AdEase_Casestudy

January 29, 2025

1 Ad Company

Ad Company is an ads and marketing based company helping businesses elicit maximum clicks @ minimum cost. AdEase is an ad infrastructure to help businesses promote themselves easily, effectively, and economically. The interplay of 3 AI modules - Design, Dispense, and Decipher, come together to make it this an end-to-end 3 step process digital advertising solution for all.

You are working in the Data Science team of Ad Company trying to understand the per page view report for different wikipedia pages for 550 days, and forecasting the number of views so that you can predict and optimize the ad placement for your clients. You are provided with the data of 145k wikipedia pages and daily view count for each of them. Your clients belong to different regions and need data on how their ads will perform on pages in different languages.

train_1.csv

Each row represents an article, and each column represents a date. The values indicate the number of visits on that date. The page name follows this format:

SPECIFIC_NAME _ LANGUAGE.wikipedia.org _ ACCESS_TYPE _ ACCESS_ORIGIN

SPECIFIC_NAME: Article name **LANGUAGE**: Wikipedia language version **ACCESS_TYPE**: Device type used (desktop/mobile) **ACCESS_ORIGIN**: Request origin (spider or browser)

Exog_Campaign_eng.csv

Contains data on campaign events that might impact page views. Applies **only to English pages**. **1** indicates a campaign/event, **0** means no event. This can be used as an external factor while training models for forecasting.

[1]:
```
import pandas as pd
import numpy as np
import pylab as p
import matplotlib.pyplot as plt
from collections import Counter
import re
import os
import seaborn as sns
```

[2]:
```python
import warnings
warnings.filterwarnings("ignore")
warnings.simplefilter("ignore")
warnings.filterwarnings("ignore", category=UserWarning, module="statsmodels")
```

train_1.csv

Each row represents an article, and each column represents a date. The values indicate the number of visits on that date. The page name follows this format:

SPECIFIC_NAME _ LANGUAGE.wikipedia.org _ ACCESS_TYPE _ ACCESS_ORIGIN

SPECIFIC_NAME: Article name **LANGUAGE**: Wikipedia language version **ACCESS_TYPE**: Device type used (desktop/mobile) **ACCESS_ORIGIN**: Request origin (spider or browser)

Exog_Campaign_eng.csv

Contains data on campaign events that might impact page views. Applies **only to English pages**. **1** indicates a campaign/event, **0** means no event. This can be used as an external factor while training models for forecasting.

[3]:
```python
exog = pd.read_csv("/home/csc/my_first_environment/adease/data/
  ↪Exog_Campaign_eng")
exog.head()
```

[3]:

	Exog
0	0
1	0
2	0
3	0
4	0

[4]:
```python
exog.describe()
```

[4]:

	Exog
count	550.000000
mean	0.098182
std	0.297831
min	0.000000
25%	0.000000
50%	0.000000
75%	0.000000
max	1.000000

[5]:
```python
exog.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 550 entries, 0 to 549
```

```
Data columns (total 1 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Exog    550 non-null    int64
dtypes: int64(1)
memory usage: 4.4 KB
```

Exog data doesn't have any Nulls. We will use it later on when required while creating the ML model.

[4]:
```python
train = pd.read_csv('/home/csc/my_first_environment/adease/data/train_1.csv')
```

[11]:
```python
train.shape
```

[11]:
```
(145063, 551)
```

[5]:
```python
train.head()
```

[5]:
```
                                          Page  2015-07-01  2015-07-02  \
0          2NE1_zh.wikipedia.org_all-access_spider        18.0        11.0
1           2PM_zh.wikipedia.org_all-access_spider        11.0        14.0
2            3C_zh.wikipedia.org_all-access_spider         1.0         0.0
3       4minute_zh.wikipedia.org_all-access_spider        35.0        13.0
4  52_Hz_I_Love_You_zh.wikipedia.org_all-access_s…         NaN         NaN

   2015-07-03  2015-07-04  2015-07-05  2015-07-06  2015-07-07  2015-07-08  \
0         5.0        13.0        14.0         9.0         9.0        22.0
1        15.0        18.0        11.0        13.0        22.0        11.0
2         1.0         1.0         0.0         4.0         0.0         3.0
3        10.0        94.0         4.0        26.0        14.0         9.0
4         NaN         NaN         NaN         NaN         NaN         NaN

   2015-07-09  …  2016-12-22  2016-12-23  2016-12-24  2016-12-25  \
0        26.0  …        32.0        63.0        15.0        26.0
1        10.0  …        17.0        42.0        28.0        15.0
2         4.0  …         3.0         1.0         1.0         7.0
3        11.0  …        32.0        10.0        26.0        27.0
4         NaN  …        48.0         9.0        25.0        13.0

   2016-12-26  2016-12-27  2016-12-28  2016-12-29  2016-12-30  2016-12-31
0        14.0        20.0        22.0        19.0        18.0        20.0
1         9.0        30.0        52.0        45.0        26.0        20.0
2         4.0         4.0         6.0         3.0         4.0        17.0
3        16.0        11.0        17.0        19.0        10.0        11.0
4         3.0        11.0        27.0        13.0        36.0        10.0

[5 rows x 551 columns]
```

[13]:
```
train.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 145063 entries, 0 to 145062
Columns: 551 entries, Page to 2016-12-31
dtypes: float64(550), object(1)
memory usage: 609.8+ MB
```

[14]:
```
train.describe()
```

[14]:
```
         2015-07-01    2015-07-02    2015-07-03    2015-07-04    2015-07-05  \
count  1.243230e+05  1.242470e+05  1.245190e+05  1.244090e+05  1.244040e+05
mean   1.195857e+03  1.204004e+03  1.133676e+03  1.170437e+03  1.217769e+03
std    7.275352e+04  7.421515e+04  6.961022e+04  7.257351e+04  7.379612e+04
min    0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00
25%    1.300000e+01  1.300000e+01  1.200000e+01  1.300000e+01  1.400000e+01
50%    1.090000e+02  1.080000e+02  1.050000e+02  1.050000e+02  1.130000e+02
75%    5.240000e+02  5.190000e+02  5.040000e+02  4.870000e+02  5.400000e+02
max    2.038124e+07  2.075219e+07  1.957397e+07  2.043964e+07  2.077211e+07

         2015-07-06    2015-07-07    2015-07-08    2015-07-09    2015-07-10  \
count  1.245800e+05  1.243990e+05  1.247690e+05  1.248190e+05  1.247210e+05
mean   1.290273e+03  1.239137e+03  1.193092e+03  1.197992e+03  1.189651e+03
std    8.054448e+04  7.576288e+04  6.820002e+04  7.149717e+04  7.214536e+04
min    0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00
25%    1.100000e+01  1.300000e+01  1.300000e+01  1.400000e+01  1.400000e+01
50%    1.130000e+02  1.150000e+02  1.170000e+02  1.150000e+02  1.130000e+02
75%    5.550000e+02  5.510000e+02  5.540000e+02  5.490000e+02  5.450000e+02
max    2.254467e+07  2.121089e+07  1.910791e+07  1.999385e+07  2.020182e+07

       …    2016-12-22    2016-12-23    2016-12-24    2016-12-25  \
count  …  1.412100e+05  1.414790e+05  1.418740e+05  1.413190e+05
mean   …  1.394096e+03  1.377482e+03  1.393099e+03  1.523740e+03
std    …  8.574880e+04  7.732794e+04  8.478533e+04  8.752210e+04
min    …  0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00
25%    …  2.200000e+01  2.200000e+01  2.000000e+01  2.100000e+01
50%    …  1.490000e+02  1.430000e+02  1.320000e+02  1.450000e+02
75%    …  6.070000e+02  5.980000e+02  5.690000e+02  6.280000e+02
max    …  2.420108e+07  2.253925e+07  2.505662e+07  2.586575e+07

         2016-12-26    2016-12-27    2016-12-28    2016-12-29    2016-12-30  \
count  1.411450e+05  1.413620e+05  1.412410e+05  1.412370e+05  1.414280e+05
mean   1.679607e+03  1.678302e+03  1.633966e+03  1.684308e+03  1.467943e+03
std    9.794534e+04  9.232482e+04  9.185831e+04  9.014266e+04  8.155481e+04
min    0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00
25%    2.200000e+01  2.300000e+01  2.400000e+01  2.300000e+01  2.300000e+01
50%    1.600000e+02  1.620000e+02  1.630000e+02  1.600000e+02  1.540000e+02
```

```
75%    6.590000e+02  6.680000e+02  6.540000e+02  6.490000e+02  6.350000e+02
max    2.834288e+07  2.691699e+07  2.702505e+07  2.607382e+07  2.436397e+07

         2016-12-31
count  1.415980e+05
mean   1.478282e+03
std    8.873567e+04
min    0.000000e+00
25%    2.100000e+01
50%    1.360000e+02
75%    5.610000e+02
max    2.614954e+07

[8 rows x 550 columns]
```

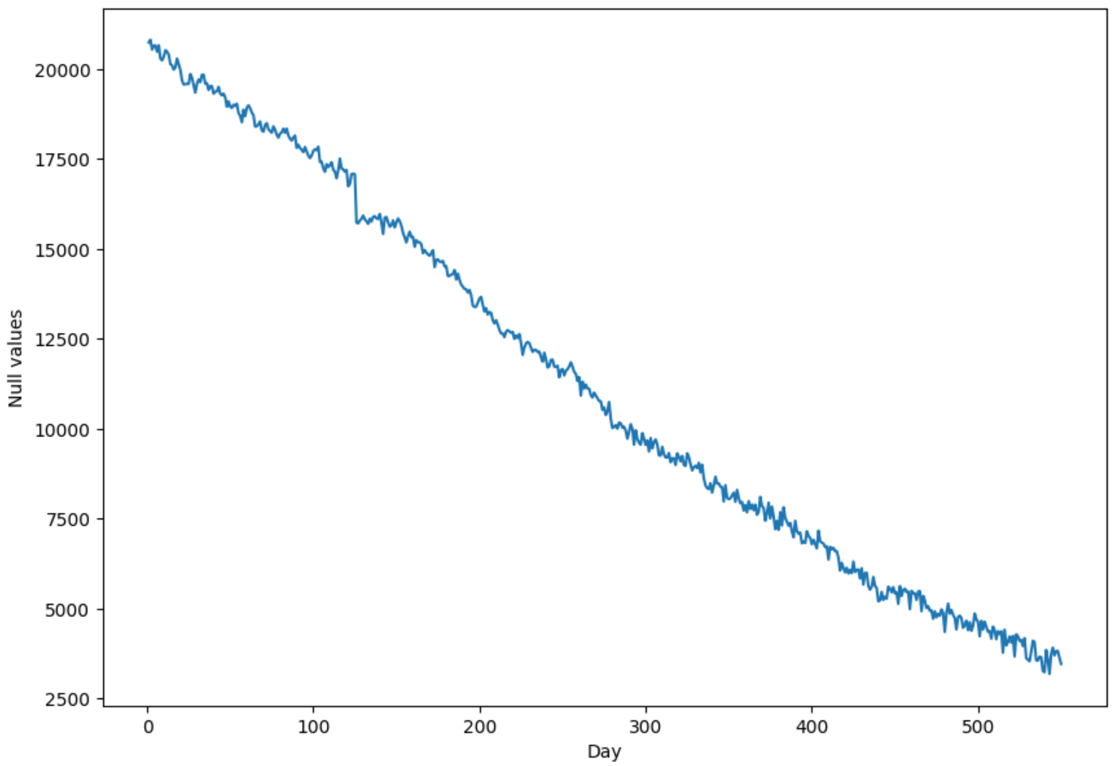
2 Checking missing values using plot:

[15]:
```
train.isnull().sum()
```

[15]:
```
Page              0
2015-07-01    20740
2015-07-02    20816
2015-07-03    20544
2015-07-04    20654
              …
2016-12-27     3701
2016-12-28     3822
2016-12-29     3826
2016-12-30     3635
2016-12-31     3465
Length: 551, dtype: int64
```

[21]:
```
plt.figure(figsize=(10,7))
plt.xlabel('Day')
plt.ylabel('Null values')
plt.plot(range(1, len(train.columns)), train.isnull().sum()[1:])
```

[21]:
```
[<matplotlib.lines.Line2D at 0x70c9c3079720>]
```



From the plot above, we can see that the number of null values decreases over time. This suggests that these pages were not created initially, which is why they have no views.

To clean the data, we first remove rows where all values are NULL. Then, we drop rows with more than 300 null values. Since we have a total of 551 records, keeping rows with over 300 null values would mean that more than half of the data is missing, which would not be useful for model creation.

[5]:
```
print(train.shape)
train=train.dropna(how='all')
#‘all’ : If all values are NA, drop that row or column.
print(train.shape)
```

```
(145063, 551)
(145063, 551)
```

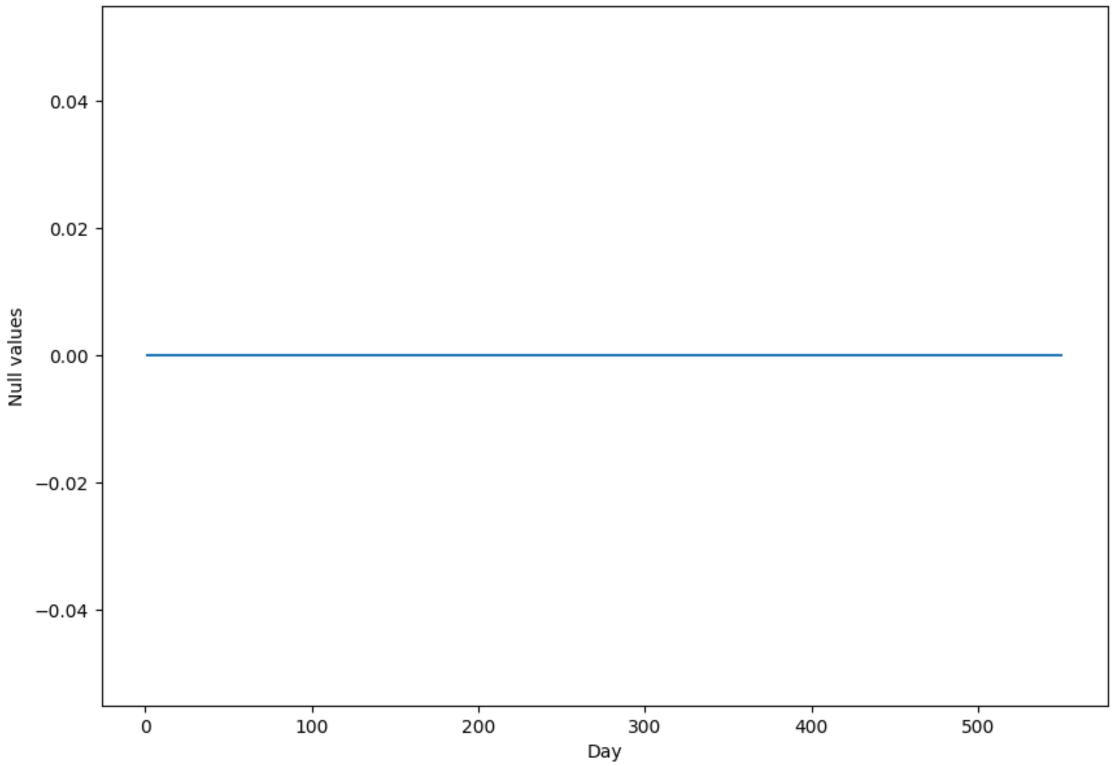
We haven’t lost much data after the removal of NULLs so we can proceed with the cleaned data now.

Filling all the remaining NULLs with 0

[6]:
```
train=train.fillna(0)
```

[25]:
```
plt.figure(figsize=(10,7))
plt.xlabel('Day')
plt.ylabel('Null values')
plt.plot(range(1, len(train.columns)), train.isnull().sum()[1:])
```

[25]:
```
[<matplotlib.lines.Line2D at 0x70c9c0039600>]
```



3 EDA

The page name contains data in this format:

SPECIFIC NAME _ LANGUAGE.wikipedia.org _ ACCESS TYPE _ ACCESS ORIGIN

having information about the page name, the main domain, the device type used to access the page, and also the request origin(spider or browser agent)

We will split the data given in the page name column to find out the different parts of the data.

[7]:
```
# Function to split page name
def split_page(page):
    parts = page.rsplit('_', 3)  # Split only the last 3 occurrences of '_'
    title = parts[0].rsplit('.', 1)[0]  # Remove any trailing extension
```

```
    language = parts[-3].split('.')[0]  # Extract language before ".wikipedia.
↪org"
    return title, language, parts[-2], parts[-1]

# Apply function and create DataFrame
df_split = train['Page'].astype(str).apply(split_page).apply(pd.Series)
df_split.columns = ['Title', 'Language', 'Access_type', 'Access_origin']

# Merge with original data
df = pd.concat([train, df_split], axis=1)

df.head()
```

[7]:

```
                                                Page  2015-07-01  2015-07-02  \
0            2NE1_zh.wikipedia.org_all-access_spider        18.0        11.0
1             2PM_zh.wikipedia.org_all-access_spider        11.0        14.0
2              3C_zh.wikipedia.org_all-access_spider         1.0         0.0
3         4minute_zh.wikipedia.org_all-access_spider        35.0        13.0
4  52_Hz_I_Love_You_zh.wikipedia.org_all-access_s…         0.0         0.0

   2015-07-03  2015-07-04  2015-07-05  2015-07-06  2015-07-07  2015-07-08  \
0         5.0        13.0        14.0         9.0         9.0        22.0
1        15.0        18.0        11.0        13.0        22.0        11.0
2         1.0         1.0         0.0         4.0         0.0         3.0
3        10.0        94.0         4.0        26.0        14.0         9.0
4         0.0         0.0         0.0         0.0         0.0         0.0

   2015-07-09  …  2016-12-26  2016-12-27  2016-12-28  2016-12-29  \
0        26.0  …        14.0        20.0        22.0        19.0
1        10.0  …         9.0        30.0        52.0        45.0
2         4.0  …         4.0         4.0         6.0         3.0
3        11.0  …        16.0        11.0        17.0        19.0
4         0.0  …         3.0        11.0        27.0        13.0

   2016-12-30  2016-12-31             Title  Language  Access_type  \
0        18.0        20.0              2NE1        zh   all-access
1        26.0        20.0               2PM        zh   all-access
2         4.0        17.0                3C        zh   all-access
3        10.0        11.0           4minute        zh   all-access
4        36.0        10.0  52_Hz_I_Love_You        zh   all-access

   Access_origin
0         spider
1         spider
2         spider
3         spider
4         spider
```

```
[5 rows x 555 columns]
```

We have got 4 new columns after spliting the Page column - Title, Language, Access_type, Access_origin

[10]:
```python
df["Language"].value_counts()
```

[10]:
```
Language
en         24108
ja         20431
de         18547
fr         17802
zh         17229
ru         15022
es         14069
commons    10555
www         7300
Name: count, dtype: int64
```

[8]:
```python
lang_dict ={'de':'German',
 'en':'English',
 'es': 'Spanish',
 'fr': 'French',
 'ja': 'Japenese' ,
 'ru': 'Russian',
 'zh': 'Chinese','commons': 'Unknown_Language','www':'Unknown_Language'}

df["Language"]=df["Language"].map(lang_dict)
df
```

[8]:
```
                                                     Page  2015-07-01  \
0                  2NE1_zh.wikipedia.org_all-access_spider        18.0
1                   2PM_zh.wikipedia.org_all-access_spider        11.0
2                    3C_zh.wikipedia.org_all-access_spider         1.0
3               4minute_zh.wikipedia.org_all-access_spider        35.0
4       52_Hz_I_Love_You_zh.wikipedia.org_all-access_s…         0.0
…                                                     …           …
145058  Underworld_(serie_de_películas)_es.wikipedia.o…         0.0
145059  Resident_Evil:_Capítulo_Final_es.wikipedia.org…         0.0
145060  Enamorándome_de_Ramón_es.wikipedia.org_all-acc…         0.0
145061  Hasta_el_último_hombre_es.wikipedia.org_all-ac…         0.0
145062  Francisco_el_matemático_(serie_de_televisión_d…         0.0

        2015-07-02  2015-07-03  2015-07-04  2015-07-05  2015-07-06  \
0             11.0         5.0        13.0        14.0         9.0
1             14.0        15.0        18.0        11.0        13.0
```

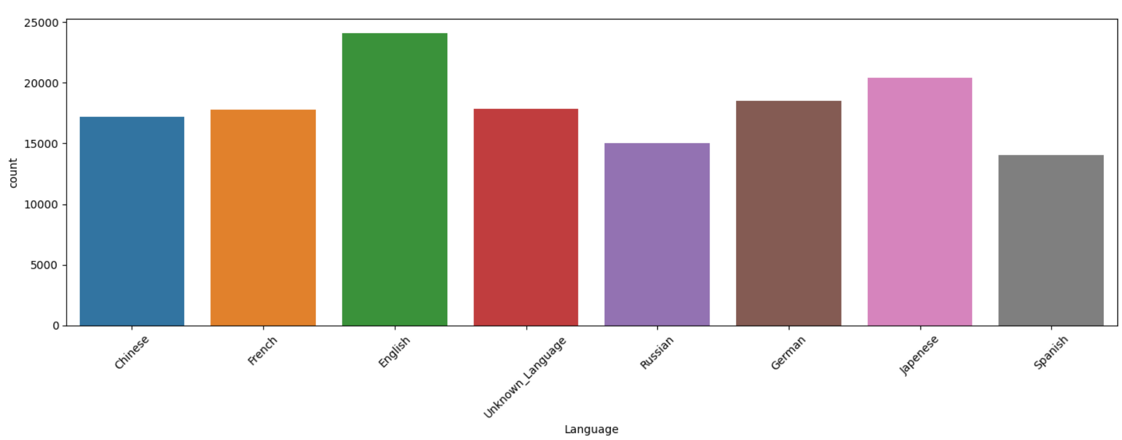
```
2              0.0         1.0         1.0         0.0         4.0
3             13.0        10.0        94.0         4.0        26.0
4              0.0         0.0         0.0         0.0         0.0
…              …           …           …           …           …
145058         0.0         0.0         0.0         0.0         0.0
145059         0.0         0.0         0.0         0.0         0.0
145060         0.0         0.0         0.0         0.0         0.0
145061         0.0         0.0         0.0         0.0         0.0
145062         0.0         0.0         0.0         0.0         0.0

        2015-07-07  2015-07-08  2015-07-09  …  2016-12-26  2016-12-27  \
0              9.0        22.0        26.0  …        14.0        20.0
1             22.0        11.0        10.0  …         9.0        30.0
2              0.0         3.0         4.0  …         4.0         4.0
3             14.0         9.0        11.0  …        16.0        11.0
4              0.0         0.0         0.0  …         3.0        11.0
…              …           …           …  …           …           …
145058         0.0         0.0         0.0  …        13.0        12.0
145059         0.0         0.0         0.0  …         0.0         0.0
145060         0.0         0.0         0.0  …         0.0         0.0
145061         0.0         0.0         0.0  …         0.0         0.0
145062         0.0         0.0         0.0  …         0.0         0.0

        2016-12-28  2016-12-29  2016-12-30  2016-12-31  \
0             22.0        19.0        18.0        20.0
1             52.0        45.0        26.0        20.0
2              6.0         3.0         4.0        17.0
3             17.0        19.0        10.0        11.0
4             27.0        13.0        36.0        10.0
…              …           …           …           …
145058        13.0         3.0         5.0        10.0
145059         0.0         0.0         0.0         0.0
145060         0.0         0.0         0.0         0.0
145061         0.0         0.0         0.0         0.0
145062         0.0         0.0         0.0         0.0

                                           Title  Language  \
0                                           2NE1   Chinese
1                                            2PM   Chinese
2                                             3C   Chinese
3                                        4minute   Chinese
4                               52_Hz_I_Love_You   Chinese
…                                              …         …
145058           Underworld_(serie_de_películas)   Spanish
145059             Resident_Evil:_Capítulo_Final   Spanish
145060                     Enamorándome_de_Ramón   Spanish
145061                    Hasta_el_último_hombre   Spanish
```

```
145062  Francisco_el_matemático_(serie_de_televisión_d…   Spanish

        Access_type  Access_origin
0        all-access         spider
1        all-access         spider
2        all-access         spider
3        all-access         spider
4        all-access         spider
…              …             …
145058   all-access         spider
145059   all-access         spider
145060   all-access         spider
145061   all-access         spider
145062   all-access         spider

[145063 rows x 555 columns]
```

[54]:
```
df["Language"].value_counts() / len(df) * 100
```

[54]:
```
Language
English             16.618986
Japenese            14.084225
German              12.785479
Unknown_Language    12.308445
French              12.271909
Chinese             11.876909
Russian             10.355501
Spanish              9.698545
Name: count, dtype: float64
```

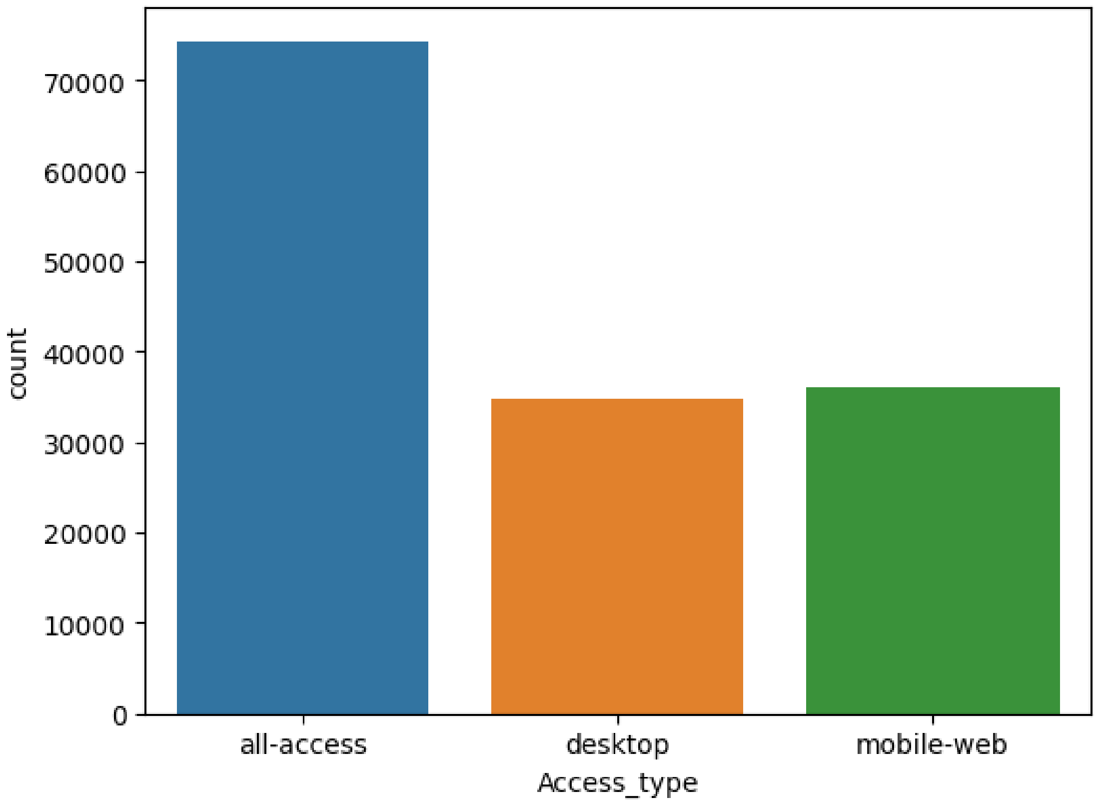
[53]:
```
plt.figure(figsize=(17, 5))
sns.countplot(x=df["Language"])
plt.xticks(rotation=45)
plt.show()
```



[37]:

```
sns.countplot(x=df["Access_type"])
```

[37]: <Axes: xlabel='Access_type', ylabel='count'>



[55]:

```
df["Access_type"].value_counts() / len(df) * 100
```

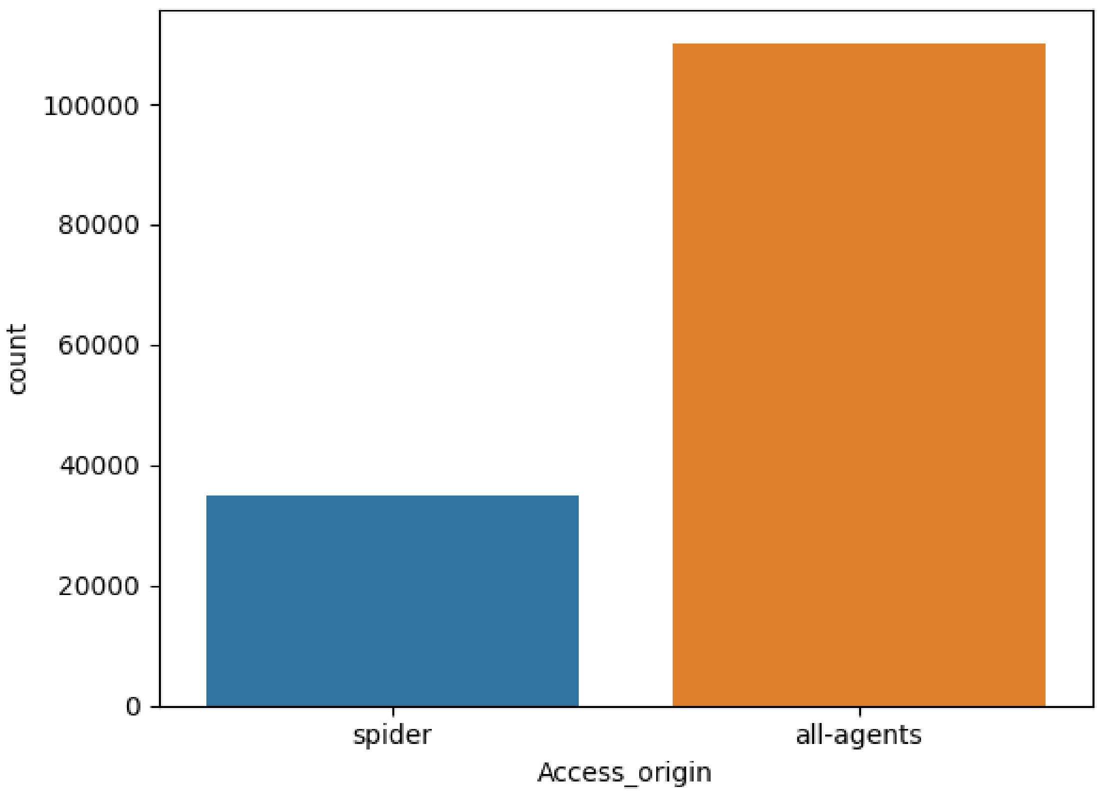
[55]:

```
Access_type
all-access    51.229466
mobile-web    24.774753
desktop       23.995781
Name: count, dtype: float64
```

[38]:

```
sns.countplot(x=df["Access_origin"])
```

[38]: <Axes: xlabel='Access_origin', ylabel='count'>



[56]:
```
df["Access_origin"].value_counts() / len(df) * 100
```

[56]:
```
Access_origin
all-agents    75.932526
spider        24.067474
Name: count, dtype: float64
```

Based on the language data we have, let's create a dataframe for languages and store the mean of those date wise and check how each language performs

[9]:
```
df_lang = df.groupby("Language").mean(numeric_only=True)
df_lang
```

[9]:
```
                   2015-07-01   2015-07-02   2015-07-03   2015-07-04  \
Language
Chinese            240.582042   240.941958   239.344071   241.653491
English           3513.862203  3502.511407  3325.357889  3462.054256
French             475.150994   478.202000   459.837659   491.508932
German             714.968405   705.229741   676.877231   621.145145
Japenese           580.647056   666.672801   602.289805   756.509177
Russian            629.999601   640.902876   594.026295   558.728132
Spanish           1085.972919  1037.814557   954.412680   896.050750
```

```
Unknown_Language    83.479922    87.471857    82.680538    70.572557

                   2015-07-05   2015-07-06   2015-07-07   2015-07-08  \
Language
Chinese            257.779674   259.114864   258.832260   265.589529
English           3575.520035  3849.736021  3643.523063  3437.871080
French             482.557746   502.741209   485.945399   476.998820
German             722.076185   794.832480   770.814256   782.077641
Japenese           725.720914   632.399148   615.184181   611.462337
Russian            595.029157   640.986287   626.293436   623.360205
Spanish            974.508210  1110.637145  1082.568342  1050.669557
Unknown_Language    78.214562    89.720190    94.939457    99.096724

                   2015-07-09   2015-07-10  …   2016-12-22   2016-12-23  \
Language                                    …
Chinese            263.964420   274.414592  …   345.165129   340.420338
English           3517.459391  3497.571594  …  4997.991248  4683.314294
French             472.061903   445.495057  …   652.004719   639.459443
German             752.939990   701.702593  …   828.738017   839.025934
Japenese           596.067642   619.299300  …   675.104792   968.007733
Russian            638.550726   731.252297  …   896.352017   884.841299
Spanish           1030.841282   937.129931  …   983.568129   935.082522
Unknown_Language    86.445477    87.353906  …   131.521983   164.889051

                   2016-12-24   2016-12-25   2016-12-26   2016-12-27  \
Language
Chinese            360.738580   381.322886   376.447443   376.019618
English           4971.831757  5140.463373  5770.371661  6040.680728
French             618.215931   666.639085   936.884788   858.413100
German             810.756187  1281.088532  1206.478029  1085.095379
Japenese           856.605012   818.374725   779.114728   789.158680
Russian            874.274597  1120.990347  1112.840833  1001.209426
Spanish            880.307911   903.643685  1195.481626  1133.367901
Unknown_Language   140.363764   164.455167   165.821563   147.038925

                   2016-12-28   2016-12-29   2016-12-30   2016-12-31
Language
Chinese            378.048639   350.719427   354.704452   365.579256
English           5860.227559  6245.127510  5201.783018  5127.916418
French             774.155769   752.712954   700.543422   646.258342
German            1032.640804   994.657141   949.265649   893.013425
Japenese           790.500465   865.483236   952.018354  1197.239440
Russian            931.987685   897.282452   803.271868   880.244508
Spanish           1178.290923  1112.171085   821.671405   787.399531
Unknown_Language   186.438029   147.297004   164.540577   143.951442

[8 rows x 550 columns]
```

[10]:
```
df_lang = df.groupby("Language").mean(numeric_only=True).T
df_lang.head(10)
```

[10]:
```
Language       Chinese      English      French      German    Japenese  \
2015-07-01  240.582042  3513.862203  475.150994  714.968405  580.647056
2015-07-02  240.941958  3502.511407  478.202000  705.229741  666.672801
2015-07-03  239.344071  3325.357889  459.837659  676.877231  602.289805
2015-07-04  241.653491  3462.054256  491.508932  621.145145  756.509177
2015-07-05  257.779674  3575.520035  482.557746  722.076185  725.720914
2015-07-06  259.114864  3849.736021  502.741209  794.832480  632.399148
2015-07-07  258.832260  3643.523063  485.945399  770.814256  615.184181
2015-07-08  265.589529  3437.871080  476.998820  782.077641  611.462337
2015-07-09  263.964420  3517.459391  472.061903  752.939990  596.067642
2015-07-10  274.414592  3497.571594  445.495057  701.702593  619.299300

Language       Russian      Spanish  Unknown_Language
2015-07-01  629.999601  1085.972919         83.479922
2015-07-02  640.902876  1037.814557         87.471857
2015-07-03  594.026295   954.412680         82.680538
2015-07-04  558.728132   896.050750         70.572557
2015-07-05  595.029157   974.508210         78.214562
2015-07-06  640.986287  1110.637145         89.720190
2015-07-07  626.293436  1082.568342         94.939457
2015-07-08  623.360205  1050.669557         99.096724
2015-07-09  638.550726  1030.841282         86.445477
2015-07-10  731.252297   937.129931         87.353906
```

[11]:
```
df_lang.reset_index(inplace=True)
df_lang.set_index('index', inplace=True)
```

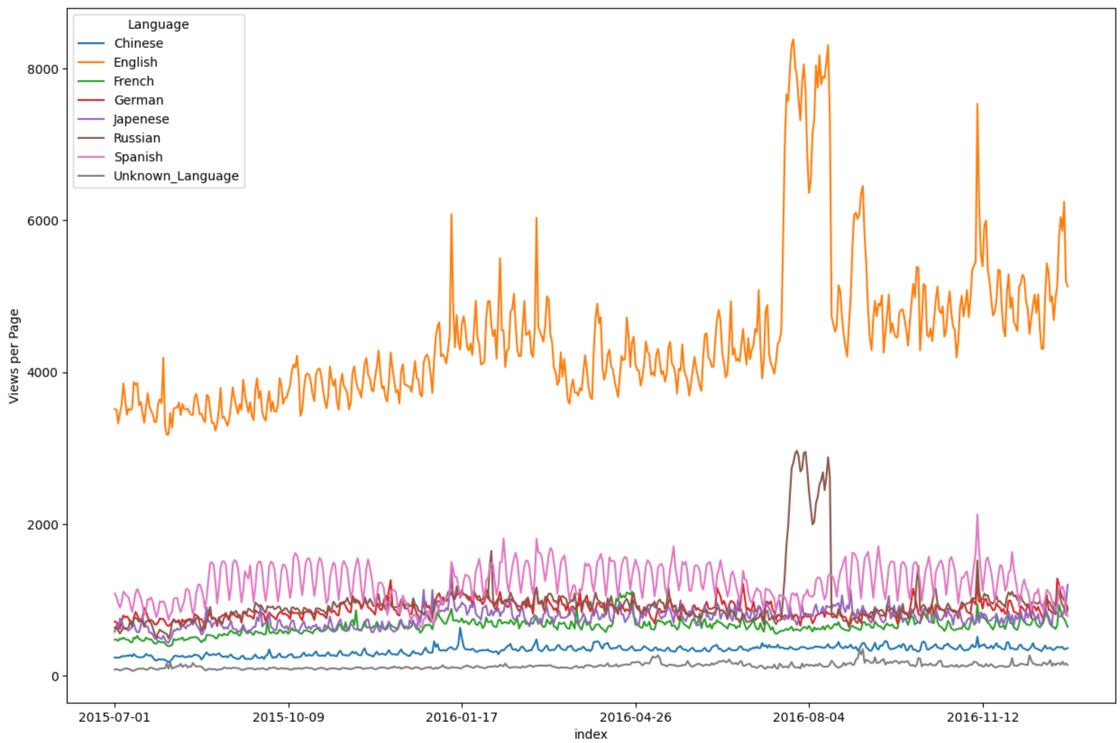
[12]:
```
df_lang
```

[12]:
```
Language       Chinese      English      French       German     Japenese  \
index
2015-07-01  240.582042  3513.862203  475.150994   714.968405   580.647056
2015-07-02  240.941958  3502.511407  478.202000   705.229741   666.672801
2015-07-03  239.344071  3325.357889  459.837659   676.877231   602.289805
2015-07-04  241.653491  3462.054256  491.508932   621.145145   756.509177
2015-07-05  257.779674  3575.520035  482.557746   722.076185   725.720914
…                …           …          …           …          …
2016-12-27  376.019618  6040.680728  858.413100  1085.095379   789.158680
2016-12-28  378.048639  5860.227559  774.155769  1032.640804   790.500465
2016-12-29  350.719427  6245.127510  752.712954   994.657141   865.483236
2016-12-30  354.704452  5201.783018  700.543422   949.265649   952.018354
2016-12-31  365.579256  5127.916418  646.258342   893.013425  1197.239440

Language        Russian      Spanish  Unknown_Language
```

```
index
2015-07-01   629.999601  1085.972919         83.479922
2015-07-02   640.902876  1037.814557         87.471857
2015-07-03   594.026295   954.412680         82.680538
2015-07-04   558.728132   896.050750         70.572557
2015-07-05   595.029157   974.508210         78.214562
…                 …           …              …
2016-12-27  1001.209426  1133.367901        147.038925
2016-12-28   931.987685  1178.290923        186.438029
2016-12-29   897.282452  1112.171085        147.297004
2016-12-30   803.271868   821.671405        164.540577
2016-12-31   880.244508   787.399531        143.951442

[550 rows x 8 columns]
```

[70]:
```python
df_lang.plot(figsize=(15,10))
plot.ylabel('Views per Page')
```

[70]: Text(0, 0.5, 'Views per Page')



The plot shows that English (en) is the most preferred language, with significantly more page views compared to others.

Notably, there are peaks in the data, especially on 2016-08-04 for both English and Russian (ru).

To explore this further, we will examine the Exogenous data for the English language.

[ ]:

```

```

4 Hypothesis Testing : if Time Series is Stationary or Trending

Null Hypothesis: The series is Non-Stationary Alternative Hypothesis: The series is Stationary Significant value : 0.05 (alpha)

if p-value > 0.05 : we failed to reject Null hypothesis:That means the series is Non-Stationary if p-value <= 0.05: we reject Null Hypothesisthat means the time series in Stationary

[16]:

```
import statsmodels.api as sm

def Dickey_Fuller_test(ts,significances_level = 0.05):
     p_value = sm.tsa.stattools.adfuller(ts)[1]
     if p_value <= significances_level:
         print("Time Series is Stationary")
     else:
         print("Time Series is NOT Stationary")
     print(f"P-value: {p_value}")
```

[17]:

```
for language in df_lang.columns:
    print(f"Language: {language}")
    result = Dickey_Fuller_test(df_lang[language])
    print()
```

```
Language: Chinese
Time Series is NOT Stationary
P-value: 0.447445792293113

Language: English
Time Series is NOT Stationary
P-value: 0.18953359279992404

Language: French
Time Series is NOT Stationary
P-value: 0.05149502195245795

Language: German
Time Series is NOT Stationary
P-value: 0.14097382319729534

Language: Japenese
Time Series is NOT Stationary
P-value: 0.10257133898557641

Language: Russian
```

```
Time Series is Stationary
P-value: 0.0018649376536617886

Language: Spanish
Time Series is Stationary
P-value: 0.033588590844791

Language: Unknown_Language
Time Series is Stationary
P-value: 0.016293558379490952
```

Chinese, English , German , Japanese and French are not stationary. Russian,Spanish & Unknown_language are stationary

English is most used language will explore more

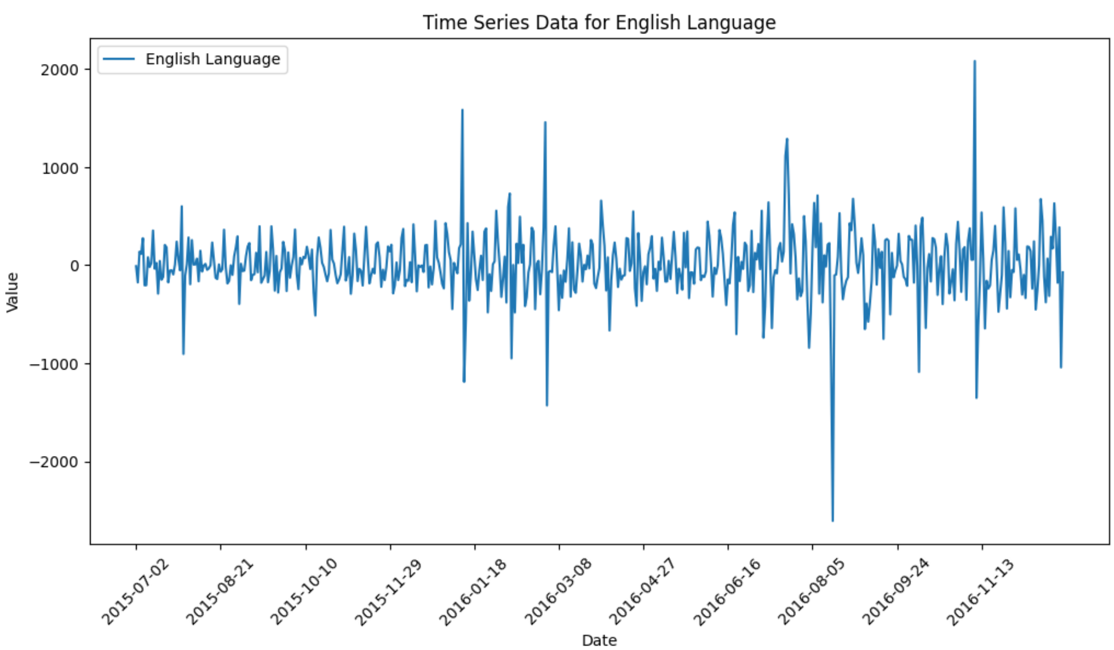
[55]:
```
df_English = df_lang.English

def adf_test(timeseries):
 print ('Results of Dickey-Fuller Test:')

 dftest = sm.tsa.stattools.adfuller(timeseries, autolag='AIC')#autolag␣
 ↪parameter is used to automatically select the optimal lag length
    ##for the test Tends to favor models with more parameters
    #autolag='AIC','BIC',None types
 df_output = pd.Series(dftest[0:4], index=['Test Statistic','p-value','#Lags␣
 ↪Used','Number of Observations Used'])
 for key, value in dftest[4].items():
     df_output['Critical Value (%s)' %key] = value
 print (df_output)
```

[18]:
```
adf_test(df_English)
```

```
Results of Dickey-Fuller Test:
Test Statistic                  -2.247284
p-value                          0.189534
#Lags Used                      14.000000
Number of Observations Used    535.000000
Critical Value (1%)             -3.442632
Critical Value (5%)             -2.866957
Critical Value (10%)            -2.569655
dtype: float64
```

5 Outliers Detection

[77]:
```
plt.figure(figsize=(12, 6))
plt.plot(df_English, label='English Language')
plt.title('Time Series Data for English Language')
plt.xlabel('Date')
plt.ylabel('Value')
plt.legend()

# Get every nth date index (e.g., every 10th date)
n = 50
plt.xticks(ticks=range(0, len(df_English), n), labels=df_English.index[::n],␣
↪rotation=45)

plt.show()
```



[73]:
```
Q1 = df_English.quantile(0.25)
Q3 = df_English.quantile(0.75)
IQR = Q3 - Q1

# Define outliers for the column (mean values)
outliers = (df_English < (Q1 - 1.5 * IQR)) | (df_English > (Q3 + 1.5 * IQR))

# Print outlier indices
outlier_indices = df_English.index[outliers]
print(f"Outliers for the 'mean' column: {outlier_indices}")
```

```
Outliers for the 'mean' column: Index(['2015-07-30', '2016-01-11', '2016-01-12',
'2016-02-08', '2016-02-09',
       '2016-02-29', '2016-03-01', '2016-06-21', '2016-07-07', '2016-07-20',
       '2016-07-21', '2016-07-22', '2016-08-03', '2016-08-08', '2016-08-16',
       '2016-08-17', '2016-09-16', '2016-10-07', '2016-11-09', '2016-11-10',
       '2016-12-30'],
      dtype='object', name='index')
```

[20]:

```
correlations = []

# Loop through lags from 1 to 29
for lag in range(1, 30):
    # Get the present time series (excluding the last 'lag' values)
    present = df_English[:-lag]

    # Get the past time series shifted by 'lag' periods (excluding the last␣
 ↪'lag' values)
    past = df_English.shift(-lag)[:-lag]

    # Calculate the correlation coefficient between present and past values
    #result is a 2x2 matrix[0, -1]
    #extracts the value from the first row and the last column of the␣
 ↪correlation matrix

    corrs = np.corrcoef(present, past)[0, -1]

    # Print the lag and its corresponding correlation coefficient
    print(f"Lag {lag}: Correlation = {corrs}")

    # Append the correlation value to the list of correlations
    correlations.append(corrs)
```

```
Lag 1: Correlation = 0.9363434527458435
Lag 2: Correlation = 0.8682966716039896
Lag 3: Correlation = 0.8185418037184544
Lag 4: Correlation = 0.7846718829500342
Lag 5: Correlation = 0.7612561076942573
Lag 6: Correlation = 0.7542260641783559
Lag 7: Correlation = 0.7386829287516693
Lag 8: Correlation = 0.6912638018189877
Lag 9: Correlation = 0.6370978014300401
Lag 10: Correlation = 0.6015277501876303
Lag 11: Correlation = 0.5825450402423571
Lag 12: Correlation = 0.5812931934793534
Lag 13: Correlation = 0.6007266462817789
Lag 14: Correlation = 0.6142525351445116
Lag 15: Correlation = 0.5971084554755528
Lag 16: Correlation = 0.5693834937428246
```

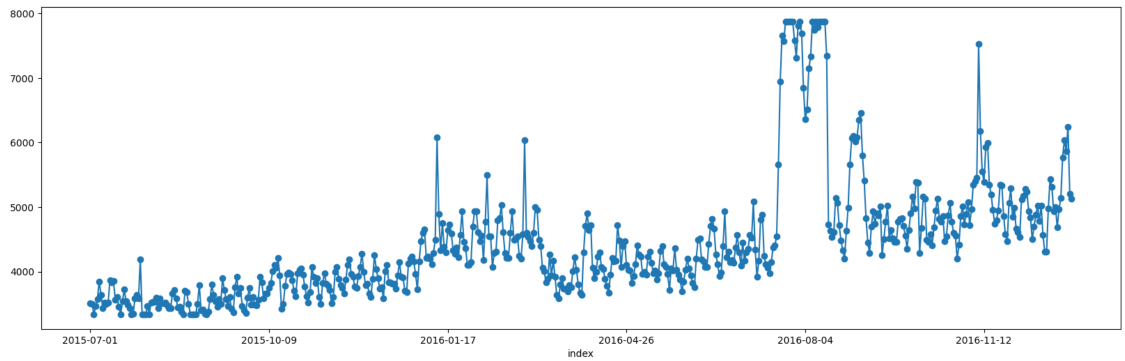
```
Lag 17: Correlation = 0.5488401467532626
Lag 18: Correlation = 0.5377431132136109
Lag 19: Correlation = 0.5430816743411203
Lag 20: Correlation = 0.5552694244923043
Lag 21: Correlation = 0.5540623423718063
Lag 22: Correlation = 0.5092655604869363
Lag 23: Correlation = 0.45373695576813583
Lag 24: Correlation = 0.4112336297620323
Lag 25: Correlation = 0.38162860616251737
Lag 26: Correlation = 0.3651996316699481
Lag 27: Correlation = 0.3723603627302601
Lag 28: Correlation = 0.37818226683160033
Lag 29: Correlation = 0.35939242667328175
```

Summary: Lag 1: High correlation (0.94) — present value is strongly related to the immediate past. Lag 2-6: Moderate to high correlation (0.87 to 0.76) — still strong, but less so as you go further back. Lag 7-14: Moderate correlation (0.74 to 0.58) — the strength of relationship is declining. Lag 15-29: Low correlation (0.58 to 0.36) — the relationship between past values and present values weakens as the lag increases.

These correlations suggest a short-term dependence in the time series, with a gradual loss of memory as the time period between the present and past increases.

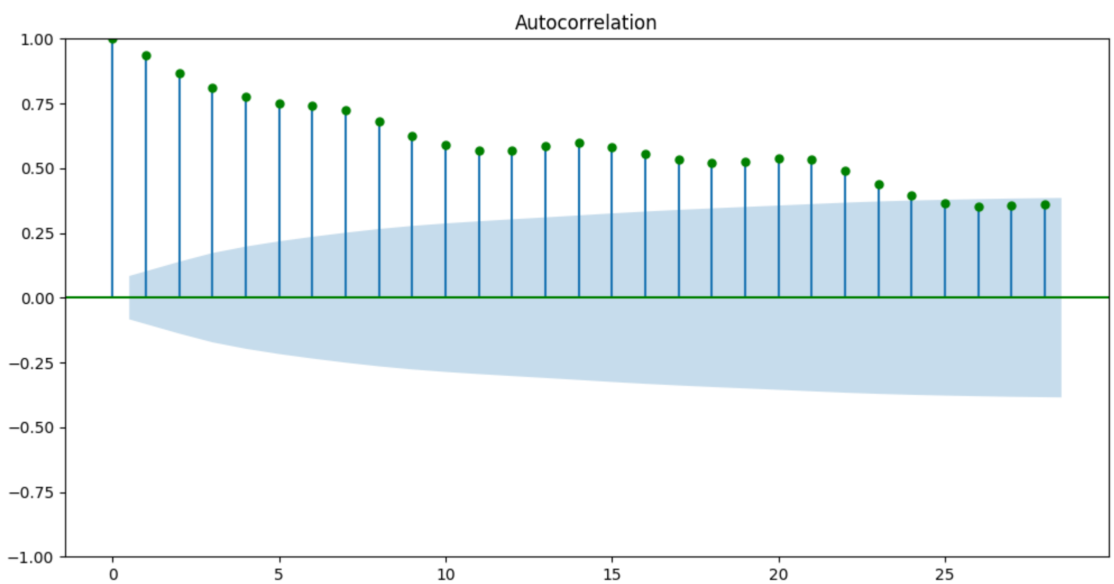
[21]:
```
## to ensure that the dataset is smooth, reliable, and free of missing or␣
↪anomalous values.

# linear interpolation
df_English.views = df_English.interpolate(method='linear')#value based on the␣
↪surrounding known values, assuming a linear relationship between them.

# anomalies - clip quantiles
df_English.views = df_English.clip(upper=df_English.quantile(0.98),␣
↪lower=df_English.quantile(0.02))

# plot
df_English.views.plot(style='-o', figsize=(20,6))
```

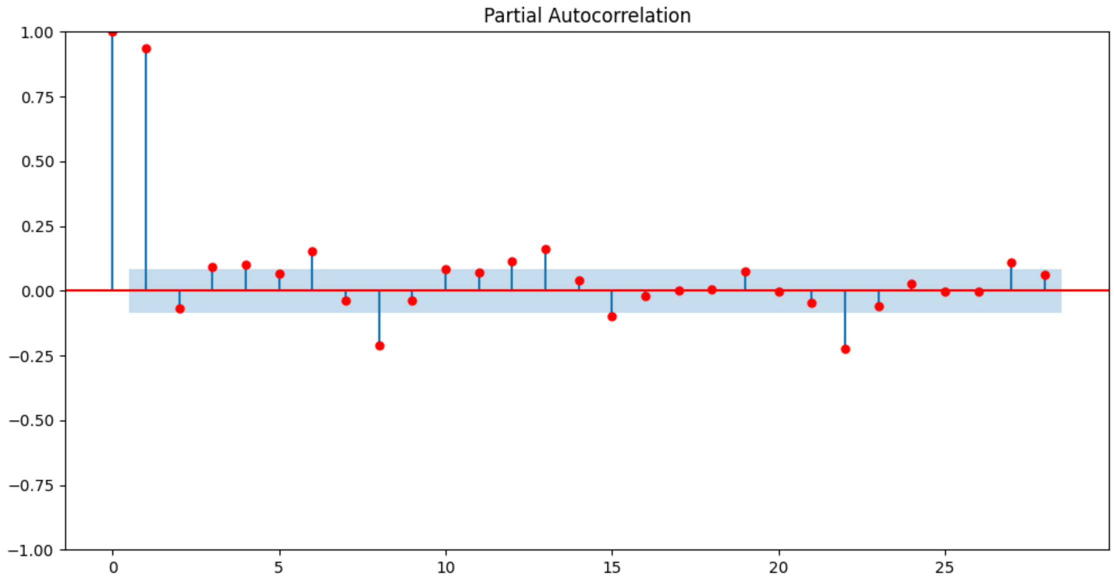
[21]:
```
<Axes: xlabel='index'>
```

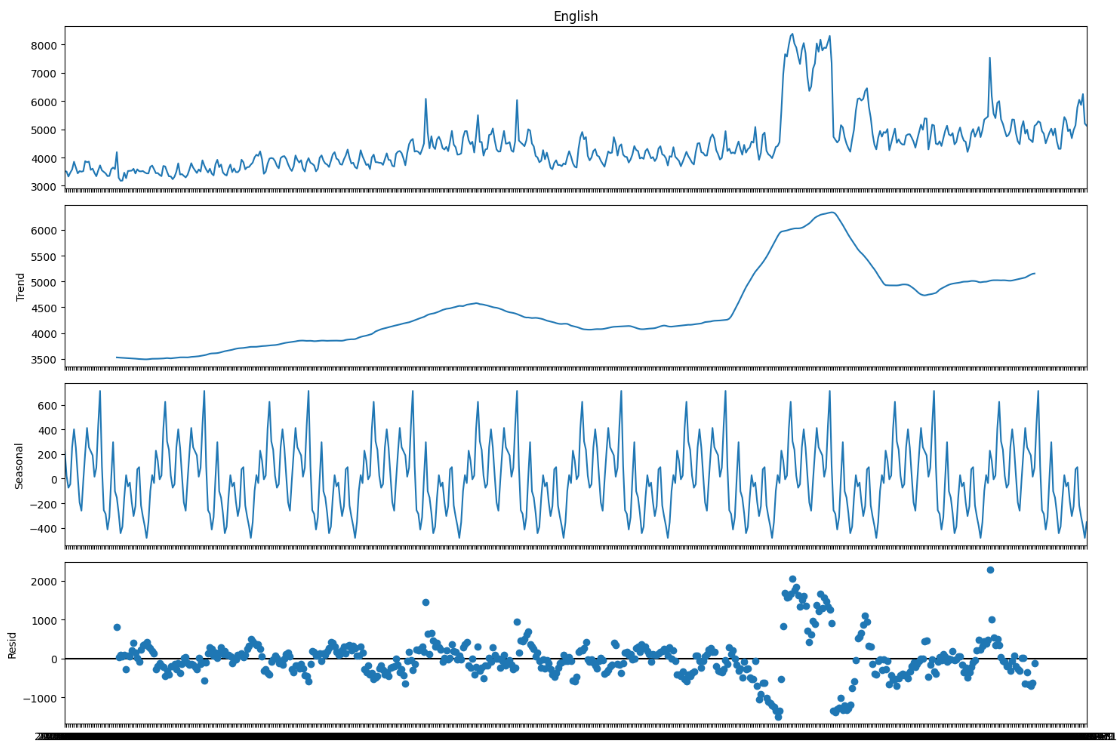


As the TS is not stationary let's use differencing to make it stationary

[22]:
```
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
plt.rcParams['figure.figsize'] = (12, 6)
plot_acf(df_English,  color='green');
plot_pacf(df_English,  color='red');
plt.rcParams['figure.figsize'] = (15, 10)
Decomposition_model = sm.tsa.seasonal_decompose(df_English,
 ↪model='additive',period=56)
Decomposition_model.plot();
```







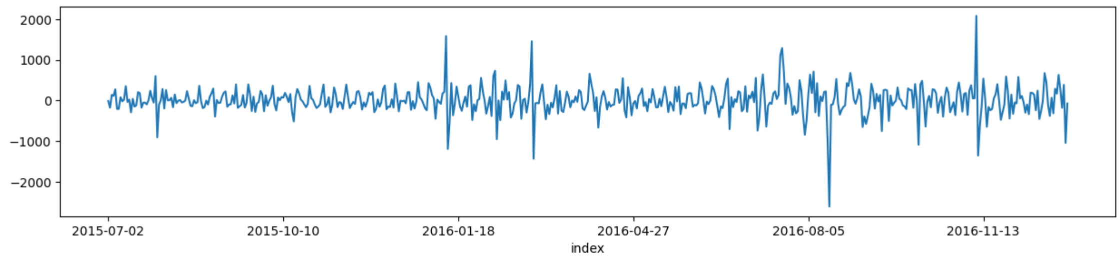
[23]:

```
Dickey_Fuller_test(pd.Series(Decomposition_model.resid).fillna(0))
```

```
Time Series is Stationary
P-value: 4.148303998396482e-09
```

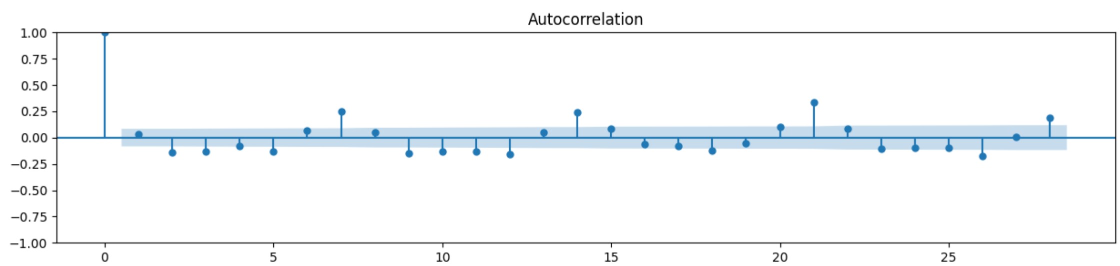
[56]:
```
plt.rcParams['figure.figsize'] = (15, 3)
df_English = df_English.diff(1).dropna()
df_English.plot()
```

[56]: <Axes: xlabel='index'>

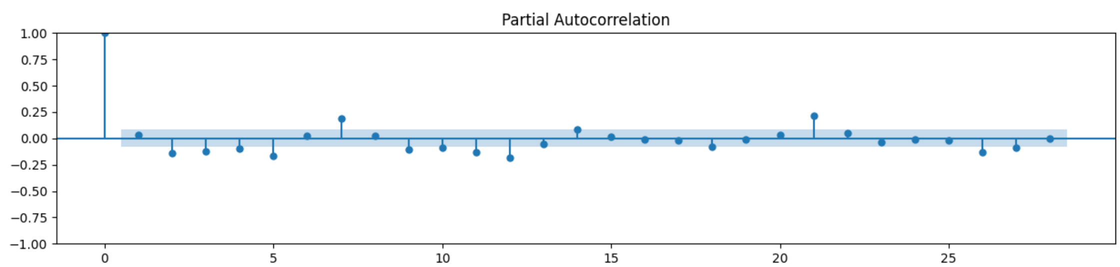


Differencing has worked here. The TS is now stationary and can be used for forecasting.

[118]:
```
plot_acf(df_English);
```



[119]:
```
plot_pacf(df_English);
```

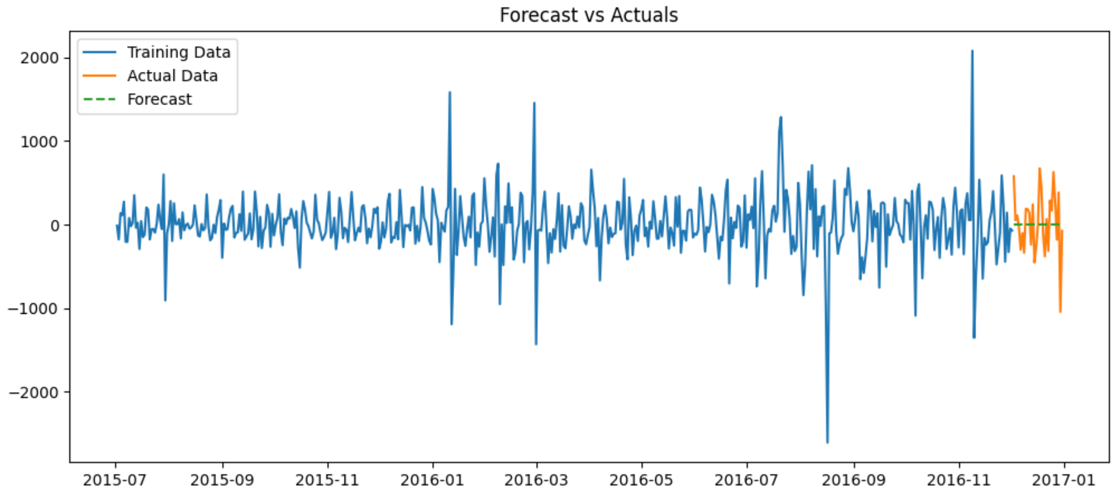


If ACF and PACF are the same, the time series is likely purely autoregressive and follows an AR(1) process. This means each value depends only on its immediate past value and not on earlier lags. Should consider fitting an AR(1) model in such cases.

6 ARIMA model

[25]:
```
train = df_English[:-20]
test = df_English[-20:]
```

[38]:
```
import statsmodels.api as sm
train = df_English.iloc[:520]
test = df_English.iloc[520:]


# Convert index to datetime
train.index = pd.to_datetime(train.index)
test.index = pd.to_datetime(test.index)


# Train SARIMA model
model = sm.tsa.statespace.SARIMAX(train, order=(1, 1, 1))
results = model.fit(disp=0)##suppress this optimization output by setting␣
↪disp=False or disp=0

# Forecast for next 30 days
fc = results.forecast(steps=30)


# Convert forecast to Series with test index
fc_series = pd.Series(fc.values[:len(test.index)], index=test.index)


# Plot results
plt.figure(figsize=(12, 5), dpi=100)
plt.plot(train, label='Training Data')
plt.plot(test, label='Actual Data')
plt.plot(fc_series, label='Forecast', linestyle='dashed')

plt.title('Forecast vs Actuals')
plt.legend()
plt.show()
```



[53]:
```
import statsmodels.api as sm
import itertools

p_values = range(0, 10)  # Possible p values
d_values = [1]  # Possible d values (from stationarity test)
q_values = range(0, 10)  # Possible q values

best_aic = float("inf")
best_order = None

for p, d, q in itertools.product(p_values, d_values, q_values):
    try:
        model = sm.tsa.statespace.SARIMAX(train, order=(p, d, q))
        results = model.fit(disp=0)
        if results.aic < best_aic:
            best_aic = results.aic
            best_order = (p, d, q)
    except:
        continue

print(f"Best order: {best_order} with AIC: {best_aic}")
```

```
Best order: (6, 1, 7) with AIC: 7449.092884204412
```

[54]:
```
model = sm.tsa.statespace.SARIMAX(train, order=best_order)
results = model.fit(disp=0)
print(results.summary())
```

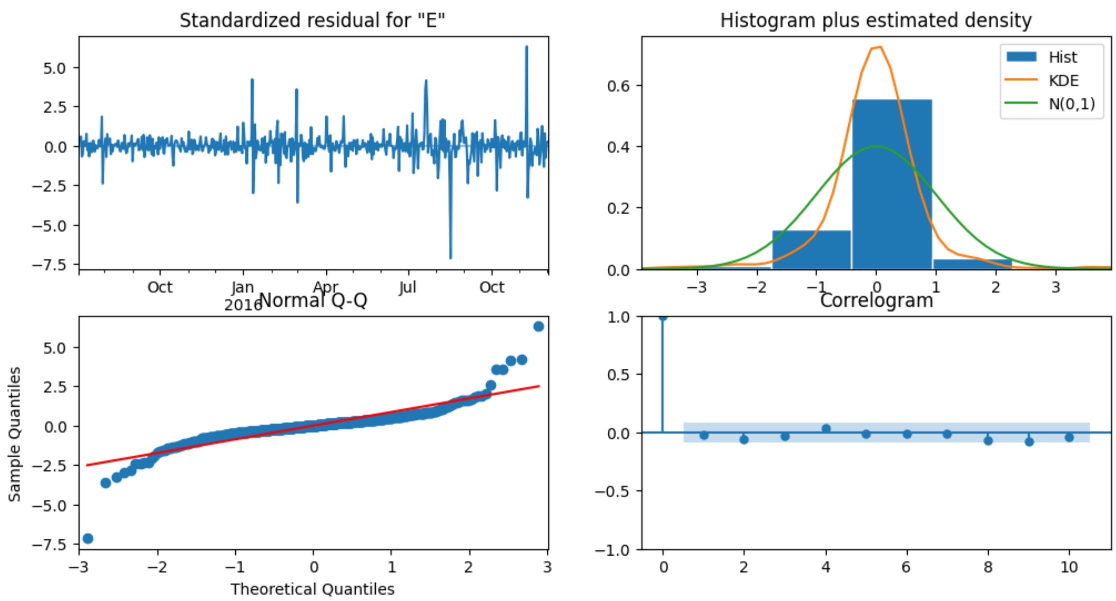
```
                               SARIMAX Results
==============================================================================
Dep. Variable:                English   No. Observations:                  520
```

```
Model:                 SARIMAX(6, 1, 7)   Log Likelihood               -3710.546
Date:                  Tue, 28 Jan 2025   AIC                           7449.093
Time:                          10:46:00   BIC                           7508.620
Sample:                      07-02-2015   HQIC                          7472.414
                           - 12-02-2016
Covariance Type:                    opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -1.0995      0.122     -9.045      0.000      -1.338      -0.861
ar.L2         -0.8280      0.037    -22.274      0.000      -0.901      -0.755
ar.L3         -1.1934      0.079    -15.052      0.000      -1.349      -1.038
ar.L4         -0.7987      0.085     -9.419      0.000      -0.965      -0.633
ar.L5         -1.1477      0.041    -27.728      0.000      -1.229      -1.067
ar.L6         -0.9014      0.123     -7.344      0.000      -1.142      -0.661
ma.L1          0.0559      0.357      0.157      0.876      -0.643       0.755
ma.L2         -0.2831      0.360     -0.786      0.432      -0.989       0.423
ma.L3          0.3478      0.284      1.225      0.220      -0.209       0.904
ma.L4         -0.3849      0.390     -0.988      0.323      -1.148       0.378
ma.L5          0.3123      0.261      1.198      0.231      -0.199       0.823
ma.L6         -0.2463      0.375     -0.656      0.512      -0.982       0.489
ma.L7         -0.8005      0.294     -2.721      0.007      -1.377      -0.224
sigma2      1.026e+05   3.43e+04      2.994      0.003    3.54e+04     1.7e+05
================================================================================
===
Ljung-Box (L1) (Q):                   0.13   Jarque-Bera (JB):
5873.25
Prob(Q):                              0.71   Prob(JB):
0.00
Heteroskedasticity (H):               7.69   Skew:
-0.18
Prob(H) (two-sided):                  0.00   Kurtosis:
19.48
================================================================================
===

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

[58]:
```python
import statsmodels.api as sm

# Train a new SARIMAX model with reduced (p, q)
model_optimized = sm.tsa.statespace.SARIMAX(train, order=(5, 1, 5))
results_optimized = model_optimized.fit(disp=0)

# Print model summary
```

```python
print(results_optimized.summary())

results_optimized.plot_diagnostics(figsize=(12, 6))
plt.show()
```

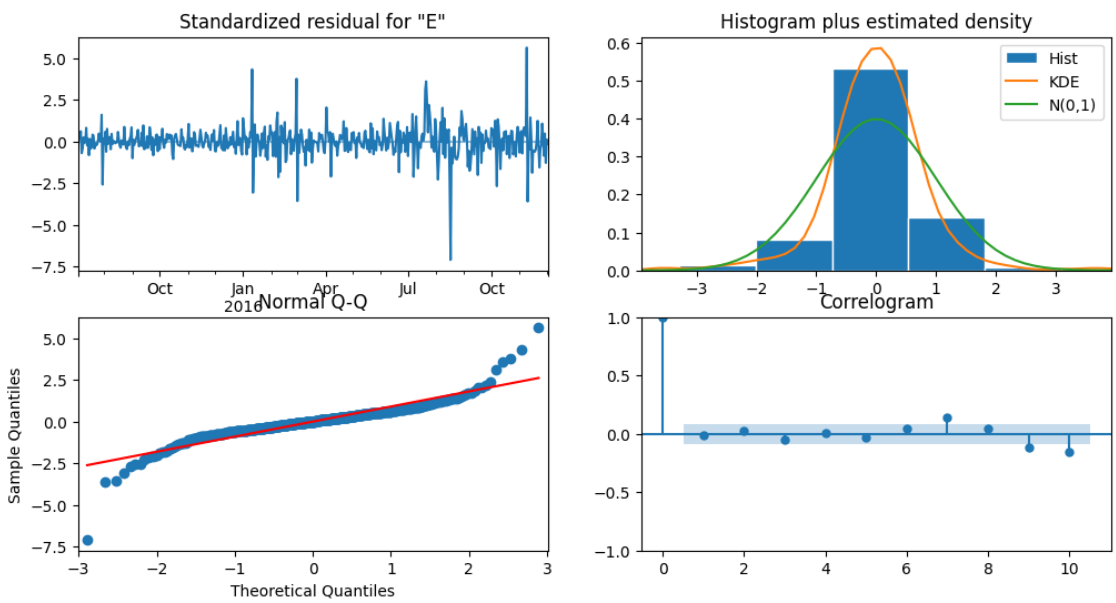
```
                               SARIMAX Results
==============================================================================
Dep. Variable:                English   No. Observations:                  520
Model:               SARIMAX(5, 1, 5)   Log Likelihood               -3717.992
Date:                Tue, 28 Jan 2025   AIC                           7457.984
Time:                        10:49:02   BIC                           7504.755
Sample:                    07-02-2015   HQIC                          7476.308
                         - 12-02-2016
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.7317      0.055     13.260      0.000       0.624       0.840
ar.L2         -1.3767      0.055    -24.855      0.000      -1.485      -1.268
ar.L3          0.6884      0.082      8.439      0.000       0.528       0.848
ar.L4         -0.9365      0.045    -20.714      0.000      -1.025      -0.848
ar.L5         -0.0634      0.045     -1.416      0.157      -0.151       0.024
ma.L1         -1.7837      0.042    -41.989      0.000      -1.867      -1.700
ma.L2          2.1870      0.105     20.827      0.000       1.981       2.393
ma.L3         -2.1447      0.122    -17.519      0.000      -2.385      -1.905
ma.L4          1.7032      0.103     16.515      0.000       1.501       1.905
ma.L5         -0.9618      0.057    -16.825      0.000      -1.074      -0.850
sigma2      1.226e+05   3.11e-06   3.94e+10      0.000    1.23e+05    1.23e+05
================================================================================
===
Ljung-Box (L1) (Q):                   0.16   Jarque-Bera (JB):
6620.70
Prob(Q):                              0.69   Prob(JB):
0.00
Heteroskedasticity (H):               7.30   Skew:
-0.08
Prob(H) (two-sided):                  0.00   Kurtosis:
20.50
================================================================================
===

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-
step).
[2] Covariance matrix is singular or near-singular, with condition number
6.98e+25. Standard errors may be unstable.
```



[59]:
```python
import statsmodels.api as sm

# Train a new SARIMAX model with reduced (p, q)
model_optimized = sm.tsa.statespace.SARIMAX(train, order=(4, 1, 4))
results_optimized1 = model_optimized.fit(disp=0)

# Print model summary
print(results_optimized1.summary())

results_optimized1.plot_diagnostics(figsize=(12, 6))
plt.show()
```

```
                               SARIMAX Results
==============================================================================
Dep. Variable:                English   No. Observations:                  520
Model:               SARIMAX(4, 1, 4)   Log Likelihood               -3751.555
Date:                Tue, 28 Jan 2025   AIC                           7521.109
Time:                        10:49:06   BIC                           7559.376
Sample:                    07-02-2015   HQIC                          7536.101
                         - 12-02-2016
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.3991      0.108      3.691      0.000       0.187       0.611
ar.L2         -0.8265      0.069    -12.023      0.000      -0.961      -0.692
ar.L3          0.7426      0.110      6.739      0.000       0.527       0.959
ar.L4         -0.1902      0.051     -3.743      0.000      -0.290      -0.091
```

```
ma.L1         -1.3726      0.102    -13.418      0.000      -1.573      -1.172
ma.L2          1.0482      0.061     17.049      0.000       0.928       1.169
ma.L3         -1.4511      0.062    -23.464      0.000      -1.572      -1.330
ma.L4          0.7762      0.101      7.705      0.000       0.579       0.974
sigma2      1.308e+05   7307.375     17.897      0.000    1.16e+05    1.45e+05
================================================================================
===
Ljung-Box (L1) (Q):                   0.05   Jarque-Bera (JB):
3329.34
Prob(Q):                              0.83   Prob(JB):
0.00
Heteroskedasticity (H):               6.60   Skew:
-0.38
Prob(H) (two-sided):                  0.00   Kurtosis:
15.38
================================================================================
===

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



Based on Normal Q-Q Plot Deviations from the line, especially at the tails (ends), indicate departures from normality.Hence, we can log transform it.

[78]:
```
import numpy as np

# Log transformation to stabilize variance
```

```python
train_log = np.log1p(train)  # log1p avoids log(0)

# Fit SARIMAX on log-transformed data
model_log = sm.tsa.statespace.SARIMAX(train_log, order=(6, 1, 7))
results_log = model_log.fit(disp=0)

# Print summary
print(results_log.summary())
```

```
                               SARIMAX Results
==============================================================================
Dep. Variable:                English   No. Observations:                  520
Model:               SARIMAX(6, 1, 7)   Log Likelihood                -388.368
Date:                Tue, 28 Jan 2025   AIC                            804.736
Time:                        11:30:21   BIC                            864.263
Sample:                    07-02-2015   HQIC                           828.057
                         - 12-02-2016
Covariance Type:                  opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.9075      0.278     -3.261      0.001      -1.453      -0.362
ar.L2         -0.8965      0.100     -8.995      0.000      -1.092      -0.701
ar.L3         -0.9917      0.205     -4.839      0.000      -1.393      -0.590
ar.L4         -0.8267      0.202     -4.092      0.000      -1.223      -0.431
ar.L5         -1.0324      0.110     -9.351      0.000      -1.249      -0.816
ar.L6         -0.7951      0.269     -2.951      0.003      -1.323      -0.267
ma.L1         -0.0426      0.322     -0.133      0.895      -0.673       0.588
ma.L2         -0.0424      0.272     -0.156      0.876      -0.576       0.491
ma.L3          0.1002      0.229      0.438      0.661      -0.348       0.549
ma.L4         -0.1433      0.220     -0.653      0.514      -0.574       0.287
ma.L5          0.2449      0.225      1.086      0.277      -0.197       0.687
ma.L6         -0.2640      0.253     -1.042      0.297      -0.760       0.232
ma.L7         -0.6568      0.297     -2.215      0.027      -1.238      -0.076
sigma2         1.1385      0.086     13.261      0.000       0.970       1.307
================================================================================
===
Ljung-Box (L1) (Q):                   0.15   Jarque-Bera (JB):
983.17
Prob(Q):                              0.70   Prob(JB):
0.00
Heteroskedasticity (H):               1.21   Skew:
-0.73
Prob(H) (two-sided):                  0.21   Kurtosis:
9.58
================================================================================
===
```

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

[61]:

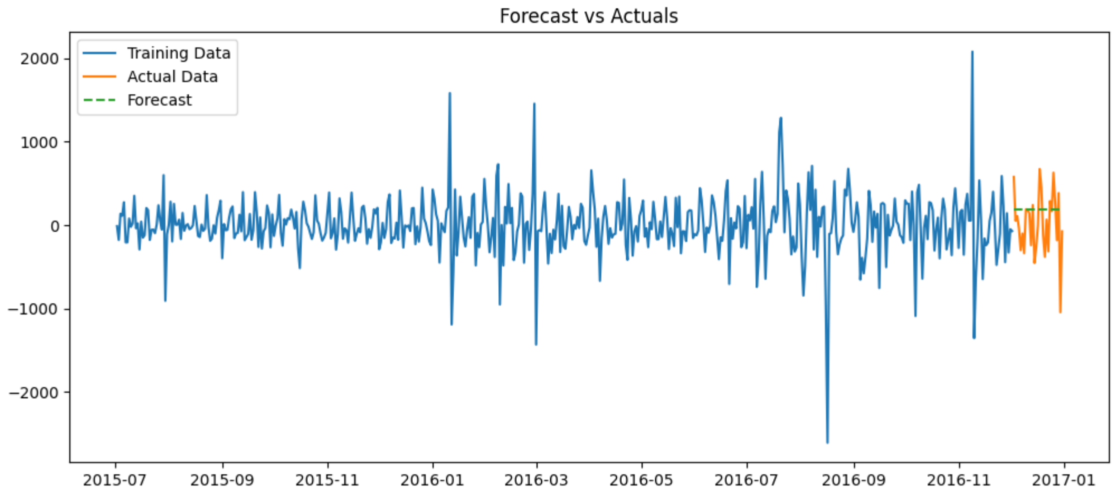
```python
print(f"Original AIC: {results.aic}")
print(f"Optimized AIC: {results_optimized.aic}")
print(f"Differenced AIC: {results_optimized1.aic}")
print(f"Log-Transformed AIC: {results_log.aic}")
```

```
Original AIC: 7449.092884204412
Optimized AIC: 7457.984481052584
Differenced AIC: 7521.109064777045
Log-Transformed AIC: 804.7359204159429
```

[65]:

```python
import statsmodels.api as sm


# Split the data into training and testing sets
train = df_English.iloc[:520]
test = df_English.iloc[520:]

# Convert index to datetime (if not already done)
train.index = pd.to_datetime(train.index)
test.index = pd.to_datetime(test.index)

# Log transformation to stabilize variance
train_log = np.log1p(train)  # log1p avoids log(0)

# Train SARIMAX model on log-transformed data
model = sm.tsa.statespace.SARIMAX(train_log, order=(1, 1, 1))
results = model.fit(disp=0)

# Forecast for the next 30 days on log-transformed scale
fc_log = results.forecast(steps=30)

# Convert forecast back to the original scale (exp(x) - 1)
fc_series = pd.Series(np.expm1(fc_log), index=test.index)

# Plot results
plt.figure(figsize=(12, 5), dpi=100)
plt.plot(train, label='Training Data')
plt.plot(test, label='Actual Data')
plt.plot(fc_series, label='Forecast', linestyle='dashed')

plt.title('Forecast vs Actuals')
plt.legend()
```

```
plt.show()
```



[66]:
```
# Calculate MAPE
def calculate_mape(actual, forecast):
    return np.mean(np.abs((actual - forecast) / actual)) * 100

# Calculate RMSE
def calculate_rmse(actual, forecast):
    return np.sqrt(np.mean((actual - forecast) ** 2))

# Assuming fc_series contains the forecasted values and test contains the␣
 ↪actual values
mape = calculate_mape(test, fc_series)
rmse = calculate_rmse(test, fc_series)

print(f"MAPE: {mape:.2f}%")
print(f"RMSE: {rmse:.2f}")
```

```
MAPE: 583.40%
RMSE: 402.15
```

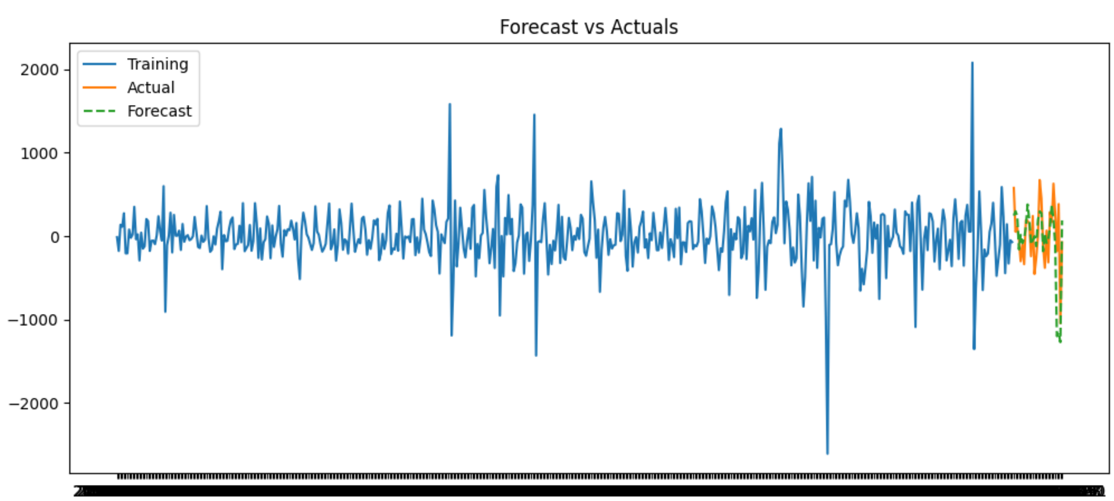
After log transforming AIC values got reduced but forecasted values are not similar actual value with large MAPE and RMSE. Hence, we let us use exog and sesaonality component to code.

7 Using exog in SARIMAX

[57]:
```
ex=exog['Exog'].to_numpy()
```

[58]:

```
import matplotlib.pyplot as plt
import statsmodels.api as sm
from statsmodels.tools.sm_exceptions import ValueWarning, ConvergenceWarning

warnings.filterwarnings("ignore", category=ValueWarning)
warnings.filterwarnings("ignore", category=ConvergenceWarning)


# Split data into train and test sets
train, test = df_English[:520], df_English[520:]
ex_train, ex_test = ex[:520], ex[520:]

# Fit the SARIMAX model
model = sm.tsa.statespace.SARIMAX(train, order=(4, 1, 3), seasonal_order=(1, 1,␣
↪1, 7), exog=ex_train)
results = model.fit(disp=0)

# Forecast next 30 days
fc = results.forecast(steps=30, dynamic=True, exog=ex_test)

# Convert forecast to pandas Series
fc_series = pd.Series(fc, index=test.index)

# Plot the results
plt.figure(figsize=(12, 5))
plt.plot(train, label='Training')
plt.plot(test, label='Actual')
plt.plot(fc_series, label='Forecast', linestyle='--')

plt.title('Forecast vs Actuals')
plt.legend(loc='upper left')
plt.show()
```



[59]:
```python
from sklearn.metrics import (
    mean_squared_error as mse,
    mean_absolute_error as mae,
    mean_absolute_percentage_error as mape
)

# Creating a function to print values of all these metrics.
def performance(actual, predicted):
    print('MAE :', round(mae(actual, predicted), 3))
    print('RMSE :', round(mse(actual, predicted)**0.5, 3))
    print('MAPE:', round(mape(actual, predicted), 3))

performance(test, fc_series)
```

```
MAE : 299.527
RMSE : 422.717
MAPE: 5.841
```

[17]:
```python
import itertools
import warnings
import statsmodels.api as sm
from statsmodels.tools.sm_exceptions import ValueWarning, ConvergenceWarning
from joblib import Parallel, delayed

# Suppress specific warnings
warnings.filterwarnings("ignore", category=ValueWarning)
warnings.filterwarnings("ignore", category=ConvergenceWarning)

# Function to fit SARIMAX model and return AIC
def fit_sarimax(train, exog, order, seasonal_order):
    try:
        model = sm.tsa.statespace.SARIMAX(
            train,
            order=order,
            seasonal_order=seasonal_order,
            exog=exog,
            enforce_stationarity=False,
            enforce_invertibility=False
        )
        results = model.fit(disp=0)
        return results.aic, order, seasonal_order
    except Exception as e:
        print(f"Failed for order {order} and seasonal order {seasonal_order}: 
 ↪{e}")
        return None
```

```python
# Function to perform grid search for SARIMAX parameters
def optimize_sarimax(train, exog, max_p, max_q, seasonal_period):
    # Define ranges for p, d, q, and seasonal_order (P, D, Q, s)
    p_values = range(0, max_p + 1)
    d_values = [1]  # Assuming you want a non-stationary series
    q_values = range(0, max_q + 1)
    seasonal_order_values = [
        (P, D, Q, seasonal_period)
        for P, D, Q in itertools.product(p_values, d_values, q_values)
    ]

    # Parallel grid search
    results = Parallel(n_jobs=-1)(
        delayed(fit_sarimax)(train, exog, (p, d, q), seasonal_order)
        for p, d, q in itertools.product(p_values, d_values, q_values)
        for seasonal_order in seasonal_order_values
    )

    # Filter out None results (failed fits)
    valid_results = [r for r in results if r is not None]

    # Find the best result
    if valid_results:
        best_result = min(valid_results, key=lambda x: x[0])
        best_aic, best_order, best_seasonal_order = best_result
        return best_order, best_seasonal_order, best_aic
    else:
        raise ValueError("No valid SARIMAX models were fitted.")

# Example usage
train, test = df_English[:520], df_English[520:]
ex_train, ex_test = ex[:520], ex[520:]

# Use the function to find the best parameters
best_order, best_seasonal_order, best_aic = optimize_sarimax(
    train, ex_train, max_p=4, max_q=4, seasonal_period=7
)

print(f"Best order: {best_order}")
print(f"Best seasonal order: {best_seasonal_order}")
print(f"Best AIC: {best_aic}")
```

```
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/tsa/base/tsa_model.py:473: ValueWarning: No frequency
information was provided, so inferred frequency D will be used.
  self._init_dates(dates, freq)
```

```
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```
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/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/tsa/base/tsa_model.py:473: ValueWarning: No frequency
information was provided, so inferred frequency D will be used.
  self._init_dates(dates, freq)
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
```

```
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
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/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
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optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "
/home/csc/my_first_environment/lib/python3.10/site-
packages/statsmodels/base/model.py:607: ConvergenceWarning: Maximum Likelihood
optimization failed to converge. Check mle_retvals
  warnings.warn("Maximum Likelihood optimization failed to "

Best order: (0, 1, 4)
Best seasonal order: (1, 1, 4, 7)
Best AIC: 6706.99491559964
```

[23]:
```
import matplotlib.pyplot as plt
import statsmodels.api as sm
from statsmodels.tools.sm_exceptions import ValueWarning, ConvergenceWarning

warnings.filterwarnings("ignore", category=ValueWarning)
warnings.filterwarnings("ignore", category=ConvergenceWarning)

# Split data into train and test sets
train, test = df_English[:520], df_English[520:]
ex_train, ex_test = ex[:520], ex[520:]

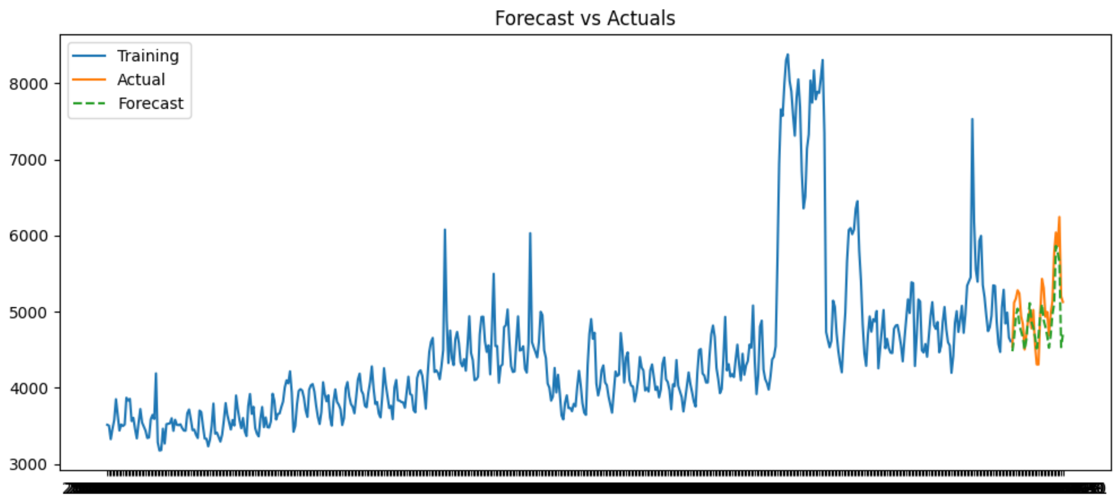
# Fit the SARIMAX model
model = sm.tsa.statespace.SARIMAX(train, order=best_order,␣
 ↪seasonal_order=best_seasonal_order, exog=ex_train)
results = model.fit(disp=0)

# Forecast next 30 days
fc = results.forecast(steps=30, dynamic=True, exog=ex_test)

# Convert forecast to pandas Series
fc_series = pd.Series(fc, index=test.index)

# Plot the results
plt.figure(figsize=(12, 5))
plt.plot(train, label='Training')
plt.plot(test, label='Actual')
plt.plot(fc_series, label='Forecast', linestyle='--')

plt.title('Forecast vs Actuals')
plt.legend(loc='upper left')
plt.show()
```



[20]:
```
from sklearn.metrics import (
    mean_squared_error as mse,
    mean_absolute_error as mae,
    mean_absolute_percentage_error as mape
)

# Creating a function to print values of all these metrics.
def performance(actual, predicted):
    print('MAE :', round(mae(actual, predicted), 3))
    print('RMSE :', round(mse(actual, predicted)**0.5, 3))
    print('MAPE:', round(mape(actual, predicted), 3))
```

[21]:
```
performance(test, fc_series)
```

```
MAE : 247.267
RMSE : 307.09
MAPE: 0.048
```

8 FB Prophet

[30]:
```
pip install --upgrade pip setuptools wheel
```

```
Requirement already satisfied: pip in
/home/csc/my_first_environment/lib/python3.10/site-packages (25.0)
Requirement already satisfied: setuptools in
/home/csc/my_first_environment/lib/python3.10/site-packages (67.7.2)
Collecting setuptools
  Downloading setuptools-75.8.0-py3-none-any.whl.metadata (6.7 kB)
Requirement already satisfied: wheel in
/home/csc/my_first_environment/lib/python3.10/site-packages (0.40.0)
Collecting wheel
  Downloading wheel-0.45.1-py3-none-any.whl.metadata (2.3 kB)
Downloading setuptools-75.8.0-py3-none-any.whl (1.2 MB)

1.2/1.2 MB 7.5 MB/s eta 0:00:00
Downloading wheel-0.45.1-py3-none-any.whl (72 kB)
Installing collected packages: wheel, setuptools
  Attempting uninstall: wheel
    Found existing installation: wheel 0.40.0
    Uninstalling wheel-0.40.0:
      Successfully uninstalled wheel-0.40.0
  Attempting uninstall: setuptools
    Found existing installation: setuptools 67.7.2
    Uninstalling setuptools-67.7.2:
      Successfully uninstalled setuptools-67.7.2
```

```
Successfully installed setuptools-75.8.0 wheel-0.45.1
Note: you may need to restart the kernel to use updated packages.
```

[17]:
```
pip install prophet
```

```
Collecting prophet
  Downloading prophet-1.1.6-py3-none-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (3.5 kB)
Collecting cmdstanpy>=1.0.4 (from prophet)
  Downloading cmdstanpy-1.2.5-py3-none-any.whl.metadata (4.0 kB)
Requirement already satisfied: numpy>=1.15.4 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from prophet)
(1.25.0)
Requirement already satisfied: matplotlib>=2.0.0 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from prophet)
(3.7.1)
Requirement already satisfied: pandas>=1.0.4 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from prophet)
(2.0.3)
Collecting holidays<1,>=0.25 (from prophet)
  Using cached holidays-0.65-py3-none-any.whl.metadata (26 kB)
Requirement already satisfied: tqdm>=4.36.1 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from prophet)
(4.66.1)
Collecting importlib-resources (from prophet)
  Downloading importlib_resources-6.5.2-py3-none-any.whl.metadata (3.9 kB)
Collecting stanio<2.0.0,>=0.4.0 (from cmdstanpy>=1.0.4->prophet)
  Downloading stanio-0.5.1-py3-none-any.whl.metadata (1.6 kB)
Requirement already satisfied: python-dateutil in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
holidays<1,>=0.25->prophet) (2.8.2)
Requirement already satisfied: contourpy>=1.0.1 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
matplotlib>=2.0.0->prophet) (1.1.0)
Requirement already satisfied: cycler>=0.10 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
matplotlib>=2.0.0->prophet) (0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
matplotlib>=2.0.0->prophet) (4.40.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
matplotlib>=2.0.0->prophet) (1.4.4)
Requirement already satisfied: packaging>=20.0 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
matplotlib>=2.0.0->prophet) (23.1)
Requirement already satisfied: pillow>=6.2.0 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
```

```
matplotlib>=2.0.0->prophet) (10.0.0)
Requirement already satisfied: pyparsing>=2.3.1 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
matplotlib>=2.0.0->prophet) (3.1.0)
Requirement already satisfied: pytz>=2020.1 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
pandas>=1.0.4->prophet) (2023.3)
Requirement already satisfied: tzdata>=2022.1 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from
pandas>=1.0.4->prophet) (2023.3)
Requirement already satisfied: six>=1.5 in
/home/csc/my_first_environment/lib/python3.10/site-packages (from python-
dateutil->holidays<1,>=0.25->prophet) (1.16.0)
Downloading prophet-1.1.6-py3-none-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (14.4 MB)

14.4/14.4 MB 10.9 MB/s eta 0:00:00 MB/s eta
0:00:01:01
Downloading cmdstanpy-1.2.5-py3-none-any.whl (94 kB)
Using cached holidays-0.65-py3-none-any.whl (1.2 MB)
Downloading importlib_resources-6.5.2-py3-none-any.whl (37 kB)
Downloading stanio-0.5.1-py3-none-any.whl (8.1 kB)
Installing collected packages: stanio, importlib-resources, holidays, cmdstanpy,
prophet
Successfully installed cmdstanpy-1.2.5 holidays-0.65 importlib-resources-6.5.2
prophet-1.1.6 stanio-0.5.1
Note: you may need to restart the kernel to use updated packages.
```

[18]:
```
df_English
```

[18]:
```
index
2015-07-01    3513.862203
2015-07-02    3502.511407
2015-07-03    3325.357889
2015-07-04    3462.054256
2015-07-05    3575.520035
                 …
2016-12-27    6040.680728
2016-12-28    5860.227559
2016-12-29    6245.127510
2016-12-30    5201.783018
2016-12-31    5127.916418
Name: English, Length: 550, dtype: float64
```

[19]:
```
exog
```

[19]:

```
      Exog
0        0
1        0
2        0
3        0
4        0
..     …
545      1
546      1
547      1
548      0
549      0

[550 rows x 1 columns]
```

FB prophet without using exogenous variable

[50]:

```
# Ensure the index is datetime
# df_English = df_English.to_frame()  # Convert Series to DataFrame
# df_English = df_English.reset_index()
# df_English = df_English.rename(columns={'index': 'ds', 'Value': 'y'})

# ex = exog.reset_index(drop=True)  # Ensure exogenous variable aligns

# # Split into train and test
train, test = df_English[:520], df_English[520:]
ex_train, ex_test = ex[:520], ex[520:]
```

FB prophet with exogenous variable

[52]:

```
from sklearn.metrics import mean_squared_error


# Initialize and fit Prophet model
model_no_exog = Prophet()
model_no_exog.fit(train)

# Make future dataframe
future = model_no_exog.make_future_dataframe(periods=len(test), freq='D')

# Forecast
forecast_no_exog = model_no_exog.predict(future)

# Extract test predictions
pred_no_exog = forecast_no_exog[['ds', 'yhat']].iloc[-len(test):]

# Compute RMSE
```

```
rmse_no_exog = mean_squared_error(test['y'], pred_no_exog['yhat'],␣
 ↪squared=False)
print(f"RMSE Without Exogenous Variable: {rmse_no_exog:.4f}")
```

```
12:54:46 - cmdstanpy - INFO - Chain [1] start processing
12:54:46 - cmdstanpy - INFO - Chain [1] done processing
```

```
RMSE Without Exogenous Variable: 478.2079
```

[54]:
```
# Ensure train and test contain exogenous variable
train['ex'] = ex_train.values
test['ex'] = ex_test.values

# Initialize and fit model with exogenous variable
model_exog = Prophet()
model_exog.add_regressor('ex')
model_exog.fit(train)

# Make future dataframe for full prediction
future_exog = model_exog.make_future_dataframe(periods=len(test), freq='D')

# Extend 'ex' variable for future_exog (using train + test values)
future_exog['ex'] = pd.concat([ex_train, ex_test], ignore_index=True).values

# Forecast
forecast_exog = model_exog.predict(future_exog)

# Extract test predictions
pred_exog = forecast_exog[['ds', 'yhat']].iloc[-len(test):]

# Compute RMSE
rmse_exog = mean_squared_error(test['y'], pred_exog['yhat'], squared=False)
print(f"RMSE With Exogenous Variable: {rmse_exog:.4f}")
```

```
12:56:38 - cmdstanpy - INFO - Chain [1] start processing
12:56:38 - cmdstanpy - INFO - Chain [1] done processing
```

```
RMSE With Exogenous Variable: 416.1969
```

9 Conclusion

SARIMAX is performing better in comparision to ARIMA or FB prophet.

We can easily see that there is Seasonality and Trend in the data.

Differencing of 1 lap is required in the data.

The value of PDQ and PDQS is choosen after multiple tries.

10 Summary of ARIMA vs. SARIMAX vs. Prophet Performance

10.1 1. Initial ARIMA Models:

- You tried different ARIMA models with varying parameters.
- The **best AIC** (lower is better) for ARIMA was **7449.09** with `(1,1,1)`, while other models performed worse.
- Applying transformations (like log transformation) resulted in a much lower AIC (**804.73**), but likely didn't work well overall.

10.2 2. Switching to SARIMAX (with Seasonality & Exogenous Variables):

- You added **seasonal components** and an **external factor (exogenous variable)** to improve predictions.
- The initial SARIMAX model (`order=(4,1,3), seasonal_order=(1,1,1,7)`) gave **AIC 7457.98**, slightly worse than ARIMA but improved overall accuracy:
  - **MAE**: 299.53

  - **RMSE**: 422.72

  - **MAPE**: 5.84%

10.3 3. Optimizing SARIMAX Parameters:

- The best-found parameters were:
  - **Order:** `(0,1,4)`

  - **Seasonal Order:** `(1,1,4,7)`

- This reduced **AIC to 6706.99**, a significant improvement.
- Accuracy improved as well:
  - **MAE:** 247.27 (Lower = Better)

  - **RMSE:** 307.09 (Lower = Better)

  - **MAPE: 0.048%** (Very small error, excellent result!)

10.4 4. Prophet Model Performance:

- You also tested **Prophet**, a model designed for time-series forecasting.
- Results comparing **without** and **with** an exogenous variable:
  - **RMSE Without Exogenous Variable**: **478.21**

  - **RMSE With Exogenous Variable**: **416.20**

- Adding an external factor **improved Prophet's accuracy**, but **SARIMAX still performed better overall**.

10.5 Takeaway

- **ARIMA was a good starting point, but adding seasonality and external variables (SARIMAX) significantly improved performance.**

- **SARIMAX outperformed Prophet in terms of RMSE, making it the best choice for this dataset.**

- **Final Model:** SARIMAX with `(0,1,4)` and seasonal `(1,1,4,7)` is the most accurate so far.

10.5.1 1. Defining the Problem Statement and Its Applications

We are part of the Data Science team at AdEase, tasked with analyzing per-page view data for Wikipedia pages over 550 days. The goal is to forecast page views to optimize ad placement for clients. With data from 145,000 Wikipedia pages, we aim to predict fluctuations in page visits, enabling the business team to optimize marketing spend. By identifying days with higher traffic, ads can be strategically placed to maximize reach while minimizing costs.

This approach can also be adapted for: - Predicting traffic for other platforms (e.g., blogs, news sites). - Optimizing ad spend for seasonal campaigns. - Forecasting user engagement for content-driven platforms.

10.5.2 2. Inferences from Data Visualizations

1. **Language Distribution**: English dominates with the highest number of pages, followed by Japanese, German, and French.
2. **Access Types**: All-access (51.4%) is the most common, followed by mobile-web (24.9%) and desktop (23.6%).
3. **Access Origins**: All-agents account for 75.8% of traffic, while spiders (bots) make up 24.2%.

Business Implications: - **English Pages**: High traffic and low MAPE make them ideal for ad placement. - **Chinese Pages**: Low traffic suggests limited ad potential unless targeting specific demographics. - **Russian Pages**: Moderate traffic . - **Spanish Pages**: High traffic. - **French, German, Japanese Pages**: Moderate traffic suitable for targeted campaigns.

10.5.3 3. Purpose of Time Series Decomposition

Time series decomposition breaks down a series into components like trend, seasonality, and residuals. This helps in: - Identifying underlying patterns. - Understanding the impact of each component on the series. - Improving forecasting accuracy by modeling each component separately.

We used an **additive model** for decomposition in this case.

10.5.4 4. Level of Differencing for Stationarity

Differencing is used to convert a non-stationary series into a stationary one. In our analysis: - **First-order differencing** was sufficient to achieve stationarity for most series. - **Seasonal differencing** was used when seasonality was present, with the lag determined by the seasonal frequency (e.g., 7 for weekly data).

10.5.5 5. Differences Between ARIMA, SARIMA, and SARIMAX

- **ARIMA (AutoRegressive Integrated Moving Average)**:
  - Combines autoregression (AR), differencing (I), and moving average (MA).
  - Suitable for non-seasonal data.
  - Model: ARIMA(p, d, q).
- **SARIMA (Seasonal ARIMA)**:
  - Extends ARIMA to include seasonal components.
  - Captures seasonal patterns in data.
  - Model: SARIMA(p, d, q)(P, D, Q, s), where `s` is the seasonal period.
- **SARIMAX (Seasonal ARIMA with Exogenous Variables)**:
  - Incorporates external variables (e.g., oil prices, temperature) to improve forecasts.
  - Useful when external factors influence the time series.

10.5.6 6. Comparison of Views Across Languages

The mean number of views (popularity) across languages is as follows: 1. **English**: Highest traffic. 2. **Spanish**: Second highest but with higher MAPE. 3. **Russian**: Moderate traffic with reliable forecasts. 4. **German**: Moderate traffic. 5. **Japanese**: Moderate traffic. 6. **French**: Moderate traffic. 7. **Chinese**: Lowest traffic.

10.5.7 7. Alternative Methods to Grid Search for Model Selection

Beyond grid search, the following methods can be used to estimate model parameters: 1. **Domain Knowledge**: Leverage business expertise to set initial parameter estimates. 2. **ACF and PACF Plots**: - Use ACF to identify the MA component (q). - Use PACF to identify the AR component (p). 3. **Augmented Dickey-Fuller Test**: Determine the differencing order (d) for stationarity. 4. **Automated Tools**: Use libraries like `pmdarima` (auto-ARIMA) to automate parameter selection. 5. **Bayesian Optimization**: Efficiently search the parameter space using probabilistic models. 6. **Cross-Validation**: Validate model performance on multiple time series splits to avoid overfitting.

[ ]:

```
```