In [ ]:

```
import pandas as pd
import math
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
import datetime
import matplotlib.dates as mdates
from scipy.stats import poisson
from scipy.stats import geom
from scipy.stats import binom
import csv
```

1. Data pre-processing

Copy the states data from google Drive

In [ ]:

```
!cp -r /content/drive/MyDrive/ProbStat_HW/2.csv /content
```

```
cp: cannot stat '/content/drive/MyDrive/ProbStat_HW/2.csv': No such file or d
irectory
```

In [ ]:

```
data = pd.read_csv("/content/2.csv")
print(data)
```

```
           Date  AR confirmed  AZ confirmed  AR deaths  AZ deaths
0    2020-01-22             0             0          0          0
1    2020-01-23             0             0          0          0
2    2020-01-24             0             0          0          0
3    2020-01-25             0             0          0          0
4    2020-01-26             0             1          0          0
..          ...           ...           ...        ...        ...
433  2021-03-30        330188        841192       5661      16942
434  2021-03-31        330401        841884       5669      16968
435  2021-04-01        330611        842273       5678      16979
436  2021-04-02        330756        843174       5679      16998
437  2021-04-03        330972        844328       5681      17005

[438 rows x 5 columns]
```

In [ ]:

```
if( not data.isnull().values.any()):
    print("Dataset has no NA values")
else:
    print(data)
    data.dropna(inplace=True)
    print(data)
```

In [ ]:

```
data["cases_ar"] = data["AR confirmed"].diff()
data["cases_az"] = data["AZ confirmed"].diff()
data["deaths_ar"] = data["AR deaths"].diff()
data["deaths_az"] = data["AZ deaths"].diff()
print(data)
```

```
           Date  AR confirmed  AZ confirmed  ...  cases_az  deaths_ar  deaths
_az
0    2020-01-22             0             0  ...       NaN        NaN
NaN
1    2020-01-23             0             0  ...       0.0        0.0
0.0
2    2020-01-24             0             0  ...       0.0        0.0
0.0
3    2020-01-25             0             0  ...       0.0        0.0
0.0
4    2020-01-26             0             1  ...       1.0        0.0
0.0
..          ...           ...           ...  ...       ...        ...
...
433  2021-03-30        330188        841192  ...     578.0       12.0        2
1.0
434  2021-03-31        330401        841884  ...     692.0        8.0        2
6.0
435  2021-04-01        330611        842273  ...     389.0        9.0        1
1.0
436  2021-04-02        330756        843174  ...     901.0        1.0        1
9.0
437  2021-04-03        330972        844328  ...    1154.0        2.0
7.0

[438 rows x 9 columns]
```

setting all values at 0th index to 0 as they're NaN otherwise.

In [ ]:

```
data.loc[0, 'cases_ar'] = 0
data.loc[0, 'cases_az'] = 0
data.loc[0, 'deaths_ar'] = 0
data.loc[0, 'deaths_az'] = 0
```

In [ ]:

```
print(data)
```

In [ ]:

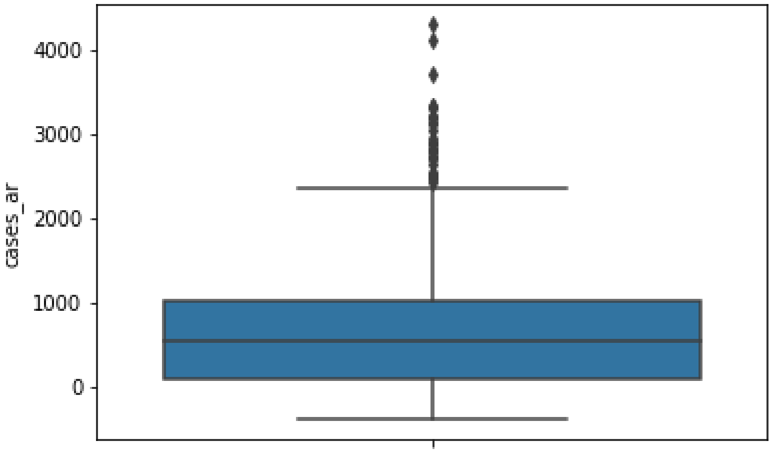
```
def remove_outliers(data, parameters):
    preprocessed = pd.DataFrame()
    for parameter in parameters:

        q1 = data[parameter].quantile(0.25)
        q2 = data[parameter].quantile(0.50)
        q3 = data[parameter].quantile(0.75)
        q4 = data[parameter].quantile(1.00)

        print("----",parameter,"----")
        print("q1 is", q1)
        print("q2 is", q2)
        print("q3 is", q3)
        print("q4 is", q4)

        iqr = q3 - q1

        print("IQR is", iqr)

        tukeys_upper = q3 + (iqr*1.5)
        tukeys_lower = q1 - (iqr*1.5)

        print("Tukey's Upper : ", tukeys_upper)
        print("Tukey's Lower : ", tukeys_lower)

        colData = data[["Date",parameter]]

        outliers = colData.loc[ ((colData[parameter] < tukeys_lower) | (colData[parameter] > tukeys_upper) & colData[parameter] != 0 ), ['Date',parameter] ]
        outliers.to_csv("outliers_"+parameter+".csv")
        print("number of outliers", outliers.shape[0])

        #filtering out values that are 0 or are >= tukeys lower and <= tukeys upper
        preprocessed = colData.loc[ (colData[parameter] == 0) | ((colData[parameter] >= tukeys_lower) & (colData[parameter] <= tukeys_upper)), ['Date',parameter] ]

        #replacing negative values with zeroes:
        preprocessed.loc[preprocessed[parameter]<0, parameter] = 0
        sns.boxplot(y=data[parameter])
        plt.show()
        print("Preprocessed", parameter ,"is")
        print(preprocessed)
        preprocessed.to_csv("processed_"+parameter+".csv")
```

In [ ]:

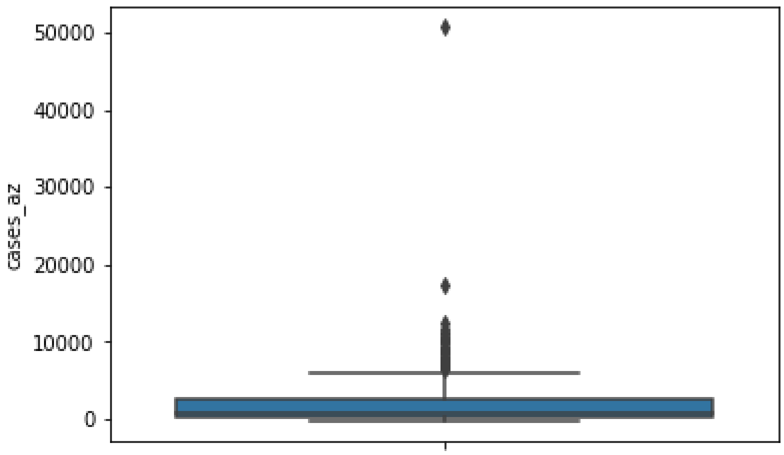
```
def plot_data(data, parameters):
    for parameter in parameters:
        y=[datetime.datetime.strptime(d,'%Y-%m-%d').date() for d in data["Dat
e"]]
        x=data[parameter]
        plt.ylabel(parameter)
        plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y-%m-%d'))
        plt.gca().xaxis.set_major_locator(mdates.DayLocator(interval=50))
        plt.plot(y,x)
        plt.gcf().autofmt_xdate()
        plt.show()
```

```
In [ ]: cols = ["cases_ar","cases_az", "deaths_ar", "deaths_az" ]
        remove_outliers(data, cols)
```

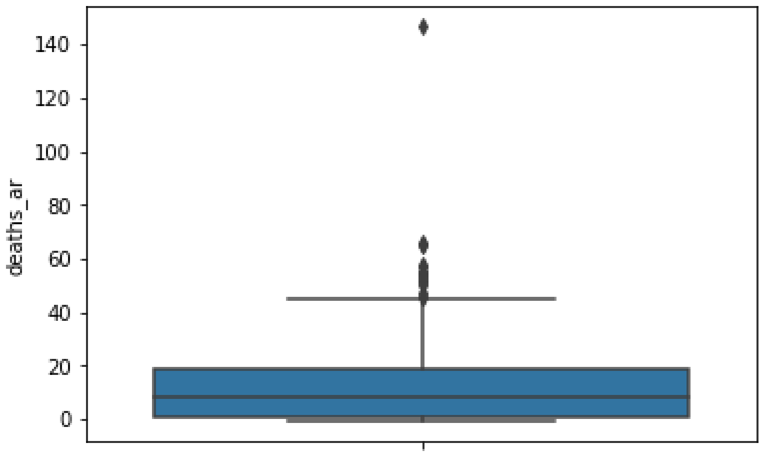
```
---- cases_ar ----
q1 is 92.5
q2 is 534.0
q3 is 1016.5
q4 is 4304.0
IQR is 924.0
Tukey's Upper :  2402.5
Tukey's Lower :  -1293.5
number of outliers 30
```



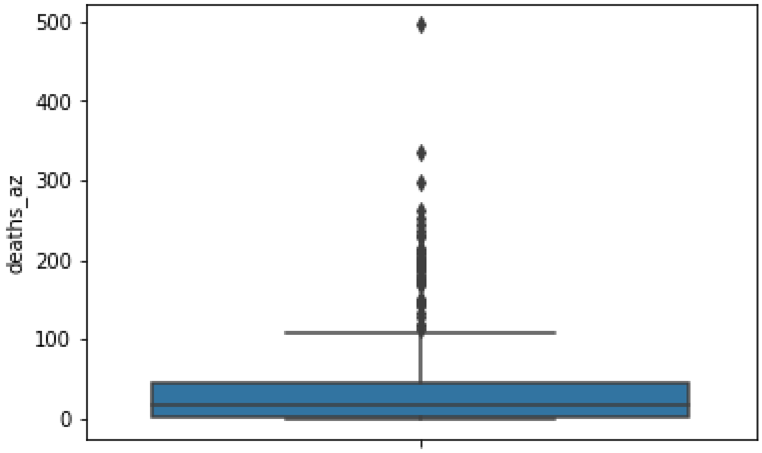
```
Preprocessed cases_ar is
           Date  cases_ar
0    2020-01-22       0.0
1    2020-01-23       0.0
2    2020-01-24       0.0
3    2020-01-25       0.0
4    2020-01-26       0.0
..          ...       ...
433  2021-03-30     175.0
434  2021-03-31     213.0
435  2021-04-01     210.0
436  2021-04-02     145.0
437  2021-04-03     216.0

[408 rows x 2 columns]
---- cases_az ----
q1 is 208.0
q2 is 795.0
q3 is 2554.25
q4 is 50826.0
IQR is 2346.25
Tukey's Upper :  6073.625
Tukey's Lower :  -3311.375
number of outliers 29
```



```
Preprocessed cases_az is
           Date  cases_az
0    2020-01-22       0.0
1    2020-01-23       0.0
2    2020-01-24       0.0
3    2020-01-25       0.0
4    2020-01-26       1.0
..          ...       ...
433  2021-03-30     578.0
434  2021-03-31     692.0
435  2021-04-01     389.0
436  2021-04-02     901.0
437  2021-04-03    1154.0

[409 rows x 2 columns]
---- deaths_ar ----
q1 is 1.0
q2 is 8.0
q3 is 18.75
q4 is 147.0
IQR is 17.75
Tukey's Upper :  45.375
Tukey's Lower :  -25.625
number of outliers 18
```



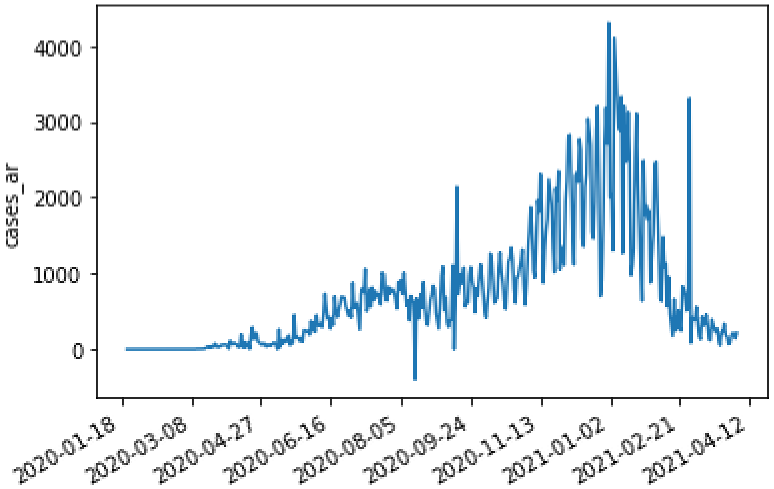
```
Preprocessed deaths_ar is
           Date  deaths_ar
0    2020-01-22        0.0
1    2020-01-23        0.0
2    2020-01-24        0.0
3    2020-01-25        0.0
4    2020-01-26        0.0
..          ...        ...
433  2021-03-30       12.0
434  2021-03-31        8.0
435  2021-04-01        9.0
436  2021-04-02        1.0
437  2021-04-03        2.0

[420 rows x 2 columns]
---- deaths_az ----
q1 is 1.0
q2 is 16.0
q3 is 44.75
q4 is 498.0
IQR is 43.75
Tukey's Upper :  110.375
Tukey's Lower :  -64.625
number of outliers 44
```

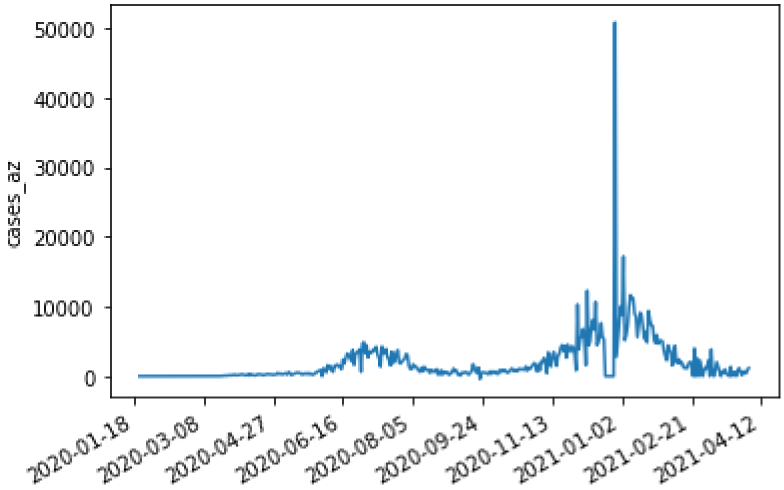


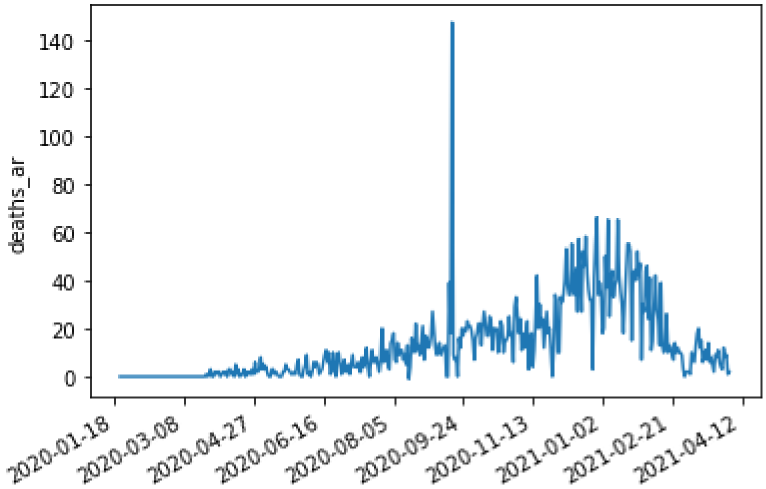
```
Preprocessed deaths_az is
           Date  deaths_az
0    2020-01-22        0.0
1    2020-01-23        0.0
2    2020-01-24        0.0
3    2020-01-25        0.0
4    2020-01-26        0.0
..          ...        ...
433  2021-03-30       21.0
434  2021-03-31       26.0
435  2021-04-01       11.0
436  2021-04-02       19.0
437  2021-04-03        7.0

[394 rows x 2 columns]
```

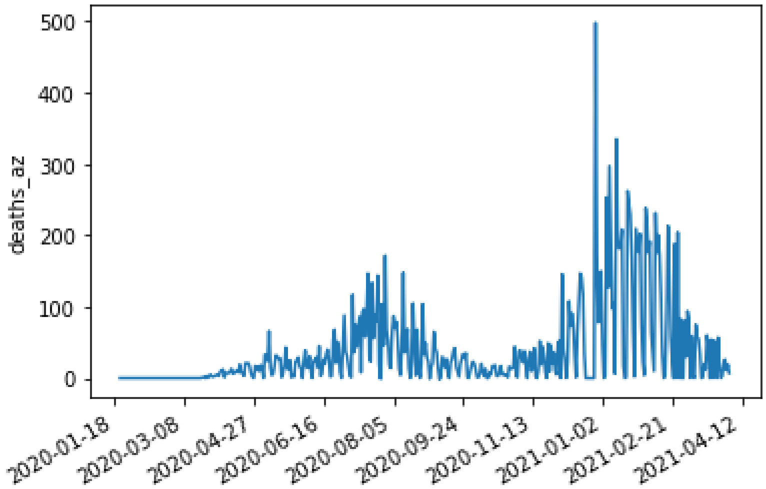
In [ ]:

```
plot_data(data, cols)
```


cases_ar
4000
3000
2000
1000
0
2020-01-18
2020-03-08
2020-04-27
2020-06-16
2020-08-05
2020-09-24
2020-11-13
2021-01-02
2021-02-21
2021-04-12


cases_az
50000
40000
30000
20000
10000
0
2020-01-18
2020-03-08
2020-04-27
2020-06-16
2020-08-05
2020-09-24
2020-11-13
2021-01-02
2021-02-21
2021-04-12


deaths_ar
140
120
100
80
60
40
20
0
2020-01-18
2020-03-08
2020-04-27
2020-06-16
2020-08-05
2020-09-24
2020-11-13
2021-01-02
2021-02-21
2021-04-12



Question 2

Inference 1

In [ ]:

```
def linear_regression(x, y):
    xt = np.transpose(x)
    xt_x = np.matmul(xt, x)
    xt_x_inverse = np.linalg.pinv(xt_x)
    xt_x_inverse_xt = np.matmul(xt_x_inverse, xt)
    b = np.matmul(xt_x_inverse_xt, y)
    return b


def calculate_MAPE(y1, y2):
    y1_modified = np.array([])
    y2_modified = np.array([])
    for i in range(len(y1)):
        if y1[i] != 0:
            y1_modified = np.append(y1_modified, y1[i])
            y2_modified = np.append(y2_modified, y2[i])
    return np.sum((np.abs(y1_modified - y2_modified)) / y1_modified) * (100 / 
len(y1_modified))


def calculate_MSE(y1, y2):
    return np.sum((y1 - y2) * (y1 - y2)) / len(y1)

def prepare_table(x, t):
    x = np.atleast_2d(x)
    for i in range(t):
        x = np.insert(x, i + 1, 0, axis=1)
        x[i + 1:, i + 1] = x[:-(i + 1), 0]
    return x[t:]
```

In [ ]:

```
df = pd.read_csv('processed_cases_ar.csv')
data = df.to_numpy()
data = data[192:220, :]
```

In [ ]:

```
data
```

Out[ ]:

```
array([[192, '2020-08-01', 662.0],
       [193, '2020-08-02', 537.0],
       [194, '2020-08-03', 887.0],
       [195, '2020-08-04', 784.0],
       [196, '2020-08-05', 912.0],
       [197, '2020-08-06', 735.0],
       [198, '2020-08-07', 1011.0],
       [199, '2020-08-08', 772.0],
       [200, '2020-08-09', 572.0],
       [201, '2020-08-10', 645.0],
       [202, '2020-08-11', 383.0],
       [203, '2020-08-12', 703.0],
       [204, '2020-08-13', 652.0],
       [205, '2020-08-14', 626.0],
       [206, '2020-08-15', 0.0],
       [207, '2020-08-16', 673.0],
       [208, '2020-08-17', 412.0],
       [209, '2020-08-18', 410.0],
       [210, '2020-08-19', 729.0],
       [211, '2020-08-20', 549.0],
       [212, '2020-08-21', 887.0],
       [213, '2020-08-22', 547.0],
       [214, '2020-08-23', 375.0],
       [215, '2020-08-24', 320.0],
       [216, '2020-08-25', 480.0],
       [217, '2020-08-26', 649.0],
       [218, '2020-08-27', 722.0],
       [219, '2020-08-28', 838.0]], dtype=object)
```

In [ ]:

```
data = data[:, 2:].astype(np.float64)
x = prepare_table(data, 3)
y = data[3:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]),
b))

    # EWMA
    predicted_y = 0
    multiplier = 0.5
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
3.1286977753924367e-13
3.53444305263311e-24
154.18028468246587
565521.4493848376
```

In [ ]:

```
x = prepare_table(data, 5)
y = data[5:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]),
b))

    # EWMA
    predicted_y = 0
    multiplier = 0.8
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
4.954068238136502e-13
7.84621431483056e-24
136.06646430852174
454720.72314023116
```

In [ ]:

```
df = pd.read_csv('processed_cases_az.csv')
data = df.to_numpy()
data = data[192:220, :]
```

In [ ]:
```
data
```

Out[ ]:
```
array([[192, '2020-08-01', 2992.0],
       [193, '2020-08-02', 1465.0],
       [194, '2020-08-03', 1030.0],
       [195, '2020-08-04', 1008.0],
       [196, '2020-08-05', 1698.0],
       [197, '2020-08-06', 1444.0],
       [198, '2020-08-07', 1406.0],
       [199, '2020-08-08', 1054.0],
       [200, '2020-08-09', 816.0],
       [201, '2020-08-10', 600.0],
       [202, '2020-08-11', 1214.0],
       [203, '2020-08-12', 706.0],
       [204, '2020-08-13', 1351.0],
       [205, '2020-08-14', 927.0],
       [206, '2020-08-15', 933.0],
       [207, '2020-08-16', 883.0],
       [208, '2020-08-17', 468.0],
       [209, '2020-08-18', 915.0],
       [210, '2020-08-19', 637.0],
       [211, '2020-08-20', 723.0],
       [212, '2020-08-21', 619.0],
       [213, '2020-08-22', 996.0],
       [214, '2020-08-23', 208.0],
       [215, '2020-08-24', 310.0],
       [216, '2020-08-25', 860.0],
       [217, '2020-08-26', 186.0],
       [218, '2020-08-27', 680.0],
       [219, '2020-08-28', 519.0]], dtype=object)
```

In [ ]:

```
data = data[:, 2:].astype(np.float64)
x = prepare_table(data, 3)
y = data[3:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]),
b))

    # EWMA
    predicted_y = 0
    multiplier = 0.5
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
4.045762202680555e-13
3.035688224584256e-24
372.5972205567083
1472736.3560948467
```

In [ ]:

```
x = prepare_table(data, 5)
y = data[5:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]),
b))

    # EWMA
    predicted_y = 0
    multiplier = 0.8
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
1.563700831295593e-12
3.1431593887124137e-23
336.03397414319295
1164369.2151349573
```

In [ ]:

```
df = pd.read_csv('processed_deaths_ar.csv')
data = df.to_numpy()
data = data[192:220, :]
```

In [ ]:

```
data
```

Out[ ]:

```
array([[192, '2020-08-01', 5.0],
       [193, '2020-08-02', 3.0],
       [194, '2020-08-03', 14.0],
       [195, '2020-08-04', 15.0],
       [196, '2020-08-05', 18.0],
       [197, '2020-08-06', 7.0],
       [198, '2020-08-07', 6.0],
       [199, '2020-08-08', 14.0],
       [200, '2020-08-09', 9.0],
       [201, '2020-08-10', 11.0],
       [202, '2020-08-11', 11.0],
       [203, '2020-08-12', 7.0],
       [204, '2020-08-13', 9.0],
       [205, '2020-08-14', 5.0],
       [206, '2020-08-15', 13.0],
       [207, '2020-08-16', 0.0],
       [208, '2020-08-17', 4.0],
       [209, '2020-08-18', 16.0],
       [210, '2020-08-19', 12.0],
       [211, '2020-08-20', 10.0],
       [212, '2020-08-21', 22.0],
       [213, '2020-08-22', 11.0],
       [214, '2020-08-23', 13.0],
       [215, '2020-08-24', 9.0],
       [216, '2020-08-25', 15.0],
       [217, '2020-08-26', 21.0],
       [218, '2020-08-27', 7.0],
       [219, '2020-08-28', 17.0]], dtype=object)
```

In [ ]:

```
data = data[:, 2:].astype(np.float64)
x = prepare_table(data, 3)
y = data[3:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]),
b))

    # EWMA
    predicted_y = 0
    multiplier = 0.5
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
1.8866271605601273e-13
6.987053731957533e-28
131.0793234496849
212.04056998621758
```

In [ ]:

```
x = prepare_table(data, 5)
y = data[5:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]),
b))

    # EWMA
    predicted_y = 0
    multiplier = 0.8
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
2.5720417452814995e-13
1.0552705023556507e-27
125.42159183050956
201.16734370022036
```

In [ ]:

```
df = pd.read_csv('processed_deaths_az.csv')
data = df.to_numpy()
data = data[187:214, :]
```

In [ ]:
```
data
```

Out[ ]:
```
array([[192, '2020-08-01', 53.0],
       [193, '2020-08-02', 18.0],
       [194, '2020-08-03', 14.0],
       [195, '2020-08-04', 66.0],
       [196, '2020-08-05', 87.0],
       [197, '2020-08-06', 70.0],
       [198, '2020-08-07', 79.0],
       [199, '2020-08-08', 56.0],
       [200, '2020-08-09', 13.0],
       [201, '2020-08-10', 4.0],
       [202, '2020-08-11', 45.0],
       [204, '2020-08-13', 36.0],
       [205, '2020-08-14', 40.0],
       [206, '2020-08-15', 69.0],
       [207, '2020-08-16', 14.0],
       [208, '2020-08-17', 0.0],
       [209, '2020-08-18', 23.0],
       [210, '2020-08-19', 105.0],
       [211, '2020-08-20', 50.0],
       [212, '2020-08-21', 4.0],
       [213, '2020-08-22', 68.0],
       [214, '2020-08-23', 15.0],
       [215, '2020-08-24', 0.0],
       [216, '2020-08-25', 21.0],
       [217, '2020-08-26', 104.0],
       [218, '2020-08-27', 33.0],
       [219, '2020-08-28', 49.0]], dtype=object)
```

In [ ]:

```
data = data[:, 2:].astype(np.float64)
x = prepare_table(data, 3)
y = data[3:]
x = np.insert(x, x.shape[1], 1, axis=1)
y_actual = np.array([])
y_predicted = np.array([])
y_predicted_ewma = np.array([])

for j in range(7):
    x1 = x[:-(7 - j)]
    y1 = y[:-(7 - j)]

    # Auto Regression
    b = linear_regression(x1, y1)
    y_actual = np.append(y_actual, y[-(7 - j)])
    y_predicted = np.append(y_predicted, np.matmul(np.transpose(x[-(7 - j)]), b))

    # EWMA
    predicted_y = 0
    multiplier = 0.5
    for k in range(len(x1)):
        predicted_y += multiplier * x1[-(1 + k)][0]
        multiplier *= (1 - multiplier)
    y_predicted_ewma = np.append(y_predicted_ewma, predicted_y)

MAPE_error_ar = calculate_MAPE(y_actual, y_predicted)
MSE_error_ar = calculate_MSE(y_actual, y_predicted)
print(MAPE_error_ar)
print(MSE_error_ar)
MAPE_error_ewma = calculate_MAPE(y_actual, y_predicted_ewma)
MSE_error_ewma = calculate_MSE(y_actual, y_predicted_ewma)
print(MAPE_error_ewma)
print(MSE_error_ewma)
```

```
6.760715996855616e-14
2.8780214737875472e-27
196.14259432433573
3734.8918130018837
```

Inference 2

Extracting feb 2021 and march 2021 data for both the states AR and AZ

In [ ]:

```
dataar = pd.read_csv('processed_cases_ar.csv')
ar_feb_cases = (dataar.loc[(pd.to_datetime(dataar["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 2, 1) ) & (pd.to_datetime(dataar["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 2, 28 )) ])
ar_march_cases = (dataar.loc[ (pd.to_datetime(dataar["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 3, 1) ) & (pd.to_datetime(dataar["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 3, 31)) ])

dataaz = pd.read_csv('processed_cases_az.csv')
az_feb_cases = (dataaz.loc[(pd.to_datetime(dataaz["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 2, 1) ) & (pd.to_datetime(dataaz["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 2, 28 )) ])
az_march_cases = (dataaz.loc[ (pd.to_datetime(dataaz["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 3, 1) ) & (pd.to_datetime(dataaz["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 3, 31)) ])

datar = pd.read_csv('processed_deaths_ar.csv')
ar_feb_d = (datar.loc[(pd.to_datetime(datar["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 2, 1) ) & (pd.to_datetime(datar["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 2, 28 )) ])
ar_march_d = (datar.loc[ (pd.to_datetime(datar["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 3, 1) ) & (pd.to_datetime(datar["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 3, 31))])

dataz = pd.read_csv('processed_deaths_az.csv')
az_feb_d = (dataz.loc[(pd.to_datetime(dataz["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 2, 1) ) & (pd.to_datetime(dataz["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 2, 28 )) ])
az_march_d = (dataz.loc[ (pd.to_datetime(dataz["Date"], format="%Y-%m-%d") >= datetime.datetime(2021, 3, 1) ) & (pd.to_datetime(dataz["Date"], format="%Y-%m-%d") <= datetime.datetime(2021, 3, 31))])
```

In [ ]:

```
print(dataar)
print(ar_feb_cases)
print(ar_march_cases)
print(dataaz)
print(datar)
print(dataz)
```

```
     Unnamed: 0        Date  cases_ar
0             0  2020-01-22       0.0
1             1  2020-01-23       0.0
2             2  2020-01-24       0.0
3             3  2020-01-25       0.0
4             4  2020-01-26       0.0
..          ...         ...       ...
403         433  2021-03-30     175.0
404         434  2021-03-31     213.0
405         435  2021-04-01     210.0
406         436  2021-04-02     145.0
407         437  2021-04-03     216.0

[408 rows x 3 columns]
     Unnamed: 0        Date  cases_ar
349         376  2021-02-01    1226.0
350         377  2021-02-02    1510.0
351         380  2021-02-05    1824.0
352         381  2021-02-06    1341.0
353         382  2021-02-07     674.0
354         383  2021-02-08     636.0
355         384  2021-02-09    1475.0
356         385  2021-02-10    1093.0
357         386  2021-02-11    1130.0
358         387  2021-02-12     567.0
359         388  2021-02-13     955.0
360         389  2021-02-14     467.0
361         390  2021-02-15     325.0
362         391  2021-02-16     175.0
363         392  2021-02-17     662.0
364         393  2021-02-18     247.0
365         394  2021-02-19     270.0
366         395  2021-02-20     515.0
367         396  2021-02-21     284.0
368         397  2021-02-22     243.0
369         398  2021-02-23     830.0
370         399  2021-02-24     798.0
371         400  2021-02-25     725.0
372         401  2021-02-26     511.0
373         402  2021-02-27     557.0
     Unnamed: 0        Date  cases_ar
374         404  2021-03-01      83.0
375         405  2021-03-02     416.0
376         406  2021-03-03     389.0
377         407  2021-03-04     392.0
378         408  2021-03-05     560.0
379         409  2021-03-06     326.0
380         410  2021-03-07     166.0
381         411  2021-03-08     131.0
382         412  2021-03-09     430.0
383         413  2021-03-10     315.0
384         414  2021-03-11     336.0
385         415  2021-03-12     458.0
386         416  2021-03-13     312.0
387         417  2021-03-14     129.0
388         418  2021-03-15     119.0
389         419  2021-03-16     394.0
```

```
390         420  2021-03-17     326.0
391         421  2021-03-18     262.0
392         422  2021-03-19     226.0
393         423  2021-03-20     274.0
394         424  2021-03-21     112.0
395         425  2021-03-22      52.0
396         426  2021-03-23     233.0
397         427  2021-03-24     226.0
398         428  2021-03-25     337.0
399         429  2021-03-26     185.0
400         430  2021-03-27     165.0
401         431  2021-03-28      69.0
402         432  2021-03-29      79.0
403         433  2021-03-30     175.0
404         434  2021-03-31     213.0
     Unnamed: 0        Date  cases_az
0             0  2020-01-22       0.0
1             1  2020-01-23       0.0
2             2  2020-01-24       0.0
3             3  2020-01-25       0.0
4             4  2020-01-26       1.0
..          ...         ...       ...
404         433  2021-03-30     578.0
405         434  2021-03-31     692.0
406         435  2021-04-01     389.0
407         436  2021-04-02     901.0
408         437  2021-04-03    1154.0

[409 rows x 3 columns]
     Unnamed: 0        Date  deaths_ar
0             0  2020-01-22        0.0
1             1  2020-01-23        0.0
2             2  2020-01-24        0.0
3             3  2020-01-25        0.0
4             4  2020-01-26        0.0
..          ...         ...        ...
415         433  2021-03-30       12.0
416         434  2021-03-31        8.0
417         435  2021-04-01        9.0
418         436  2021-04-02        1.0
419         437  2021-04-03        2.0

[420 rows x 3 columns]
     Unnamed: 0        Date  deaths_az
0             0  2020-01-22        0.0
1             1  2020-01-23        0.0
2             2  2020-01-24        0.0
3             3  2020-01-25        0.0
4             4  2020-01-26        0.0
..          ...         ...        ...
389         433  2021-03-30       21.0
390         434  2021-03-31       26.0
391         435  2021-04-01       11.0
392         436  2021-04-02       19.0
393         437  2021-04-03        7.0

[394 rows x 3 columns]
```

Walds one sample test for cases for the state AR

In [ ]:
```
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is equal to the mean of daily cases for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR")
mcfAR = ar_feb_cases["cases_ar"].mean()

mcmAR = ar_march_cases["cases_ar"].mean()
# print(mcmAR)

num = mcmAR - mcfAR
den = (mcmAR/len(ar_march_cases["cases_ar"]))
den = math.sqrt(den)

print("walds 1 sample testing statistic is |w|=",abs(num/den)," which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is equal to the mean of daily cases for
Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AR
walds 1 sample testing statistic is |w|= 176.97136033181553  which is greater
than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is equal to the mean of daily cases for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR

walds 1 sample testing statistic is |w|= 176.97136033181553 which is greater than z_alpha/2 = 1.96

so reject the NULL hypothesis

Walds one sample test for cases for the state AZ

In [ ]:

```python
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is equal to the mean of daily cases for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ")
mcfAZ = az_feb_cases["cases_az"].mean()

mcmAZ = az_march_cases["cases_az"].mean()
# print(mcmAR)

num = mcmAZ - mcfAZ
den = (mcmAR/len(az_march_cases["cases_az"]))
den = math.sqrt(den)

print("walds 1 sample testing statistic is |w|=",abs(num/den)," which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is equal to the mean of daily cases for
Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AZ
walds 1 sample testing statistic is |w|= 469.68524098962575  which is greater
than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is equal to the mean of daily cases for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ

walds 1 sample testing statistic is |w|= 469.68524098962575 which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis

Walds one sample test for deaths for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily dea
ths for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily
deaths for Feb’21 for state AR")
mdfAR = ar_feb_d['deaths_ar'].mean()
# print(mcfAR)

mdmAR = ar_march_d['deaths_ar'].mean()
# print(mcmAR)

num = mdmAR - mdfAR
den = mdmAR/len(ar_march_d['deaths_ar'])
den = math.sqrt(den)

print("walds 1 sample testing statistic is |w|=",abs(num/den)," which is great
er than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AR
walds 1 sample testing statistic is |w|= 22.676078418998358  which is greater
than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR

walds 1 sample testing statistic is |w|= 22.676078418998358 which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis

Walds one sample test for deaths for the state AZ

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily dea
ths for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily
deaths for Feb’21 for state AZ")
mdfAR = az_feb_d['deaths_az'].mean()
# print(mcfAR)

mdmAR = az_march_d['deaths_az'].mean()
# print(mcmAR)

num = mdmAR - mdfAR
den = mdmAR/len(az_march_d['deaths_az'])
den = math.sqrt(den)

print("walds 1 sample testing statistic is |w|=",abs(num/den)," which is great
er than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AZ
walds 1 sample testing statistic is |w|= 5.132697088004606  which is greater
than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ

walds 1 sample testing statistic is |w|= 5.132697088004606 which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis

Z test for cases for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR")
mcfAR = ar_feb_cases["cases_ar"].mean()

mcmAR = ar_march_cases["cases_ar"].mean()
# print(mcmAR)

num = mcmAR - mcfAR
div = (1/(len(dataar["cases_ar"]) - 1) )
sum = 0
for i in range(len(dataar)):
    sum = sum + math.pow((dataar["cases_ar"].mean() - dataar["cases_ar"][i]),2)
sum = sum /div
sigma =math.sqrt(sum)
den = sigma * (1/math.sqrt(len(ar_march_cases)))

print("z test statistic is |z|=",abs(num/den)," which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR
z test statistic is |z|= 0.011774503724912604  which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR

z test statistic is |z|= 0.011774503724912604 which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis

Z test for cases for the state AZ

```
In [ ]: print("Null hypothesis (H0):")
        print("the mean of daily cases for March’21 is eqaul to the mean of daily case
        s for Feb’21 for state AZ")
        print("Alternate hypothesis(H1):")
        print("the mean of daily cases for March’21 is not equal to the mean of daily
         cases for Feb’21 for state AZ")
        mcfAR = az_feb_cases["cases_az"].mean()

        mcmAR = az_march_cases["cases_az"].mean()
        # print(mcmAR)

        num = mcmAR - mcfAR
        div = (1/(len(dataaz["cases_az"]) - 1) )
        sum = 0
        for i in range(len(dataaz)):
            sum = sum + math.pow((dataaz["cases_az"].mean() - dataaz["cases_az"][i]),2
        )
        sum = sum /div
        sigma =math.sqrt(sum)
        den = sigma * (1/math.sqrt(len(az_march_cases)))

        print("z test statistic is |z|=",abs(num/den)," which is less than z_alpha/2 =
        1.96 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for
Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AZ
z test statistic is |z|= 0.011955757502414467  which is less than z_alpha/2 =
1.96 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ

z test statistic is |z|= 0.011955757502414467 which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis

Z test for deaths for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily dea
ths for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily
deaths for Feb’21 for state AR")
mcfAR = ar_feb_d['deaths_ar'].mean()

mcmAR = ar_march_d['deaths_ar'].mean()
# print(mcmAR)

num = mcmAR - mcfAR
div = (1/(len(datar["deaths_ar"]) - 1) )
sum = 0
for i in range(len(datar)):
    sum = sum + math.pow((datar["deaths_ar"].mean() - datar["deaths_ar"][i]),2
)
sum = sum /div
sigma =math.sqrt(sum)
den = sigma * (1/math.sqrt(len(ar_march_d['deaths_ar'])))

print("z test statistic is |z|=",abs(num/den)," which is less than z_alpha/2 =
1.96 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AR
z test statistic is |z|= 0.012708532191771404  which is less than z_alpha/2 =
1.96 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR

z test statistic is |z|= 0.012708532191771404 which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis

Z test for deaths for the state AZ

In [ ]:
```
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ")
mcfAR = az_feb_d['deaths_az'].mean()

mcmAR = az_march_d['deaths_az'].mean()
# print(mcmAR)

num = mcmAR - mcfAR
div = (1/(len(dataz["deaths_az"]) - 1) )
sum = 0
for i in range(len(dataz)):
    sum = sum + math.pow((dataz["deaths_az"].mean() - dataz["deaths_az"][i]),2)
sum = sum /div
sigma =math.sqrt(sum)
den = sigma * (1/math.sqrt(len(az_march_d['deaths_az'])))

print("z test statistic is |z|=",abs(num/den)," which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AZ
z test statistic is |z|= 0.002833449982254319  which is less than z_alpha/2 =
1.96 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ

z test statistic is |z|= 0.002833449982254319 which is less than z_alpha/2 = 1.96 so fail to reject the NULL hypothesis

One sample T test for cases for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is eqaul to the mean of daily case
s for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily
 cases for Feb’21 for state AR")

mcfAR = ar_feb_cases['cases_ar'].mean()

mcmAR = ar_march_cases['cases_ar'].mean()
# print(mcmAR)

num = mcmAR - mcfAR
div = (1/(len(ar_march_cases['cases_ar']) - 1) )
sum = 0

for i in range(len(ar_march_cases)):
    # print(march2021["AR confirmed"][0])
    sum = sum + math.pow((ar_march_cases['cases_ar'].mean() - ar_march_cases[
'cases_ar'].iloc[i]),2)
sum = sum /div
sigma =math.sqrt(sum)
den = sigma * (1/math.sqrt(len(ar_march_cases)))
print("T statistic |T|=",abs(num/den),"which is less than t(",len(ar_march_cas
es)-1,",alpha/2)=2.0423 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for
Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AR
T statistic |T|= 0.7181046741596464 which is less than t( 30 ,alpha/2)=2.0423
so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR

T statistic |T|= 0.7181046741596464 which is less than t(30 ,alpha/2)=2.0423 so fail to reject the NULL hypothesis

One sample T test for cases for the state AZ

In [ ]:
```
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is eqaul to the mean of daily case
s for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily
 cases for Feb’21 for state AZ")
mcfAR = az_feb_cases['cases_az'].mean()

mcmAR = az_march_cases['cases_az'].mean()
# print(mcmAR)

num = mcmAR - mcfAR
div = (1/(len(az_march_cases['cases_az']) - 1) )
sum = 0

for i in range(len(az_march_cases['cases_az'])):
    # print(march2021["AR confirmed"][0])
    sum = sum + math.pow((az_march_cases['cases_az'].mean() - az_march_cases[
'cases_az'].iloc[i]),2)
sum = sum /div
sigma =math.sqrt(sum)
den = sigma * (1/math.sqrt(len(az_march_cases['cases_az'])))
print("T statistic |T|=",abs(num/den),"which is less than t(",len(az_march_cas
es['cases_az'])-1,",alpha/2)=2.0423 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for
Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AZ
T statistic |T|= 0.3050772115889984 which is less than t( 30 ,alpha/2)=2.0423
so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ

T statistic |T|= 0.3050772115889984 which is less than t(30 ,alpha/2)=2.0423 so fail to reject the NULL hypothesis

One sample T test for deaths for the state AR

```
In [ ]: print("Null hypothesis (H0):")
        print("the mean of daily deaths for March’21 is eqaul to the mean of daily dea
        ths for Feb’21 for state AR")
        print("Alternate hypothesis(H1):")
        print("the mean of daily deaths for March’21 is not equal to the mean of daily
        deaths for Feb’21 for state AR")
        mcfAR = ar_feb_d['deaths_ar'].mean()

        mcmAR = ar_march_d['deaths_ar'].mean()
        # print(mcmAR)

        num = mcmAR - mcfAR
        div = (1/(len(ar_march_d['deaths_ar']) - 1) )
        sum = 0

        for i in range(len(ar_march_d['deaths_ar'])):
            # print(march2021["AR confirmed"][0])
            sum = sum + math.pow((ar_march_d['deaths_ar'].mean() - ar_march_d['deaths_
        ar'].iloc[i]),2)
        sum = sum /div
        sigma =math.sqrt(sum)
        den = sigma * (1/math.sqrt(len(ar_march_d['deaths_ar'])))
        print("T statistic |T|=",abs(num/den),"which is less than t(",len(ar_march_d[
        'deaths_ar'])-1,",alpha/2)=2.0423 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AR
T statistic |T|= 0.41897656409142037 which is less than t( 30 ,alpha/2)=2.042
3 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR

T statistic |T|= 0.41897656409142037 which is less than t(30 ,alpha/2)=2.0423 so fail to reject the NULL hypothesis

One sample T test for deaths for the state AZ

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ")
mcfAR = az_feb_d['deaths_az'].mean()

mcmAR = az_march_d['deaths_az'].mean()
# print(mcmAR)

num = mcmAR - mcfAR
div = (1/(len(az_march_d['deaths_az']) - 1) )
sum = 0

for i in range(len(az_march_d)):
    # print(march2021["AR confirmed"][0])
    sum = sum + math.pow((az_march_d['deaths_az'].mean() - az_march_d['deaths_az'].iloc[i]),2)
sum = sum /div
sigma =math.sqrt(sum)
den = sigma * (1/math.sqrt(len(az_march_d['deaths_az'])))
print("T statistic |T|=",abs(num/den),"which is less than t(",len(az_march_d['deaths_az'])-1,",alpha/2)=2.0423 so fail to reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AZ
T statistic |T|= 0.032173587986571585 which is less than t( 30 ,alpha/2)=2.04
23 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ

T statistic |T|= 0.032173587986571585 which is less than t(30 ,alpha/2)=2.0423 so fail to reject the NULL hypothesis

Two sample walds test for cases for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR")
mcfAR = ar_feb_cases['cases_ar'].mean()

mcmAR = ar_march_cases['cases_ar'].mean()
# print(mcmAR)

num = mcfAR - mcmAR
den = (mcfAR/len(ar_feb_cases)) + (mcmAR/len(ar_march_cases))
den = math.sqrt(den)

print("walds 2 sample testing statistic is |w|=",abs(num/den)," which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR
walds 2 sample testing statistic is |w|= 81.5397058501656  which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR

walds 2 sample testing statistic is |w|= 81.5397058501656 which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis

Two sample walds test for cases for the state AZ

```
In [ ]: print("Null hypothesis (H0):")
        print("the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AZ")
        print("Alternate hypothesis(H1):")
        print("the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ")

        mcfAZ = az_feb_cases['cases_az'].mean()

        mcmAZ = az_march_cases['cases_az'].mean()

        num = mcfAZ - mcmAZ
        den = (mcfAZ/len(az_feb_cases)) + (mcmAZ/len(az_march_cases))
        den = math.sqrt(den)

        print("walds 2 sample testing statistic is |w|=",abs(num/den)," which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ
walds 2 sample testing statistic is |w|= 134.02823750811478  which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Two sample walds test for deaths for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is equal to the mean of daily dea
ths for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily
deaths for Feb’21 for state AR")

mdfAR = ar_feb_d['deaths_ar'].mean()
# print(mcfAR)

mdmAR = ar_march_d['deaths_ar'].mean()
# print(mcmAR)

num = mdfAR - mdmAR
den = (mdfAR/len(ar_feb_d)) + (mdmAR/len(ar_march_d))
den = math.sqrt(den)

print("walds 2 sample testing statistic is |w|=",abs(num/den)," which is great
er than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is equal to the mean of daily deaths fo
r Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AR
walds 2 sample testing statistic is |w|= 11.58885289733292  which is greater
than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is equal to the mean of daily deaths for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR

walds 2 sample testing statistic is |w|= 11.58885289733292 which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis

Two sample walds test for deaths for the state AZ

```
In [ ]: print("Null hypothesis (H0):")
        print("the mean of daily deaths for March’21 is equal to the mean of daily dea
        ths for Feb’21 for state AZ")
        print("Alternate hypothesis(H1):")
        print("the mean of daily deaths for March’21 is not equal to the mean of daily
        deaths for Feb’21 for state AZ")

        mdfAZ = az_feb_d['deaths_az'].mean()
        # print(mcfAR)

        mdmAZ = az_march_d['deaths_az'].mean()
        # print(mcmAR)

        num = mdfAZ - mdmAZ
        den = (mdfAZ/len(az_feb_d)) + (mdmAZ/len(az_march_d))
        den = math.sqrt(den)

        print("walds 2 sample testing statistic is |w|=",abs(num/den)," which is great
        er than z_alpha/2 = 1.96 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is equal to the mean of daily deaths fo
r Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AZ
walds 2 sample testing statistic is |w|= 3.1069078221911486  which is greater
than z_alpha/2 = 1.96 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is equal to the mean of daily deaths for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ

walds 2 sample testing statistic is |w|= 3.1069078221911486 which is greater than z_alpha/2 = 1.96 so reject the NULL hypothesis

Unpaired t test for cases for the state AR

In [ ]:

```
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is eqaul to the mean of daily case
s for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily
 cases for Feb’21 for state AR")
mcfAR = ar_feb_cases['cases_ar'].mean()

mcfAR = ar_march_cases['cases_ar'].mean()

# print(mcmAR)

num = mcmAR - mcfAR

sigmaFnum = 0
for i in range(len(ar_feb_cases['cases_ar'])):
    sigmaFnum = sigmaFnum + math.pow((ar_feb_cases['cases_ar'].mean() - ar_feb
_cases['cases_ar'].iloc[i]),2)
sigmaFnum = sigmaFnum / (len(ar_feb_cases['cases_ar'])-1)
denF = sigmaFnum / len(ar_feb_cases['cases_ar'])

sigmaMnum = 0
for i in range(len(ar_march_cases['cases_ar'])):
    sigmaMnum = sigmaMnum + math.pow((ar_march_cases['cases_ar'].mean() - ar_m
arch_cases['cases_ar'].iloc[i]),2)
sigmaMnum = sigmaMnum / (len(ar_march_cases['cases_ar'])-1)
denM = sigmaMnum / len(ar_march_cases['cases_ar'])

den = math.sqrt(denF + denM)

print("T statistic |T|=",abs(num/den),"which is greater than t(",len(ar_feb_ca
ses['cases_ar'])+len(ar_march_cases['cases_ar'])-1,",alpha/2)=2.30442596 so re
ject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for
Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AR
T statistic |T|= 0.0 which is greater than t( 55 ,alpha/2)=2.30442596 so reje
ct the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AR

T statistic |T|= 0.0 which is greater than t(55 ,alpha/2)=2.30442596 so reject the NULL hypothesis

Unpaired t test for cases for the state AZ

In [ ]:

```
### FOR CASES IN AZ
print("Null hypothesis (H0):")
print("the mean of daily cases for March’21 is eqaul to the mean of daily case
s for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily cases for March’21 is not equal to the mean of daily
 cases for Feb’21 for state AZ")
mcfAR = az_feb_cases['cases_az'].mean()

mcmAR = az_march_cases['cases_az'].mean()
# print(mcmAR)

num = mcmAR - mcfAR

sigmaFnum = 0
for i in range(len(az_feb_cases['cases_az'])):
    sigmaFnum = sigmaFnum + math.pow((az_feb_cases['cases_az'].mean() - az_feb
_cases['cases_az'].iloc[i]),2)
sigmaFnum = sigmaFnum / (len(az_feb_cases['cases_az'])-1)
denF = sigmaFnum / len(az_feb_cases['cases_az'])

sigmaMnum = 0
for i in range(len(az_march_cases['cases_az'])):
    sigmaMnum = sigmaMnum + math.pow((az_march_cases['cases_az'].mean() - az_m
arch_cases['cases_az'].iloc[i]),2)
sigmaMnum = sigmaMnum / (len(az_march_cases['cases_az'])-1)
denM = sigmaMnum / len(az_march_cases['cases_az'])

den = math.sqrt(denF + denM)

print("T statistic |T|=",abs(num/den),"which is greater than t(",len(az_feb_ca
ses['cases_az'])+len(az_march_cases['cases_az'])-1,",alpha/2)=2.30442596 so re
ject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily cases for March’21 is eqaul to the mean of daily cases for
Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily cases for March’21 is not equal to the mean of daily cases
for Feb’21 for state AZ
T statistic |T|= 4.891790301401789 which is greater than t( 58 ,alpha/2)=2.30
442596 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily cases for March’21 is eqaul to the mean of daily cases for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily cases for March’21 is not equal to the mean of daily cases for Feb’21 for state AZ

T statistic |T|= 4.891790301401789 which is greater than t(58 ,alpha/2)=2.30442596 so reject the NULL hypothesis

Unpaired t test for deaths for the state AR

In [ ]:

```
### FOR CASES IN AR
print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AR")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR")

mcfAR = ar_feb_d['deaths_ar'].mean()

mcmAR = ar_march_d['deaths_ar'].mean()
# print(mcmAR)

num = mcmAR - mcfAR

sigmaFnum = 0
for i in range(len(ar_feb_d)):
    sigmaFnum = sigmaFnum + math.pow((ar_feb_d['deaths_ar'].mean() - ar_feb_d['deaths_ar'].iloc[i]),2)
sigmaFnum = sigmaFnum / (len(ar_feb_d['deaths_ar'])-1)
denF = sigmaFnum / len(ar_feb_d['deaths_ar'])

sigmaMnum = 0
for i in range(len(ar_march_d['deaths_ar'])):
    sigmaMnum = sigmaMnum + math.pow((ar_march_d['deaths_ar'].mean() - ar_march_d['deaths_ar'].iloc[i]),2)
sigmaMnum = sigmaMnum / (len(ar_march_d['deaths_ar'])-1)
denM = sigmaMnum / len(ar_march_d['deaths_ar'])

den = math.sqrt(denF + denM)
print("T statistic |T|=",abs(num/den),"which is greater than t(",len(ar_feb_d['deaths_ar'])+len(ar_march_d['deaths_ar'])-1,",alpha/2)=2.30442596 so reject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AR
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR
T statistic |T|= 4.699150987256173 which is greater than t( 57 ,alpha/2)=2.30442596 so reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AR

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AR

T statistic |T|= 4.699150987256173 which is greater than t(57 ,alpha/2)=2.30442596 so reject the NULL hypothesis

Unpaired t test for deaths for the state AZ

In [ ]:

```
### FOR deaths IN AZ

print("Null hypothesis (H0):")
print("the mean of daily deaths for March’21 is eqaul to the mean of daily dea
ths for Feb’21 for state AZ")
print("Alternate hypothesis(H1):")
print("the mean of daily deaths for March’21 is not equal to the mean of daily
deaths for Feb’21 for state AZ")
mcfAR = az_feb_d['deaths_az'].mean()

mcmAR = az_march_d['deaths_az'].mean()
# print(mcmAR)

num = mcmAR - mcfAR

sigmaFnum = 0
for i in range(len(az_feb_d['deaths_az'])):
    sigmaFnum = sigmaFnum + math.pow((az_feb_d['deaths_az'].mean() - az_feb_d[
'deaths_az'].iloc[i]),2)
sigmaFnum = sigmaFnum / (len(az_feb_d['deaths_az'])-1)
denF = sigmaFnum / len(az_feb_d['deaths_az'])

sigmaMnum = 0
for i in range(len(az_march_d['deaths_az'])):
    sigmaMnum = sigmaMnum + math.pow((az_march_d['deaths_az'].mean() - az_marc
h_d['deaths_az'].iloc[i]),2)
sigmaMnum = sigmaMnum / (len(az_march_d['deaths_az'])-1)
denM = sigmaMnum / len(az_march_d['deaths_az'])

den = math.sqrt(denF + denM)

print("T statistic |T|=",abs(num/den),"which is less than t(",len(az_feb_d['de
aths_az'])+len(az_march_d['deaths_az'])-1,",alpha/2)= 2.30442596 so fail to re
ject the NULL hypothesis")
```

```
Null hypothesis (H0):
the mean of daily deaths for March’21 is eqaul to the mean of daily deaths fo
r Feb’21 for state AZ
Alternate hypothesis(H1):
the mean of daily deaths for March’21 is not equal to the mean of daily death
s for Feb’21 for state AZ
T statistic |T|= 0.5362318941822285 which is less than t( 45 ,alpha/2)= 2.304
42596 so fail to reject the NULL hypothesis
```

Null hypothesis (H0):

the mean of daily deaths for March’21 is eqaul to the mean of daily deaths for Feb’21 for state AZ

Alternate hypothesis(H1):

the mean of daily deaths for March’21 is not equal to the mean of daily deaths for Feb’21 for state AZ

T statistic |T|= 0.5362318941822285 which is less than t(45 ,alpha/2)= 2.30442596 so fail to reject the NULL hypothesis

Inference 3

In [ ]:

```
```

KS One Population test for cases

In [ ]:

```
df = pd.read_csv('processed_cases_ar.csv')
data = df.to_numpy()
data = data[253:333, :]
```

```
In [ ]: data
```

```
Out[ ]: array([[253, '2020-10-01', 1124.0],
               [254, '2020-10-02', 958.0],
               [255, '2020-10-03', 746.0],
               [256, '2020-10-04', 488.0],
               [257, '2020-10-05', 417.0],
               [258, '2020-10-06', 641.0],
               [259, '2020-10-07', 809.0],
               [260, '2020-10-08', 1265.0],
               [261, '2020-10-09', 1167.0],
               [262, '2020-10-10', 908.0],
               [263, '2020-10-11', 613.0],
               [264, '2020-10-12', 654.0],
               [265, '2020-10-13', 680.0],
               [266, '2020-10-14', 1079.0],
               [267, '2020-10-15', 1278.0],
               [268, '2020-10-16', 1015.0],
               [269, '2020-10-17', 883.0],
               [270, '2020-10-18', 644.0],
               [271, '2020-10-19', 531.0],
               [272, '2020-10-20', 844.0],
               [273, '2020-10-21', 1155.0],
               [274, '2020-10-22', 1202.0],
               [275, '2020-10-23', 1337.0],
               [276, '2020-10-24', 1183.0],
               [277, '2020-10-25', 797.0],
               [278, '2020-10-26', 612.0],
               [279, '2020-10-27', 952.0],
               [280, '2020-10-28', 961.0],
               [281, '2020-10-29', 1072.0],
               [282, '2020-10-30', 1162.0],
               [283, '2020-10-31', 1316.0],
               [284, '2020-11-01', 864.0],
               [285, '2020-11-02', 586.0],
               [286, '2020-11-03', 873.0],
               [287, '2020-11-04', 1292.0],
               [288, '2020-11-05', 1555.0],
               [289, '2020-11-06', 1870.0],
               [290, '2020-11-07', 1598.0],
               [291, '2020-11-08', 1038.0],
               [292, '2020-11-09', 945.0],
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               [294, '2020-11-11', 1962.0],
               [295, '2020-11-12', 1809.0],
               [296, '2020-11-13', 2311.0],
               [297, '2020-11-14', 1846.0],
               [298, '2020-11-15', 876.0],
               [299, '2020-11-16', 1307.0],
               [300, '2020-11-17', 1556.0],
               [301, '2020-11-18', 1715.0],
               [302, '2020-11-19', 2238.0],
               [303, '2020-11-20', 2061.0],
               [304, '2020-11-21', 1905.0],
               [305, '2020-11-22', 1352.0],
               [306, '2020-11-23', 1017.0],
               [307, '2020-11-24', 2122.0],
               [308, '2020-11-25', 1965.0],
               [309, '2020-11-26', 2347.0],
               [310, '2020-11-27', 1053.0],
               [311, '2020-11-28', 1349.0],
               [312, '2020-11-29', 1221.0],
               [313, '2020-11-30', 1112.0],
               [314, '2020-12-01', 1950.0],
               [315, '2020-12-02', 2212.0],
               [318, '2020-12-05', 2245.0],
               [319, '2020-12-06', 1543.0],
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               [321, '2020-12-08', 2283.0],
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               [323, '2020-12-10', 2202.0],
               [326, '2020-12-13', 1450.0],
               [327, '2020-12-14', 1355.0],
               [328, '2020-12-15', 2141.0],
               [329, '2020-12-16', 2306.0],
               [333, '2020-12-20', 1537.0],
               [334, '2020-12-21', 1457.0],
               [335, '2020-12-22', 1941.0],
               [338, '2020-12-25', 2122.0],
               [339, '2020-12-26', 702.0],
               [340, '2020-12-27', 908.0],
               [341, '2020-12-28', 1651.0]], dtype=object)
```

In [ ]:

```
cases_ar = data[:, 2]
cases_sample_mean = np.mean(cases_ar)
cases_sample_variance = np.var(cases_ar)
cases_mme_poisson = cases_sample_mean
cases_mme_geometric = 1/cases_sample_mean
cases_mme_p_binomial = 1 - cases_sample_variance / cases_sample_mean
cases_mme_n_binomial = cases_sample_mean**2/(cases_sample_mean-cases_sample_variance)
```

In [ ]:

```
print(cases_mme_poisson)
print(cases_mme_geometric)
print(cases_mme_n_binomial)
print(cases_mme_p_binomial)
```

```
1338.9125
0.0007468747957764231
-6.167274072287688
-217.0995620279518
```

In [ ]:

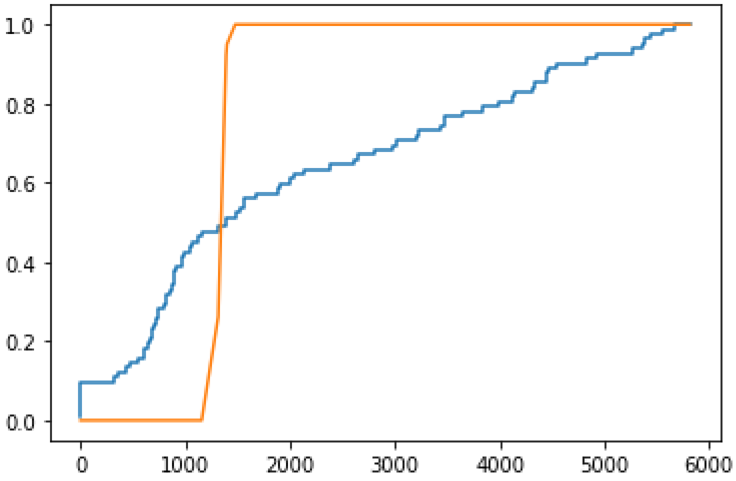
```
df = pd.read_csv('processed_cases_az.csv')
data = df.to_numpy()
data = data[253:335, :]
```

```
In [ ]: data
```

```
Out[ ]: array([[253, '2020-10-01', 705.0],
               [254, '2020-10-02', 551.0],
               [255, '2020-10-03', 636.0],
               [256, '2020-10-04', 355.0],
               [257, '2020-10-05', 316.0],
               [258, '2020-10-06', 864.0],
               [259, '2020-10-07', 604.0],
               [260, '2020-10-08', 863.0],
               [261, '2020-10-09', 683.0],
               [262, '2020-10-10', 894.0],
               [263, '2020-10-11', 597.0],
               [264, '2020-10-12', 475.0],
               [265, '2020-10-13', 684.0],
               [266, '2020-10-14', 901.0],
               [267, '2020-10-15', 1113.0],
               [268, '2020-10-16', 738.0],
               [269, '2020-10-17', 921.0],
               [270, '2020-10-18', 742.0],
               [271, '2020-10-19', 714.0],
               [272, '2020-10-20', 1074.0],
               [273, '2020-10-21', 975.0],
               [274, '2020-10-22', 994.0],
               [275, '2020-10-23', 976.0],
               [276, '2020-10-24', 890.0],
               [277, '2020-10-25', 1391.0],
               [278, '2020-10-26', 800.0],
               [279, '2020-10-27', 1157.0],
               [280, '2020-10-28', 1045.0],
               [281, '2020-10-29', 1315.0],
               [282, '2020-10-30', 1565.0],
               [283, '2020-10-31', 1901.0],
               [284, '2020-11-01', 1527.0],
               [285, '2020-11-02', 666.0],
               [286, '2020-11-03', 1679.0],
               [287, '2020-11-04', 815.0],
               [288, '2020-11-05', 2134.0],
               [289, '2020-11-06', 1997.0],
               [290, '2020-11-07', 2620.0],
               [291, '2020-11-08', 1880.0],
               [292, '2020-11-09', 435.0],
               [293, '2020-11-10', 3434.0],
               [294, '2020-11-11', 2030.0],
               [295, '2020-11-12', 1399.0],
               [296, '2020-11-13', 3015.0],
               [297, '2020-11-14', 3476.0],
               [298, '2020-11-15', 2382.0],
               [299, '2020-11-16', 1477.0],
               [300, '2020-11-17', 2984.0],
               [301, '2020-11-18', 3206.0],
               [302, '2020-11-19', 4123.0],
               [303, '2020-11-20', 4471.0],
               [304, '2020-11-21', 3638.0],
               [305, '2020-11-22', 4331.0],
               [306, '2020-11-23', 2659.0],
               [307, '2020-11-24', 4544.0],
               [308, '2020-11-25', 3981.0],
               [309, '2020-11-26', 3477.0],
               [310, '2020-11-27', 4312.0],
               [311, '2020-11-28', 4136.0],
               [312, '2020-11-29', 3221.0],
               [313, '2020-11-30', 822.0],
               [315, '2020-12-02', 3840.0],
               [316, '2020-12-03', 5442.0],
               [317, '2020-12-04', 5680.0],
               [319, '2020-12-06', 5376.0],
               [320, '2020-12-07', 1567.0],
               [322, '2020-12-09', 4444.0],
               [323, '2020-12-10', 4928.0],
               [328, '2020-12-15', 4451.0],
               [329, '2020-12-16', 4837.0],
               [330, '2020-12-17', 5817.0],
               [332, '2020-12-19', 5560.0],
               [333, '2020-12-20', 5366.0],
               [334, '2020-12-21', 0.0],
               [335, '2020-12-22', 0.0],
               [336, '2020-12-23', 0.0],
               [337, '2020-12-24', 0.0],
               [338, '2020-12-25', 0.0],
               [339, '2020-12-26', 0.0],
               [340, '2020-12-27', 0.0],
               [342, '2020-12-29', 2799.0],
               [343, '2020-12-30', 5267.0]], dtype=object)
```

In [ ]:

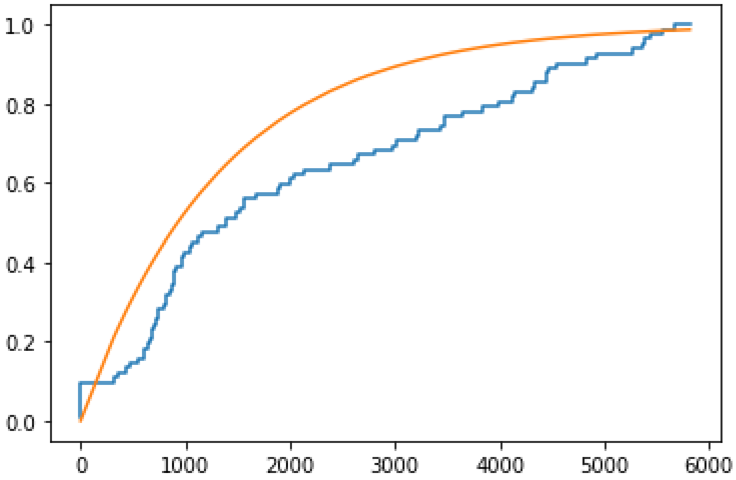
```
cases_az = data[:, 2]
cases_az = np.sort(cases_az)
cdf_y = np.array([])
cdf = 0
n = len(cases_az)
max_diff = 0
poisson_cdf = np.array([])
for i in cases_az:
    poisson_point = poisson.cdf(i, cases_mme_poisson)
    poisson_cdf = np.append(poisson_cdf, poisson_point)
    if max_diff < np.abs(cdf-poisson_point):
        max_diff = np.abs(cdf-poisson_point)
    cdf += 1/n
    cdf_y = np.append(cdf_y, cdf)

plt.step(cases_az, cdf_y)
plt.plot(cases_az, poisson_cdf)
plt.show()
print(max_diff)
```



```
0.49990398129899105
```

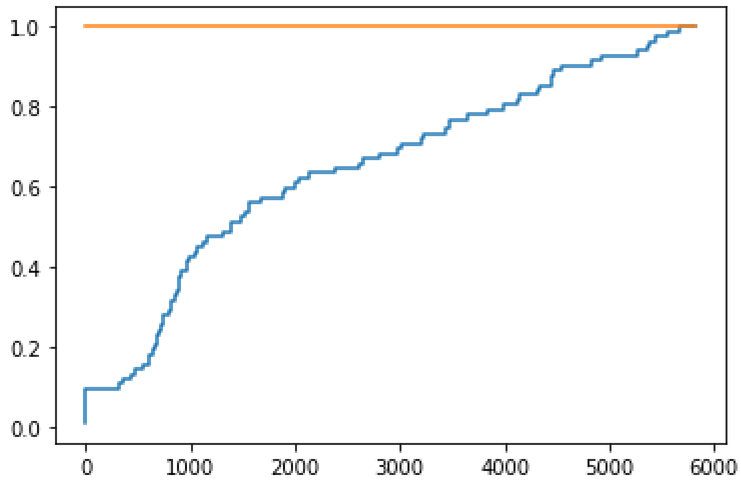
In [ ]:

```
cdf_y = np.array([])
cdf = 0
max_diff = 0
geom_cdf = np.array([])
for i in cases_az:
    geom_point = geom.cdf(i, cases_mme_geometric)
    geom_cdf = np.append(geom_cdf, geom_point)
    if max_diff < np.abs(cdf - geom_point):
        max_diff = np.abs(cdf - geom_point)
    cdf += 1 / n
    cdf_y = np.append(cdf_y, cdf)

plt.step(cases_az, cdf_y)
plt.plot(cases_az, geom_cdf)
plt.show()
print(max_diff)
```



```
0.22464873365371807
```

```
In [ ]: cdf_y = np.array([])
        cdf = 0
        max_diff = 0
        binom_cdf = np.array([])
        for i in cases_az:
            binom_point = binom.cdf(i, cases_mme_n_binomial, cases_mme_p_binomial)
            binom_cdf = np.append(binom_cdf, binom_point)
            if max_diff < np.abs(cdf - binom_point):
                max_diff = np.abs(cdf - binom_point)
            cdf += 1 / n
            cdf_y = np.append(cdf_y, cdf)

        plt.step(cases_az, cdf_y)
        plt.plot(cases_az, binom_cdf)
        plt.show()
        print(max_diff)
```



```
1.0
```

One Population test for deaths

```
In [ ]: df = pd.read_csv('processed_deaths_ar.csv')
        data = df.to_numpy()
        data = data[252:336, :]
```

In [ ]:

```
data
```

```
Out[ ]: array([[253, '2020-10-01', 15.0],
               [254, '2020-10-02', 7.0],
               [255, '2020-10-03', 16.0],
               [256, '2020-10-04', 18.0],
               [257, '2020-10-05', 22.0],
               [258, '2020-10-06', 22.0],
               [259, '2020-10-07', 13.0],
               [260, '2020-10-08', 21.0],
               [261, '2020-10-09', 27.0],
               [262, '2020-10-10', 22.0],
               [263, '2020-10-11', 17.0],
               [264, '2020-10-12', 17.0],
               [265, '2020-10-13', 25.0],
               [266, '2020-10-14', 23.0],
               [267, '2020-10-15', 11.0],
               [268, '2020-10-16', 20.0],
               [269, '2020-10-17', 19.0],
               [270, '2020-10-18', 20.0],
               [271, '2020-10-19', 10.0],
               [272, '2020-10-20', 14.0],
               [273, '2020-10-21', 23.0],
               [274, '2020-10-22', 21.0],
               [275, '2020-10-23', 10.0],
               [276, '2020-10-24', 15.0],
               [277, '2020-10-25', 15.0],
               [278, '2020-10-26', 17.0],
               [279, '2020-10-27', 25.0],
               [280, '2020-10-28', 17.0],
               [281, '2020-10-29', 18.0],
               [282, '2020-10-30', 6.0],
               [283, '2020-10-31', 29.0],
               [284, '2020-11-01', 33.0],
               [285, '2020-11-02', 26.0],
               [286, '2020-11-03', 18.0],
               [287, '2020-11-04', 24.0],
               [288, '2020-11-05', 11.0],
               [289, '2020-11-06', 18.0],
               [290, '2020-11-07', 12.0],
               [291, '2020-11-08', 17.0],
               [292, '2020-11-09', 23.0],
               [293, '2020-11-10', 3.0],
               [294, '2020-11-11', 13.0],
               [295, '2020-11-12', 18.0],
               [296, '2020-11-13', 4.0],
               [297, '2020-11-14', 11.0],
               [298, '2020-11-15', 25.0],
               [299, '2020-11-16', 42.0],
               [300, '2020-11-17', 20.0],
               [301, '2020-11-18', 30.0],
               [302, '2020-11-19', 21.0],
               [303, '2020-11-20', 24.0],
               [304, '2020-11-21', 12.0],
               [305, '2020-11-22', 20.0],
               [306, '2020-11-23', 27.0],
               [307, '2020-11-24', 18.0],
               [308, '2020-11-25', 20.0],
               [309, '2020-11-26', 11.0],
               [310, '2020-11-27', 0.0],
               [311, '2020-11-28', 11.0],
               [312, '2020-11-29', 34.0],
               [313, '2020-11-30', 32.0],
               [314, '2020-12-01', 10.0],
               [315, '2020-12-02', 10.0],
               [316, '2020-12-03', 33.0],
               [317, '2020-12-04', 31.0],
               [318, '2020-12-05', 34.0],
               [319, '2020-12-06', 40.0],
               [321, '2020-12-08', 38.0],
               [322, '2020-12-09', 34.0],
               [323, '2020-12-10', 34.0],
               [325, '2020-12-12', 36.0],
               [326, '2020-12-13', 34.0],
               [327, '2020-12-14', 45.0],
               [328, '2020-12-15', 27.0],
               [330, '2020-12-17', 39.0],
               [331, '2020-12-18', 27.0],
               [335, '2020-12-22', 43.0],
               [336, '2020-12-23', 36.0],
               [337, '2020-12-24', 32.0],
               [338, '2020-12-25', 32.0],
               [339, '2020-12-26', 3.0],
               [340, '2020-12-27', 41.0],
               [343, '2020-12-30', 34.0],
               [344, '2020-12-31', 39.0]], dtype=object)
```

In [ ]:

```
deaths_ar = data[:, 2]
deaths_sample_mean = np.mean(deaths_ar)
deaths_sample_variance = np.var(deaths_ar)
deaths_mme_poisson = deaths_sample_mean
deaths_mme_geometric = 1 / deaths_sample_mean
deaths_mme_p_binomial = 1 - deaths_sample_variance / deaths_sample_mean
deaths_mme_n_binomial = deaths_sample_mean ** 2 / (deaths_sample_mean - deaths
_sample_variance)
```

In [ ]:

```
print(deaths_mme_poisson)
print(deaths_mme_geometric)
print(deaths_mme_n_binomial)
print(deaths_mme_p_binomial)
```

```
22.202380952380953
0.04504021447721179
-5.734658143825416
-3.8716136856887546
```

In [ ]:

```
df = pd.read_csv('processed_deaths_az.csv')
data = df.to_numpy()
data = data[247:332, :]
```

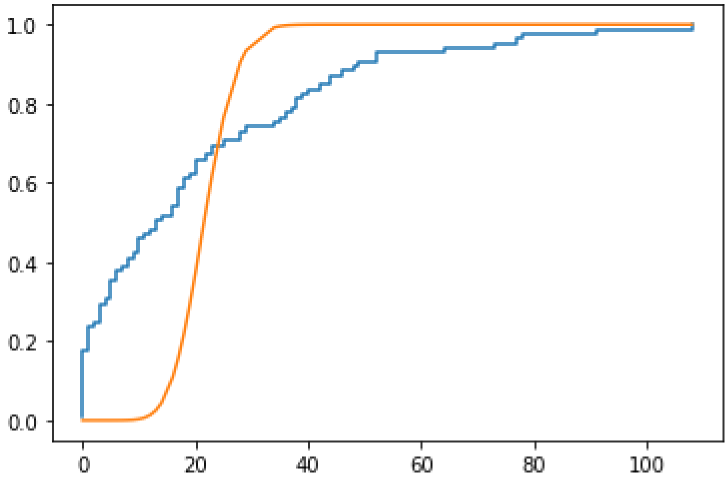
In [ ]:

```
data
```

```
Out[ ]: array([[253, '2020-10-01', 23.0],
               [254, '2020-10-02', 20.0],
               [255, '2020-10-03', 12.0],
               [256, '2020-10-04', 1.0],
               [257, '2020-10-05', 1.0],
               [258, '2020-10-06', 6.0],
               [259, '2020-10-07', 20.0],
               [260, '2020-10-08', 10.0],
               [261, '2020-10-09', 3.0],
               [262, '2020-10-10', 13.0],
               [263, '2020-10-11', 0.0],
               [264, '2020-10-12', 0.0],
               [265, '2020-10-13', 8.0],
               [266, '2020-10-14', 5.0],
               [267, '2020-10-15', 17.0],
               [268, '2020-10-16', 17.0],
               [269, '2020-10-17', 18.0],
               [270, '2020-10-18', 3.0],
               [271, '2020-10-19', 3.0],
               [272, '2020-10-20', 7.0],
               [273, '2020-10-21', 17.0],
               [274, '2020-10-22', 5.0],
               [275, '2020-10-23', 6.0],
               [276, '2020-10-24', 4.0],
               [277, '2020-10-25', 5.0],
               [278, '2020-10-26', 1.0],
               [279, '2020-10-27', 16.0],
               [280, '2020-10-28', 14.0],
               [281, '2020-10-29', 13.0],
               [282, '2020-10-30', 16.0],
               [283, '2020-10-31', 44.0],
               [284, '2020-11-01', 3.0],
               [285, '2020-11-02', 1.0],
               [286, '2020-11-03', 38.0],
               [287, '2020-11-04', 39.0],
               [288, '2020-11-05', 28.0],
               [289, '2020-11-06', 22.0],
               [290, '2020-11-07', 38.0],
               [291, '2020-11-08', 17.0],
               [292, '2020-11-09', 0.0],
               [293, '2020-11-10', 28.0],
               [294, '2020-11-11', 37.0],
               [295, '2020-11-12', 10.0],
               [296, '2020-11-13', 18.0],
               [297, '2020-11-14', 42.0],
               [298, '2020-11-15', 2.0],
               [299, '2020-11-16', 0.0],
               [300, '2020-11-17', 11.0],
               [301, '2020-11-18', 52.0],
               [302, '2020-11-19', 19.0],
               [303, '2020-11-20', 44.0],
               [304, '2020-11-21', 29.0],
               [305, '2020-11-22', 8.0],
               [306, '2020-11-23', 0.0],
               [307, '2020-11-24', 49.0],
               [308, '2020-11-25', 9.0],
               [309, '2020-11-26', 46.0],
               [310, '2020-11-27', 20.0],
               [311, '2020-11-28', 36.0],
               [312, '2020-11-29', 10.0],
               [313, '2020-11-30', 5.0],
               [314, '2020-12-01', 48.0],
               [315, '2020-12-02', 52.0],
               [316, '2020-12-03', 0.0],
               [318, '2020-12-05', 40.0],
               [319, '2020-12-06', 25.0],
               [320, '2020-12-07', 0.0],
               [321, '2020-12-08', 23.0],
               [322, '2020-12-09', 108.0],
               [323, '2020-12-10', 73.0],
               [324, '2020-12-11', 91.0],
               [325, '2020-12-12', 77.0],
               [326, '2020-12-13', 35.0],
               [327, '2020-12-14', 1.0],
               [328, '2020-12-15', 64.0],
               [329, '2020-12-16', 108.0],
               [333, '2020-12-20', 34.0],
               [334, '2020-12-21', 0.0],
               [335, '2020-12-22', 0.0],
               [336, '2020-12-23', 0.0],
               [337, '2020-12-24', 0.0],
               [338, '2020-12-25', 0.0],
               [339, '2020-12-26', 0.0],
               [340, '2020-12-27', 0.0],
               [343, '2020-12-30', 78.0]], dtype=object)
```

In [ ]:

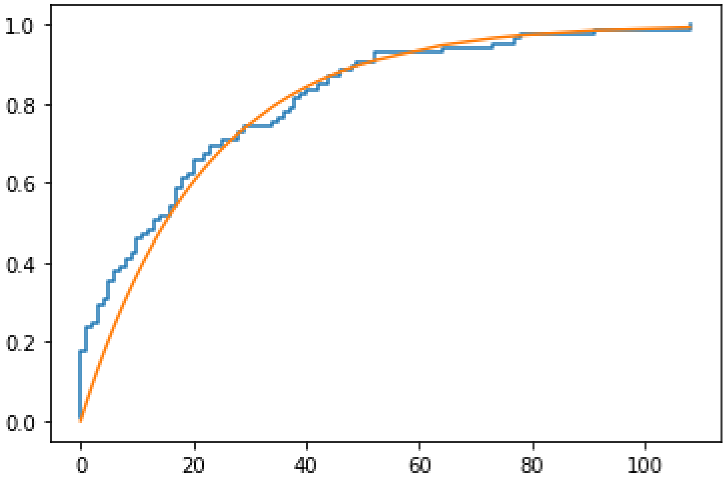
```
deaths_az = data[:, 2]
deaths_az = np.sort(deaths_az)
cdf_y = np.array([])
cdf = 0
n = len(deaths_az)
max_diff = 0
poisson_cdf = np.array([])
for i in deaths_az:
    poisson_point = poisson.cdf(i, deaths_mme_poisson)
    poisson_cdf = np.append(poisson_cdf, poisson_point)
    if max_diff < np.abs(cdf - poisson_point):
        max_diff = np.abs(cdf - poisson_point)
    cdf += 1 / n
    cdf_y = np.append(cdf_y, cdf)

plt.step(deaths_az, cdf_y)
plt.plot(deaths_az, poisson_cdf)
plt.show()
print(max_diff)
```



```
0.45702829377886567
```

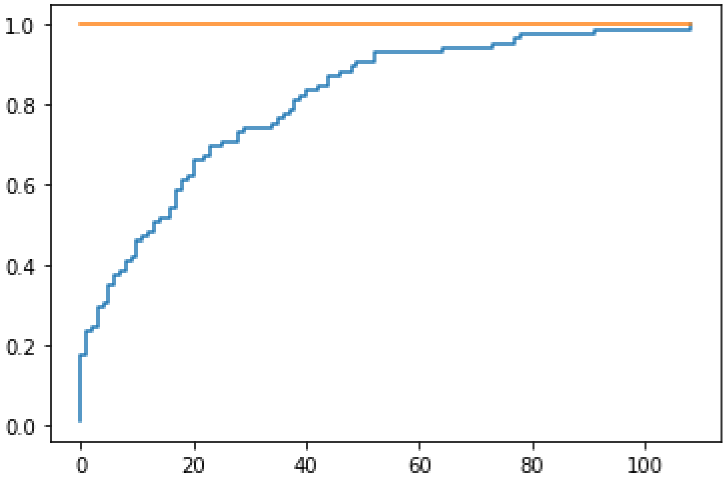
In [ ]:

```
cdf_y = np.array([])
cdf = 0
max_diff = 0
geom_cdf = np.array([])
for i in deaths_az:
    geom_point = geom.cdf(i,  deaths_mme_geometric)
    geom_cdf = np.append(geom_cdf, geom_point)
    if max_diff < np.abs(cdf - geom_point):
        max_diff = np.abs(cdf - geom_point)
    cdf += 1 / n
    cdf_y = np.append(cdf_y, cdf)

plt.step(deaths_az, cdf_y)
plt.plot(deaths_az, geom_cdf)
plt.show()
print(max_diff)
```



```
0.16672449140514123
```

```
In [ ]: cdf_y = np.array([])
        cdf = 0
        max_diff = 0
        binom_cdf = np.array([])
        for i in deaths_az:
            binom_point = binom.cdf(i, deaths_mme_n_binomial, deaths_mme_p_binomial)
            binom_cdf = np.append(binom_cdf, binom_point)
            if max_diff < np.abs(cdf - binom_point):
                max_diff = np.abs(cdf - binom_point)
            cdf += 1 / n
            cdf_y = np.append(cdf_y, cdf)

        plt.step(deaths_az, cdf_y)
        plt.plot(deaths_az, binom_cdf)
        plt.show()
        print(max_diff)
```



```
1.0
```

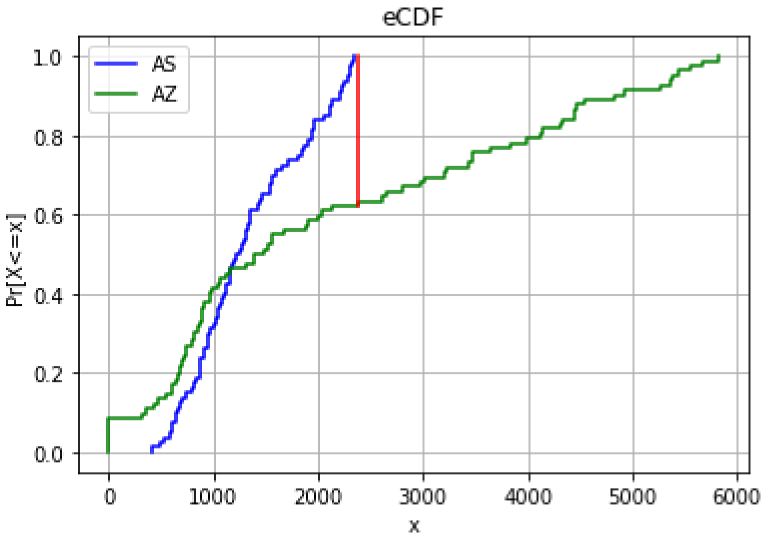
Two Population Test

```
In [ ]: def plot_eCDF(input_list, label, color):
            input_list.sort()
            # sort input array
            n = len(input_list)

            # initialize x and y to plt CDF
            x = [input_list[0]]
            y = [0]
            for point in input_list:
                value = y[len(y) - 1] + 1 / n
                # update x and y values
                x = x + [point, point]
                y = y + [y[len(y) - 1], value]

            # eCDF step function plot
            plt.plot(x, y, label=label, color=color)
            return x[1:], y[1:]
```

In [ ]:

```
X = cases_ar
Y = cases_az

# plot the graphs
plt.figure('eCDF')
x1, y1 = plot_eCDF(X, 'AS', color='blue')
x2, y2 = plot_eCDF(Y, 'AZ', color='green')

max_difference = 0
point = 0
point_y1 = 0
point_y2 = 0
i = 0
j = 0
while i < len(x2):
    y2_left, y2_right = y2[i], y2[i + 1]
    while j + 2 < len(x1) and x1[j + 2] < x2[i]:
        j += 2
    if x2[i] == x1[j]:
        y1_left, y1_right = y1[j], y1[j + 1]
    else:
        y1_left, y1_right = y1[j + 1], y1[j + 1]
    if max_difference < np.max([max_difference, np.absolute(y1_left - y2_left
), np.absolute(y1_right - y2_right)]):
        max_difference = np.max([max_difference, np.absolute(y1_left - y2_left
), np.absolute(y1_right - y2_right)])
        point_y1 = y1_left
        point_y2 = y2_left
        point = x2[i]
    i += 2
print('Max Difference: ', max_difference)
print('Point with max Difference: ', point)

# graph properties
plt.plot([point, point], [point_y1, point_y2], color='red')
plt.xlabel('x')
plt.ylabel('Pr[X<=x]')
plt.title('eCDF')
plt.legend(loc="upper left")
plt.grid()
plt.show()

if max_difference > 0.05:
    print('Reject Null Hypothesis')
else:
    print('Accept Null Hypothesis')
```

```
Max Difference:  0.378048780487803
Point with max Difference:  2382.0
```

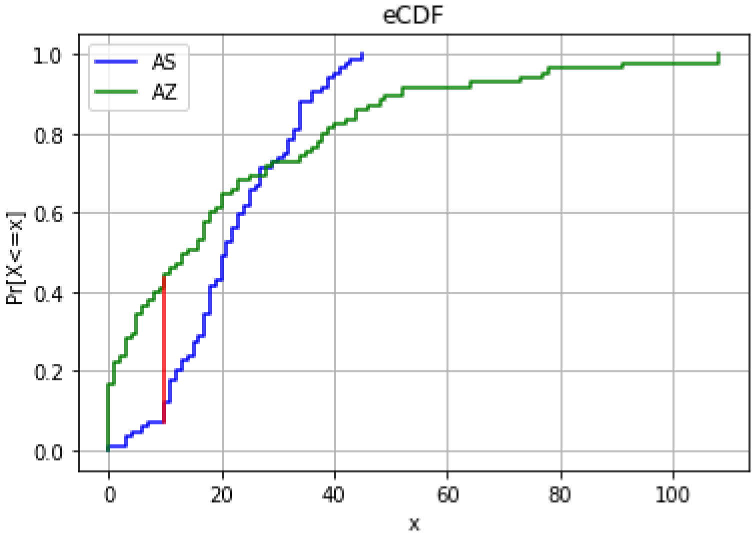


```
Reject Null Hypothesis
```

In [ ]:

```
X = deaths_ar
Y = deaths_az

# plot the graphs
plt.figure('eCDF')
x1, y1 = plot_eCDF(X, 'AS', color='blue')
x2, y2 = plot_eCDF(Y, 'AZ', color='green')

max_difference = 0
point = 0
point_y1 = 0
point_y2 = 0
i = 0
j = 0
while i < len(x2):
    y2_left, y2_right = y2[i], y2[i + 1]
    while j + 2 < len(x1) and x1[j + 2] < x2[i]:
        j += 2
    if x2[i] == x1[j]:
        y1_left, y1_right = y1[j], y1[j + 1]
    else:
        y1_left, y1_right = y1[j + 1], y1[j + 1]
    if max_difference < np.max([max_difference, np.absolute(y1_left - y2_left
), np.absolute(y1_right - y2_right)]):
        max_difference = np.max([max_difference, np.absolute(y1_left - y2_left
), np.absolute(y1_right - y2_right)])
        point_y1 = y1_left
        point_y2 = y2_left
        point = x2[i]
    i += 2
print('Max Difference: ', max_difference)
print('Point with max Difference: ', point)

# graph properties
plt.plot([point, point], [point_y1, point_y2], color='red')
plt.xlabel('x')
plt.ylabel('Pr[X<=x]')
plt.title('eCDF')
plt.legend(loc="upper left")
plt.grid()
plt.show()

if max_difference > 0.05:
    print('Reject Null Hypothesis')
else:
    print('Accept Null Hypothesis')
```

```
Max Difference:  0.37563025210084067
Point with max Difference:  10.0
```



```
Reject Null Hypothesis
```

Permutation Test

In [ ]:

```python
x1 = cases_ar
y1 = cases_az

X_avg = np.mean(x1)
Y_avg = np.mean(y1)
t_obs = np.absolute(X_avg - Y_avg)

number = 0
combined = np.append(x1, y1, axis=0)
for i in range(1000):
    permutation = np.random.permutation(combined)
    X_permutation = permutation[: len(x1)]
    Y_permutation = permutation[len(x1):]
    t_predict = np.absolute(np.mean(X_permutation) - np.mean(Y_permutation))
    if t_predict > t_obs:
        number += 1

p_value = number / 1000
print(p_value)
if p_value > 0.05:
    print('Reject Null Hypothesis')
else:
    print('Accept Null Hypothesis')
```

```
0.0
Accept Null Hypothesis
```

In [ ]:

```
x2 = deaths_ar
y2 = deaths_az

X_avg = np.mean(x2)
Y_avg = np.mean(y2)
t_obs = np.absolute(X_avg - Y_avg)

number = 0
combined = np.append(x2, y2, axis=0)
for i in range(1000):
    permutation = np.random.permutation(combined)
    X_permutation = permutation[: len(x2)]
    Y_permutation = permutation[len(x2):]
    t_predict = np.absolute(np.mean(X_permutation) - np.mean(Y_permutation))
    if t_predict > t_obs:
        number += 1

p_value = number / 1000
print(p_value)
if p_value > 0.05:
    print('Reject Null Hypothesis')
else:
    print('Accept Null Hypothesis')
```

```
0.877
Reject Null Hypothesis
```

Inference 4

In [ ]:

```
from scipy.stats import gamma
```

This function plots the posterior distributions

In [ ]:

```
def plot_posterior(alpha, beta, label):
    x = np.linspace(gamma.ppf(0.01, alpha, scale=1/beta),
                    gamma.ppf(0.99, alpha, scale=1/beta), 1000)
    pdf = gamma.pdf(x, alpha, scale=1/beta)
    print(label,"MAP :", x[np.argmax(pdf)])
    plt.plot(x, pdf, label=label + "MAP : " + str(x[np.argmax(pdf)]))
    plt.xlabel("Count")
    plt.ylabel("pdf of Gamma distribution")
    plt.legend()
```

Read the files that have the processed data.

In [ ]:

```
cases_ar = pd.read_csv("/content/processed_cases_ar.csv")
cases_az = pd.read_csv("/content/processed_cases_az.csv")
```

```
     Unnamed: 0        Date  cases_ar
0             0  2020-01-22       0.0
1             1  2020-01-23       0.0
2             2  2020-01-24       0.0
3             3  2020-01-25       0.0
4             4  2020-01-26       0.0
..          ...         ...       ...
403         433  2021-03-30     175.0
404         434  2021-03-31     213.0
405         435  2021-04-01     210.0
406         436  2021-04-02     145.0
407         437  2021-04-03     216.0

[408 rows x 3 columns]
```

Get the stats in both states for the given range.

In [ ]:

```
cases_ar_range = cases_ar[(cases_ar.Date >= '2020-06-01') & (cases_ar.Date < '2020-07-28')]
cases_az_range = cases_az[(cases_az.Date >= '2020-06-01') & (cases_az.Date < '2020-07-28')]
```

Create a dataframe that has sum of cases in both states

In [ ]:

```
sum_cases = pd.DataFrame(cases_ar_range["cases_ar"] + cases_az_range["cases_az"])
sum_cases.columns = ["combined_sum_cases"]
```

```
In [ ]: print(sum_cases)
```

```
     combined_sum_cases
131               194.0
132              1499.0
133              1218.0
134               893.0
135              1807.0
136              1570.0
137              1761.0
138              1100.0
139               959.0
140              1846.0
141              1859.0
142              2387.0
143              2088.0
144              1638.0
145              1432.0
146              2665.0
147              2243.0
148              2840.0
149              3944.0
150              3621.0
151              3016.0
152              2717.0
153              4362.0
154              2315.0
155              3743.0
156              4110.0
157              4163.0
158              4365.0
159              1064.0
160              5202.0
161              5297.0
162              4211.0
163              4980.0
164              3280.0
165              4143.0
166              3791.0
167              3912.0
168              4254.0
169              4863.0
170              4972.0
171              4099.0
172              3040.0
173              1929.0
174              5067.0
175              3821.0
176              4076.0
177              4558.0
178              3513.0
179              3054.0
180              2258.0
181              4228.0
182              2517.0
183              3348.0
184              4347.0
185              4480.0
```

```
186                2607.0
187                2637.0
```

Intervals refers to the weeks where we observe the data for Bayesian Inference after prior. 35 corresponds to 5th week, 42 corresponds to the 6th week, 49 corresponds to 7th week and 56 corresponds to 8th week.

lambda_mme is 1/sample mean

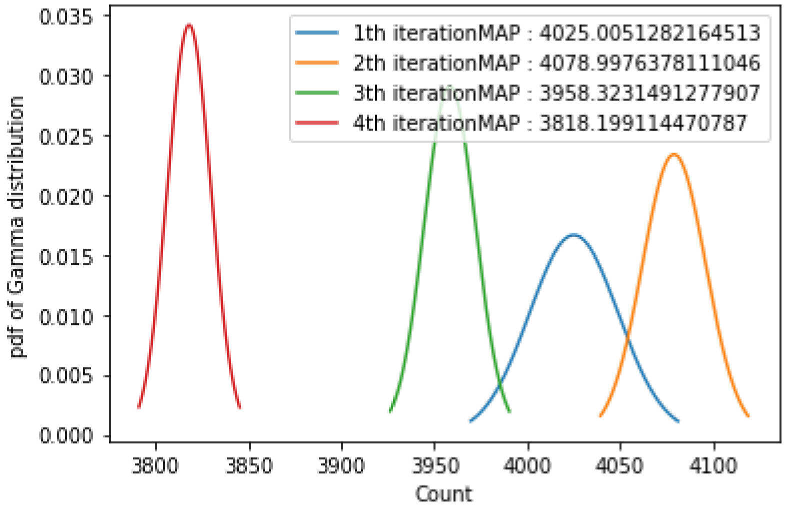
```
In [ ]: intervals = [35,42,49,56]

        lambda_mme = (len(sum_cases[0:28]))/sum_cases[0:28]['combined_sum_cases'].sum
        ()
```

Since the prior is an exponential distribution which is a Gamma(1,beta) distribution and the data is Poisson Distributed, the posteriors will also be Gamma distributions with alpha = 1 + sum of data points and beta = 7*iteration number + lambda_mme.

In [ ]:
```
i=1
for interval in intervals:
    print("-------",i,"-------")
    alpha = 1 + sum_cases[28:interval]['combined_sum_cases'].sum()
    beta = 7*i + lambda_mme
    print("alpha is",alpha)
    print("beta is",beta)
    plot_posterior(alpha, beta, str(i)+"th iteration")
    i = i+1
plt.show()
```

```
------- 1 -------
alpha is 28178.0
beta is 7.000421972722478
1th iteration MAP : 4025.0051282164513
------- 2 -------
alpha is 57109.0
beta is 14.000421972722478
2th iteration MAP : 4078.9976378111046
------- 3 -------
alpha is 83127.0
beta is 21.000421972722478
3th iteration MAP : 3958.3231491277907
------- 4 -------
alpha is 106912.0
beta is 28.000421972722478
4th iteration MAP : 3818.199114470787
```



In [ ]:
```
deaths_ar = pd.read_csv("/content/processed_deaths_ar.csv")
deaths_az = pd.read_csv("/content/processed_deaths_az.csv")
```

In [ ]:
```
deaths_ar_range = deaths_ar[(deaths_ar.Date >= '2020-06-01') & (deaths_ar.Date
< '2020-07-28')]
deaths_az_range = deaths_az[(deaths_az.Date >= '2020-06-01') & (deaths_az.Date
< '2020-07-28')]
```

In [ ]:

```
sum_deaths = pd.DataFrame(deaths_ar_range["deaths_ar"] + deaths_az_range["deaths_az"])
sum_deaths.columns = ["combined_sum_deaths"]
sum_deaths.dropna(inplace=True)
```

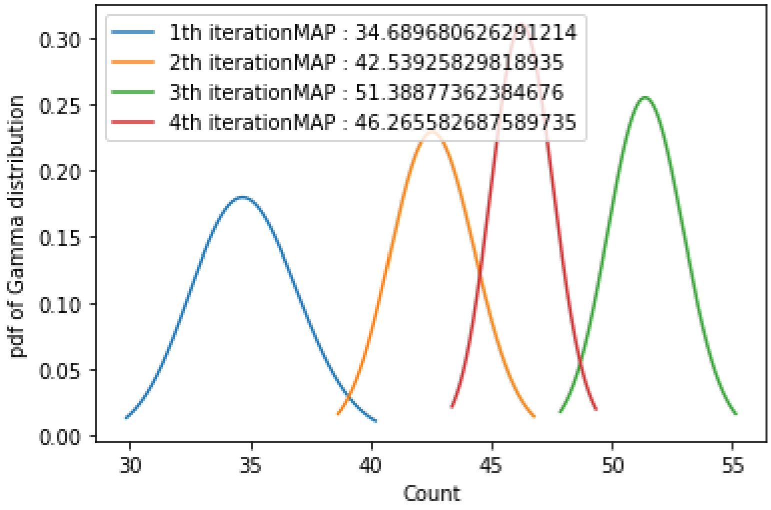
In [ ]:

```
lambda_mme = (len(sum_deaths[0:28]))/sum_deaths[0:28]['combined_sum_deaths'].sum()
```

In [ ]:

```
i=1
for interval in intervals:
    print("-------",i,"-------")
    alpha = 1 + sum_deaths[28:interval]['combined_sum_deaths'].sum()
    beta = 7*i + lambda_mme
    print("alpha is",alpha)
    print("beta is",beta)
    plot_posterior(alpha, beta, str(i)+"th iteration")
    i = i+1
plt.show()
```

```
------- 1 -------
alpha is 245.0
beta is 7.034610630407911
1th iteration MAP : 34.689680626291214
------- 2 -------
alpha is 598.0
beta is 14.034610630407911
2th iteration MAP : 42.53925829818935
------- 3 -------
alpha is 1082.0
beta is 21.03461063040791
3th iteration MAP : 51.38877362384676
------- 4 -------
alpha is 1298.0
beta is 28.03461063040791
4th iteration MAP : 46.265582687589735
```



Question 3

In [ ]:

```
!cp -r /content/drive/MyDrive/ProbStat_HW/US_confirmed.csv /content
!cp -r /content/drive/MyDrive/ProbStat_HW/US_deaths.csv /content
!cp -r /content/drive/MyDrive/ProbStat_HW/aqi_data.csv /content
```

Data Preprocessing

In [ ]:

```
data = []

with open('US_confirmed.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        data.append(row)

headers = data[0]
data = data[1:]

for row in data:
    if row[0] == 'MA':
        data = row
        break

headers = headers[1:]
data = data[1:]

case_data = [0]
for i in range(1, len(data)):
    if (int(data[i])  - int(data[i-1])) < 0:
        case_data.append(0)
    else:
        case_data.append(int(data[i])  - int(data[i-1]))

data = {'date': headers, 'cases': case_data}
df = pd.DataFrame(data=data)
# print(df)

df.to_csv('processed_cases_ma.csv')
```

In [ ]:

```
data = []

with open('US_deaths.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        data.append(row)

headers = data[0]
data = data[1:]

for row in data:
    if row[0] == 'MA':
        data = row
        break

headers = headers[1:]
data = data[1:]

case_data = [0]
for i in range(1, len(data)):
    if (int(data[i])  - int(data[i-1])) < 0:
        case_data.append(0)
    else:
        case_data.append(int(data[i])  - int(data[i-1]))

data = {'date': headers, 'deaths': case_data}
df = pd.DataFrame(data=data)
# print(df)

df.to_csv('processed_deaths_ma.csv')
```

Chi Square Test: Checking independence between Air Quality Index(AQI) and Covid Cases/deaths in Greater Boston Area. The null hypothesis is: AQI and covid cases/deaths are independent in Greater Boston Area.

In [ ]:

```
cases_ma = []
aqi = []
deaths_ma = []

with open('processed_cases_ma.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        cases_ma.append(row)

with open('processed_deaths_ma.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        deaths_ma.append(row)

with open('aqidaily2020.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        aqi.append(row)

aqi = aqi[22:]
cases_ma = cases_ma[1:346]
deaths_ma = deaths_ma[1:346]
data = []
for row in aqi:
    data.append(int(row[1]))
aqi = np.array(data)

data = []
for row in cases_ma:
    data.append(int(row[2]))
cases_ma = np.array(data)

data = []
for row in deaths_ma:
    data.append(int(row[2]))
deaths_ma = np.array(data)
```

In [ ]:

```
np.sort(aqi)
combined = np.append(np.atleast_2d(cases_ma).T, np.atleast_2d(aqi).T, axis=1)
mean_cases_40 = np.mean(combined[combined[:,1]<40][:, 0])
test = combined[combined[:,1]>40]
test = test[test[:,1]<60]
mean_cases_60 = np.mean(test[:,0])

test = combined[combined[:,1]>60]
test = test[test[:,1]<80]
mean_cases_80 = np.mean(test[:,0])

test = combined[combined[:,1]>60]
test = test[test[:,1]<80]
mean_cases_80 = np.mean(test[:,0])

test = combined[combined[:,1]>80]
test = test[test[:,1]<100]
mean_cases_100 = np.mean(test[:,0])

list_cases = [mean_cases_40, mean_cases_60, mean_cases_80, mean_cases_100]

list_cases
```

Out[ ]:

```
[1145.6328125, 897.9171597633136, 1317.5454545454545, 321.0]
```

In [ ]:

```
combined = np.append(np.atleast_2d(deaths_ma).T, np.atleast_2d(aqi).T, axis=1)
mean_deaths_40 = np.mean(combined[combined[:,1]<40][:, 0])
test = combined[combined[:,1]>40]
test = test[test[:,1]<60]
mean_deaths_60 = np.mean(test[:,0])

test = combined[combined[:,1]>60]
test = test[test[:,1]<80]
mean_deaths_80 = np.mean(test[:,0])

test = combined[combined[:,1]>60]
test = test[test[:,1]<80]
mean_deaths_80 = np.mean(test[:,0])

test = combined[combined[:,1]>80]
test = test[test[:,1]<100]
mean_deaths_100 = np.mean(test[:,0])

list_deaths = [mean_deaths_40, mean_deaths_60, mean_deaths_80, mean_deaths_100
]

list_deaths
```

Out[ ]:

```
[30.78125, 44.094674556213015, 25.09090909090909, 9.333333333333334]
```

```
In [ ]: total_cases = np.sum(list_cases)
        total_deaths = np.sum(list_deaths)
        total = total_cases + total_deaths
        total_aqi_range = []

        for i in range(0, len(list_cases)):
            total_aqi_range.append(list_cases[i] + list_deaths[i])

        q_obs = 0

        for i in range(0, len(list_cases)):
            expected = (total_aqi_range[i] * total_cases)/total
            q_obs += ( ((expected - list_cases[i])*(expected - list_cases[i]))/expecte
        d )

        for i in range(0, len(list_deaths)):
            expected = (total_aqi_range[i] * total_deaths)/total
            q_obs += ( ((expected - list_deaths[i])*(expected - list_deaths[i]))/expec
        ted )

        df = 3
        print('Q observer is: ', q_obs, ' Degrees of freedom:',df)
        print('p-value from table lookup 0.001076  < 0.05')
        print('We are rejecting null hypothesis, so AQI(air quality index) and covid c
        ases/deaths are not independent in Greater Boston Area.')
```

```
Q observer is:  16.111272972266054  Degrees of freedom: 3
p-value from table lookup 0.001076  < 0.05
We are rejecting null hypothesis, so AQI(air quality index) and covid cases/d
eaths are not independent in Greater Boston Area.
```

We are rejecting null hypothesis, so AQI(air quality index) and covid cases/deaths are not independent in Greater Boston Area.

Pearson Correlation Test: To check correlation between Air Quality Index and Covid Cases/Deaths at Greater Boston Area.

In [ ]:

```
cases_ma = []
aqi = []
deaths_ma = []

with open('processed_cases_ma.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        cases_ma.append(row)

with open('processed_deaths_ma.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        deaths_ma.append(row)

with open('aqidaily2020.csv') as csv_file:
    csv_reader = csv.reader(csv_file, delimiter=',')
    for row in csv_reader:
        aqi.append(row)

aqi = aqi[22:]
cases_ma = cases_ma[1:346]
deaths_ma = deaths_ma[1:346]

data = []
for row in aqi:
    data.append(int(row[1]))
aqi = data

data = []
for row in cases_ma:
    data.append(int(row[2]))
cases_ma = data

data = []
for row in deaths_ma:
    data.append(int(row[2]))
deaths_ma = data

print(aqi)


m1 = np.mean(aqi)
m2 = np.mean(cases_ma)
v1 = np.var(aqi)
v2 = np.var(cases_ma)
sum = 0
n = len(aqi)
for i in range(0, n):
    sum += ((aqi[i] - m1)*(cases_ma[i] - m2))
numerator = sum/n
denominator = np.sqrt(v1*v2)
pc = numerator/denominator
print("Pearson correlation for Cases and AQI",pc)

m1 = np.mean(aqi)
m2 = np.mean(deaths_ma)
```

```
v1 = np.var(aqi)
v2 = np.var(deaths_ma)
sum = 0
n = len(aqi)
for i in range(0, n):
    sum += ((aqi[i] - m1)*(deaths_ma[i] - m2))
numerator = sum/n
denominator = np.sqrt(v1*v2)
pc = numerator/denominator
print("Pearson correlation for Deaths and AQI", pc)
```

```
[58, 67, 63, 39, 31, 23, 38, 40, 38, 46, 51, 57, 46, 54, 41, 33, 35, 36, 36,
45, 54, 38, 45, 36, 36, 42, 45, 38, 40, 40, 39, 46, 56, 57, 58, 53, 46, 40, 3
7, 40, 52, 54, 40, 42, 48, 42, 44, 49, 55, 39, 37, 39, 40, 44, 41, 39, 43, 4
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1, 33, 33]
Pearson correlation for Cases and AQI -0.04631518185689359
Pearson correlation for Deaths and AQI -0.025444986580568325
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Conclusion for the above test: Negative values indicate negative correlation between AQI and Cases/Deaths. So as Covid Cases/Deaths increase, the AQI decreases.