals')
27 plt.legend(loc="best")
28 plt.tight_layout()

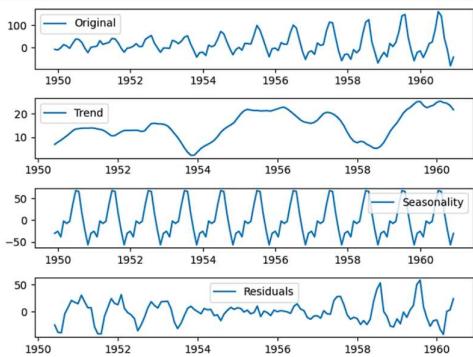
```



```
[ ] 1 rolling_mean = air_passengers.rolling(window = 12).mean()
2 passengers_rolled_detrended = air_passengers['Passengers'] - rolling_mean['Passengers']
3
4
5 ax1 = plt.subplot(121)
6 passengers_rolled_detrended.plot(figsize=(12,4),color="tab:red", title="Differenced With Rolling Mean over 12 month", ax=ax1);
7 ax2 = plt.subplot(122)
8 air_passengers.plot(figsize=(12,4), color="tab:red", title="Original Values", ax=ax2);
```



```
[ ] 1 # perform seasonal decompose on logged transformed
2
3 decompose_result = seasonal_decompose(passengers_rolled_detrended.dropna(), model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
4
5 # perform seasonal decomposing using additive model type
6
7 trend = decompose_result.trend # get trend
8 seasonal = decompose_result.seasonal #get seasonal
9 residual = decompose_result.resid #get residual
10
11 #plot the decompose result
12 # decompose_result.plot("Multiplicative Decomposition")
13
14 plt.subplot(411)
15 plt.plot(passengers_rolled_detrended, label='Original')
16 plt.legend(loc='best')
17
18 plt.subplot(412)
19 plt.plot(trend, label='Trend')
20 plt.legend(loc='best')
21
22 plt.subplot(413)
23 plt.plot(seasonal,label='Seasonality')
24 plt.legend(loc='best')
25
26 plt.subplot(414)
27 plt.plot(residual, label='Residuals')
28 plt.legend(loc='best')
29 plt.tight_layout()
```



#### Applying Moving Window Function on Log Transformed Time-Series

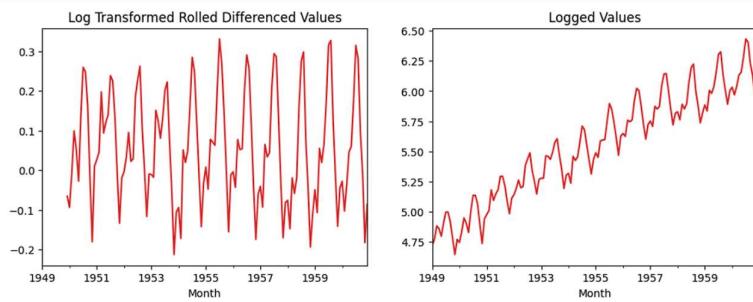
We can apply more than one transformation as well. We'll first apply log transformation to time-series, then take a rolling mean over a period of 12 months and then subtract rolled time-series from log-transformed time-series to get final time-series.

```
[ ] 1 logged_passengers
```

Month	Passenger Count
1949-01-01	4.718499
1949-02-01	4.770685
1949-03-01	4.882802
1949-04-01	4.859812
1949-05-01	4.795791
...	
1960-08-01	6.486880
1960-09-01	6.230491
1960-10-01	6.133398
1960-11-01	5.966147
1960-12-01	6.068426

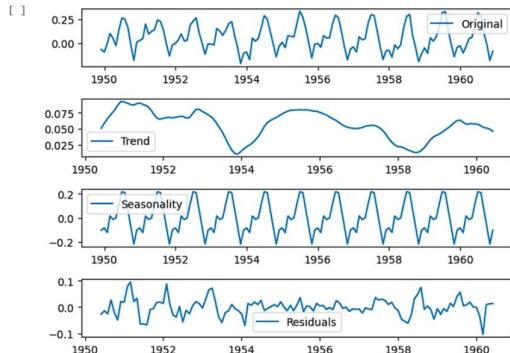
Name: Passengers, Length: 144, dtype: float64

```
[ ] 1 # take log transformed and rolling mean for 12 months period time
2 rolling_mean = logged_passengers.rolling(window = 12).mean()
3 passengers_log_rolled_detrended = logged_passengers - rolling_mean
4
5
6 # plot the passengers_log_rolled_detrended
7 ax1 = plt.subplot(121)
8 passengers_log_rolled_detrended.plot(figsize=(12,4),color="tab:red", title="Log Transformed Rolled Differenced Values", ax=ax1);
9 ax2 = plt.subplot(122)
10 logged_passengers.plot(color="tab:red", title="Logged Values", ax=ax2);
```



From the above the first chart, we can see that we are able to removed the trend from time-series data.

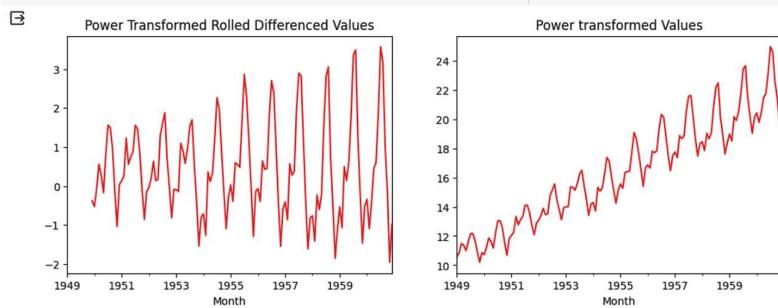
```
[ ] 1 # perform seasonal decompose on logged transformed
2
3 decompose_result = seasonal_decompose(passengers_log_rolled_detrended.dropna(), model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
4
5 # perform seasonal decomposing using additive model type
6
7 trend = decompose_result.trend # get trend
8 seasonal = decompose_result.seasonal #get seasonal
9 residual = decompose_result.resid #get residual
10
11 #plot the decompose result
12 # decompose_result.plot("Multiplicative Decomposition")
13
14 plt.subplot(411)
15 plt.plot(passengers_log_rolled_detrended, label='Original')
16 plt.legend(loc='best')
17
18 plt.subplot(412)
19 plt.plot(trend, label='Trend')
20 plt.legend(loc='best')
21
22 plt.subplot(413)
23 plt.plot(seasonal,label='Seasonality')
24 plt.legend(loc='best')
25
26 plt.subplot(414)
27 plt.plot(residual, label='Residuals')
28 plt.legend(loc='best')
29 plt.tight_layout()
```



#### Applying Moving Window Function on Power Transformed Time-Series

We can apply more than one transformation as well. We'll first apply power transformation to time-series, then take a rolling mean over a period of 12 months and then subtract rolled time-series from power-transformed time-series to get final time-series.

```
[ ] 1 rolling_mean = power_passengers.rolling(window = 12).mean()
2 passengers_pov_rolled_detrended = power_passengers - rolling_mean # take the difference of power transformed and rolling mean on powered transformed
3
4 # plot the passengers_log_rolled_detrended
5 ax1 = plt.subplot(121)
6 passengers_pov_rolled_detrended.plot(figsize=(12,4) ,color="tab:red", title="Power Transformed Rolled Differenced Values", ax=ax1);
7 ax2 = plt.subplot(122)
8 power_passengers.plot(color="tab:red", title="Power transformed Values", ax=ax2);
```



From the above the first chart, we can see that we are able to remove the trend from time-series data.

```

1 # perform seasonal decompose on logged transformed
2
3 decompose_result = seasonal_decompose(passengers_pow_rolled_detrended.dropna(), model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
4
5 # perform seasonal decomposing using additive model type
6
7 trend = decompose_result.trend # get trend
8 seasonal = decompose_result.seasonal #get seasonal
9 residual = decompose_result.resid #get residual
10
11 #plot the decompose result
12 # decompose_result.plot("Multiplicative Decomposition")
13
14 plt.subplot(411)
15 plt.plot(passengers_pow_rolled_detrended, label='Original')
16 plt.legend(loc='best')
17
18 plt.subplot(412)
19 plt.plot(trend, label='Trend')
20 plt.legend(loc='best')
21
22 plt.subplot(413)
23 plt.plot(seasonal,label='Seasonality')
24 plt.legend(loc='best')
25
26 plt.subplot(414)
27 plt.plot(residual, label='Residuals')
28 plt.legend(loc='best')
29 plt.tight_layout()

```

**Applying Linear Regression to Remove Trend**

We can also apply a linear regression model to remove the trend. Below we are fitting a linear regression model to our time-series data. We are then using a fit model to predict time-series values from beginning to end. We are then subtracting predicted values from original time-series to remove the trend.

```

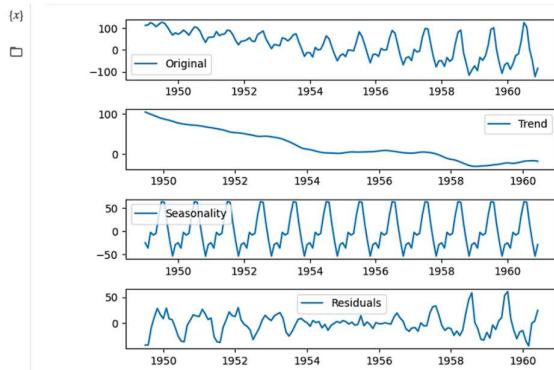
1 from statsmodels.regression.linear_model import OLS
2
3 least_squares = OLS(air_passengers["Passengers"].values, list(range(air_passengers.shape[0])))
4 result = least_squares.fit()
5
6 fit = pd.Series(result.predict(list(range(air_passengers.shape[0]))), index = air_passengers.index)
7
8 passengers_ols_detrended = air_passengers["Passengers"] - fit
9
10
11 # plot the regressed model
12 ax1 = plt.subplot(121)
13 passengers_ols_detrended.plot(figsize=(12,4) ,color="tab:red", title="Regression best fit Differenced Values", ax=ax1);
14 ax2 = plt.subplot(122)
15 air_passengers.plot(color="tab:red", title="Original Values", ax=ax2);

```

```

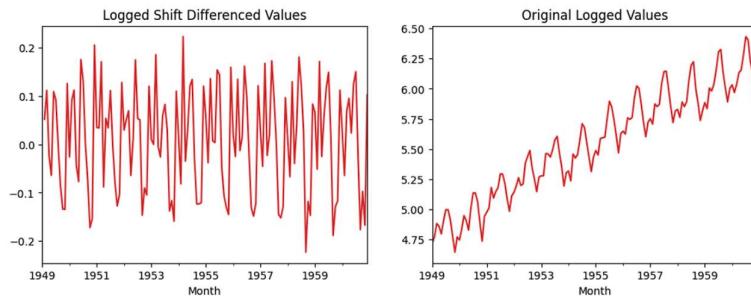
1 # perform seasonal decompose on logged transformed
2
3 decompose_result = seasonal_decompose(passengers_ols_detrended, model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
4
5 # perform seasonal decomposing using additive model type
6
7 trend = decompose_result.trend # get trend
8 seasonal = decompose_result.seasonal #get seasonal
9 residual = decompose_result.resid #get residual
10
11 #plot the decompose result
12 # decompose_result.plot("Multiplicative Decomposition")
13
14 plt.subplot(411)
15 plt.plot(passengers_ols_detrended, label='Original')
16 plt.legend(loc='best')
17
18 plt.subplot(412)
19 plt.plot(trend, label='Trend')
20 plt.legend(loc='best')
21
22 plt.subplot(413)
23 plt.plot(seasonal,label='Seasonality')
24 plt.legend(loc='best')
25
26 plt.subplot(414)
27 plt.plot(residual, label='Residuals')
28 plt.legend(loc='best')
29 plt.tight_layout()

```



**Differencing Over Log Transformed Time-Series** We have applied differencing to log-transformed time-series by shifting its value by 1 period and subtracting it from original log-transformed time-series

```
[ ] 1 logged_passengers_diff = logged_passengers - logged_passengers.shift()
2
3 # plot the logged passengers_diff
4 ax1 = plt.subplot(121)
5 logged_passengers_diff.plot(figsize=(12,4) ,color="tab:red", title="Logged Shift Differenced Values", ax=ax1);
6 ax2 = plt.subplot(122)
7 logged_passengers.plot(color="tab:red", title="Original Logged Values", ax=ax2);
```



```
[ ] 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(logged_passengers_diff.dropna(), autolag = 'AIC')
5
6 print("1. ADF : ",dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)
```

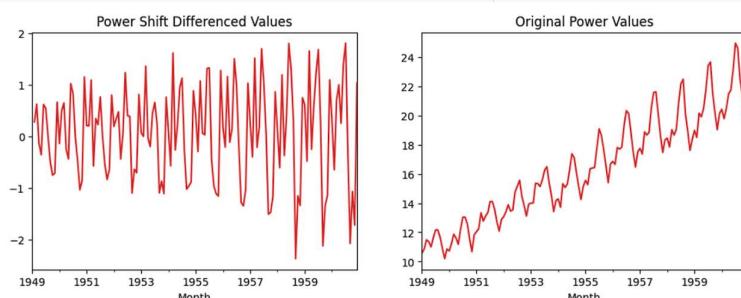
1. ADF : -2.71730598388114  
2. P-Value : 0.07112054815086184  
3. Num Of Lags :  
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 128  
5. Critical Values :  
    1% : -3.482506939887997  
    5% : -2.88439784161377  
    10% : -2.578960197755906

From our dicky-fuller test results, we can confirm that time-series is NOT STATIONARY due to the p-value of 0.07 greater than 0.05.

**Differencing Over Power Transformed Time-Series**

We have applied differencing to power transformed time-series by shifting its value by 1 period and subtracting it from original power transformed time-series

```
[ ] 1 powered_passengers_diff = power_passengers - power_passengers.shift()
2
3 # plot the logged_passengers_diff
4 ax1 = plt.subplot(121)
5 powered_passengers_diff.plot(figsize=(12,4) ,color="tab:red", title="Power Shift Differenced Values", ax=ax1);
6 ax2 = plt.subplot(122)
7 power_passengers.plot(color="tab:red", title="Original Power Values", ax=ax2);
```



```
[ ] 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(powered_passengers_diff.dropna(), autolag = 'AIC')
5
6 print("1. ADF : ",dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)

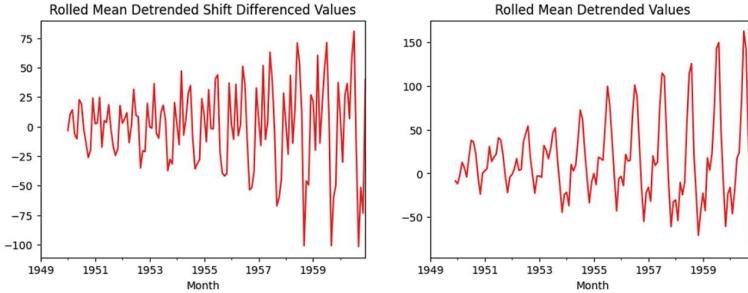
1. ADF : -3.1864222911641904
2. P-Value : 0.026784185571268328
3. Num Of Lags : 12
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 130
5. Critical Values :
    1% : -3.4816817173418295
    5% : -2.8840418343195267
    10% : -2.578770059171598
```

From our dickey-fuller test results, we can confirm that time-series is STATIONARY due to a p-value of 0.02 less than 0.05.

#### Differencing Over Time-Series with Rolling Mean taken over 12 Months

We have applied differencing to mean rolled time-series by shifting its value by 1 period and subtracting it from original mean rolled time-series

```
[ ] 1 # plot and calculate the rolled detrended diff
2 passengers_rolled_detrended_diff = passengers_rolled_detrended - passengers_rolled_detrended.shift()
3
4 # plot the logged_passengers_diff
5 ax1 = plt.subplot(121)
6 passengers_rolled_detrended_diff.plot(figsize=(12,4) ,color="tab:red", title="Rolled Mean Detrended Shift Differenced Values", ax=ax1);
7 ax2 = plt.subplot(122)
8 passengers_rolled_detrended.plot(color="tab:red", title="Rolled Mean Detrended Values", ax=ax2);
```

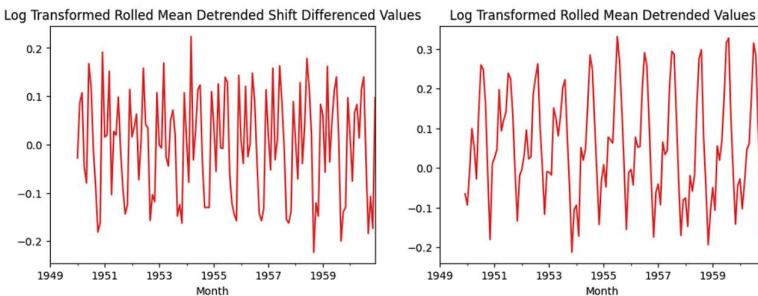


```
[ ] 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(passengers_rolled_detrended_diff.dropna(), autolag = 'AIC')
5
6 print("1. ADF : ",dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)

1. ADF : -3.154482634863533
2. P-Value : 0.02277526497859258
3. Num Of Lags : 12
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 119
5. Critical Values :
    1% : -3.4865346059036564
    5% : -2.8861598858476264
    10% : -2.57986892796057
```

From our dickey-fuller test results, we can confirm that time-series is STATIONARY due to a p-value of 0.02 less than 0.05.

```
[ ] 1 # difference the log rolled detrended diff and plot
2 passengers_log_rolled_detrended_diff = passengers_log_rolled_detrended - passengers_log_rolled_detrended.shift()
3
4 # plot the logged_passengers_diff
5 ax1 = plt.subplot(121)
6 passengers_log_rolled_detrended_diff.plot(figsize=(12,4) ,color="tab:red", title="Log Transformed Rolled Mean Detrended Shift Differenced Values", ax=ax1);
7 ax2 = plt.subplot(122)
8 passengers_log_rolled_detrended.plot(color="tab:red", title="Log Transformed Rolled Mean Detrended Values", ax=ax2);
```



```

[ ] 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(passengers_log_rolled_detrended.dropna(), autolag = 'AIC')
5
6 print("1. ADF : ",dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)

```

1. ADF : -3.9129812454195174  
2. P-Value : 0.0019413623769364548  
3. Num Of Lags : 13  
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 118  
5. Critical Values :  
  1% : -3.4870216863700767  
  5% : -2.8863625166643136  
  10% : -2.5800099261419193

From our dickey-fuller test results, we can confirm that time-series is STATIONARY due to a p-value of 0.001 less than 0.05.

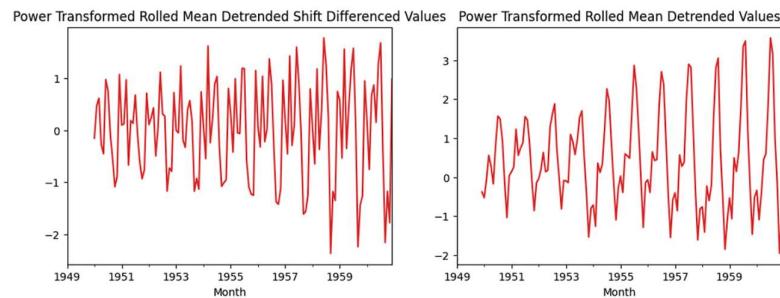
#### Differencing Over Power Transformed & Mean Rolled Time-Series

We have applied differencing to power transformed & mean rolled time-series by shifting its value by 1 period and subtracting it from original time-series

```

[ ] 1 # difference the power rolled detrended diff and plot
2 passengers_pow_rolled_detrended_diff = passengers_pow_rolled_detrended - passengers_pow_rolled_detrended.shift()
3
4 # plot the power_passengers_diff
5 ax1 = plt.subplot(121)
6 passengers_pow_rolled_detrended_diff.plot(figsize=(12,4) ,color="tab:red", title="Power Transformed Rolled Mean Detrended Shift Differenced Values", ax=ax1);
7 ax2 = plt.subplot(122)
8 passengers_pow_rolled_detrended.plot(color="tab:red", title="Power Transformed Rolled Mean Detrended Values", ax=ax2);

```



```

[ ] 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(passengers_pow_rolled_detrended_diff.dropna(), autolag = 'AIC')
5
6 print("1. ADF : ",dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)

```

1. ADF : -3.622485336190725  
2. P-Value : 0.005345423958262613  
3. Num Of Lags : 13  
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 118  
5. Critical Values :  
  1% : -3.4870216863700767  
  5% : -2.8863625166643136  
  10% : -2.5800099261419193

From our dickey-fuller test results, we can confirm that time-series is STATIONARY due to a p-value of 0.005 less than 0.05.

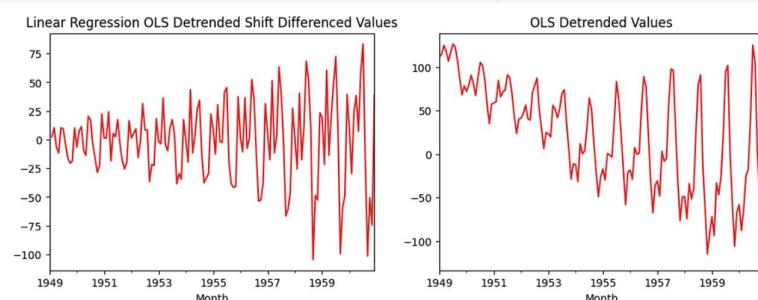
#### Differencing Over Linear Regression Transformed Time-Series

We have applied differencing to linear regression transformed time-series by shifting its value by 1 period and subtracting it from original log-transformed time-series

```

[ ] 1 # take the difference of linear regressed transformed with a shift and then plot
2 passengers_ols_detrended_diff = passengers_ols_detrended - passengers_ols_detrended.shift()
3
4 # plot the power_passengers_diff
5 ax1 = plt.subplot(121)
6 passengers_ols_detrended_diff.plot(figsize=(12,4) ,color="tab:red", title="Linear Regression OLS Detrended Shift Differenced Values", ax=ax1);
7 ax2 = plt.subplot(122)
8 passengers_ols_detrended.plot(color="tab:red", title="OLS Detrended Values", ax=ax2);

```



```

[ ] 1 # perform ADF test
2 # perform the ADF test
3 from statsmodels.tsa.stattools import adfuller
4
5 dfstest = adfuller(passenger_ols_detrended_diff.dropna(), autolag = 'AIC')
6
7 print("1. ADF : ",dfstest[0])
8 print("2. P-Value : ", dfstest[1])
9 print("3. Num Of Lags : ", dfstest[2])
10 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
11 print("5. Critical Values :")
12 for key, val in dfstest[4].items():
13     print("\t",key, ":", val)

1. ADF : -2.8292668241780043
2. P-Value : 0.05421329028382486
3. Num Of Lags : 12
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 130
5. Critical Values :
    1% : -3.4816817173418295
    5% : -2.8840418343195267
    10% : -2.578770059171598

```

From our dicky-fuller test results, we can confirm that time-series is NOT STATIONARY due to the p-value of 0.054 greater than 0.05.

## RESULT

The implementation was successful.

# Experiment 4

## AIM

To Remove Seasonality (Differencing Over Log Transformed Time-Series, Differencing Over Power Transformed Time-Series, Differencing Over Time-Series with Rolling Mean taken over 12 Months, Differencing Over Power Transformed & Mean Rolled Time-Series, Differencing Over Linear Regression Transformed Time-Series), ), Dicky-Fuller Test for Stationarity.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

GOOG.csv is the google stock price dataset with size (251 x 7).

## CODE AND OUTPUT

The screenshot shows a Google Colaboratory notebook titled "Hitesh\_Lab4\_August\_17\_2023.ipynb". The code cell contains imports for pandas, numpy, matplotlib.pyplot, statsmodels.api, seasonal\_decompose, adfuller, kpss, plot\_acf, plot\_pacf, LinearRegression, mean\_squared\_error, and ARIMA. It then reads a CSV file named "GOOG.csv" and prints the first few rows of the DataFrame. The output shows the closing price data from August 9 to August 15, 2022. Finally, it plots the closing price over time.

```
[ ] 1 import pandas as pd
2 import numpy as np
3 import matplotlib.pyplot as plt
4 import statsmodels.api as sm
5 from statsmodels.tsa.seasonal import seasonal_decompose
6 from statsmodels.tsa.stattools import adfuller
7 from statsmodels.tsa.stattools import kpss
8 from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
9 from sklearn.linear_model import LinearRegression
10 from sklearn.metrics import mean_squared_error
11 from statsmodels.tsa.arima.model import ARIMA

[ ] 1 %matplotlib inline

[ ] 1 file_path = "/content/GOOG.csv"

[ ] 1 df = pd.read_csv(file_path, index_col=0, parse_dates=True)

[ ] 1 df.head()

Open      High       Low     Close   Adj Close   Volume
Date
2022-08-09  117.989998  118.199997  116.559998  117.500000  117.500000  15424300
2022-08-10  119.589996  121.779999  119.360001  120.650002  120.650002  20497000
2022-08-11  122.080002  122.339996  119.550003  119.820000  119.820000  16671600
2022-08-12  121.160004  122.650002  120.400002  122.650002  122.650002  16121100
2022-08-15  122.209999  123.260002  121.570000  122.879997  122.879997  15525000

[ ] 1 # Plot the closing price
2
3 plt.rcParams['font.size']=10
4
5 plt.figure(figsize=(10, 10))
6 plt.plot(df['Close'])
7 plt.title('Google Stock Closing Price')
8 plt.xlabel('Date')
9 plt.ylabel('Closing Price')
10 plt.show()
```



```

[ ] 1 X = df['Close'].values
2 result = adfuller(X)
3 print('ADF Statistic: %f' % result[0])
4 print('p-value: %f' % result[1])
5 print('Critical Values:')
6 for key, value in result[4].items():
7     print('\t%s: %f' % (key, value))
8
9 if result[0] < result[4]['5%']:
10    print ('Reject H0 - Time Series is Stationary')
11 else:
12    print ('Failed to Reject H0 - Time Series is Non-Stationary')

ADF Statistic: -0.893703
p-value: 0.790039
Critical Values:
    1%: -3.457
    5%: -2.873
    10%: -2.573
Failed to Reject H0 - Time Series is Non-Stationary

```

```

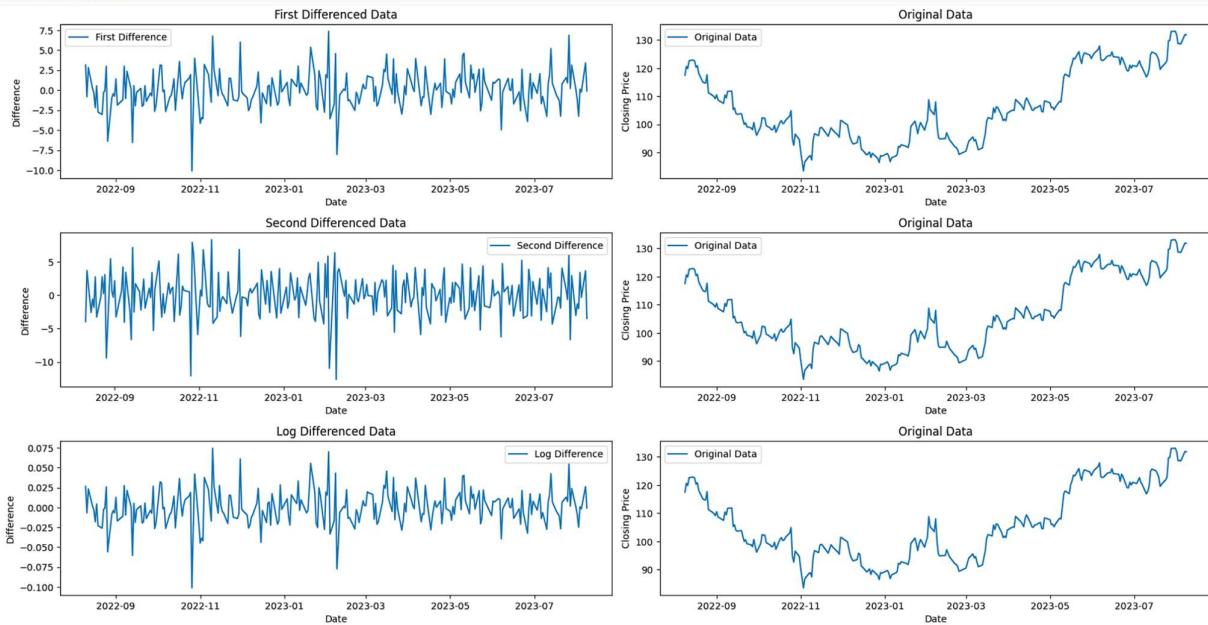
[ ] 1 # Apply differencing methods
2 df_diff1 = df['Close'].diff().dropna() # First difference
3
4 df_diff2 = df['Close'].diff().diff().dropna() # Second difference
5
6 df_log_diff = df['Close'].apply(np.log).diff().dropna() # Log difference

```

```

[ ] 1 # Plot the differenced data
2 plt.figure(figsize=(18, 12))
3
4
5 plt.subplot(421)
6 plt.plot(df_diff1, label='First Difference')
7 plt.legend(loc='best')
8 plt.title('First Differenced Data')
9 plt.xlabel('Date')
10 plt.ylabel('Difference')
11
12
13 plt.subplot(422)
14 plt.plot(df['Close'], label='Original Data')
15 plt.legend(loc='best')
16 plt.title('Original Data')
17 plt.xlabel('Date')
18 plt.ylabel('Closing Price')
19
20
21
22 plt.subplot(423)
23 plt.plot(df_diff2, label='Second Difference')
24 plt.legend(loc='best')
25 plt.title('Second Differenced Data')
26 plt.xlabel('Date')
27 plt.ylabel('Difference')
28
29
30
31 plt.subplot(424)
32 plt.plot(df['Close'], label='Original Data')
33 plt.legend(loc='best')
34 plt.title('Original Data')
35 plt.xlabel('Date')
36 plt.ylabel('Closing Price')
37
38
39
40 plt.subplot(425)
41 plt.plot(df_log_diff, label='Log Difference')
42 plt.legend(loc='best')
43 plt.title('Log Differenced Data')
44 plt.xlabel('Date')
45 plt.ylabel('Difference')
46
47
48
49 plt.subplot(426)
50 plt.plot(df['Close'], label='Original Data')
51 plt.legend(loc='best')
52 plt.title('Original Data')
53 plt.xlabel('Date')
54 plt.ylabel('Closing Price')
55
56
57
58 plt.tight_layout()

```



```

{x} [1] 1 # ADF and KPSS tests for stationarity
2 def test_stationarity(timeseries):
3     # ADF test
4
5     adf_test = adfuller(timeseries, autolag='AIC')
6     print("ADF Test Results:")
7     print(f"ADF Test Statistic: {adf_test[0]}")
8     print(f"p-value: {adf_test[1]}")
9     # Critical Values:
10    for key, value in adf_test[4].items():
11        print(f"\t{key}: {value}")
12
13    if adf_test[0] < adf_test[4]["5%"]:
14        print ("Reject H0 - Time Series is Stationary")
15    else:
16        print ("Failed to Reject H0 - Time Series is Non-Stationary")
17
18
19
20
21
22
23
24    # KPSS test
25    kpss_test = kpss(timeseries, nlags='auto')
26    print("\nKPSS Test Results:")
27    print(f"KPSS Test Statistic: {kpss_test[0]}")
28    print(f"p-value: {kpss_test[1]}")
29    print(f"Critical Values: {kpss_test[3]}")

[ ] 1 print("\nFirst Difference:")
2 test_stationarity(df_diff1)

[ ] First Difference:
ADF Test Results:
ADF Test Statistic: -11.971825846310379
p-value: 3.882320630634504e-22
Critical Values:
1%: -3.45996278199053
5%: -2.8732659015936024
10%: -2.573018897632674
Reject H0 - Time Series is Stationary

KPSS Test Results:
KPSS Test Statistic: 0.3514938486705948
p-value: 0.99806299626267465
Critical Values: {'10%': 0.347, '5%': 0.463, '2.5%': 0.574, '1%': 0.739}

[ ] 1 print("\nSecond Difference:")
2 test_stationarity(df_diff2)

Second Difference:
ADF Test Results:
ADF Test Statistic: -8.353684562399444
p-value: 2.94802700957099e-13
Critical Values:
1%: -3.4582467982399105
5%: -2.8738137461081323
10%: -2.5733111490323846
Reject H0 - Time Series is Stationary

KPSS Test Results:
KPSS Test Statistic: 0.1315324284233876
p-value: 0.1
Critical Values: {'10%': 0.347, '5%': 0.463, '2.5%': 0.574, '1%': 0.739}
<ipython-input-20-92d4b23f3d2b>:25: InterpolationWarning: The test statistic is outside of the range of p-values available in the look-up table. The actual p-value is greater than the p-value returned.

kpss_test = kpss(timeseries, nlags='auto')

[ ] 1 print("\nLog Difference:")
2 test_stationarity(df_log_diff)

[ ] Log Difference:
ADF Test Results:
ADF Test Statistic: -12.110976964109183
p-value: 1.9197212216094285e-22
Critical Values:
1%: -3.459962781990573
5%: -2.8732659015936024
10%: -2.573018897632674
Reject H0 - Time Series is Stationary

KPSS Test Results:
KPSS Test Statistic: 0.31381152797403866
p-value: 0.1
Critical Values: {'10%': 0.347, '5%': 0.463, '2.5%': 0.574, '1%': 0.739}
<ipython-input-20-92d4b23f3d2b>:25: InterpolationWarning: The test statistic is outside of the range of p-values available in the look-up table. The actual p-value is greater than the p-value returned.

kpss_test = kpss(timeseries, nlags='auto')


```

**Auto Regressive Model**

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \dots + \beta_p Y_{t-p} + \epsilon_t$$

```

[ ] 1 df

```

Date	Open	High	Low	Close	Adj Close	Volume
2022-08-09	117.989998	118.199997	116.559998	117.500000	117.500000	15424300
2022-08-10	119.589996	121.779999	119.360001	120.650002	120.650002	20497000
2022-08-11	122.080002	122.339996	119.550003	119.820000	119.820000	16671600
2022-08-12	121.160004	122.650002	120.400002	122.650002	122.650002	16121100
2022-08-15	122.209999	123.260002	121.570000	122.879997	122.879997	15525000
...	...	...	...	...	...	...
2023-08-02	129.839996	130.419998	127.849998	128.639999	128.639999	22705800
2023-08-03	128.369995	129.770004	127.775002	128.770004	128.770004	15018100
2023-08-04	129.600006	131.929993	128.315002	128.539993	128.539993	20509500
2023-08-07	129.509995	132.059998	129.429993	131.940002	131.940002	17621000
2023-08-08	130.979996	131.940002	130.130005	131.839996	131.839996	16828300

251 rows x 6 columns

```

[ ] 1 sdi = df.asefreq('D')
2 sdi = sdi[['Close']]
3 sdi

```

```

Close
Date
2022-08-09 117.500000
2022-08-10 120.650002
2022-08-11 119.820000
2022-08-12 122.650002
2022-08-13      NaN
...
...
2023-08-04 128.539993
2023-08-05      NaN
2023-08-06      NaN
2023-08-07 131.940002
2023-08-08 131.839996
365 rows × 1 columns

[ ] 1 from statsmodels.tsa.seasonal import STL

[ ] 1 # in this place "use linear interpolation here" use the commands for linear interpolation.
2 # sdi = Seasonal Decomposition and Interpolation to interpolate missing values in the daily frequency of data
3
4 res = STL(sdi['Close'].interpolate(method="linear"), seasonal=13).fit()

[ ] 1 res.plot()

```

**Close**

The plot displays four stacked time series components. The top component, 'Close', shows a general upward trend with some fluctuations. The second component, 'Trend', highlights the overall linear growth. The third component, 'Season', shows a clear seasonal pattern with high-frequency oscillations. The bottom component, 'Resid', represents the residuals after removing the seasonal and trend components, appearing as a relatively flat line around zero.

```

[ ] 1 seasonal_component = res.seasonal
2 seasonal_component.head()

Date
2022-08-09 -1.224121
2022-08-10 -0.260225
2022-08-11  0.852518
2022-08-12  0.272024
2022-08-13  0.208928
Freq: D, Name: season, dtype: float64

[ ] 1 sdi_deseasonalised = sdi['Close'] - seasonal_component
2 sdi_deseasonalised_imputed = sdi_deseasonalised.interpolate(method="spline",order=3)
3 sdi_imputed = sdi_deseasonalised_imputed + seasonal_component
4
5 sdi_imputed = sdi_imputed.to_frame().rename(columns={0: 'Close'})
6
7 # plot
8 ax = sdi_imputed.plot(linestyle="-", marker=".", figsize=[20, 5], legend=None)
9 ax = sdi_imputed[sdi.isnull()].plot(ax=ax, legend=None, marker="x", color="r")
10 ax.set_title('Google Stock Prices with missing observations')
11 ax.set_ylabel('Closing Price')
12 ax.set_xlabel('Date')

```

**Google Stock Prices with missing observations**

This line plot compares the original stock price data (blue line) against the data with missing observations filled using the STL decomposition and spline interpolation (red line with 'x' markers). The x-axis represents the date from September 2022 to August 2023. The y-axis represents the closing price. The red line closely follows the blue line, indicating that the imputation method effectively fills the gaps while preserving the overall trend and seasonal pattern.

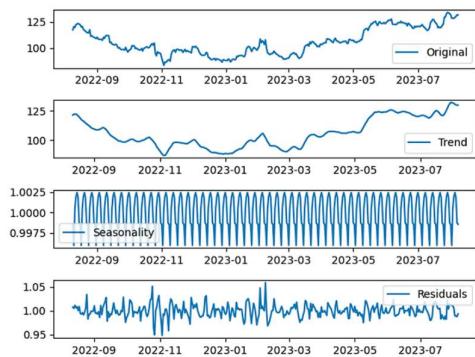
```

[ ] 1 sdi_imputed

Close
Date
2022-08-09 117.500000
2022-08-10 120.650002
2022-08-11 119.820000
2022-08-12 122.650002
2022-08-13 123.090103
...
...
2023-08-04 128.539993
2023-08-05 129.406770
2023-08-06 130.415954
2023-08-07 131.940002
2023-08-08 131.839996
365 rows × 1 columns

```

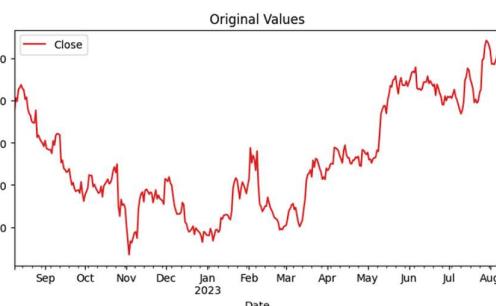
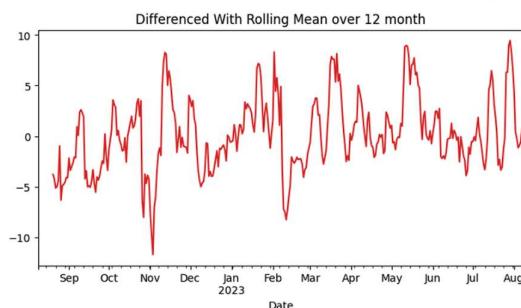
```
[ ] 1 # perform seasonal decompose on logged transformed
2
3 decompose_result = seasonal_decompose(sdi_imputed, model='multiplicative', filt=None, period=None, two_sided=True, extrapolate_trend=0)
4
5 # perform seasonal decomposing using additive model type
6
7 trend = decompose_result.trend # get trend
8 seasonal = decompose_result.seasonal #get seasonal
9 residual = decompose_result.resid #get residual
10
11 #plot the decompose result
12 # decompose_result.plot("Multiplicative Decomposition")
13
14 plt.subplot(411)
15 plt.plot(sdi_imputed, label='Original')
16 plt.legend(loc='best')
17
18 plt.subplot(412)
19 plt.plot(trend, label='Trend')
20 plt.legend(loc='best')
21
22 plt.subplot(413)
23 plt.plot(seasonal,label='Seasonality')
24 plt.legend(loc='best')
25
26 plt.subplot(414)
27 plt.plot(residual, label='Residuals')
28 plt.legend(loc='best')
29 plt.tight_layout()
```



```
[x] 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(sdi_imputed, autolag = 'AIC')
5
6 print("1. ADF : ", dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)

1. ADF : -1.0295989868277595
2. P-Value : 0.313162782004037
3. Num Of Lags : 4
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 360
5. Critical Values :
   1% : -3.4464545946352023
   5% : -2.869602139060357
   10% : -2.5710650077160495
```

```
(x) 1 rolling_mean = sdi_imputed.rolling(window = 12).mean()
2 sdi_rolled_detrended = sdi_imputed['Close'] - rolling_mean['Close']
3
4
5 ax1 = plt.subplot(121)
6 sdi_rolled_detrended.plot(figsize=(18,4),color="tab:red", title="Differenced With Rolling Mean over 12 month", ax=ax1);
7 ax2 = plt.subplot(122)
8 sdi_imputed.plot(figsize=(18,4), color="tab:red", title="Original Values", ax=ax2);
```



```

[ ] 1 sdi_rolled_detrended
Date
2022-08-09      NaN
2022-08-10      NaN
2022-08-11      NaN
2022-08-12      NaN
2022-08-13      NaN
...
2023-08-04   -1.153109
2023-08-05   -0.530563
2023-08-06   -0.530876
2023-08-07    0.794173
2023-08-08   0.530000
Freq: D, Name: Close, Length: 365, dtype: float64

❶ 1 decompose_result = seasonal_decompose(sdi_rolled_detrended.dropna(), model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
2
3 # perform seasonal decomposing using multiplicative model type
4
5 trend = decompose_result.trend # get trend
6 seasonal = decompose_result.seasonal #get seasonal
7 residual = decompose_result.resid #get residual
8
9 #plot the decompose result
10 # decompose_result.plot("Multiplicative Decomposition")
11
12 plt.subplot(411)
13 plt.plot(sdi_rolled_detrended, label='Original')
14 plt.legend(loc='best')
15
16 plt.subplot(412)
17 plt.plot(trend, label='Trend')
18 plt.legend(loc='best')
19
20 plt.subplot(413)
21 plt.plot(seasonal,label='Seasonality')
22 plt.legend(loc='best')
23
24 plt.subplot(414)
25 plt.plot(residual, label='Residuals')
26 plt.legend(loc='best')
27 plt.tight_layout()

```

```

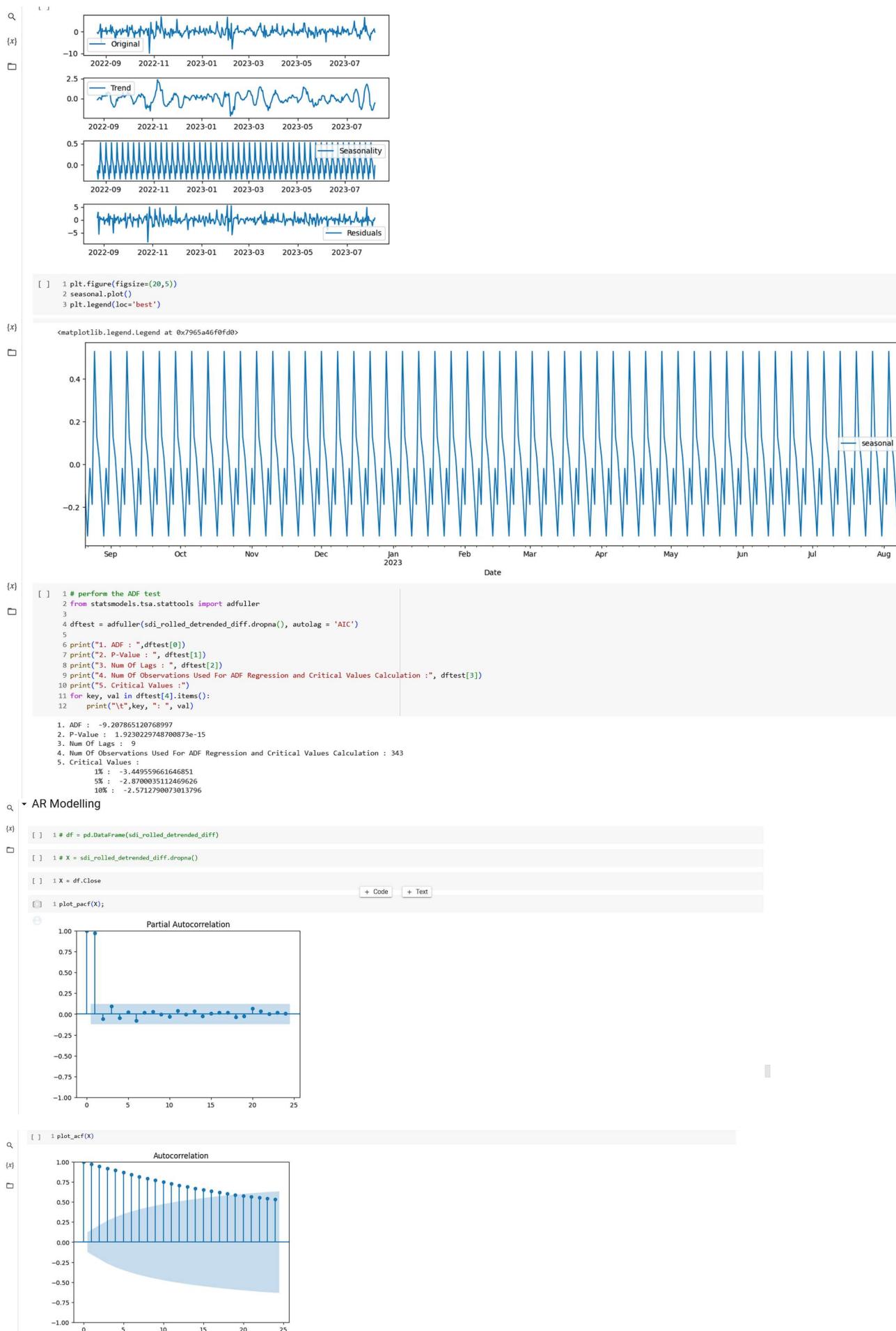
[ ] 1 sdi_rolled_detrended_diff = sdi_rolled_detrended - sdi_rolled_detrended.shift()
2
3 # plot the logged passengers_diff
4 ax1 = plt.subplot(121)
5 sdi_rolled_detrended_diff.plot(figsize=(18,6) ,color="tab:red", title="Rolled Mean Detrended Shift Differenced Values", ax=ax1);
6 ax2 = plt.subplot(122)
7 sdi_rolled_detrended.plot(color="tab:red", title="Rolled Mean Detrended Values", ax=ax2);

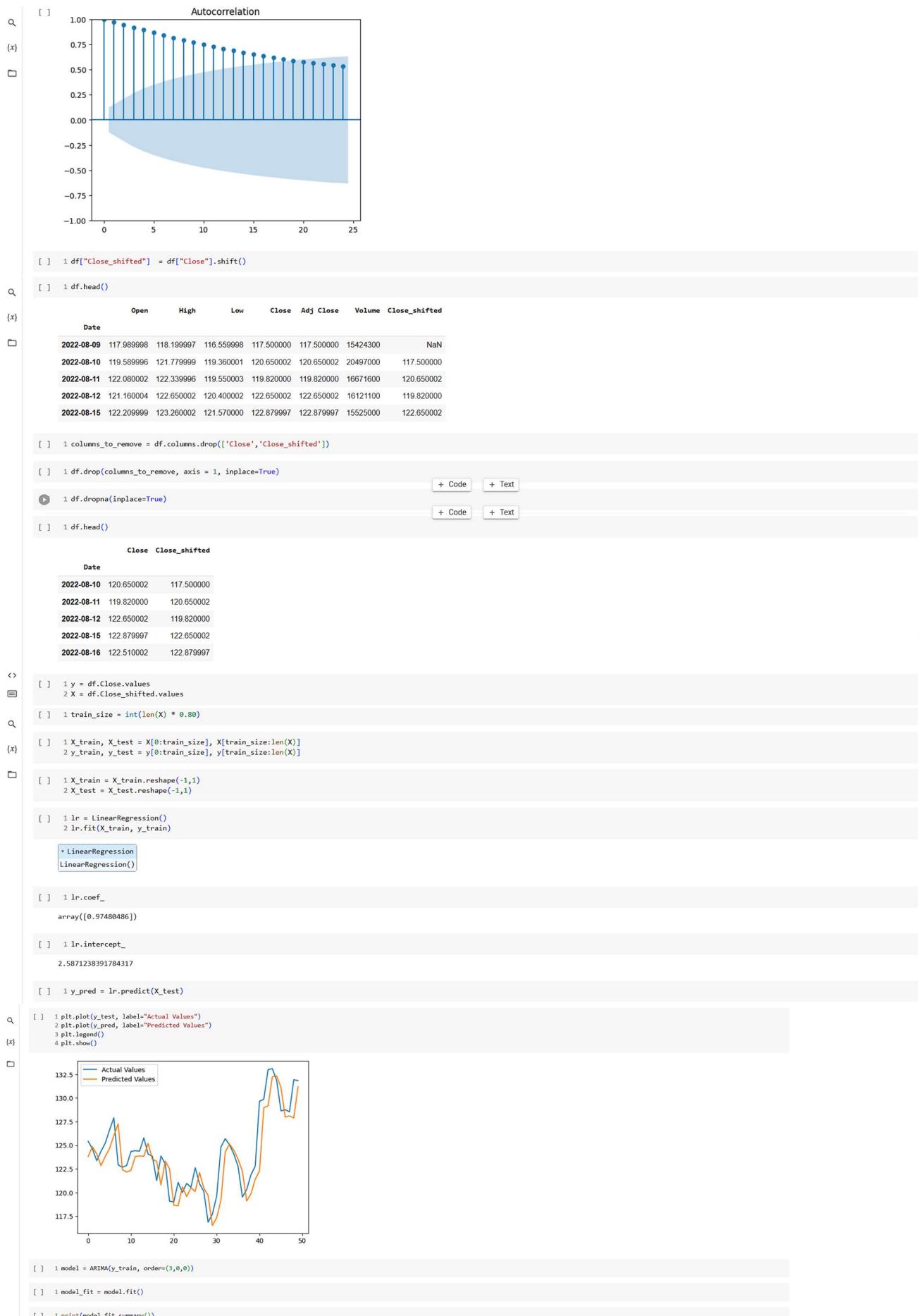
```

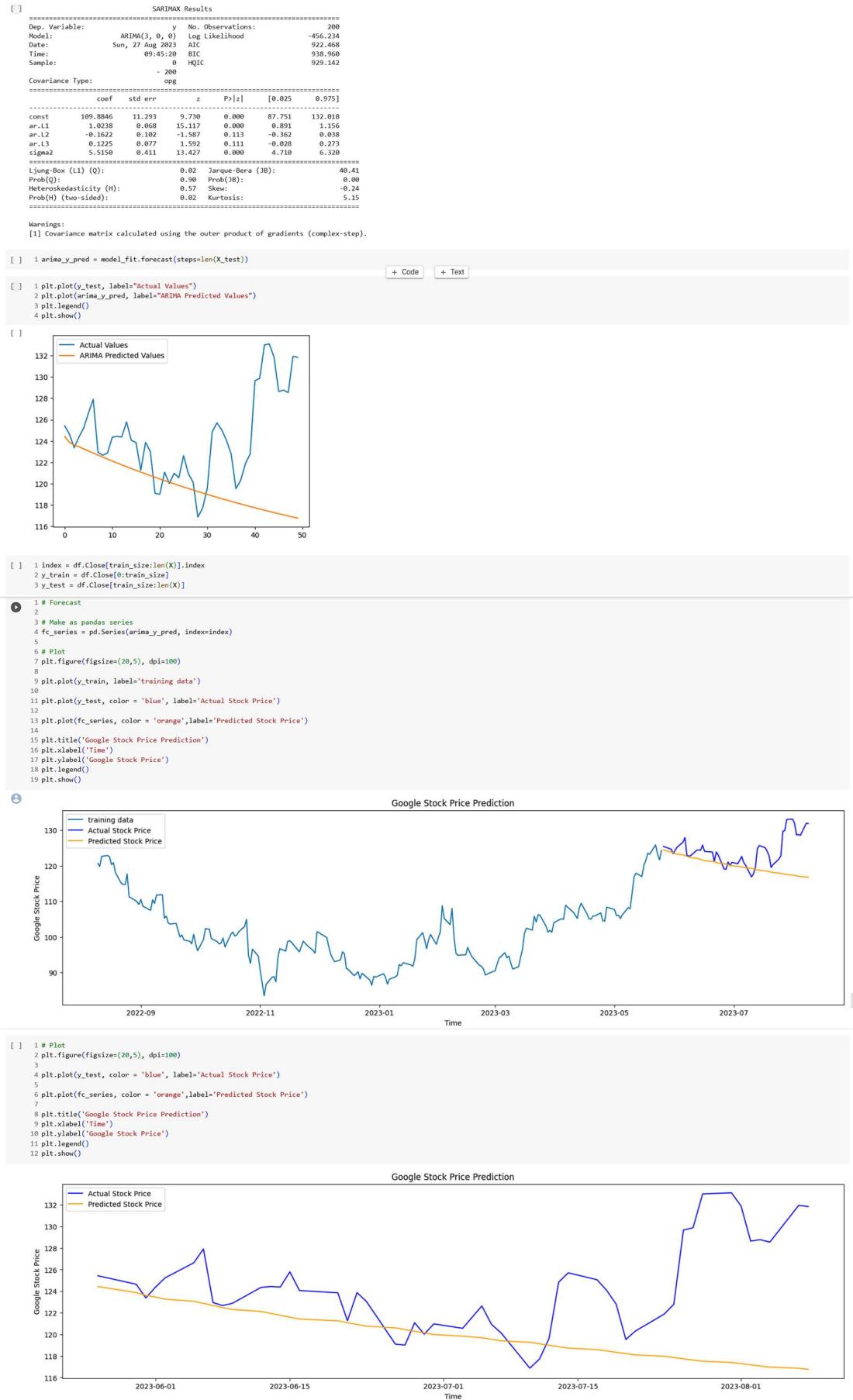
```

[ ] 1 decompose_result = seasonal_decompose(sdi_rolled_detrended_diff.dropna(), model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
2
3 # perform seasonal decomposing using multiplicative model type
4
5 trend = decompose_result.trend # get trend
6 seasonal = decompose_result.seasonal #get seasonal
7 residual = decompose_result.resid #get residual
8
9 #plot the decompose result
10 # decompose_result.plot("Multiplicative Decomposition")
11
12 plt.subplot(411)
13 plt.plot(sdi_rolled_detrended_diff, label='Original')
14 plt.legend(loc='best')
15
16 plt.subplot(412)
17 plt.plot(trend, label='Trend')
18 plt.legend(loc='best')
19
20 plt.subplot(413)
21 plt.plot(seasonal,label='Seasonality')
22 plt.legend(loc='best')
23
24 plt.subplot(414)
25 plt.plot(residual, label='Residuals')
26 plt.legend(loc='best')
27 plt.tight_layout()

```







## RESULT

The implementation was successful.

# Experiment 5

## AIM

Implementation of Auto regression (AR) model, and using Auto correlation function (ACF) to find the order of AR model.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

GOOG.csv is the google stock price dataset with size (251 x 7).

## CODE AND OUTPUT

```
▼ TSA LAB 5: ADF and KPSS Test and Implement ARIMA Model - Google Stock Price Data
[x]
[ ] 1 import pandas as pd
2 import numpy as np
3 import matplotlib.pyplot as plt
4 import statsmodels.api as sm
5 from statsmodels.tsa.seasonal import seasonal_decompose
6 from statsmodels.tsa.stattools import adfuller
7 from statsmodels.tsa.stattools import kpss
8 from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
9 from sklearn.linear_model import LinearRegression
10 from sklearn.metrics import mean_squared_error
11 from statsmodels.tsa.arima.model import ARIMA

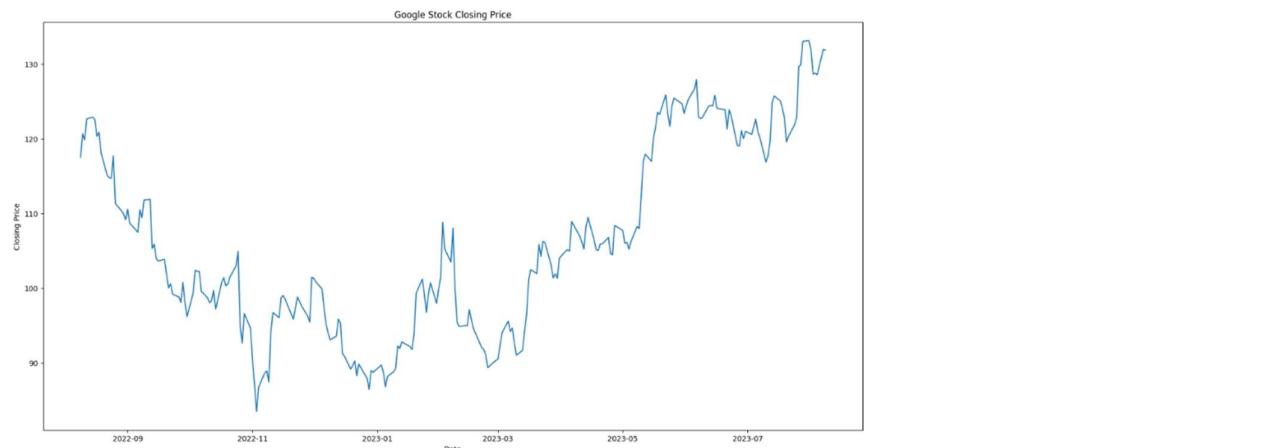
[ ] 1 %matplotlib inline

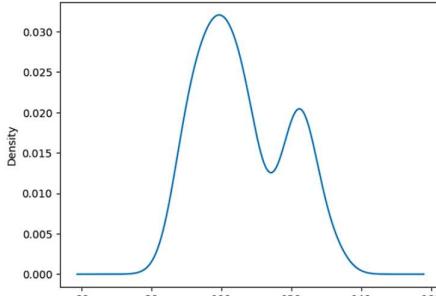
[ ] 1 file_path = "/content/GOOG.csv"

[ ] 1 df = pd.read_csv(file_path, index_col=0, parse_dates=True)

[ ] 1 df.head()

      Open      High       Low     Close   Adj Close    Volume
Date
2022-08-09  117.989998  118.199997  116.559998  117.500000  117.500000  15424300
2022-08-10  119.589996  121.779999  119.360001  120.650002  120.650002  20497000
2022-08-11  122.080002  122.339996  119.550003  119.820000  119.820000  16671600
2022-08-12  121.160004  122.650002  120.400002  122.650002  122.650002  16121100
2022-08-15  122.209999  123.260002  121.570000  122.879997  122.879997  15525000
<>
```



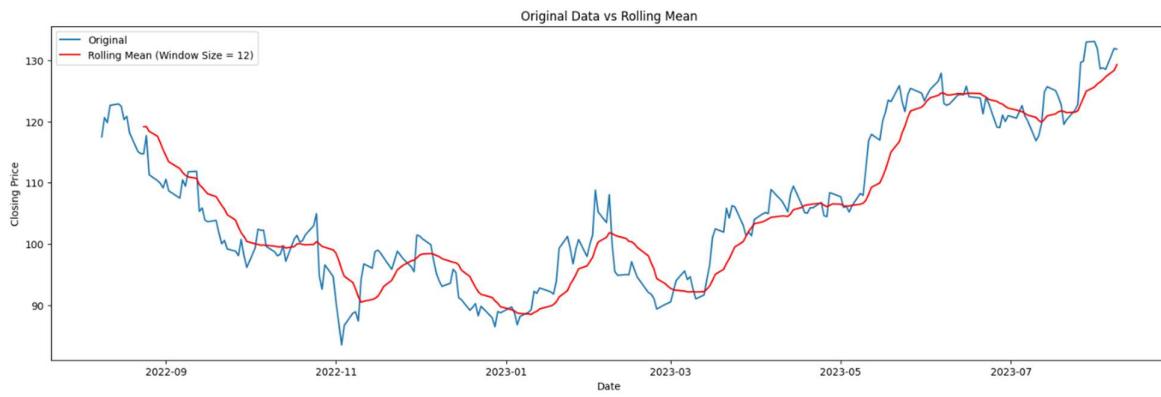
```
[ ] 1 df_close = df['Close']
2 df_close.plot(kind='kde')
<Axes: ylabel='Density'>

{x}
[ ] 1 # Split the data into 3 parts
2 num_splits = 3
3 split_size = len(df) // num_splits
4 data_splits = [df.iloc[i * split_size:(i + 1) * split_size] for i in range(num_splits)]
5

[ ] 1 # Calculate the mean and variance for each split
2 for i, data_split in enumerate(data_splits):
3     mean = np.mean(data_split['Close'])
4     variance = np.var(data_split['Close'])
5     print(f"Split {i + 1} - Mean: {mean:.2f}, Variance: {variance:.2f}")
6

Split 1 - Mean: 102.91, Variance: 82.49
Split 2 - Mean: 95.75, Variance: 33.28
Split 3 - Mean: 118.68, Variance: 67.52

[ ] 1 # Calculate the rolling mean and plot the graph
2 rolling_mean = df['Close'].rolling(window=12).mean()

[ ] 1 plt.figure(figsize=(20, 6))
2 plt.plot(df['Close'], label='Original')
3 plt.plot(rolling_mean, label='Rolling Mean (Window Size = 12)', color='red')
4 plt.legend()
5 plt.title('Original Data vs Rolling Mean')
6 plt.xlabel('Date')
7 plt.ylabel('Closing Price')
8 plt.show()
```



```
[ ] 1 X = df["Close"].values
2 result = adfuller(X)
3 print("ADF Statistic: %f" % result[0])
4 print("p-value: %f" % result[1])
5 print("Critical Values:")
6 for key, value in result[4].items():
7     print("\t%s: %f" % (key, value))
8
9 if result[0] < result[4]["5%"]:
10    print ("Reject H0 - Time Series is Stationary")
11 else:
12    print ("Failed to Reject H0 - Time Series is Non-Stationary")

ADF Statistic: -0.893703
p-value: 0.790039
Critical Values:
    1%: -3.457
    5%: -2.875
    10%: -2.573
Failed to Reject H0 - Time Series is Non-Stationary

[ ] 1 # Apply differencing methods
2 df_diff1 = df['Close'].diff().dropna() # First difference
3
4 df_diff2 = df['Close'].diff().diff().dropna() # Second difference
5
6 df_log_diff = df['Close'].apply(np.log).diff().dropna() # Log difference
```

```

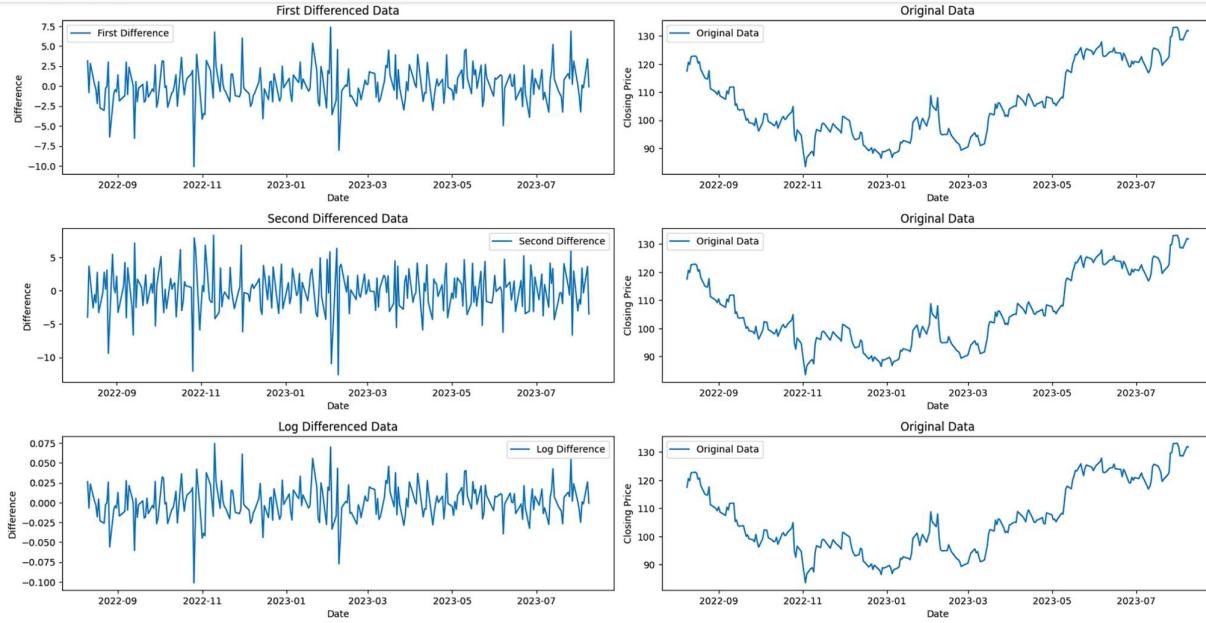
[ ] 1 # Plot the differenced data
2 plt.figure(figsize=(18, 12))
3
4
5 plt.subplot(421)
6 plt.plot(df_diff1, label='First Difference')
7 plt.legend(loc='best')
8 plt.title('First Differenced Data')
9 plt.xlabel('Date')
10 plt.ylabel('Difference')
11
12
13 plt.subplot(422)
14 plt.plot(df["Close"], label='Original Data')
15 plt.legend(loc='best')
16 plt.title('Original Data')
17 plt.xlabel('Date')
18 plt.ylabel('Closing Price')
19
20
21
22 plt.subplot(423)
23 plt.plot(df_diff2, label='Second Difference')
24 plt.legend(loc='best')
25 plt.title('Second Differenced Data')
26 plt.xlabel('Date')
27 plt.ylabel('Difference')
28
29
30
31 plt.subplot(424)
32 plt.plot(df["Close"], label='Original Data')
33 plt.legend(loc='best')
34 plt.title('Original Data')
35 plt.xlabel('Date')
36 plt.ylabel('Closing Price')
37
38
39
40 plt.subplot(425)
41 plt.plot(df_log_diff, label='Log Difference')
42 plt.legend(loc='best')
43 plt.title('Log Differenced Data')
44 plt.xlabel('Date')

```

```

[ ] 48
49 plt.subplot(426)
50 plt.plot(df["Close"], label='Original Data')
51 plt.legend(loc='best')
52 plt.title('Original Data')
53 plt.xlabel('Date')
54 plt.ylabel('Closing Price')
55
56
57
58 plt.tight_layout()

```



```

[ ] 1 # ADF and KPSS tests for stationarity
2 def test_stationarity(timeseries):
3     # ADF test
4
5     adf_test = adfuller(timeseries, autolag='AIC')
6     print("\nADF Test Results:")
7     print(f"\nADF Test Statistic: {adf_test[0]}")
8     print(f"\np-value: {adf_test[1]}")
9     # print(f"Critical Values: {adf_test[4]}")
10
11    # result = adfuller(timeseries, autolag='AIC')
12    # print(f"\nADF Statistic: {result[0]} % result[1]")
13    # print(f"\np-value: {result[1]} % result[1]")
14    print("Critical Values:")
15    for key, value in adf_test[4].items():
16        print(f"\t{key}: {value}")
17
18    if adf_test[0] < adf_test[4][5%]:
19        print ("Reject H0 - Time Series is Stationary")
20    else:
21        print ("Failed to Reject H0 - Time Series is Non-Stationary")
22
23
24    # KPSS test
25    kpss_test = kpss(timeseries, nlags='auto')
26    print("\nKPSS Test Results:")
27    print(f"\nKPSS Test Statistic: {kpss_test[0]}")
28    print(f"\np-value: {kpss_test[1]}")
29    print(f"\nCritical Values: {kpss_test[3]}")

```

```

[ ] 1 print("\nFirst Difference:")
2 test_stationarity(df_diff1)

```

```

[ ] First Difference:
ADF Test Results:
ADF Test Statistic: -11.971825846310379
p-value: 3.88230630634504e-22
Critical Values:
1%: -3.456962781990573
5%: -2.8732659015936024
10%: -2.573018897632674
Reject Ho - Time Series is Stationary

KPSS Test Results:
KPSS Test Statistic: 0.3514938486705948
p-value: 0.99806299626267465
Critical Values: {'10%': 0.347, '5%': 0.463, '2.5%': 0.574, '1%': 0.739}

[ ] 1 print("\nSecond Difference:")
2 test_stationarity(df_diff)

Second Difference:
ADF Test Results:
ADF Test Statistic: -8.353684562399444
p-value: 2.04803206957099e-13
Critical Values:
1%: -3.4582467982399105
5%: -2.8738137461081323
10%: -2.5733111499323846
Reject Ho - Time Series is Stationary

KPSS Test Results:
KPSS Test Statistic: 0.13153242844233876
p-value: 0.1
Critical Values: {'10%': 0.347, '5%': 0.463, '2.5%': 0.574, '1%': 0.739}
<ipython-input-16-92d4b2f3fd3d2b>:25: InterpolationWarning: The test statistic is outside of the range of p-values available in the look-up table. The actual p-value is greater than the p-value returned.

kpss_test = kpss(timeseries, nlags='auto')

[ ] 1 print("\nLog Difference:")
2 test_stationarity(df_log_diff)

Log Difference:
ADF Test Results:
ADF Test Statistic: -12.110976964109183
p-value: 1.9197212216094285e-22
Critical Values:
1%: -3.456962781990573
5%: -2.8732659015936024
10%: -2.573018897632674
Reject Ho - Time Series is Stationary

KPSS Test Results:
KPSS Test Statistic: 0.31381152797403866
p-value: 0.1
Critical Values: {'10%': 0.347, '5%': 0.463, '2.5%': 0.574, '1%': 0.739}
<ipython-input-16-92d4b2f3fd3d2b>:25: InterpolationWarning: The test statistic is outside of the range of p-values available in the look-up table. The actual p-value is greater than the p-value returned.

kpss_test = kpss(timeseries, nlags='auto')

[ ] 1 sdi = df.asfreq('D')
2 sdi = sdi[['Close']]
3 sdi

Close
Date
2022-08-09    117.500000
2022-08-10    120.650002
2022-08-11    119.820000
2022-08-12    122.650002
2022-08-13      NaN
...
2023-08-04    128.539993
2023-08-05      NaN
2023-08-06      NaN
2023-08-07    131.940002
2023-08-08    131.839996
365 rows × 1 columns

[ ] 1 from statsmodels.tsa.seasonal import STL

[ ] 1 # in this place "use linear interpolation here" use the commands for linear interpolation.
2 # sdi = Seasonal Decomposition and Interpolation to interpolate missing values in the daily frequency of data
3
4 res = STL(sdi["Close"].interpolate(method="linear"), seasonal=13).fit()

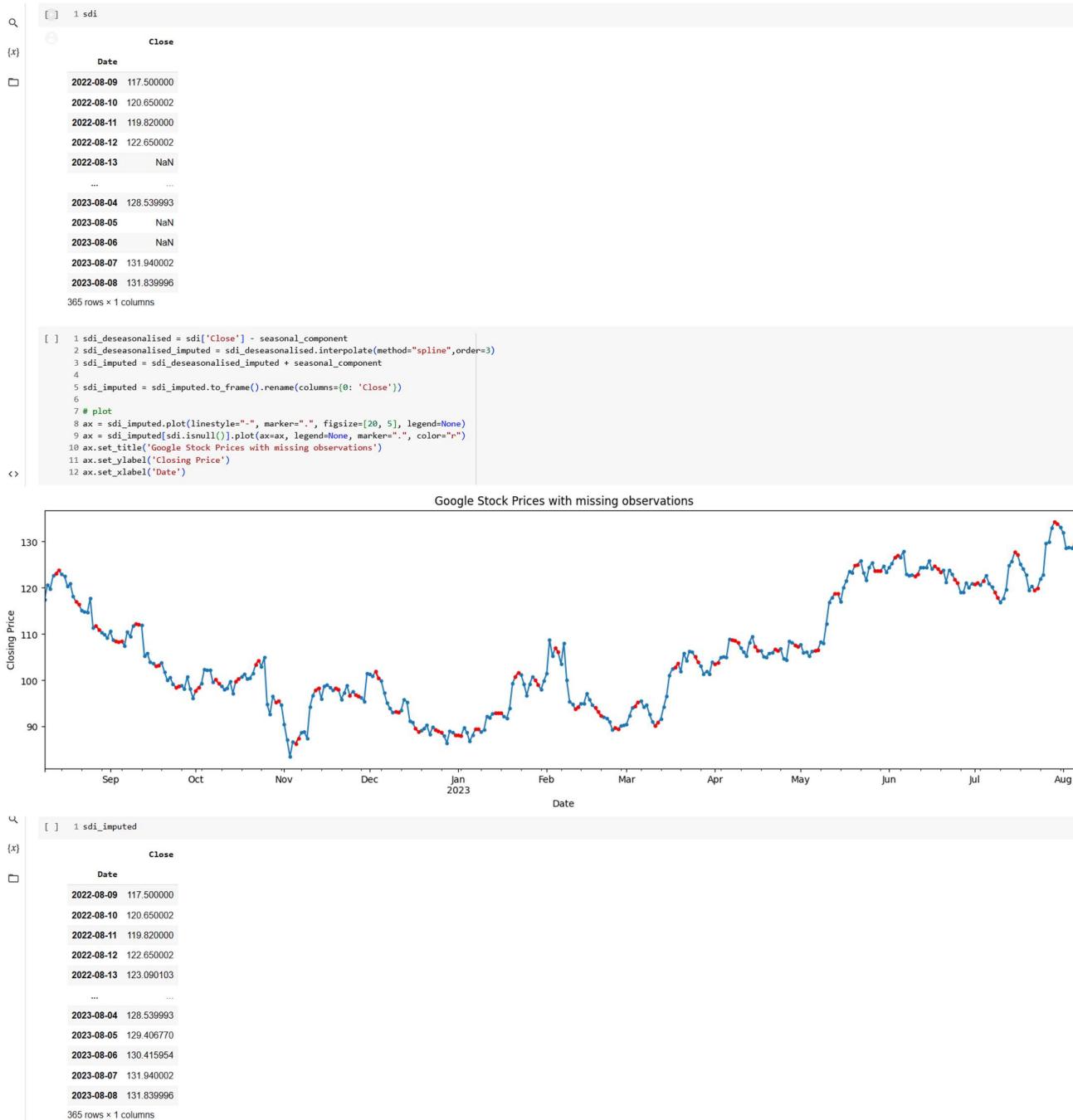
[ ] 1 res.plot()

Close
Trend
Season
Resid
2022-08-09 2022-10-22 2022-12-23 2023-01-23 2023-03-23 2023-05-23 2023-07-23 2023-08-08

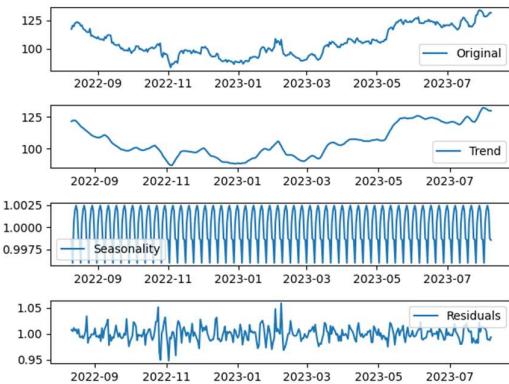
[ ] 1 seasonal_component = res.seasonal
2 seasonal_component.head()

Date
2022-08-09   -1.224121
2022-08-10   -0.260225
2022-08-11    0.852518
2022-08-12    0.277024
2022-08-13    0.208928
Freq: D, Name: season, dtype: float64

```



```
[ ] 1 # perform seasonal decompose on logged transformed
2
3 decompose_result = seasonal_decompose(sdi_imputed, model='multiplicative', filt=None, period=None, two_sided=True, extrapolate_trend=0)
4
5 # perform seasonal decomposing using additive model type
6
7 trend = decompose_result.trend # get trend
8 seasonal = decompose_result.seasonal #get seasonal
9 residual = decompose_result.resid #get residual
10
11 #plot the decompose result
12 # decompose_result.plot("Multiplicative Decomposition")
13
14 plt.subplot(411)
15 plt.plot(sdi_imputed, label='Original')
16 plt.legend(loc='best')
17
18 plt.subplot(412)
19 plt.plot(trend, label='Trend')
20 plt.legend(loc='best')
21
22 plt.subplot(413)
23 plt.plot(seasonal,label='Seasonality')
24 plt.legend(loc='best')
25
26 plt.subplot(414)
27 plt.plot(residual, label='Residuals')
28 plt.legend(loc='best')
29 plt.tight_layout()
```



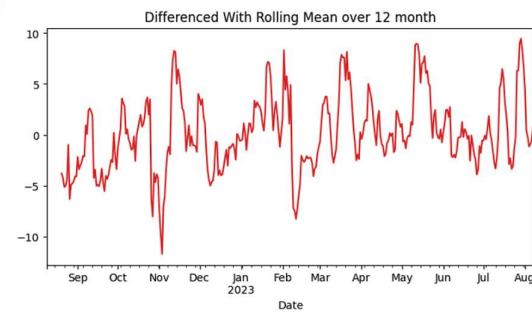
```
(i) 1 # perform the ADF test
2 from statsmodels.tsa.stattools import adfuller
3
4 dfstest = adfuller(sdi_imputed, autolag = 'AIC')
5
6 print("1. ADF : ",dfstest[0])
7 print("2. P-Value : ", dfstest[1])
8 print("3. Num Of Lags : ", dfstest[2])
9 print("4. Num Of Observations Used For ADF Regression and Critical Values Calculation : ", dfstest[3])
10 print("5. Critical Values :")
11 for key, val in dfstest[4].items():
12     print("\t",key, ":", val)
```

```
1. ADF : -1.0295989868277595
2. P-Value : 0.7423162782004037
3. Num Of Lags : 4
4. Num Of Observations Used For ADF Regression and Critical Values Calculation : 360
5. Critical Values :
   1% : -3.44864594635203
   5% : -2.869602139060357
   10% : -2.5710650077160495
```

```
[ ] 1 sdi_imputed.isnull().any()
```

```
Close    False
dtype: bool
```

```
(i) 1 rolling_mean = sdi_imputed.rolling(window = 12).mean()
2 sdi_rolled_detrended = sdi_imputed['Close'] - rolling_mean['Close']
3
4
5 ax1 = plt.subplot(121)
6 sdi_rolled_detrended.plot(figsize=(18,4),color="tab:red", title="Differenced With Rolling Mean over 12 month", ax=ax1);
7 ax2 = plt.subplot(122)
8 sdi_imputed.plot(figsize=(18,4), color="tab:red", title="Original Values", ax=ax2);
```



Original Values



```
[ ] 1 sdi_rolled_detrended
```

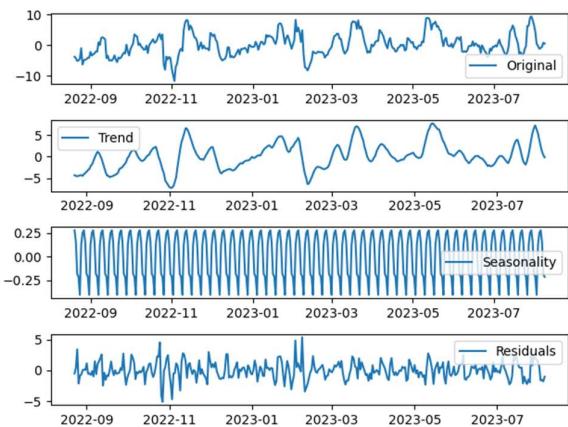
Date	Close
2022-08-09	NaN
2022-08-10	NaN
2022-08-11	NaN
2022-08-12	NaN
2022-08-13	NaN
...	
2023-08-04	-1.153109
2023-08-05	-0.915563
2023-08-06	-0.539876
2023-08-07	0.794173
2023-08-08	0.530000

Freq: D, Name: Close, Length: 365, dtype: float64

```

1 decompose_result = seasonal_decompose(sdi_rolled_detrended.dropna(), model='additive', filt=None, period=None, two_sided=True, extrapolate_trend=0)
2
3 # perform seasonal decomposing using multiplicative model type
4
5 trend = decompose_result.trend # get trend
6 seasonal = decompose_result.seasonal #get seasonal
7 residual = decompose_result.resid #get residual
8
9 #plot the decompose result
10 # decompose_result.plot("Multiplicative Decomposition")
11
12 plt.subplot(411)
13 plt.plot(sdi_rolled_detrended, label='Original')
14 plt.legend(loc='best')
15
16 plt.subplot(412)
17 plt.plot(trend, label='Trend')
18 plt.legend(loc='best')
19
20 plt.subplot(413)
21 plt.plot(seasonal,label='Seasonality')
22 plt.legend(loc='best')
23
24 plt.subplot(414)
25 plt.plot(residual, label='Residuals')
26 plt.legend(loc='best')
27 plt.tight_layout()

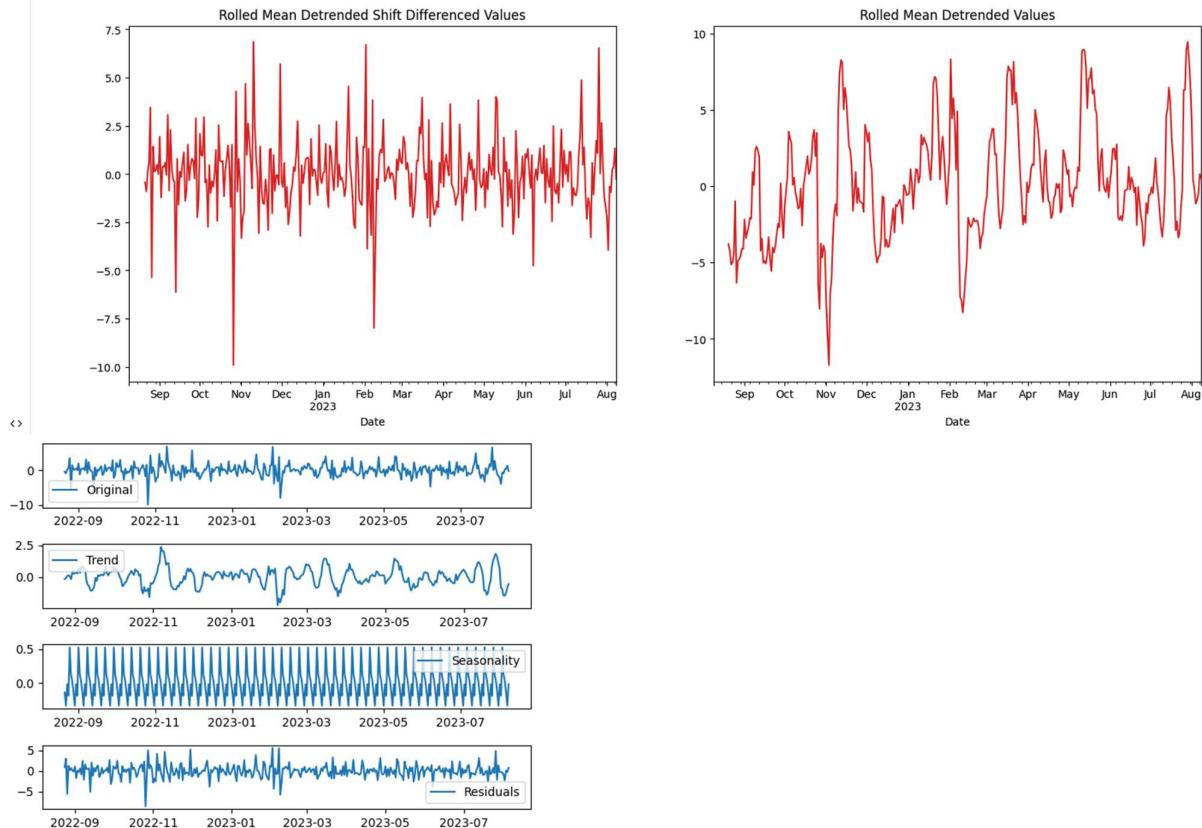
```

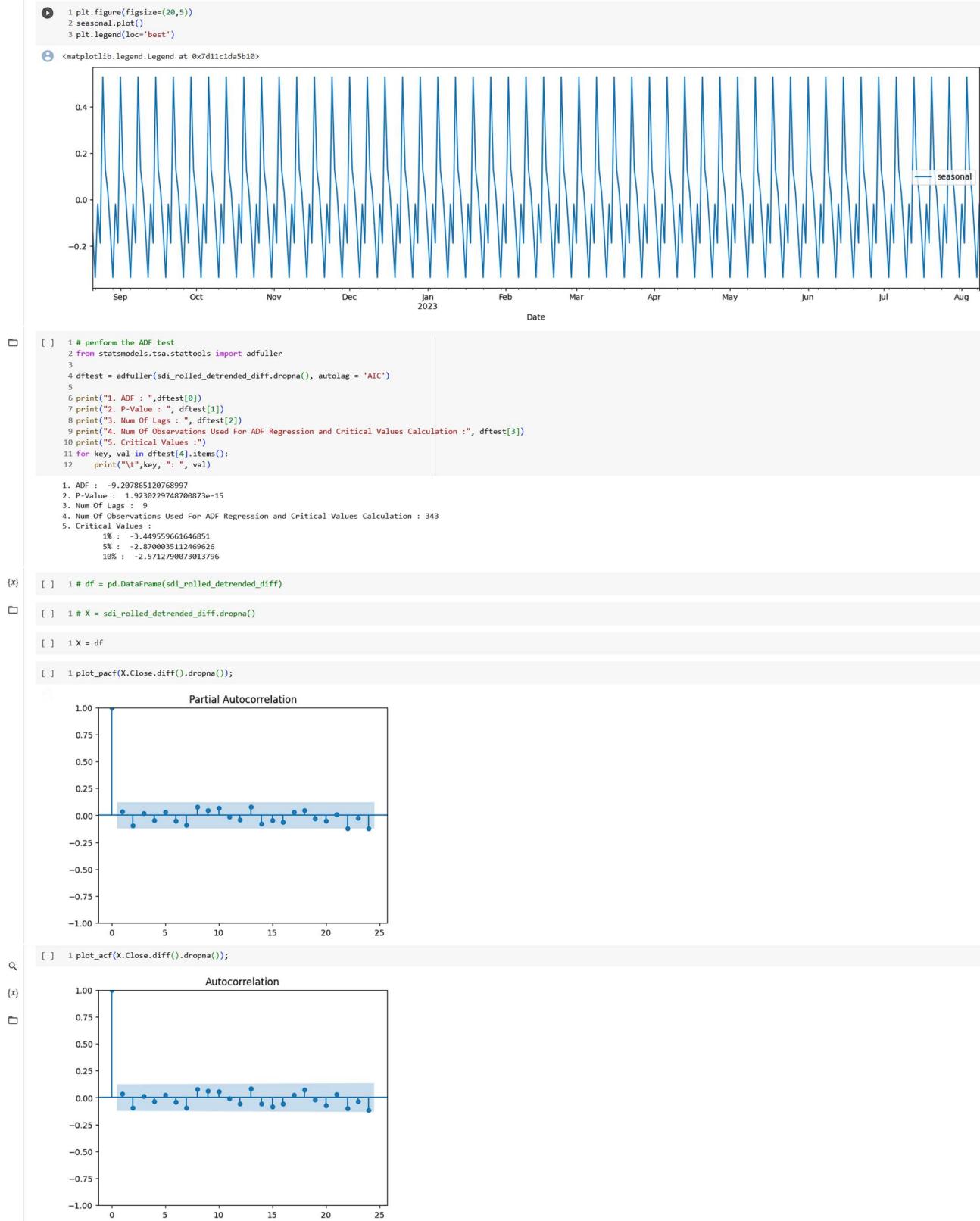


```

[ ] 1 sdi_rolled_detrended_diff = sdi_rolled_detrended - sdi_rolled_detrended.shift()
2
3 # plot the logged_passengers_diff
4 ax1 = plt.subplot(121)
5 sdi_rolled_detrended_diff.plot(figsize=(18,6),color="tab:red", title="Rolled Mean Detrended Shift Differenced Values", ax=ax1);
6 ax2 = plt.subplot(122)
7 sdi_rolled_detrended_diff.plot(color="tab:red", title="Rolled Mean Detrended Values", ax=ax2);

```





```

[ ] 1 df["Close_shifted"] = df["Close"].shift()
[ ] 1 df.head()

```

Date	Open	High	Low	Close	Adj Close	Volume	Close_shifted
2022-08-09	117.989998	118.199997	118.559998	117.500000	117.500000	15424300	NaN
2022-08-10	119.589996	121.779999	119.360001	120.650002	120.650002	20497000	117.500000
2022-08-11	122.080002	122.339996	119.550003	119.820000	119.820000	16671600	120.650002
2022-08-12	121.160004	122.650002	120.400002	122.650002	122.650002	16121100	119.820000
2022-08-15	122.209999	123.260002	121.570000	122.879997	122.879997	15525000	122.650002

+ Code + Text

```

[ ] 1 columns_to_remove = df.columns.drop(['Close','Close_shifted'])
[ ] 1 df.drop(columns_to_remove, axis = 1, inplace=True)

```

+ Code + Text

```

[ ] 1 df.dropna(inplace=True)

```

+ Code + Text

```

[ ] 1 df.head()

```

Date	Close	Close_shifted
2022-08-10	120.650002	117.500000
2022-08-11	119.820000	120.650002
2022-08-12	122.650002	119.820000
2022-08-13	122.879997	122.650002
2022-08-16	122.510002	122.879997

+ Code + Text

```

[ ] 1 y = df.Close.values
[ ] 2 X = df.Close_shifted.values

```

+ Code + Text

```

[ ] 1 train_size = int(len(X) * 0.80)

```

+ Code + Text

```

[ ] 1 X_train, X_test = X[0:train_size], X[train_size:len(X)]
[ ] 2 y_train, y_test = y[0:train_size], y[train_size:len(X)]

```

+ Code + Text

```

[ ] 1 X_train = X_train.reshape(-1,1)
[ ] 2 X_test = X_test.reshape(-1,1)

```

+ Code + Text

```

[ ] 1 lr = LinearRegression()
[ ] 2 lr.fit(X_train, y_train)

```

+ LinearRegression  
LinearRegression()

+ Code + Text

```

[ ] 1 lr.coef_
array([0.97480486])

```

+ Code + Text

```

[ ] 1 lr.intercept_
2.5871238391784317

```

+ Code + Text

```

[ ] 1 y_pred = lr.predict(X_test)

```

+ Code + Text

```

[ ] 1 plt.plot(y_test, label="Actual Values")
[ ] 2 plt.plot(y_pred, label="Predicted Values")
[ ] 3 plt.legend()
[ ] 4 plt.show()

```

+ Code + Text

+ Code + Text

```

[ ] 1 model = ARIMA(y_train, order=(1,1,2))

```

+ Code + Text

```

[ ] 1 model_fit = model.fit()

```

```
[ ] 1 print(model_fit.summary())
SARIMAX Results
=====
Dep. Variable: y No. Observations: 200
Model: ARIMA(1, 1, 2) Log Likelihood: -451.844
Date: Sun, 27 Aug 2023 AIC: 911.689
Time: 10:55:36 BIC: 924.862
Sample: 0 - 200 HQIC: 917.020
Covariance Type: opg
=====
```

coef	std err	z	P> z	[0.025	0.975]	
ar.L1	-0.4444	0.301	-1.474	0.140	-1.035	0.146
ma.L1	0.4964	0.311	1.598	0.110	-0.113	1.105
ma.L2	-0.1230	0.095	-1.294	0.195	-0.309	0.063
sigma2	5.4898	0.396	13.852	0.000	4.713	6.267

Ljung-Box (L1) (Q): 0.00 Jarque-Bera (JB): 43.59  
Prob(Q): 0.98 Prob(JB): 0.00  
Heteroskedasticity (H): 0.56 Skew: -0.22  
Prob(H) (two-sided): 0.02 Kurtosis: 5.25

Warnings:  
[1] Covariance matrix calculated using the outer product of gradients (complex-step).

```
[ ] 1 arima_y_pred = model_fit.forecast(steps=len(y_test))

❶ 1 plt.figure(figsize=(20,6))
2 plt.plot(y_test, label="Actual Values")
3 plt.plot(arima_y_pred, label="ARIMA Predicted Values")
4 plt.title('Google Stock Price Prediction')
5 plt.xlabel('Time')
6 plt.ylabel('Google Stock Price')
7 plt.legend()
8 plt.show()
```

```
[ ] 1 import math
2 from sklearn.metrics import mean_squared_error, mean_absolute_error

❷ 1 # report performance
2 mse = mean_squared_error(y_test, arima_y_pred)
3 print("MSE: "+str(mse))
4
5 mae = mean_absolute_error(y_test, arima_y_pred)
6 print("MAE: "+str(mae))
7
8 rmse = math.sqrt(mean_squared_error(y_test, arima_y_pred))
9 print("RMSE: "+str(rmse))
10
11 mape = np.mean(np.abs(arima_y_pred - y_test)/np.abs(y_test))
12 print("MAPE: "+str(mape))

❸ MSE: 15.96584803707989
MAE: 3.092057823292232
RMSE: 3.995728724160324
MAPE: 0.024711890161486717
```

## RESULT

The implementation was successful.

# Experiment 6

## AIM

Implementing Autoregressive integrated moving average (ARIMA) model, also implement Auto- ARIMA model.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

AirPassengers.csv which is a flight dataset giving the no. of passengers over time with size (144 x 1).

## CODE AND OUTPUT

The screenshot shows the Google Colaboratory interface with the following structure:

- Search Bar:** TSA LAB 6: Auto ARIMA Model - Air Passengers Dataset
- Code Cell:** About the Dataset
- The dataset contains number of air passengers of each month from the year 1949 to 1960.
- Code Cell:** Import statements and dataset loading.
- First let's load the dataset and get a general overview.
- Code Cell:** Data preview using head command.

Month	Passengers
1949-01-01	112
1949-02-01	118
1949-03-01	132
1949-04-01	129
1949-05-01	121

- Code Cell:** Renaming the column and previewing again.

Month	Passengers
1949-01-01	112
1949-02-01	118
1949-03-01	132
1949-04-01	129
1949-05-01	121

- Code Cell:** Checking data shape.

(144, 1)

- Code Cell:** Describing the data.

	Passengers
count	144.000000
mean	280.298611
std	119.966317
min	104.000000
25%	180.000000
50%	265.500000
75%	360.500000
max	622.000000

```

[ ] 1 import matplotlib.pyplot as plt
2 from statsmodels.tsa.arima.model import ARIMA
3 import pandas as pd

{x}
[ ] 1 data = original
[ ] 1 data.dropna(inplace=True)

[ ] 1 train_size = int(len(data) * 0.80)

[ ] 1 y_train, y_test = data[0:train_size], data[train_size:]
[ ] 1 !pip install pmdarima
2
3 from pmdarima.arima import auto_arima

{x}
[ ] 1 model_autoARIMA = auto_arima(y_train, start_p=0, start_q=0,
2                                test='adf',      # use adftest to find optimal 'd'
3                                max_p=20, max_q=20, # maximum p and q
4                                m=1,           # frequency of series
5                                seasonal=False, # No Seasonality
6                                start_P=0,
7                                D=0,
8                                trace=True,
9                                error_action='ignore',
10                               suppress_warnings=True,
11                               stepwise=True)
12
13
14
15 print(model_autoARIMA.summary())
16 model_autoARIMA.plot_diagnostics(figsize=(15,8))
17 plt.show()
18

Performing stepwise search to minimize aic
ARIMA(0,0,0)[0,0,0][0] : AIC=1604.291, Time=0.02 sec
ARIMA(1,0,0)[0,0,0][0] : AIC=inf, Time=0.04 sec
ARIMA(0,0,1)[0,0,0][0] : AIC=inf, Time=0.07 sec
ARIMA(1,0,1)[0,0,0][0] : AIC=1079.817, Time=0.06 sec
ARIMA(2,0,1)[0,0,0][0] : AIC=1074.529, Time=0.07 sec
ARIMA(2,0,0)[0,0,0][0] : AIC=inf, Time=0.05 sec
ARIMA(3,0,1)[0,0,0][0] : AIC=1075.775, Time=0.11 sec
ARIMA(2,0,2)[0,0,0][0] : AIC=1075.654, Time=0.12 sec
ARIMA(1,0,2)[0,0,0][0] : AIC=1076.976, Time=0.08 sec
ARIMA(3,0,0)[0,0,0][0] : AIC=inf, Time=0.08 sec
ARIMA(3,0,2)[0,0,0][0] : AIC=inf, Time=0.28 sec
ARIMA(2,0,1)[0,0,0][0] intercept : AIC=1073.718, Time=0.38 sec
ARIMA(1,0,1)[0,0,0][0] intercept : AIC=1078.074, Time=0.14 sec
ARIMA(2,0,0)[0,0,0][0] intercept : AIC=1083.134, Time=0.21 sec
ARIMA(3,0,1)[0,0,0][0] intercept : AIC=1074.610, Time=0.41 sec
ARIMA(2,0,2)[0,0,0][0] intercept : AIC=1074.541, Time=0.44 sec
ARIMA(1,0,0)[0,0,0][0] intercept : AIC=1092.214, Time=0.08 sec
ARIMA(1,0,2)[0,0,0][0] intercept : AIC=1076.299, Time=0.22 sec
ARIMA(3,0,0)[0,0,0][0] intercept : AIC=1081.054, Time=0.22 sec
ARIMA(3,0,2)[0,0,0][0] intercept : AIC=inf, Time=0.36 sec

Best model: ARIMA(2,0,1)(0,0,0)[0] intercept
Total fit time: 3.495 seconds

```

**SARIMAX Results**

```

=====
Dep. Variable: y No. Observations: 115
Model: SARIMAX(2, 0, 1) Log Likelihood: -531.859
Date: Thu, 14 Sep 2023 AIC: 1073.718
Time: 05:00:54 BIC: 1087.443
Sample: 01-01-1949 HQIC: 1079.289
- 07-01-1958
Covariance Type: opg
=====

coef std err z P>|z| [0.025 0.975]
-----
intercept 12.5015 12.703 0.984 0.325 -12.396 37.399
ar.L1 0.4758 0.115 4.136 0.000 0.250 0.701
ar.L2 0.4765 0.122 3.912 0.000 0.238 0.715
ma.L1 0.9077 0.060 15.192 0.000 0.791 1.025
sigma2 587.7947 102.211 5.751 0.000 387.465 788.124
=====

Ljung-Box (L1) (Q): 0.12 Jarque-Bera (JB): 3.24
Prob(Q): 0.73 Prob(JB): 0.20
Heteroskedasticity (H): 4.88 Skew: 0.20
Prob(H) (two-sided): 0.00 Kurtosis: 2.28
=====
```

**Standardized residual**

**Normal Q-Q**

**Histogram plus estimated density**

**Correlogram**

```
[ ] 1 data.index.freq = 'MS'

⑤ 1 #Modeling
2 # Build Model
3 model = ARIMA(y_train, order=(3,0,2))
4 fitted = model.fit()
5 print(fitted.summary())

SARIMAX Results
=====
Dep. Variable: Passengers Observations: 115
Model: ARIMA(3, 0, 2) Log Likelihood: -531.307
Date: Thu, 14 Sep 2023 AIC: 1076.614
Time: 05:04:16 BIC: 1095.828
Sample: 01-01-1949 HQIC: 1084.413
Covariance Type: opg
=====
coef std err z P>|z| [0.025 0.975]
-----
const 240.0202 73.518 3.265 0.001 95.928 384.113
ar.L1 0.3270 0.975 0.335 0.737 -1.584 2.238
ar.L2 0.6475 0.417 1.554 0.120 -0.169 1.464
ar.L3 -0.0392 0.530 -0.074 0.941 -1.078 1.000
ma.L1 1.1032 0.987 1.118 0.264 -0.831 3.038
ma.L2 0.1447 0.924 0.157 0.876 -1.666 1.956
sigma2 581.4949 105.575 5.508 0.000 374.571 788.419
=====
Ljung-Box (L1) (Q): 0.00 Jarque-Bera (JB): 3.94
Prob(Q): 0.95 Prob(JB): 0.14
Heteroskedasticity (H): 5.11 Skew: 0.32
Prob(H) (two-sided): 0.00 Kurtosis: 2.36
=====

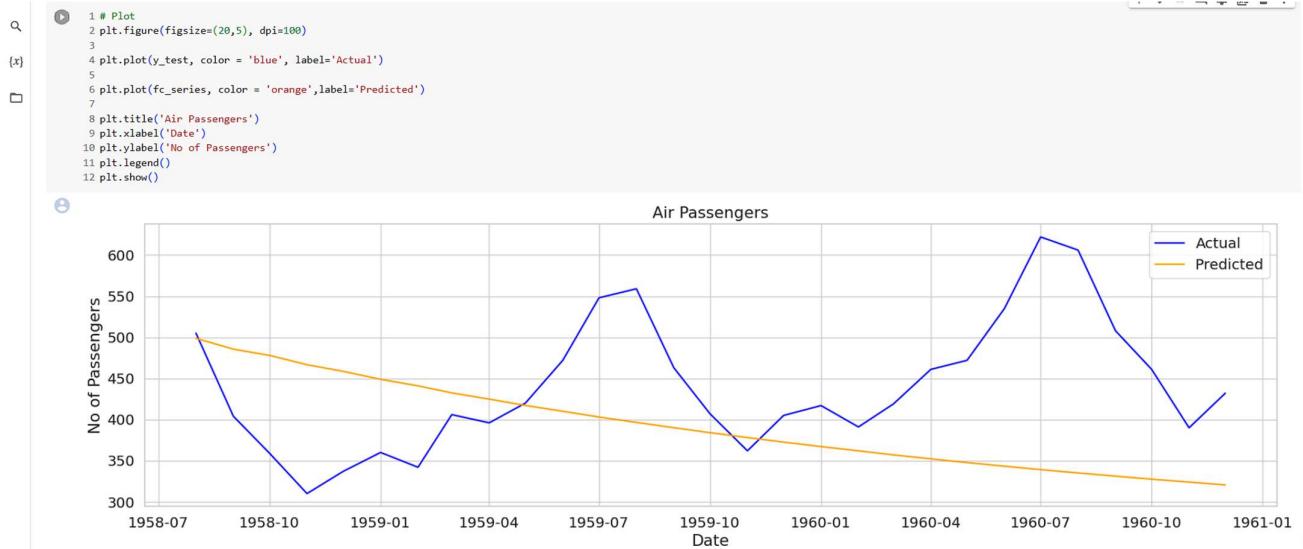
[ ] 1 data

Passengers
Month
1949-01-01 112
1949-02-01 118
1949-03-01 132
1949-04-01 129
1949-05-01 121
...
1960-08-01 606
1960-09-01 508
1960-10-01 461
1960-11-01 390
1960-12-01 432
144 rows × 1 columns

[ ] 1 index = data[train_size: ].index
2 y_train = data[0:train_size]
3 y_test = data[train_size:]

⑤ 1 # Forecast
2 fc = fitted.forecast(steps=len(y_test)) # 95% conf
3 # Make as pandas series
4 fc_series = pd.Series(fc, index=index)
5 # Plot
6 plt.figure(figsize=(20,5), dpi=100)
7
8 plt.plot(y_train, label='training data')
9
10 plt.plot(y_test, color = 'blue', label='Actual')
11
12 plt.plot(fc_series, color = 'orange',label='Predicted')
13
14 plt.title('Air Passenger')
15 plt.xlabel('Date')
16 plt.ylabel('No')
17 plt.legend()
18 plt.show()
19
```

Air Passenger



## RESULT

The implementation was successful.

# Experiment 7

AIM

## Implementing Random Forest Regressor Model for time series Forecasting

## **SOFTWARE USED**

# Google Colaboratory

## DATASET USED

Daily-total-female-births.csv is a female birth dataset on GitHub with size (365 x 2).

## CODE AND OUTPUT

- ▶ TSA LAB 7: Random Forest Regressor Model - Female Birth Dataset

```

Q [ ] 1 data.dropna(inplace=True)
(x) [ ] 2 train_size = int(len(data.x) * 0.80)
      3 train = data[0:train_size]
      4 test = data[train_size:len(data)]

[ ] 1 from sklearn.ensemble import RandomForestRegressor
      2 import numpy as np

[ ] 1 train = np.asarray(train)
      2 trainX, trainy = train[:, :-1], train[:, -1]
      3 model = RandomForestRegressor(n_estimators=1000)
      4 model.fit(trainX, trainy)

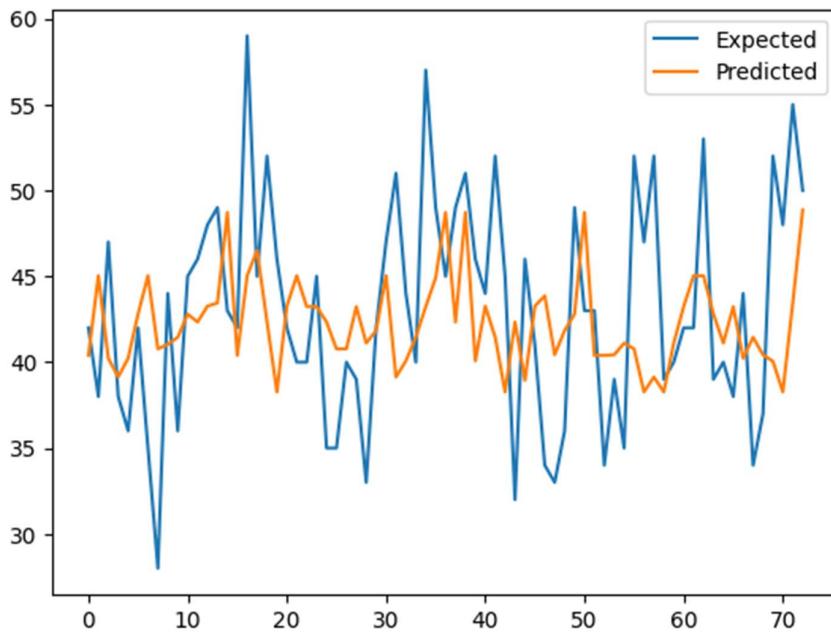
      RandomForestRegressor(n_estimators=1000)

[ ] 1 test = np.asarray(test)
      2 testX, testy = test[:, :-1], test[:, -1]
      3 yhat = model.predict(testX)

[ ] 1 import matplotlib.pyplot as plt

[ ] 1 plt.plot(testy, label='Expected')
      2 plt.plot(yhat, label='Predicted')
      3 plt.legend()
      4 plt.show()

```



## RESULT

The implementation was successful.

# Experiment 8

## AIM

Implementing 1D CNN for time series Forecasting.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

Webtraffic.csv is a web traffic session dataset with size (4896 x 2).

## CODE AND OUTPUT

```
[ ] 1 from google.colab import drive
2 drive.mount('/content/drive/')

{x} Drive already mounted at /content/drive/; to attempt to forcibly remount, call drive.mount("/content/drive/", force_remount=True).

[ ] 1 import pandas as pd
2 import numpy as np

[ ] 1 data = pd.read_csv('/content/drive/MyDrive/Hitesh TSA (CSE471) LAB Work/DATASETs/LAB 8/webtraffic (2).csv')

[ ] 1 data.shape
(4896, 2)

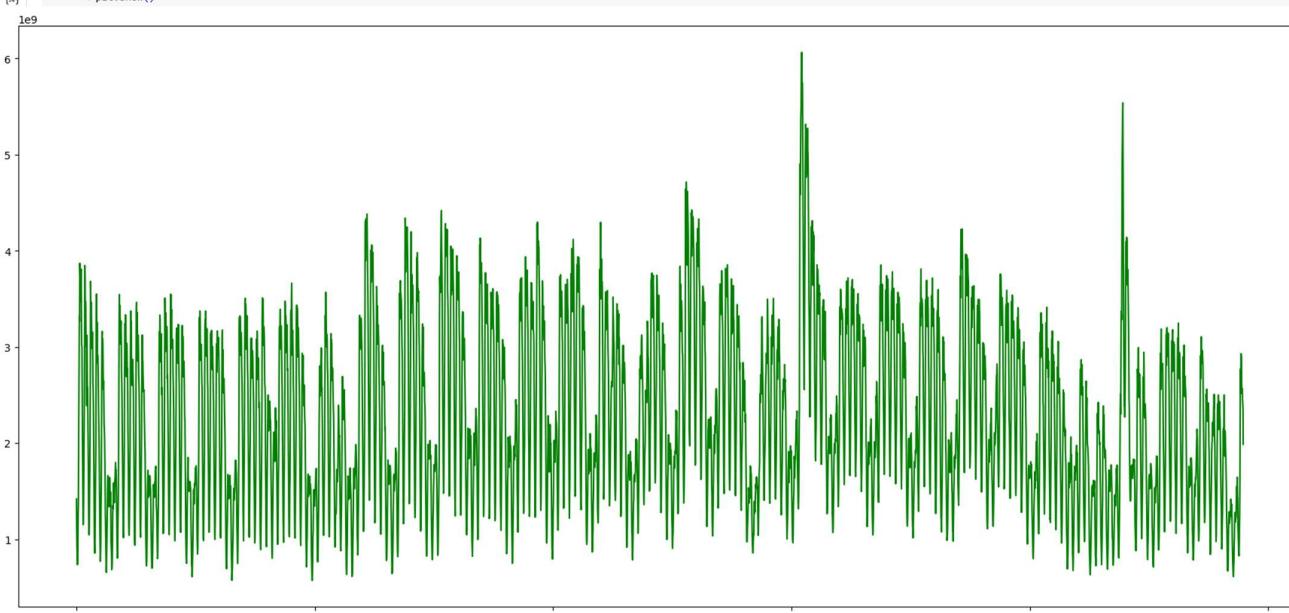
[ ] 1 data.head()

   Hour Index Sessions
0      0  1418159421
1      1  1113769116
2      2   919158921
3      3   822352824
4      4   735526737

[ ] 1 import matplotlib.pyplot as plt

[ ] 1 sessions = data['Sessions']

{x} 1 ar = np.arange(len(sessions))
2 plt.figure(figsize=(22,10))
3 plt.plot(ar, sessions,'g')
4 plt.show()
```





```

 1 #Define the optimizer and loss:
 2 model.compile(loss='mse',optimizer='adam')
 3 # Define the callback to save the best model during the training
 4 mc = ModelCheckpoint('best_model.hdf5', monitor='val_loss', verbose=1,
 5   save_best_only=True, mode='min')

[ ] 1 # Train the model for 30 epochs with batch size of 32:
2 history=model.fit(x_tr, y_tr ,epochs=30, batch_size=32, validation_data=(x_val,y_val),
3   callbacks=[mc])

[ ] Epoch 1/30
131/133 [=====>.....] - ETA: 0s - loss: 0.0867
Epoch 1: val_loss improved from inf to 0.03510, saving model to best_model.hdf5
133/133 [=====>.....] - 2s 14ms/step - loss: 0.0857 - val_loss: 0.0351
Epoch 2/30
10/133 [=>.....] - ETA: 1s - loss: 0.0302/usr/local/lib/python3.10/dist-packages/keras/src/engine/training.py:3000: UserWarning: You are saving your model as an HDF5 file via `mode=saving_api.save_model(
129/133 [=====>.....] - ETA: 0s - loss: 0.0254
Epoch 2: val_loss improved from 0.03510 to 0.02028, saving model to best_model.hdf5
133/133 [=====>.....] - 2s 12ms/step - loss: 0.0252 - val_loss: 0.0203
Epoch 3/30
130/133 [=====>.....] - ETA: 0s - loss: 0.0169
Epoch 3: val_loss improved from 0.02028 to 0.01930, saving model to best_model.hdf5
133/133 [=====>.....] - 2s 12ms/step - loss: 0.0171 - val_loss: 0.0193
Epoch 4/30
131/133 [=====>.....] - ETA: 0s - loss: 0.0147
Epoch 4: val_loss improved from 0.01930 to 0.01536, saving model to best_model.hdf5
133/133 [=====>.....] - 2s 15ms/step - loss: 0.0147 - val_loss: 0.0154
Epoch 5/30
131/133 [=====>.....] - ETA: 0s - loss: 0.0139
Epoch 5: val_loss did not improve from 0.01536
133/133 [=====>.....] - 2s 17ms/step - loss: 0.0139 - val_loss: 0.0158
Epoch 6/30
132/133 [=====>.....] - ETA: 0s - loss: 0.0123
Epoch 6: val_loss improved from 0.01536 to 0.01410, saving model to best_model.hdf5
133/133 [=====>.....] - 2s 13ms/step - loss: 0.0123 - val_loss: 0.0141
Epoch 7/30
133/133 [=====>.....] - ETA: 0s - loss: 0.0110
Epoch 7: val_loss did not improve from 0.01410
133/133 [=====>.....] - 2s 14ms/step - loss: 0.0110 - val_loss: 0.0146
Epoch 8/30
133/133 [=====>.....] - ETA: 0s - loss: 0.0109
Epoch 8: val_loss did not improve from 0.01410
133/133 [=====>.....] - 2s 18ms/step - loss: 0.0109 - val_loss: 0.0182
Epoch 9/30
130/133 [=====>.....] - ETA: 0s - loss: 0.0100
Epoch 9: val_loss did not improve from 0.01410
133/133 [=====>.....] - 2s 12ms/step - loss: 0.0100 - val_loss: 0.0160
Epoch 10/30
130/133 [=====>.....] - ETA: 0s - loss: 0.0087
Epoch 10: val_loss did not improve from 0.01410
133/133 [=====>.....] - 2s 12ms/step - loss: 0.0087 - val_loss: 0.0148
Epoch 11/30
130/133 [=====>.....] - ETA: 0s - loss: 0.0077
Epoch 11: val_loss did not improve from 0.01410
133/133 [=====>.....] - 2s 15ms/step - loss: 0.0077 - val_loss: 0.0160
Epoch 12/30
133/133 [=====>.....] - ETA: 0s - loss: 0.01341, saving model to best_model.hdf5
133/133 [=====>.....] - 2s 16ms/step - loss: 0.0076 - val_loss: 0.0134
Epoch 13/30
131/133 [=====>.....] - ETA: 0s - loss: 0.0066
Epoch 13: val_loss did not improve from 0.01341
133/133 [=====>.....] - 2s 12ms/step - loss: 0.0066 - val_loss: 0.0154
Epoch 14/30
130/133 [=====>.....] - ETA: 0s - loss: 0.0059
Epoch 14: val_loss did not improve from 0.01341
  
```

[ ] 1 model.load\_weights('best\_model.hdf5')

[ ] 1 mse = model.evaluate(x\_val,y\_val)
2 print("Mean Square Error:",mse)

[ ] 15/15 [=====>.....] - 0s 5ms/step - loss: 0.0134
Mean Square Error: 0.01340812351554632

```

[ ] 1 def forecast(x_val, no_of_pred, ind):
2   predictions[]
3   #initialize the array with previous weeks data
4   temp=x_val[ind]
5   for i in range(no_of_pred):
6     #predict for the next hour
7     pred=model.predict(temp.reshape(1,-1,1))[0][0]
8
9   #append the prediction as the last element of array
10  temp = np.insert(temp,len(temp),pred)
11  predictions.append(pred)
12  #ignore the first element of array
13  temp = temp[1:]
14  return predictions

[ ] 1 no_of_pred =24
2 ind=72
3 y_pred = forecast(x_val,no_of_pred,ind)
4 y_true = y_val[ind:ind+no_of_pred]

1/1 [=====>.....] - 0s 16ms/step
1/1 [=====>.....] - 0s 14ms/step
1/1 [=====>.....] - 0s 15ms/step
1/1 [=====>.....] - 0s 18ms/step
1/1 [=====>.....] - 0s 17ms/step
1/1 [=====>.....] - 0s 15ms/step
1/1 [=====>.....] - 0s 25ms/step
1/1 [=====>.....] - 0s 16ms/step
1/1 [=====>.....] - 0s 16ms/step
1/1 [=====>.....] - 0s 17ms/step
1/1 [=====>.....] - 0s 16ms/step
1/1 [=====>.....] - 0s 17ms/step
1/1 [=====>.....] - 0s 17ms/step
1/1 [=====>.....] - 0s 18ms/step
1/1 [=====>.....] - 0s 17ms/step
1/1 [=====>.....] - 0s 20ms/step
1/1 [=====>.....] - 0s 16ms/step
1/1 [=====>.....] - 0s 18ms/step
1/1 [=====>.....] - 0s 16ms/step
1/1 [=====>.....] - 0s 14ms/step
1/1 [=====>.....] - 0s 15ms/step
1/1 [=====>.....] - 0s 27ms/step
1/1 [=====>.....] - 0s 19ms/step
1/1 [=====>.....] - 0s 17ms/step
1/1 [=====>.....] - 0s 15ms/step

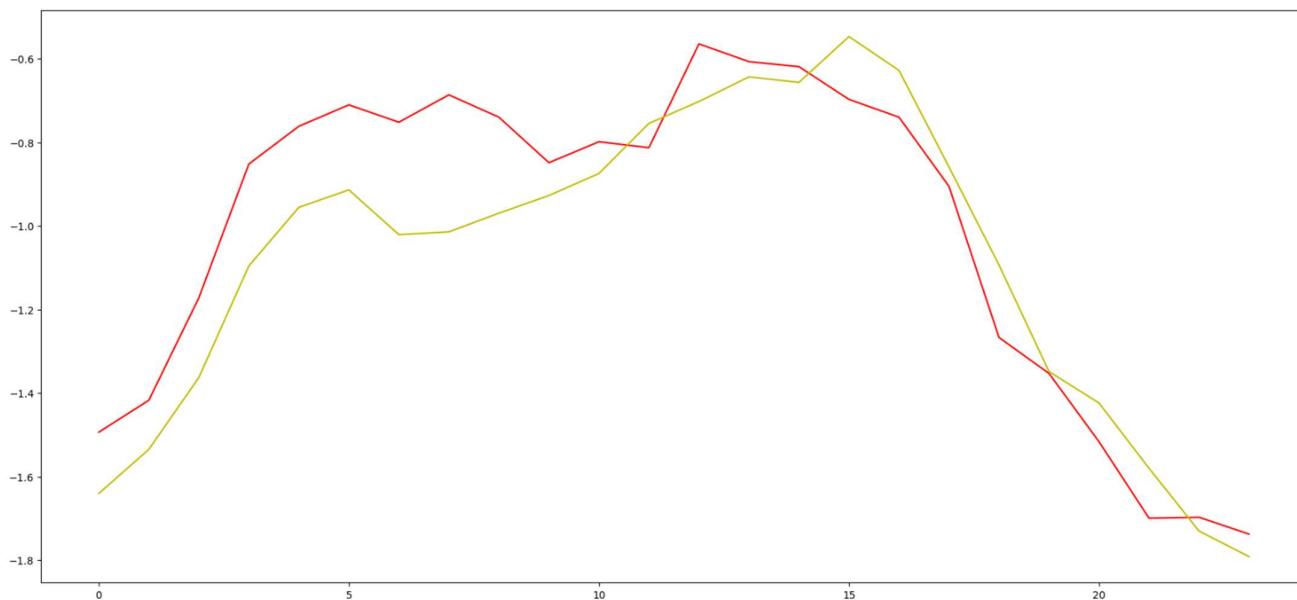
[ ] 1 type(y_pred)
list

[ ] 1 y_true = np.array(y_true)
2 y_pred = np.array(y_pred)

[ ] 1 # y_true= y_scaler.inverse_transform(y_true)
2 # y_pred= y_scaler.inverse_transform(y_pred)
3
4 y_true = y_true.reshape(-1, 1)
5 y_pred = y_pred.reshape(-1, 1)
  
```

```
[ ] 1 def plot(y_true,y_pred):
2     ar = np.arange(len(y_true))
3     plt.figure(figsize=(22,10))
4     plt.plot(ar, y_true,'r')
5     plt.plot(ar, y_pred,'y')
6     plt.show()
```

```
1 plot(y_true, y_pred)
```



## RESULT

The implementation was successful.

# Experiment 9

## AIM

Implementation of multivariate forecasting using Vector AutoRegressive (VAR) model.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

M2SLMoneyStock.csv is a money in stock dataset date wise with size (252 x 2).

PCEPersonalSpending.csv is a personal spending dataset date wise with size (252 x 2).

## CODE AND OUTPUT

### 1. Examine the data

```
(x) 1 # import necessary libraries (numpy, pandas, matplotlib)
2
3 import numpy as np
4 import pandas as pd
5 import matplotlib.pyplot as plt
[ ] 1 from google.colab import drive
2 drive.mount('/content/drive/')

Drive already mounted at /content/drive/; to attempt to forcibly remount, call drive.mount("/content/drive/", force_remount=True).

[ ] 1 #Now read the dataset
2
3 money_df = pd.read_csv('/content/drive/MyDrive/Hitesh TSA (CSE471) LAB Work/DATASETs/LAB 9/M2SLMoneyStock.csv', parse_dates = ['Date']) #read 'M2SLMoneyStock.csv'
4 spending_df = pd.read_csv('/content/drive/MyDrive/Hitesh TSA (CSE471) LAB Work/DATASETs/LAB 9/PCEPersonalSpending.csv', parse_dates = ['Date']) #read 'PCEPersonalSpending.csv'
5 df = money_df.merge(spending_df)
6 # df.to_csv('var_data.csv')

[ ] 1 df

(x) 1 df
   Date    Money  Spending
0  1995-01-01  3492.4   4851.2
1  1995-02-01  3489.9   4850.8
2  1995-03-01  3491.1   4885.4
3  1995-04-01  3499.2   4890.2
4  1995-05-01  3524.2   4933.1
...
247 ... ...
248 2015-08-01  12096.8  12394.0
249 2015-09-01  12153.8  12392.8
250 2015-10-01  12187.7  12416.1
251 2015-11-01  12277.4  12450.1
251 2015-12-01  12335.9  12469.1
252 rows × 3 columns

[ ] 1 df = df.set_index('Date')

[ ] 1 df.index = pd.to_datetime(df.index)

[ ] 1 # preview using head
2 df.head()

(x) 1 df
   Date    Money  Spending
0  1995-01-01  3492.4   4851.2
1  1995-02-01  3489.9   4850.8
2  1995-03-01  3491.1   4885.4
3  1995-04-01  3499.2   4890.2
4  1995-05-01  3524.2   4933.1
```

## 2.Check for Stationarity

```
[ ] 1 # Check both the features (Money,Spending ) whether they are stationary or not. using ADF test
[ ] 2 # perform differencing if non stationary

[ ] 1 from statsmodels.tsa.stattools import adfuller

[ ] 1 def adf_test(series,title=''):
[ ] 2     """
[ ] 3     Pass in a time series and an optional title, returns an ADF report
[ ] 4     """
[ ] 5     print(f'Augmented Dickey-Fuller Test: {title}')
[ ] 6     result = adfuller(series.dropna(),autolag='AIC') # .dropna() handles differenced data
[ ] 7     labels = ['ADF test statistic','p-value','# lags used','# observations']
[ ] 8     out = pd.Series(result[0:4],index=labels)
[ ] 9     for key,value in result[4].items():
[ ] 10         out[f'critical value ({key})']=value
[ ] 11     print(out.to_string())          # .to_string() removes the line "dtype: float64"
[ ] 12     if result[1] <= 0.05:
[ ] 13         print("Strong evidence against the null hypothesis")
[ ] 14         print("Reject the null hypothesis")
[ ] 15         print("Data has no unit root and is stationary")
[ ] 16     else:
[ ] 17         print("Weak evidence against the null hypothesis")
[ ] 18         print("Fail to reject the null hypothesis")
[ ] 19         print("Data has a unit root and is non-stationary")
```

```
[ ] 1 adf_test(df['Money'])
```

```
Augmented Dickey-Fuller Test:
ADF test statistic      4.239022
p-value                  1.000000
# lags used                4.000000
# observations            247.000000
critical value (1%)    -3.457105
critical value (5%)    -2.873314
critical value (10%)   -2.573044
Weak evidence against the null hypothesis
Fail to reject the null hypothesis
Data has a unit root and is non-stationary
```

```
[ ] 1 adf_test(df['Spending'])
```

```
Augmented Dickey-Fuller Test:
ADF test statistic      0.149796
p-value                  0.999304
# lags used                3.000000
# observations            248.000000
critical value (1%)    -3.456996
critical value (5%)    -2.873266
critical value (10%)   -2.573019
Weak evidence against the null hypothesis
Fail to reject the null hypothesis
Data has a unit root and is non-stationary
```

+ Code + Text

```
[ ] 1 df_difference = df.diff()
[ ] 1 adf_test(df_difference['Money'])
```

```
Augmented Dickey-Fuller Test:
ADF test statistic      -2.857404
p-value                  0.261984
# lags used                15.000000
# observations            235.000000
critical value (1%)    -3.454947
critical value (5%)    -2.873919
critical value (10%)   -2.573267
Weak evidence against the null hypothesis
Fail to reject the null hypothesis
Data has a unit root and is non-stationary
```

```
[ ] 1 adf_test(df_difference['Spending'])
```

```
Augmented Dickey-Fuller Test:
ADF test statistic      -7.226974e+00
p-value                  2.041027e-10
# lags used                2.000000e+00
# observations            2.480000e+02
critical value (1%)    -3.456996e+00
critical value (5%)    -2.873266e+00
critical value (10%)   -2.573019e+00
Strong evidence against the null hypothesis
Reject the null hypothesis
Data has no unit root and is stationary
```

```
[ ] 1 df_difference['Money'] = df_difference['Money'].diff()
```

```
[ ] 1 adf_test(df_difference['Money'])
```

```
Augmented Dickey-Fuller Test:
ADF test statistic      -7.077471e+00
p-value                  4.760675e-10
# lags used                1.400000e+01
# observations            2.350000e+02
critical value (1%)    -3.458487e+00
critical value (5%)    -2.873919e+00
critical value (10%)   -2.573367e+00
Strong evidence against the null hypothesis
Reject the null hypothesis
Data has no unit root and is stationary
```

## 3. Train-Test Split

```
[ ] 1 #use the last 1 year of data as a test set (last 12 months).
[ ] 2 df_difference = df_difference.dropna()

[ ] 1 test_obs = 12
[ ] 2 train = df_difference[:-test_obs]
[ ] 3 test = df_difference[-test_obs:]
```

#### 4. Grid Search for Order P

```
[x] [ ] 1 from statsmodels.tsa.api import VAR
2
[ ] 1 for i in [1,2,3,4,5,6,7,8,9,10]:
2     model = VAR(train)
3     results = model.fit(i)
4     print('Order =', i)
5     print('AIC:', results.aic)
6     print('BIC:', results.bic)
7     print()

Order = 1
AIC: 13.893730044437806
BIC: 13.981529035352619

Order = 2
AIC: 13.788978767127503
BIC: 13.935751301238756

Order = 3
AIC: 13.800828407726483
BIC: 14.00693137452656

Order = 4
AIC: 13.705254945442732
BIC: 13.971048877393326

Order = 5
AIC: 13.702894884622165
BIC: 14.028744008931731

Order = 6
AIC: 13.716410512160271
BIC: 14.102682803812531

Order = 7
AIC: 13.722463221920354
BIC: 14.169536457653054

[x] [ ] Order = 8
AIC: 13.72242698338018
BIC: 14.230664794264479

{x}
Order = 9
AIC: 13.706168588518498
BIC: 14.2795956519239289

Order = 10
AIC: 13.744769881188871
BIC: 14.37649144441732
```

#### 5. Fit VAR(5) Model

```
[x] [ ] 1 #fit the model and check the summary
2 result = model.fit(5)
3 result.summary()

Summary of Regression Results
=====
Model: VAR
Method: OLS
Date: Thu, 12, Oct, 2023
Time: 05:17:04

No. of Equations: 2.000000 BIC: 14.0287
Nobs: 233.000 HQIC: 13.8343
Log likelihood: -2235.61 FPE: 893620.
AIC: 13.7029 Det(Omega_mle): 814863.

Results for equation Money
=====
            coefficient    std. error      t-stat      prob
-----
const      -1.884757   3.499904    -0.539      0.590
L1.Money   -0.643407   0.068285    -9.422      0.000
L1.Spending -0.087249   0.054567    -1.599      0.110
L2.Money   -0.474297   0.075784    -6.259      0.000
L2.Spending -0.054360   0.053759    -1.011      0.312
L3.Money   -0.211375   0.079796    -2.649      0.008
L3.Spending 0.046893   0.053758    0.872      0.383
L4.Money   -0.275523   0.074641    -3.691      0.000
L4.Spending 0.174959   0.053884    3.248      0.001
L5.Money   -0.150267   0.066905    -2.246      0.025
L5.Spending -0.002255   0.055359    -0.041      0.968

Results for equation Spending
=====
            coefficient    std. error      t-stat      prob
-----
const      21.154909   4.395485    4.813      0.000
L1.Money   0.181967   0.085758    2.122      0.034
L1.Spending 0.006734   0.068530    0.098      0.922
L2.Money   0.094763   0.095176    0.996      0.319
L2.Spending 0.159329   0.067515    2.360      0.018
L3.Money   -0.009984   0.100215    -0.100      0.921
L3.Spending 0.144107   0.067514    2.134      0.033
L4.Money   -0.173935   0.093740    -1.855      0.064
L4.Spending 0.050403   0.067672    0.745      0.456
L5.Money   -0.111008   0.084025    -1.321      0.186
L5.Spending -0.054571   0.069525    -0.785      0.432

Correlation matrix of residuals
    Money  Spending
Money   1.000000 -0.246978
Spending -0.246978 1.000000
```

## 6 Predict Test Data

```
[ ] 1 # VAR .forecast() function requires that we pass in a lag order number of previous observations.  
2 lagged_Values = train.values[-8:]  
3 pred = result.forecast(y=lagged_Values, steps=12)  
4  
5 idx = pd.date_range('2015-01-01', periods=12, freq='MS')  
6 df_forecast=pd.DataFrame(data=pred, index=idx, columns=['money2d', 'spending2d'])
```

## 7. Invert the transformation

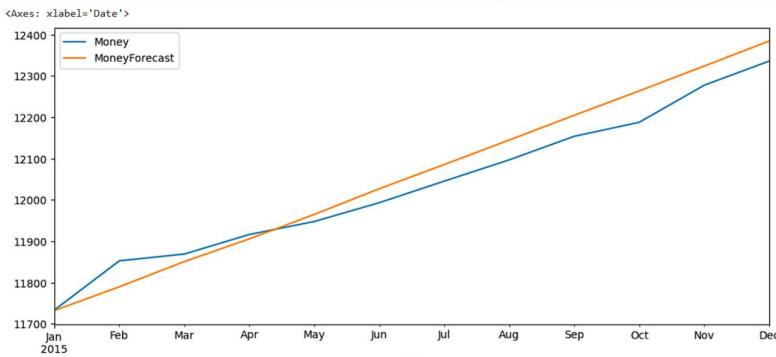
```
[ ] 1 #We have to note that the forecasted value is a second-order difference. To get it similar to original data we have to roll back each difference. This can be done by taking the most recent values of the  
2  
[ ] 1 df_forecast['MoneyId1'] = (df['Money'].iloc[-test_obs-1]-df['Money'].iloc[-test_obs-2]) + df_forecast['money2d'].cumsum()  
2 df_forecast['MoneyForecast'] = df['Money'].iloc[-test_obs-1] + df_forecast['MoneyId1'].cumsum()  
3  
[ ] 1 df_forecast['SpendingId1'] = (df['Spending'].iloc[-test_obs-1]-df['Spending'].iloc[-test_obs-2]) + df_forecast['spending2d'].cumsum()  
2 df_forecast['SpendingForecast'] = df['Spending'].iloc[-test_obs-1] + df_forecast['SpendingId1'].cumsum()
```

## Plot the result

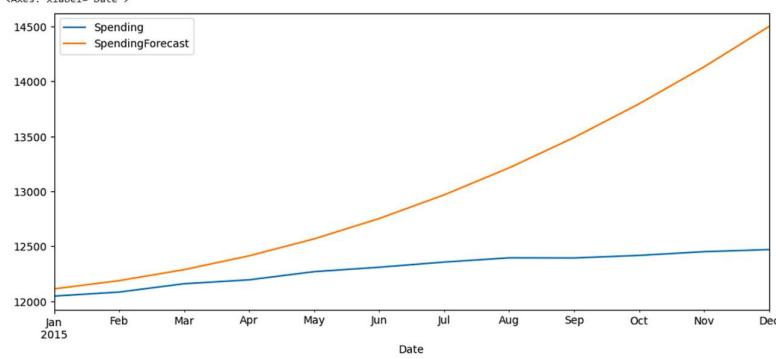
```
[x] 1 #plot the predicted v/s original values of 'Money' and 'Spending' for test data.
```

+ Code + Text

```
[ ] 2  
3 test_original = df[-test_obs:]  
4 test_original.index = pd.to_datetime(test_original.index)  
5 test_original['Money'].plot(figsize=(12,5),legend=True)  
6 df_forecast['MoneyForecast'].plot(legend=True)
```



```
[ ] 1 test_original['Spending'].plot(figsize=(12,5),legend=True)  
2 df_forecast['SpendingForecast'].plot(legend=True)
```



## RESULT

The implementation was done successfully.

# Experiment 10

## AIM

Time series forecasting using Recurrent neural network (RNN) and LSTM (Long short-term memory).

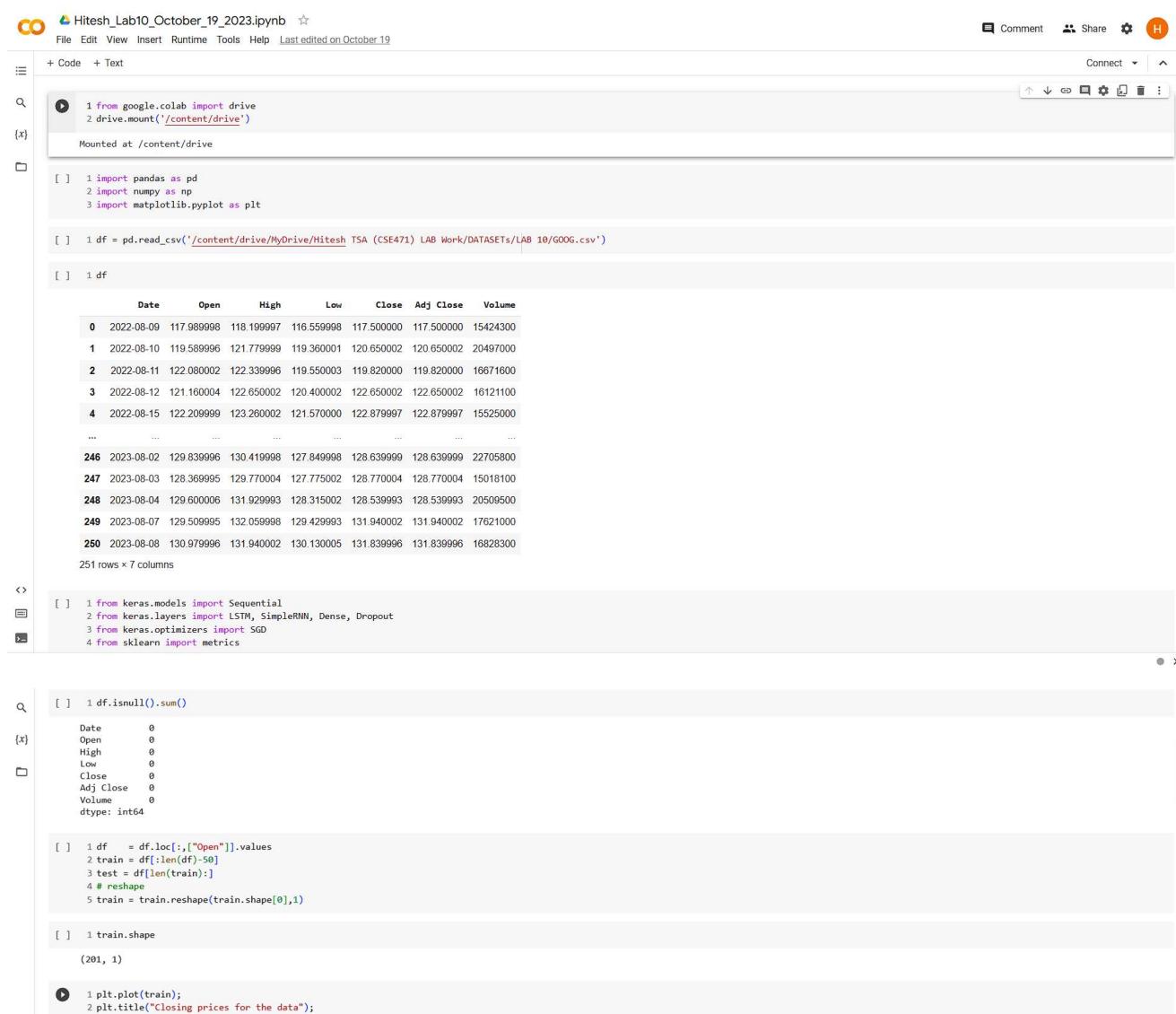
## SOFTWARE USED

Google Colaboratory

## DATASET USED

GOOG.csv is the google stock price dataset with size (251 x 7).

## CODE AND OUTPUT



The screenshot shows a Google Colaboratory notebook titled "Hitesh\_Lab10\_October\_19\_2023.ipynb". The code cell displays the following Python script:

```
1 from google.colab import drive
2 drive.mount('/content/drive')
3
4 # Mounting Google Drive
5
6 df = pd.read_csv('/content/drive/MyDrive/Hitesh_TSA (CSF471) LAB Work/DATASETS/LAB 10/GOOG.csv')
7
8 df
```

The output cell shows the first few rows of the "df" DataFrame:

	Date	Open	High	Low	Close	Adj Close	Volume
0	2022-08-09	117.889996	118.199997	116.559998	117.500000	117.500000	15424300
1	2022-08-10	119.589996	121.779999	119.360001	120.650002	120.650002	20497000
2	2022-08-11	122.080002	122.339996	119.550003	119.820000	119.820000	16671600
3	2022-08-12	121.160004	122.650002	120.400002	122.650002	122.650002	16121100
4	2022-08-15	122.209999	123.260002	121.570000	122.879997	122.879997	15525000
...	...	...	...	...	...	...	...
246	2023-08-02	129.839996	130.419988	127.849998	128.639999	128.639999	22705800
247	2023-08-03	128.369995	129.770004	127.775002	128.770004	128.770004	15018100
248	2023-08-04	129.600006	131.929993	128.315002	128.539993	128.539993	20509500
249	2023-08-07	129.509995	132.059998	129.429993	131.940002	131.940002	17621000
250	2023-08-08	130.979996	131.940002	130.130005	131.839996	131.839996	16828300

251 rows × 7 columns

The code cell continues with:

```
1 df.isnull().sum()
```

The output cell shows the sum of null values for each column:

	Date	Open	High	Low	Close	Adj Close	Volume
(x)	0	0	0	0	0	0	0

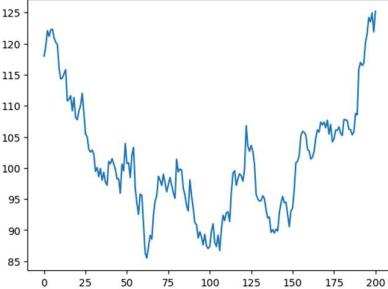
The code cell continues with:

```
1 df = df.loc[:,["Open"]].values
2 train = df[:len(df)-50]
3 test = df[len(train):]
4 # reshape
5 train = train.reshape((train.shape[0],1))

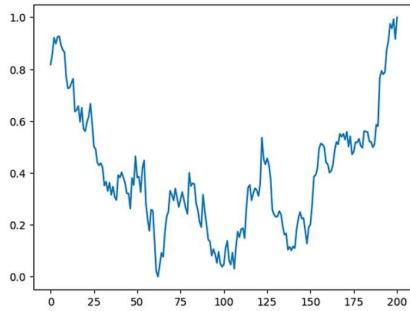
1 train.shape
(201, 1)

1 plt.plot(train);
2 plt.title("Closing prices for the data");
```

Closing prices for the data



```
[ ] 1 from sklearn.preprocessing import MinMaxScaler
2 scaler = MinMaxScaler(feature_range= (0,1)) # defining of Scaler
3 train_scaled = scaler.fit_transform(train) # applying to Scaler to train
4
5 plt.plot(train_scaled)
6 plt.show()
```



```
[ ] 1 # We add first 50 location to "X_train" and we 51. location to "y_train" .
2 X_train = []
3 y_train = []
4 timesteps = 50
5
6 for i in range(timesteps, train_scaled.shape[0]):
7     X_train.append(train_scaled[i-timesteps:i,0])
8     y_train.append(train_scaled[i,0])
9
10 X_train, y_train = np.array(X_train), np.array(y_train)
11
12
13 # Reshaping
14 X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1) # Dimension of array is 3.
```

```
[ ] 1 # Initialising the RNN
2 regressor = Sequential()
3
4 # Adding the first RNN layer and some Dropout regularisation
5 regressor.add(SimpleRNN(units = 50,activation='tanh', return_sequences = True, input_shape = (X_train.shape[1], 1)))
6 regressor.add(Dropout(0.2))
7
8 # Adding a second RNN layer and some Dropout regularisation.
9 regressor.add(SimpleRNN(units = 50,activation='tanh', return_sequences = True))
10 regressor.add(Dropout(0.2))
11
12 # Adding a third RNN layer and some Dropout regularisation.
13 regressor.add(SimpleRNN(units = 50,activation='tanh', return_sequences = True))
14 regressor.add(Dropout(0.2))
15
16 # Adding a fourth RNN layer and some Dropout regularisation.
17 regressor.add(SimpleRNN(units = 50))
18 regressor.add(Dropout(0.2))
19
20
21 # Adding the output layer
22 regressor.add(Dense(units = 1))
23
24 # Compiling the RNN
25 regressor.compile(optimizer = 'adam', loss = 'mean_squared_error')
```

```
[ ] 27 # Fitting the RNN to the Training set
28 regressor.fit(X_train, y_train, epochs = 100, batch_size = 32)

Epoch 1/100
5/5 [=====] - 0s 49ms/step - loss: 0.5492
Epoch 2/100
5/5 [=====] - 0s 48ms/step - loss: 0.3743
Epoch 3/100
5/5 [=====] - 0s 45ms/step - loss: 0.4023
Epoch 4/100
5/5 [=====] - 0s 67ms/step - loss: 0.2737
Epoch 5/100
5/5 [=====] - 0s 83ms/step - loss: 0.2703
Epoch 6/100
5/5 [=====] - 0s 90ms/step - loss: 0.2487
Epoch 7/100
5/5 [=====] - 0s 82ms/step - loss: 0.3351
Epoch 8/100
5/5 [=====] - 0s 78ms/step - loss: 0.2058
Epoch 9/100
5/5 [=====] - 0s 80ms/step - loss: 0.2488
Epoch 10/100
5/5 [=====] - 0s 87ms/step - loss: 0.3697
Epoch 11/100
5/5 [=====] - 0s 93ms/step - loss: 0.2268
Epoch 12/100
5/5 [=====] - 0s 91ms/step - loss: 0.2558
Epoch 13/100
5/5 [=====] - 0s 84ms/step - loss: 0.2247
Epoch 14/100
5/5 [=====] - 0s 86ms/step - loss: 0.2522
Epoch 15/100
5/5 [=====] - 0s 43ms/step - loss: 0.2040
Epoch 16/100
5/5 [=====] - 0s 41ms/step - loss: 0.2210
```

```

Epoch 17/100
5/5 [=====] - 0s 47ms/step - loss: 0.1628
Epoch 18/100
5/5 [=====] - 0s 43ms/step - loss: 0.1975
Epoch 19/100
5/5 [=====] - 0s 44ms/step - loss: 0.1766
Epoch 20/100
5/5 [=====] - 0s 46ms/step - loss: 0.1917
Epoch 21/100
5/5 [=====] - 0s 41ms/step - loss: 0.1418
Epoch 22/100
5/5 [=====] - 0s 46ms/step - loss: 0.1707
Epoch 23/100
5/5 [=====] - 0s 42ms/step - loss: 0.1471
Epoch 24/100
5/5 [=====] - 0s 45ms/step - loss: 0.1402
Epoch 25/100
5/5 [=====] - 0s 48ms/step - loss: 0.1194
Epoch 26/100
5/5 [=====] - 0s 50ms/step - loss: 0.1276
Epoch 27/100
5/5 [=====] - 0s 46ms/step - loss: 0.1199
Epoch 28/100
5/5 [=====] - 0s 42ms/step - loss: 0.1137
Epoch 29/100
5/5 [=====] - 0s 43ms/step - loss: 0.1204

[ ] 1 inputs = df[len(df) - len(test) - timesteps:]
2 inputs = scaler.transform(inputs) # min max scaler

[ ] 1 X_test = []
2 for i in range(timesteps, inputs.shape[0]):
3     X_test.append(inputs[i-timesteps:, 0]) # 0 dan 50 ye, 1 den 51 e gibi kaydirarak 50 elemen aliyoruz
4 X_test = np.array(X_test)
5 X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

[ ] 1 predicted_data = regressor.predict(X_test)
2 predicted_data = scaler.inverse_transform(predicted_data)

2/2 [=====] - 1s 29ms/step

[ ] 1 plt.figure(figsize=(8,4), dpi=80, facecolor='w', edgecolor='k')
2 plt.plot(test,color="orange",label="Real value")
3 plt.plot(predicted_data,color="c",label="RNN predicted result")
4 plt.legend()
5 plt.xlabel("Days")
6 plt.ylabel("Values")
7 plt.grid(True)
8 plt.show()



```

```

[ ] 1 from keras.models import Sequential
2 from keras.layers import Dense
3 from keras.layers import LSTM
4 from sklearn.preprocessing import MinMaxScaler
5 from sklearn.metrics import mean_squared_error

[ ] 1 model = Sequential()
2 model.add(LSTM(10, input_shape=(None,1)))
3 model.add(Dense(1))
4 model.compile(loss="mean_squared_error",optimizer='Adam')
5 model.fit(X_train,y_train,epochs=50, batch_size=1)

Epoch 1/50
151/151 [=====] - 4s 9ms/step - loss: 0.0897
Epoch 2/50
151/151 [=====] - 2s 15ms/step - loss: 0.0258
Epoch 3/50
151/151 [=====] - 4s 27ms/step - loss: 0.0179
Epoch 4/50
151/151 [=====] - 3s 21ms/step - loss: 0.0142
Epoch 5/50
151/151 [=====] - 2s 10ms/step - loss: 0.0120
Epoch 6/50
151/151 [=====] - 2s 10ms/step - loss: 0.0103
Epoch 7/50
151/151 [=====] - 2s 11ms/step - loss: 0.0092
Epoch 8/50
151/151 [=====] - 1s 9ms/step - loss: 0.0086
Epoch 9/50
151/151 [=====] - 2s 11ms/step - loss: 0.0082
Epoch 10/50
151/151 [=====] - 2s 13ms/step - loss: 0.0073
Epoch 11/50
151/151 [=====] - 4s 25ms/step - loss: 0.0071
Epoch 12/50
151/151 [=====] - 2s 12ms/step - loss: 0.0064
Epoch 13/50
151/151 [=====] - 1s 9ms/step - loss: 0.0063
Epoch 14/50
151/151 [=====] - 1s 9ms/step - loss: 0.0058
Epoch 15/50
151/151 [=====] - 1s 9ms/step - loss: 0.0057
Epoch 16/50
151/151 [=====] - 2s 10ms/step - loss: 0.0053
Epoch 17/50

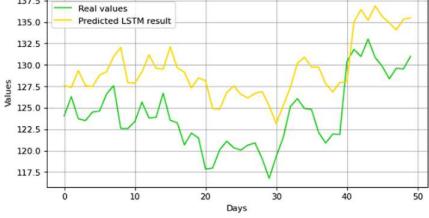
```

```

Epoch 18/50
151/151 [=====] - 2s 13ms/step - loss: 0.0053
Epoch 19/50
151/151 [=====] - 2s 16ms/step - loss: 0.0049
Epoch 20/50
151/151 [=====] - 2s 11ms/step - loss: 0.0049
Epoch 21/50
151/151 [=====] - 1s 9ms/step - loss: 0.0047
Epoch 22/50
151/151 [=====] - 1s 10ms/step - loss: 0.0046
Epoch 23/50
151/151 [=====] - 1s 9ms/step - loss: 0.0044
Epoch 24/50
151/151 [=====] - 2s 11ms/step - loss: 0.0043
Epoch 25/50
151/151 [=====] - 2s 10ms/step - loss: 0.0043
Epoch 26/50
151/151 [=====] - 2s 11ms/step - loss: 0.0042
Epoch 27/50
151/151 [=====] - 4s 29ms/step - loss: 0.0042
Epoch 28/50
151/151 [=====] - 2s 10ms/step - loss: 0.0038
Epoch 29/50
151/151 [=====] - 1s 9ms/step - loss: 0.0039
[ ] 1 predicted_data2=model.predict(X_test)
2 predicted_data2=scaler.inverse_transform(predicted_data2)

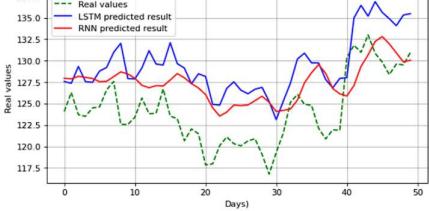
2/2 [=====] - 0s 9ms/step

[ ] 1 plt.figure(figsize=(8,4), dpi=80, facecolor='w', edgecolor='k')
2 plt.plot(test,color="LimeGreen",label="Real values")
3 plt.plot(predicted_data2,color="Gold",label="Predicted LSTM result")
4 plt.legend()
5 plt.xlabel("Days")
6 plt.ylabel("Values")
7 plt.grid(True)
8 plt.show()

[ ] 
[ ] 137.5
[ ] 135.0
[ ] 132.5
[ ] 130.0
[ ] 127.5
[ ] 125.0
[ ] 122.5
[ ] 120.0
[ ] 117.5
[ ] Values
[ ] 0 10 20 30 40 50
[ ] Days

[ ] + Code + Text

[ ] 1 plt.figure(figsize=(8,4), dpi=80, facecolor='w', edgecolor='k')
2 plt.plot(test,color="green", linestyle='dashed',label="Real values")
3 plt.plot(predicted_data2,color="blue", label="LSTM predicted result")
4 plt.plot(predicted_data,color="red",label="RNN predicted result") # ben ekledim
5 plt.legend()
6 plt.xlabel("Days")
7 plt.ylabel("Real values")
8 plt.grid(True)
9 plt.show()

[ ] 
[ ] 137.5
[ ] 135.0
[ ] 132.5
[ ] 130.0
[ ] 127.5
[ ] 125.0
[ ] 122.5
[ ] 120.0
[ ] 117.5
[ ] Real values
[ ] 0 10 20 30 40 50
[ ] Days

```

## RESULT

The implementation was done successfully.

# OPEN ENDED EXPERIMENT

## AIM

Time series forecasting of blood volume pulse readings using ARIMA model.

## SOFTWARE USED

Google Colaboratory

## DATASET USED

BVP.csv is a blood volume pulse readings dataset from PPG sensor module with size (439209 × 1).

## CODE AND OUTPUT

```
[1] # import pandas, numpy, matplotlib
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

[2] from google.colab import drive
drive.mount('/content/drive')

Mounted at /content/drive

[3] # bvp = pd.read_csv("BVP.csv")
df = pd.read_csv("/content/drive/MyDrive/dataset/stress_detection/S2/BVP.csv")

df.rename(columns = {"1502190787.00": "value"}, inplace=True)

df
```

	value
0	64.00
1	-0.00
2	-0.00
3	-0.00
4	-0.00
...	...
439204	-53.55
439205	-50.61
439206	-46.53
439207	-41.65
439208	-36.33

439209 rows × 1 columns

```
[261] df = df[200:700]

df
```

	value
200	2.07
201	2.28
202	2.51
203	2.78
204	3.06
...	...
495	-10.18
496	-7.94
497	-5.25
498	-2.26
499	0.80

300 rows × 1 columns

```
[2] from statsmodels.tsa.stattools import adfuller
from numpy import log
result = adfuller(df.value.dropna())
print('ADF Statistic: %f' % result[0])
print('p-value: %f' % result[1])

ADF Statistic: -4.183678
p-value: 0.000702
```

```

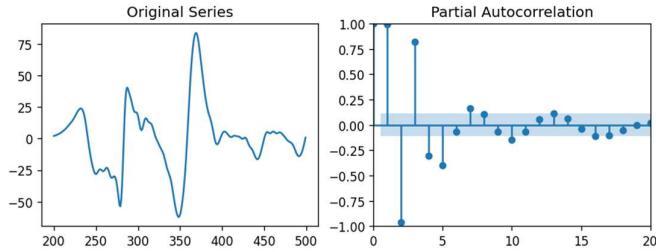
Q [298] # PACF plot of Original series
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf

plt.rcParams.update({'figure.figsize':(9,3), 'figure.dpi':120})

fig, axes = plt.subplots(1, 2, sharex=False)
axes[0].plot(df.value); axes[0].set_title('Original Series')
axes[1].set(ylim=(0,5), xlim=(0,20))
plot_pacf(df.value, ax=axes[1])

plt.show()

```



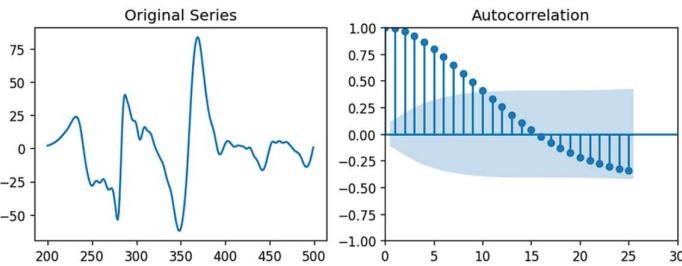
```

Q [265] from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
plt.rcParams.update({'figure.figsize':(9,3), 'figure.dpi':120})

fig, axes = plt.subplots(1, 2, sharex=False)
axes[0].plot(df.value); axes[0].set_title('Original Series')
axes[1].set(ylim=(0,1.2), xlim=(0,30))
plot_acf(df.value.dropna(), ax=axes[1])

plt.show()

```



```

Q [267] # 3,0,5 ARIMA Model
model = ARIMA(df.value, order=(3,0,5))
model_fit = model.fit()
print(model_fit.summary())

/usr/local/lib/python3.10/dist-packages/statsmodels/tsa/statespace/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found. Using zeros as starting parameters.
warn('Non-invertible starting MA parameters found.')
SARIMAX Results
=====
Dep. Variable: value No. Observations: 300
Model: ARIMA(3, 0, 5) Log Likelihood: -310.231
Date: Wed, 25 Oct 2023 AIC: -600.462
Time: 11:51:08 BIC: -563.424
Sample: 0 HQIC: -585.640
- 300
Covariance Type: opg
=====

```

	coef	std err	z	P> z	[0.025	0.975]
const	0.2879	10.371	0.028	0.978	-20.038	20.614
ar.L1	2.6284	0.026	102.442	0.000	2.578	2.679
ar.L2	-2.3851	0.050	-47.496	0.000	-2.484	-2.287
ar.L3	0.7513	0.026	28.538	0.000	0.700	0.803
ma.L1	1.9801	0.049	40.686	0.000	1.885	2.076
ma.L2	2.5652	0.048	53.743	0.000	2.632	2.978
ma.L3	2.5670	0.109	23.241	0.000	2.354	2.789
ma.L4	1.5738	0.067	18.006	0.000	1.402	1.745
ma.L5	0.5830	0.050	11.772	0.000	0.486	0.680
sigma2	0.0067	0.001	13.049	0.000	0.006	0.008

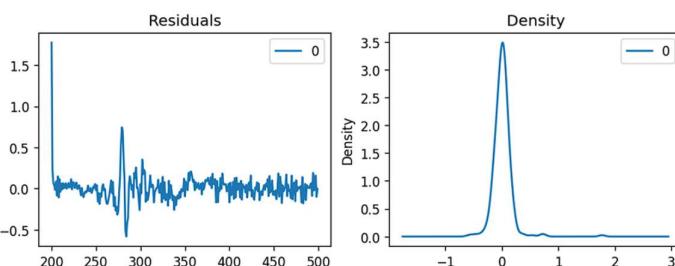
Ljung-Box (L1) (Q): 12.55 Jarque-Bera (JB): 68.24  
 Prob(Q): 0.00 Prob(JB): 0.00  
 Heteroskedasticity (H): 0.30 Skew: 0.61  
 Prob(H) (two-sided): 0.00 Kurtosis: 5.00

Warnings:  
 [1] Covariance matrix calculated using the outer product of gradients (complex-step).  
 /usr/local/lib/python3.10/dist-packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood optimization failed to converge. Check mle\_retsvals  
 warnings.warn("Maximum Likelihood optimization failed to "

```

Q [269] # Plot residual errors
residuals = pd.DataFrame(model_fit.resid)
fig, ax = plt.subplots(1,2)
residuals.plot(title="Residuals", ax=ax[0])
residuals.plot(kind='kde', title='Density', ax=ax[1])
plt.show()

```

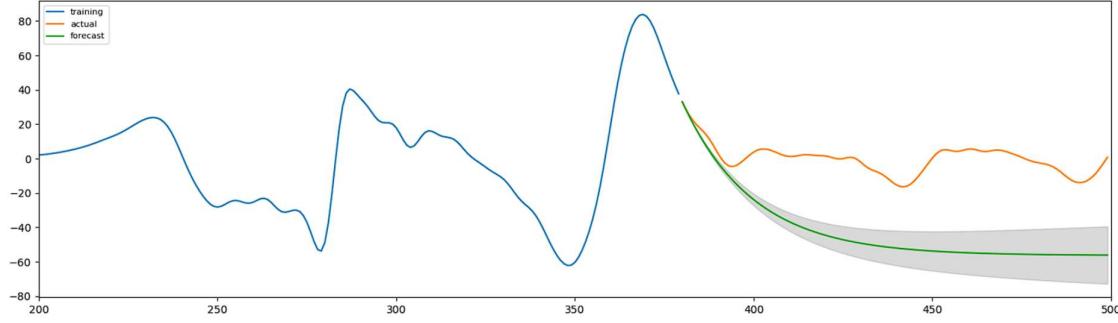


```

Q [277] # Plot
↳ plt.figure(figsize=(18,5), dpi=100)
↳ plt.plot(train, label='training')
↳ plt.plot(test, label='actual')
↳ plt.plot(fc_series, label='forecast')
↳ plt.fill_between(lower_series.index, lower_series, upper_series,
                   color='k', alpha=.15)
↳ plt.title('Forecast vs Actuals')
↳ plt.legend(loc='upper left', fontsize=8)
↳ plt.xlim(200,500)
# plt.ylim(-200,200)
plt.show()

```

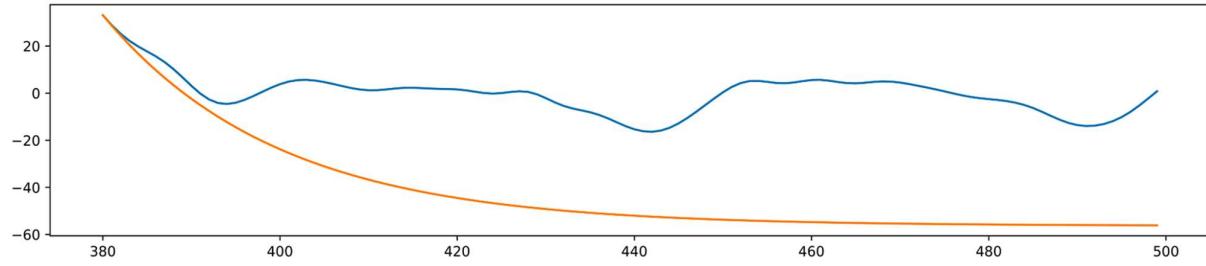
Forecast vs Actuals



```

{x} [280] plt.plot(test, label='forecast')
{x} plt.plot(fc_series, label='forecast')
{x} plt.show()

```



```

Q [281] # Build Model
{x} model = ARIMA(train, order=(2, 0, 4))
{x} fitted = model.fit()
{x} print(fitted.summary())

# Forecast
results = fitted.get_forecast(int(len(test))) # 95% conf

fc = results.predicted_mean
conf = results.conf_int(alpha=0.95)

# Make as pandas series
fc_series = pd.Series(fc, index=test.index)
lower_series = pd.Series(conf.iloc[:, 0], index=test.index)
upper_series = pd.Series(conf.iloc[:, 1], index=test.index)

/usr/local/lib/python3.10/dist-packages/statsmodels/tsa/statespace/sarimax.py:978: UserWarning: Non-invertible starting MA parameters found. Using zeros as starting parameters.
warn('Non-invertible starting MA parameters found.')
SARIMAX Results
=====
Dep. Variable:                      value
No. Observations:                  180
Model:                            ARIMA(2, 0, 4)
Date:          Wed, 25 Oct 2023
Time:          11:51:19
Sample:                 0 - 180
Covariance Type:            opg
================================================================================
              coef    std err      z   P>|z|      [0.025      0.975]
-----  

const      0.5304    7.052    0.075    0.940    -13.292     14.353
ar.L1      1.9174    0.016   121.948    0.000     1.887     1.948
ar.L2     -0.9386    0.016   -59.740    0.000     -0.969     -0.908
ma.L1      2.6172    0.187    13.964    0.000     2.250     2.985
ma.L2      3.4359    0.677    5.072    0.000     2.108     4.764
ma.L3      2.4724    0.784    3.153    0.002     0.936     4.089
ma.L4      0.8516    0.327    2.605    0.009     0.211     1.492
sigma2     0.0231    0.009    2.590    0.010     0.006     0.041
Ljung-Box (L1) (Q):                  52.30    Jarque-Bera (JB):       219.67
Prob(Q):                           0.00    Prob(JB):                  0.00
Heteroskedasticity (H):                3.42    Skew:                     0.57
Prob(H) (two-sided):                 0.00    Kurtosis:                  8.29

```

```

[282] # Plot
plt.figure(figsize=(18,5), dpi=100)
plt.plot(train, label='training')
plt.plot(test, label='actual')
plt.plot(fc_series, label='forecast')
plt.fill_between(lower_series.index, lower_series, upper_series,
                  color='k', alpha=.15)
plt.title('Forecast vs Actuals')
plt.legend(loc='upper left', fontsize=8)
plt.xlim(200,500)
# plt.ylim(-200,200)
plt.show()

```

Forecast vs Actuals

```

[283] from statsmodels.tsa.stattools import acf

# Accuracy metrics
def forecast_accuracy(forecast, actual):
    forecast = forecast.ravel() # Convert to one-dimensional arrays
    actual = actual.ravel()

    mape = np.mean(np.abs(forecast - actual)) / np.abs(actual) # MAPE
    me = np.mean(forecast - actual) # ME
    mae = np.mean(np.abs(forecast - actual)) # MAE
    mpe = np.mean((forecast - actual) / actual) # MPE
    rmse = np.mean((forecast - actual) ** 2) ** 0.5 # RMSE
    corr = np.corrcoef(forecast, actual)[0, 1] # corr
    min_max = 1 - np.mean(np.minimum(forecast, actual) / np.maximum(forecast, actual)) # minmax
    acf1 = acf(forecast - actual)[1] # ACF1
    return {
        'mape': mape, 'me': me, 'mae': mae,
        'mpe': mpe, 'rmse': rmse, 'acf1': acf1,
        'corr': corr, 'minmax': min_max
    }

forecast_accuracy(fc, test.value)

```

```

{'mape': 10.538009619778705,
'me': 0.11246634462061077,
'mae': 7.005826801865045,
'mpe': 7.349200226255846,
'rmse': 8.9130662649982458,
'acf1': 0.9899365618214546,
'corr': 0.4886930792393845,
'minmax': -3.4400099662538874}

```

```

[284] !pip install pmdarima

```

```

Requirement already satisfied: pmdarima in /usr/local/lib/python3.10/dist-packages (2.0.4)
Requirement already satisfied: joblib>=0.11 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (1.3.2)
Requirement already satisfied: cython<1.29,!=1.27,!=1.28,>=0.29 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (3.0.4)
Requirement already satisfied: numpy<1.21.2,!=1.21.1,!=1.21.0,>=1.21.0 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (1.23.5)
Requirement already satisfied: pandas>=0.19 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (1.3.2)
Requirement already satisfied: scikitlearn>=0.22 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (1.2.2)
Requirement already satisfied: scipy>=1.3.2 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (1.11.3)
Requirement already satisfied: statsmodels>=0.13.2 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (0.14.0)
Requirement already satisfied: urllib3 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (2.0.7)
Requirement already satisfied: packaging>=17.1 in /usr/local/lib/python3.10/dist-packages (from pmdarima) (67.7.2)
Requirement already satisfied: python-dateutil>=2.8.1 in /usr/local/lib/python3.10/dist-packages (from pandas>0.19>pmdarima) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas>0.19>pmdarima) (2023.3.post1)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn>0.22>pmdarima) (3.2.0)
Requirement already satisfied: patsy>=0.5.2 in /usr/local/lib/python3.10/dist-packages (from statsmodels>0.13.2>pmdarima) (0.5.3)
Requirement already satisfied: six in /usr/local/lib/python3.10/dist-packages (from patsy>0.5.2>statsmodels>0.13.2>pmdarima) (1.16.0)

```

```

[285] from statsmodels.tsa.arima_model import ARIMA

```

```

import pmdarima as pm

model=pm.arima.auto_arima(train.value,start_p=0,d=1,start_q=0,
                           max_p=5,max_d=5,max_q=5, start_P=0,
                           D=1, start_Q=0, max_P=5,max_D=5,
                           max_Q=5, m=12, seasonal=True,
                           error_action='warn',trace=True,
                           suppress_warnings=True,stepwise=True,
                           random_state=20,n_fits=50)

print(model.summary())

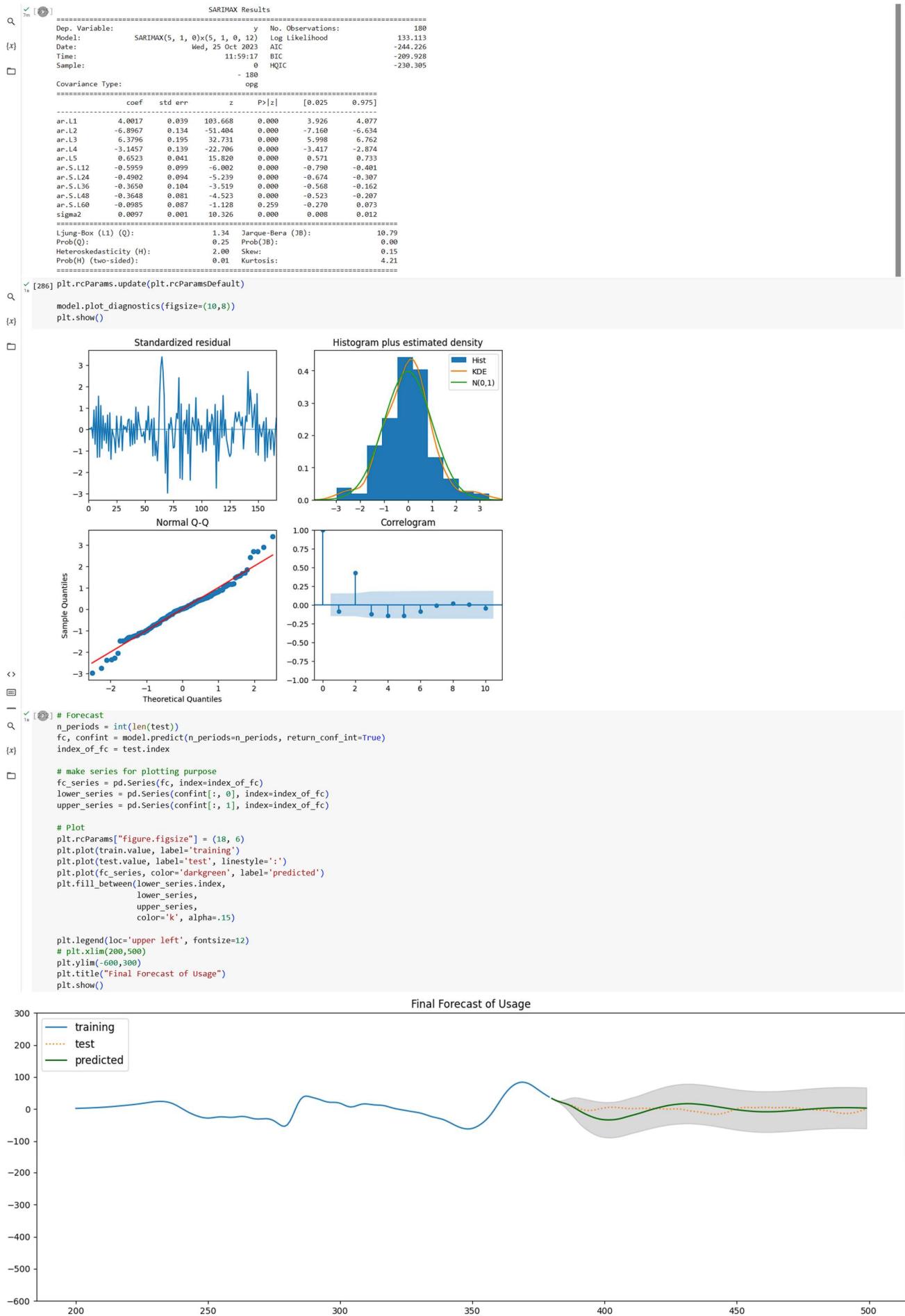
```

```

[285] ARIMA(0,1,0)[3,1,0][12] : AIC=1049.992, Time=1.28 sec
ARIMA(2,1,0)[3,1,0][12] : AIC=333.992, Time=2.52 sec
ARIMA(2,1,0)[2,1,0][12] : AIC=335.191, Time=0.98 sec
ARIMA(2,1,0)[4,1,0][12] : AIC=330.126, Time=6.32 sec
ARIMA(2,1,0)[5,1,0][12] : AIC=327.306, Time=6.02 sec
ARIMA(2,1,0)[5,1,1][12] : AIC=inf, Time=27.90 sec
ARIMA(2,1,0)[4,1,1][12] : AIC=inf, Time=17.35 sec
ARIMA(1,1,0)[5,1,0][12] : AIC=626.165, Time=4.99 sec
ARIMA(3,1,0)[5,1,0][12] : AIC=38.074, Time=16.25 sec
ARIMA(3,1,0)[4,1,0][12] : AIC=45.690, Time=10.71 sec
ARIMA(3,1,0)[5,1,1][12] : AIC=inf, Time=35.16 sec
ARIMA(3,1,0)[4,1,1][12] : AIC=inf, Time=18.03 sec
ARIMA(4,1,0)[5,1,0][12] : AIC=157.987, Time=20.93 sec
ARIMA(4,1,0)[4,1,0][12] : AIC=inf, Time=13.09 sec
ARIMA(4,1,0)[5,1,1][12] : AIC=inf, Time=20.00 sec
ARIMA(4,1,0)[4,1,1][12] : AIC=inf, Time=15.85 sec
ARIMA(5,1,0)[5,1,0][12] : AIC=-244.226, Time=32.10 sec
ARIMA(5,1,0)[4,1,0][12] : AIC=-202.400, Time=3.41 sec
ARIMA(5,1,0)[5,1,1][12] : AIC=-239.705, Time=43.16 sec
ARIMA(5,1,0)[4,1,1][12] : AIC=-241.793, Time=21.73 sec
ARIMA(5,1,0)[5,1,0][12] : AIC=-143.973, Time=38.88 sec
ARIMA(4,1,1)[5,1,0][12] : AIC=inf, Time=39.43 sec
ARIMA(5,1,0)[5,1,0][12] intercept : AIC=inf, Time=8.77 sec

```

Best model: ARIMA(5,1,0)[5,1,0][12]  
Total fit time: 471.848 seconds



```

39a [2] from statsmodels.tsa.arima_model import ARIMA
Q
import pm.darima as pm

(x) model = pm.arima.auto_arima(train.value, start_p=1, start_q=1,
                               test='adf',
                               max_p=15, max_q=15, # maximum p and q
                               m=1, # frequency of series
                               d=None, # let model determine 'd'
                               seasonal=False, # No Seasonality
                               start_P=0,
                               D=0,
                               trace=True,
                               error_action='ignore',
                               suppress_warnings=True,
                               stepwise=True)

print(model.summary())

```

Performing stepwise search to minimize aic

ARIMA(p, d, q)	AIC	Time
ARIMA(0,0,0)[0,0,0][0]	: AIC=inf, Time=0.59 sec	
ARIMA(0,0,0)(0,0,0)[0]	: AIC=1770.703, Time=0.03 sec	
ARIMA(1,0,0)(0,0,0)[0]	: AIC=1059.487, Time=0.09 sec	
ARIMA(0,0,1)(0,0,0)[0]	: AIC=inf, Time=0.24 sec	
ARIMA(2,0,0)(0,0,0)[0]	: AIC=581.159, Time=0.11 sec	
ARIMA(3,0,0)(0,0,0)[0]	: AIC=301.744, Time=0.14 sec	
ARIMA(4,0,0)(0,0,0)[0]	: AIC=-14.139, Time=0.25 sec	
ARIMA(5,0,0)(0,0,0)[0]	: AIC=-226.495, Time=0.29 sec	
ARIMA(6,0,0)(0,0,0)[0]	: AIC=-324.364, Time=0.49 sec	
ARIMA(7,0,0)(0,0,0)[0]	: AIC=-334.461, Time=0.51 sec	
ARIMA(8,0,0)(0,0,0)[0]	: AIC=-347.889, Time=1.00 sec	
ARIMA(9,0,0)(0,0,0)[0]	: AIC=-360.631, Time=1.20 sec	
ARIMA(10,0,0)(0,0,0)[0]	: AIC=-395.672, Time=0.93 sec	
ARIMA(11,0,0)(0,0,0)[0]	: AIC=-408.954, Time=1.05 sec	
ARIMA(12,0,0)(0,0,0)[0]	: AIC=-407.056, Time=2.02 sec	
ARIMA(11,0,1)(0,0,0)[0]	: AIC=-190.452, Time=11.31 sec	
ARIMA(10,0,1)(0,0,0)[0]	: AIC=inf, Time>9.38 sec	
ARIMA(12,0,1)(0,0,0)[0]	: AIC=inf, Time>nan sec	
ARIMA(11,0,0)(0,0,0)[0] intercept	: AIC=-406.927, Time=5.20 sec	

Best model: ARIMA(11, 0, 0)(0, 0, 0)[0]  
Total fit time: 39.400 seconds

```

39a [3] SARIMAX Results
=====
Dep. Variable: y No. Observations: 180
Model: SARIMAX(11, 0, 0) Log Likelihood: 216.477
Date: Wed, 25 Oct 2023 AIC: -408.954
Time: 11:59:59 BIC: -370.639
Sample: 0 HQIC: -393.419
Covariance Type: opg
=====
```

cof	std err	z	P> z	[0.025	0.975]
ar.L1	4.7398	0.068	69.319	0.000	4.606
ar.L2	-8.9992	0.354	-25.438	0.000	-9.693
ar.L3	7.5474	0.802	9.406	0.000	5.975
ar.L4	-0.4713	1.042	-0.452	0.651	-2.513
ar.L5	-3.5463	0.996	-3.560	0.000	-5.499
ar.L6	0.9799	0.962	1.018	0.308	-0.906
ar.L7	1.6762	0.866	1.935	0.053	-0.022
ar.L8	-0.3636	0.888	-0.416	0.682	-2.104
ar.L9	-1.4594	0.729	-2.003	0.045	-2.887
ar.L10	1.1869	0.338	3.514	0.000	0.525
ar.L11	-0.2914	0.068	-4.272	0.000	-0.425
sigma2	0.0043	0.000	10.355	0.000	0.005

```

Ljung-Box (L1) (Q): 0.18 Jarque-Bera (JB): 51.31
Prob(Q): 0.67 Prob(JB): 0.00
Heteroskedasticity (H): 1.37 Skew: 0.72
Prob(H) (two-sided): 0.23 Kurtosis: 5.18
=====
```

```

28 [1] plt.rcParams.update(plt.rcParamsDefault)
model.plot_diagnostics(figsize=(10,8))
plt.show()

```

Standardized residual

Histogram plus estimated density

Normal Q-Q

Correlogram

```

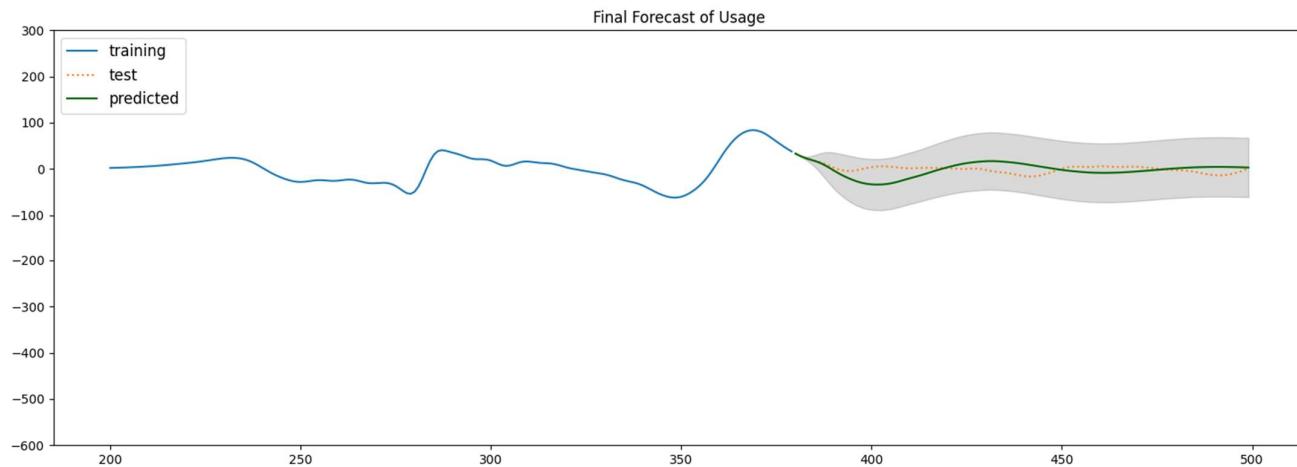
[23]: # Forecast
n_periods = int(len(test))
fc, confint = model.predict(n_periods=n_periods, return_conf_int=True)
index_of_fc = test.index

# make series for plotting purpose
fc_series = pd.Series(fc, index=index_of_fc)
lower_series = pd.Series(confint[:, 0], index=index_of_fc)
upper_series = pd.Series(confint[:, 1], index=index_of_fc)

# Plot
plt.rcParams["figure.figsize"] = (18, 6)
plt.plot(train.value, label='training')
plt.plot(test.value, label='test', linestyle=':')
plt.plot(fc_series, color='darkgreen', label='predicted')
plt.fill_between(lower_series.index,
                 lower_series,
                 upper_series,
                 color='k', alpha=.15)

plt.legend(loc='upper left', fontsize=12)
# plt.xlim(200,500)
plt.ylim(-600,300)
plt.title("Final Forecast of Usage")
plt.show()

```



## RESULT

The implementation was done successfully.