```
from dateutil.parser import parse
import matplotlib as mpl
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pandas as pd
plt.rcParams.update({'figure.figsize': (10, 7), 'figure.dpi': 120})

# Import as Dataframe
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'])
df.head()
```

	date	value
0	1991-07-01	3.526591
1	1991-08-01	3.180891
2	1991-09-01	3.252221
3	1991-10-01	3.611003
4	1991-11-01	3.565869

```
ser = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')
ser.head()
```

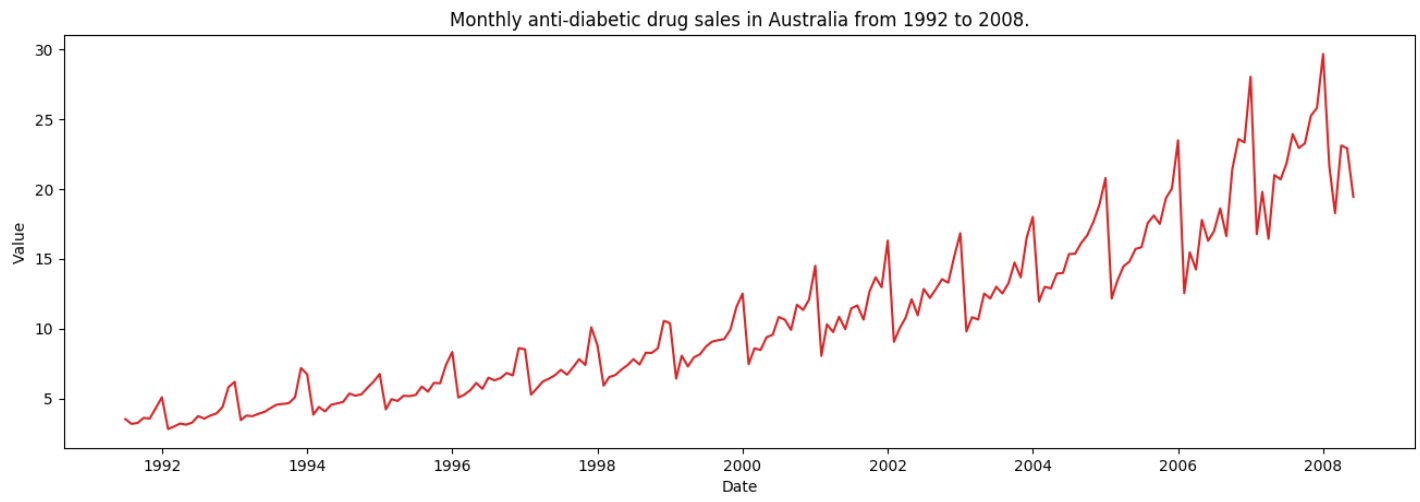
date	value
1991-07-01	3.526591
1991-08-01	3.180891
1991-09-01	3.252221
1991-10-01	3.611003
1991-11-01	3.565869

```
# dataset source: https://github.com/rouseguy
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/MarketArrivals.csv')
df = df.loc[df.market=='MUMBAI', :]
df.head()
```

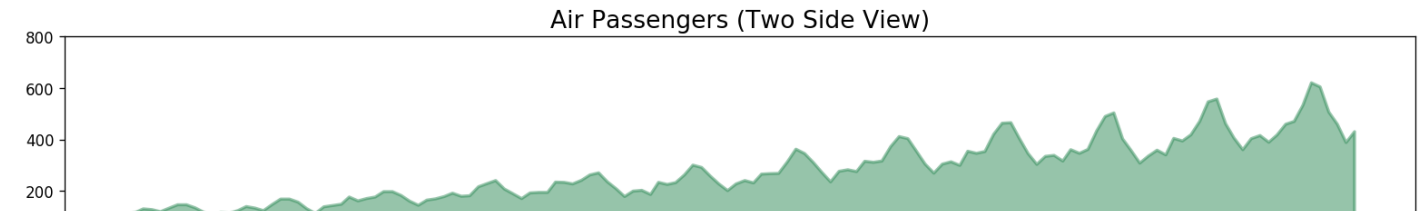
	market	month	year	quantity	priceMin	priceMax	priceMod	state	city	date
6654	MUMBAI	January	2004	267100	719	971	849	MS	MUMBAI	January-2004
6655	MUMBAI	January	2005	275845	261	513	387	MS	MUMBAI	January-2005
6656	MUMBAI	January	2006	228000	315	488	402	MS	MUMBAI	January-2006
6657	MUMBAI	January	2007	205200	866	1136	997	MS	MUMBAI	January-2007
6658	MUMBAI	January	2008	267550	348	550	448	MS	MUMBAI	January-2008

```
# Time series data source: fpp pacakge in R.
import matplotlib.pyplot as plt
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')

# Draw Plot
def plot_df(df, x, y, title="", xlabel='Date', ylabel='Value', dpi=100):
    plt.figure(figsize=(16,5), dpi=dpi)
    plt.plot(x, y, color='tab:red')
    plt.gca().set(title=title, xlabel=xlabel, ylabel=ylabel)
    plt.show()

plot_df(df, x=df.index, y=df.value, title='Monthly anti-diabetic drug sales in Australia from 1992 to 2008.')
```

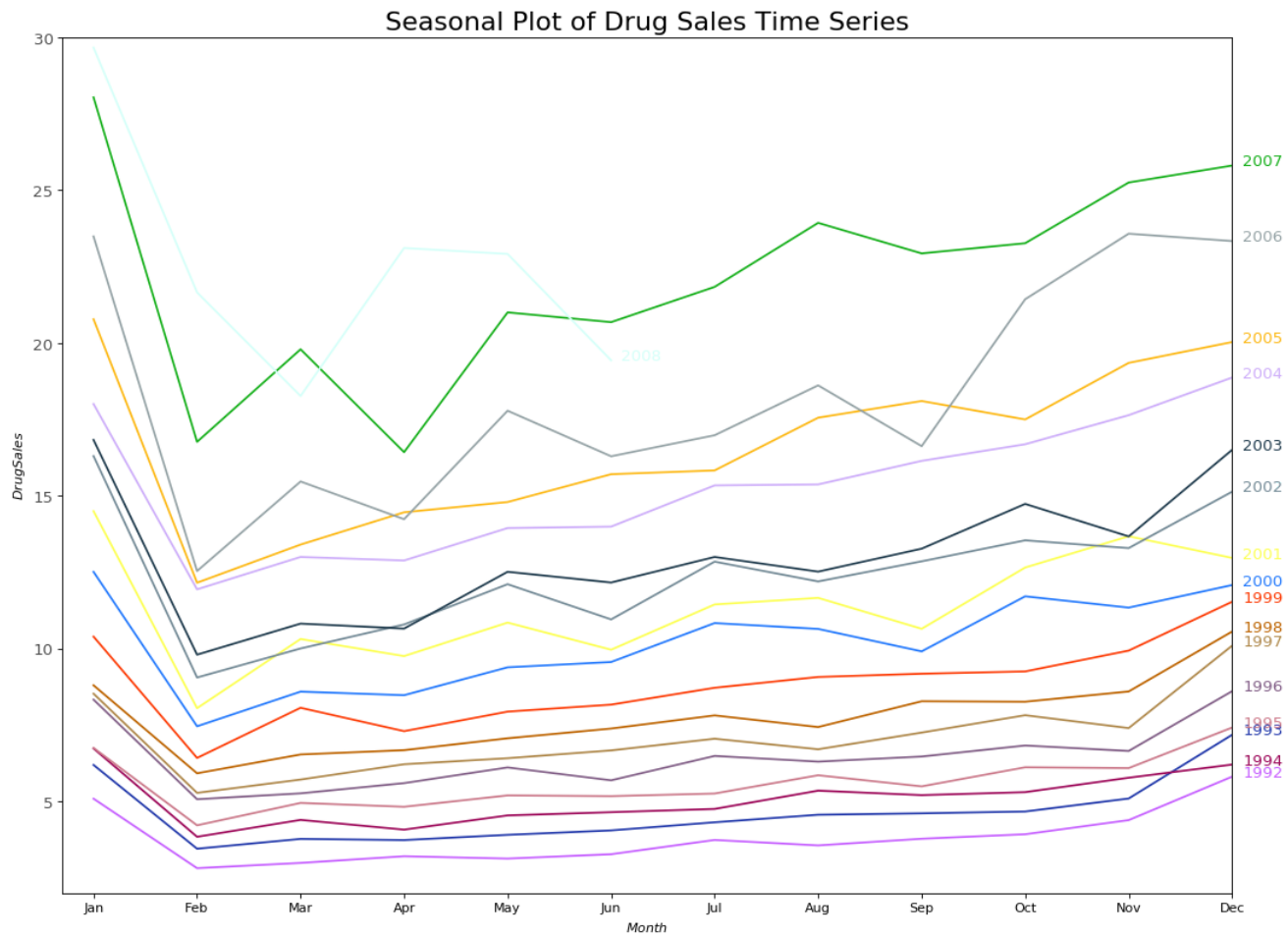
```
/usr/local/lib/python3.6/dist-packages/pandas/plotting/_converter.py:129: FutureWarning: Using an implicitly registered datetime converter for a matplotlib plotting method. The converter was registere

To register the converters:
        >>> from pandas.plotting import register_matplotlib_converters
        >>> register_matplotlib_converters()
  warnings.warn(msg, FutureWarning)
```



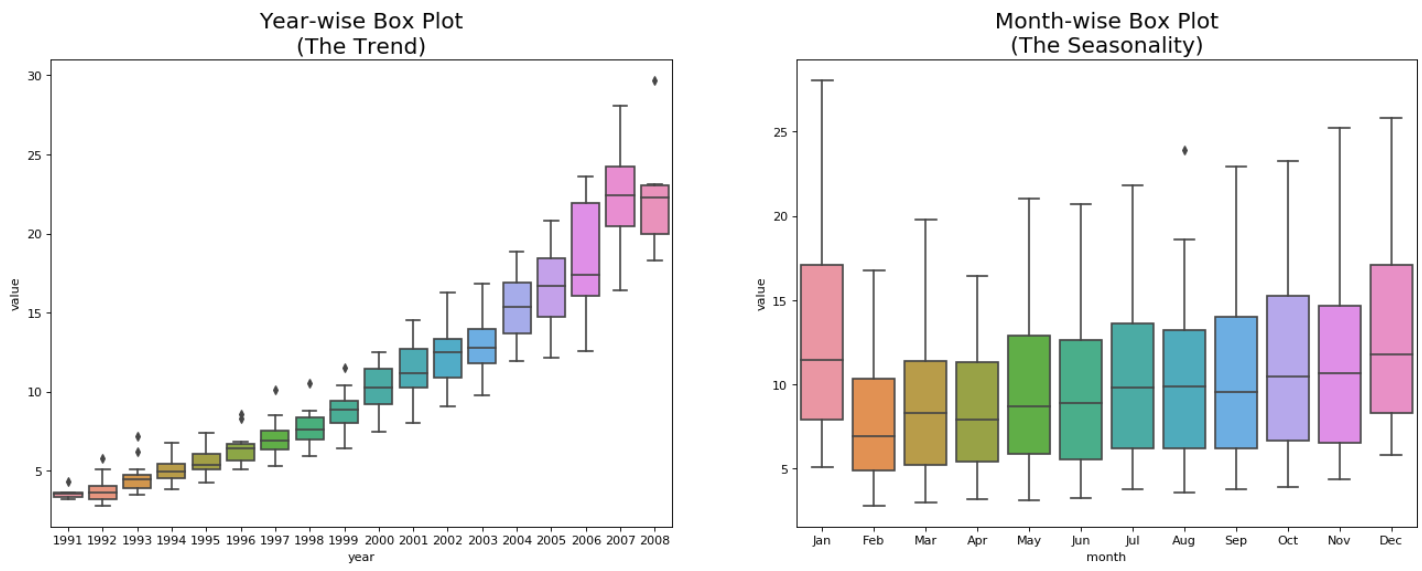

```
# Import data
df = pd.read_csv('/content/AirPassengers.csv', parse_dates=['Month'])
x = df['Month'].values
y1 = df['#Passengers']

# Plot
fig, ax = plt.subplots(1, 1, figsize=(16,5), dpi= 120)
plt.fill_between(x, y1=y1, y2=-y1, alpha=0.5, linewidth=2, color='seagreen')
plt.ylim(-800, 800)
plt.title('Air Passengers (Two Side View)', fontsize=16)
plt.hlines(y=0, xmin=np.min(df.Month), xmax=np.max(df.Month), linewidth=.5)
plt.show()
```




```
# Import Data
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')
df.reset_index(inplace=True)

# Prepare data
df['year'] = [d.year for d in df.date]
df['month'] = [d.strftime('%b') for d in df.date]
years = df['year'].unique()

# Prep Colors
np.random.seed(100)
mycolors = np.random.choice(list(mpl.colors.XKCD_COLORS.keys()), len(years), replace=False)

# Draw Plot
plt.figure(figsize=(16,12), dpi= 80)
for i, y in enumerate(years):
    if i > 0:
        plt.plot('month', 'value', data=df.loc[df.year==y, :], color=mycolors[i], label=y)
        plt.text(df.loc[df.year==y, :].shape[0]-.9, df.loc[df.year==y, 'value'][-1:].values[0], y, fontsize=12, color=mycolors[i])

# Decoration
plt.gca().set(xlim=(-0.3, 11), ylim=(2, 30), ylabel='$Drug Sales$', xlabel='$Month$')
plt.yticks(fontsize=12, alpha=.7)
plt.title("Seasonal Plot of Drug Sales Time Series", fontsize=20)
plt.show()
```



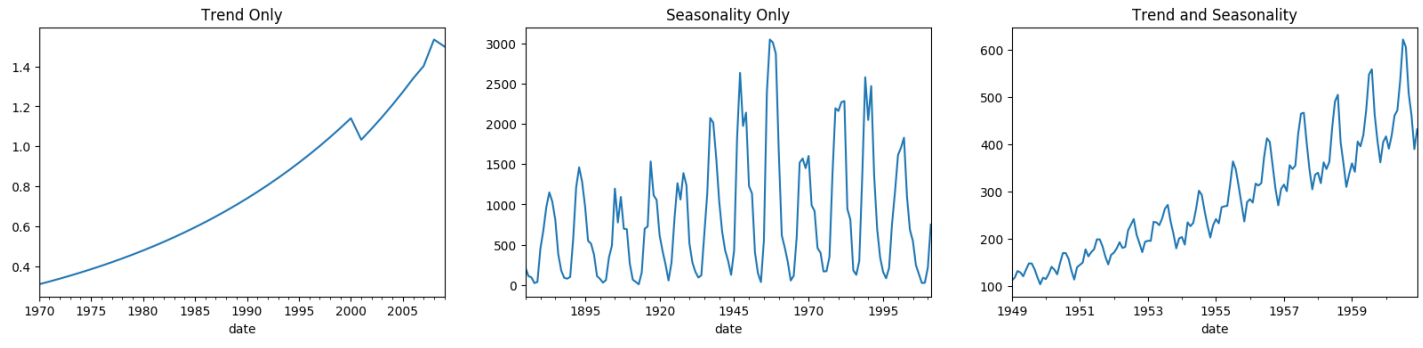

```
# Import Data
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')
df.reset_index(inplace=True)

# Prepare data
df['year'] = [d.year for d in df.date]
df['month'] = [d.strftime('%b') for d in df.date]
years = df['year'].unique()

# Draw Plot
fig, axes = plt.subplots(1, 2, figsize=(20,7), dpi= 80)
sns.boxplot(x='year', y='value', data=df, ax=axes[0])
sns.boxplot(x='month', y='value', data=df.loc[~df.year.isin([1991, 2008]), :])

# Set Title
axes[0].set_title('Year-wise Box Plot\n(The Trend)', fontsize=18);
axes[1].set_title('Month-wise Box Plot\n(The Seasonality)', fontsize=18)
plt.show()
```



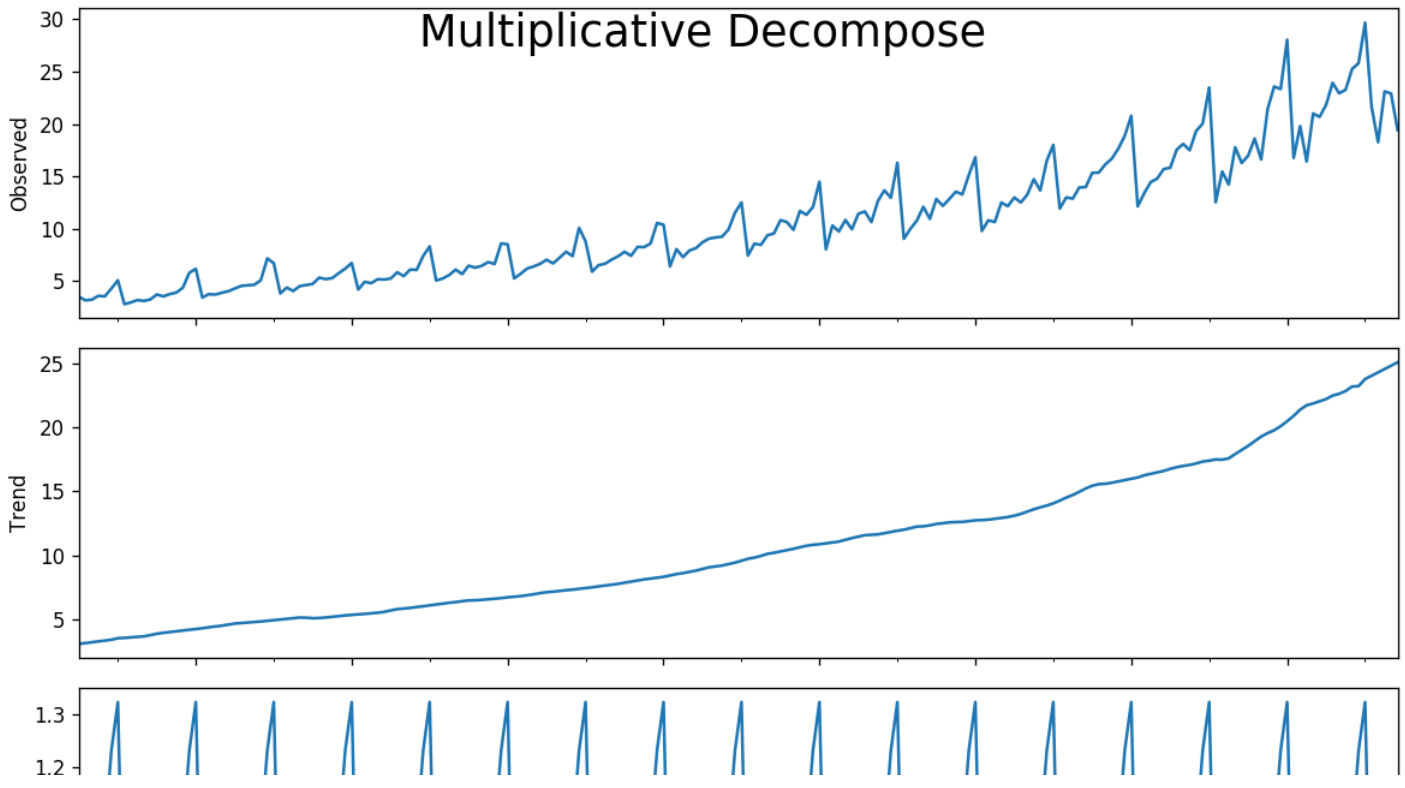

```
fig, axes = plt.subplots(1,3, figsize=(20,4), dpi=100)
pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/guinearice.csv', parse_dates=['date'], index_col='date').plot(title='Trend Only', legend=Fa
pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/sunspotarea.csv', parse_dates=['date'], index_col='date').plot(title='Seasonality Only', le
```

```
pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/AirPassengers.csv', parse_dates=['date'], index_col='date').plot(title='Trend and Seasonali
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fb130d222b0>
```




```
from statsmodels.tsa.seasonal import seasonal_decompose
from dateutil.parser import parse

# Import Data
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')

# Multiplicative Decomposition
result_mul = seasonal_decompose(df['value'], model='multiplicative', extrapolate_trend='freq')

# Additive Decomposition
result_add = seasonal_decompose(df['value'], model='additive', extrapolate_trend='freq')

# Plot
plt.rcParams.update({'figure.figsize': (10,10)})
result_mul.plot().suptitle('Multiplicative Decompose', fontsize=22)
result_add.plot().suptitle('Additive Decompose', fontsize=22)
plt.show()

```




```
# Extract the Components ----
# Actual Values = Product of (Seasonal * Trend * Resid)
df_reconstructed = pd.concat([result_mul.seasonal, result_mul.trend, result_mul.resid, result_mul.observed], axis=1)
df_reconstructed.columns = ['seas', 'trend', 'resid', 'actual_values']
df_reconstructed.head()
```

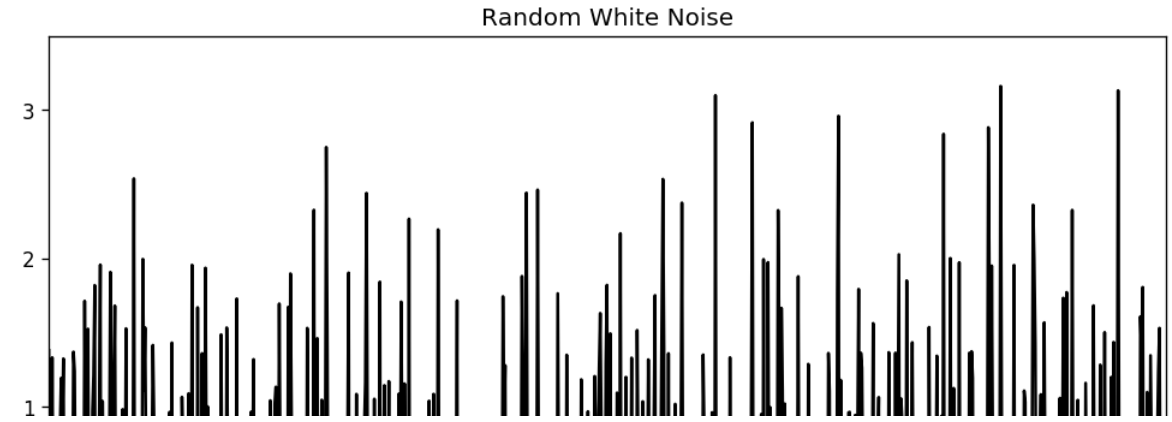
date	seas	trend	resid	actual_values
1991-07-01	0.987845	3.060085	1.166629	3.526591
1991-08-01	0.990481	3.124765	1.027745	3.180891
1991-09-01	0.987476	3.189445	1.032615	3.252221
1991-10-01	1.048329	3.254125	1.058513	3.611003
1991-11-01	1.074527	3.318805	0.999923	3.565869

```
from statsmodels.tsa.stattools import adfuller, kpss
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'])

# ADF Test
result = adfuller(df.value.values, autolag='AIC')
print(f'ADF Statistic: {result[0]}')
print(f'p-value: {result[1]}')
for key, value in result[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')

# KPSS Test
result = kpss(df.value.values, regression='c')
print('\nKPSS Statistic: %f' % result[0])
print('p-value: %f' % result[1])
for key, value in result[3].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
ADF Statistic: 3.14518568930674
p-value: 1.0
Critial Values:
   1%, -3.465620397124192
Critial Values:
   5%, -2.8770397560752436
Critial Values:
   10%, -2.5750324547306476

KPSS Statistic: 1.313675
p-value: 0.010000
Critial Values:
   10%, 0.347
Critial Values:
   5%, 0.463
Critial Values:
   2.5%, 0.574
Critial Values:
   1%, 0.739
/usr/local/lib/python3.6/dist-packages/statsmodels/tsa/stattools.py:1685: FutureWarning: The behavior of using lags=None will change in the next release. Currently lags=None is the same as lags='legac
  warn(msg, FutureWarning)
/usr/local/lib/python3.6/dist-packages/statsmodels/tsa/stattools.py:1708: InterpolationWarning: p-value is smaller than the indicated p-value
  warn("p-value is smaller than the indicated p-value", InterpolationWarning)
```

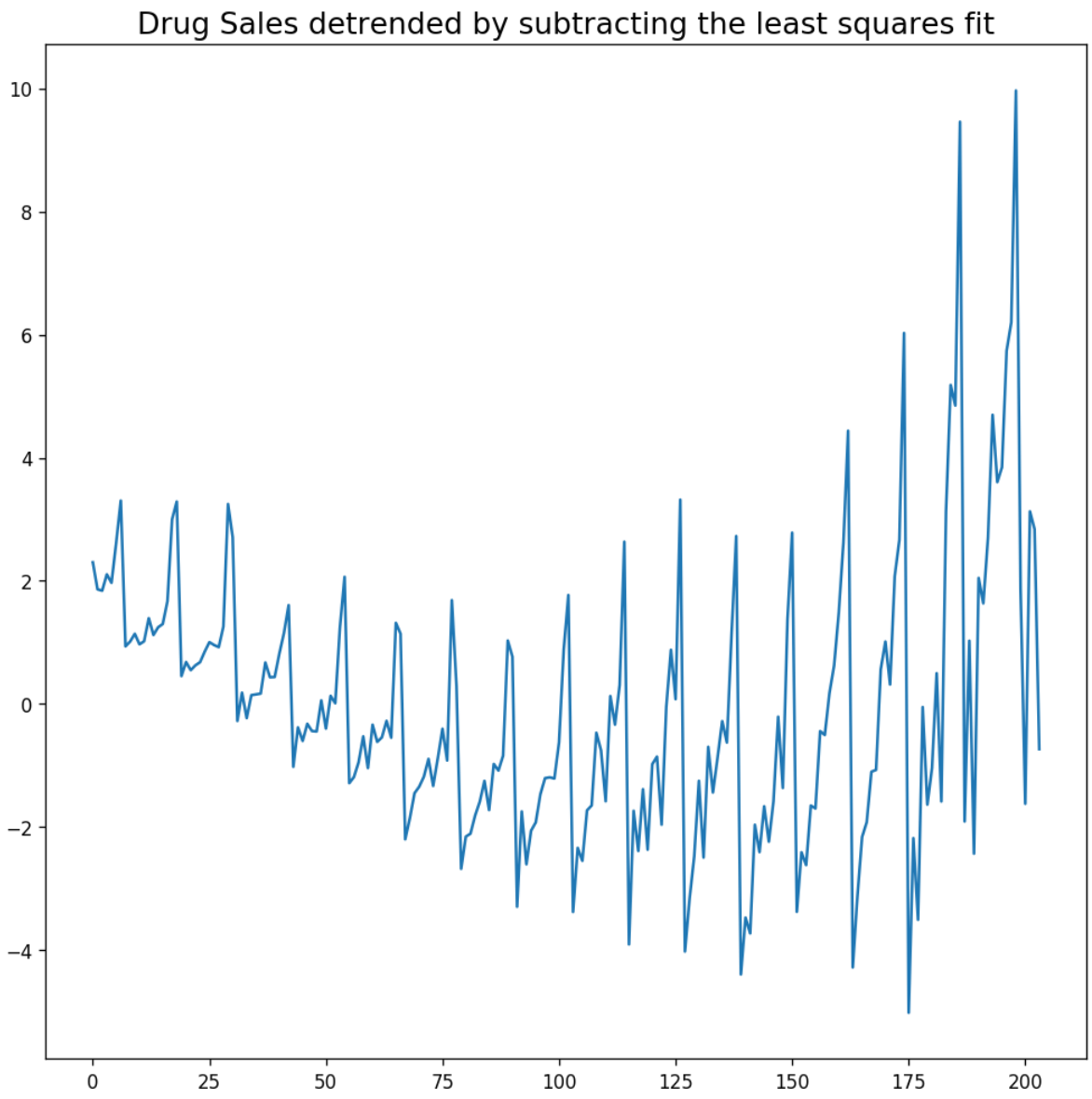
```
randvals = np.random.randn(1000)
pd.Series(randvals).plot(title='Random White Noise', color='k')
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fb131003c18>
```



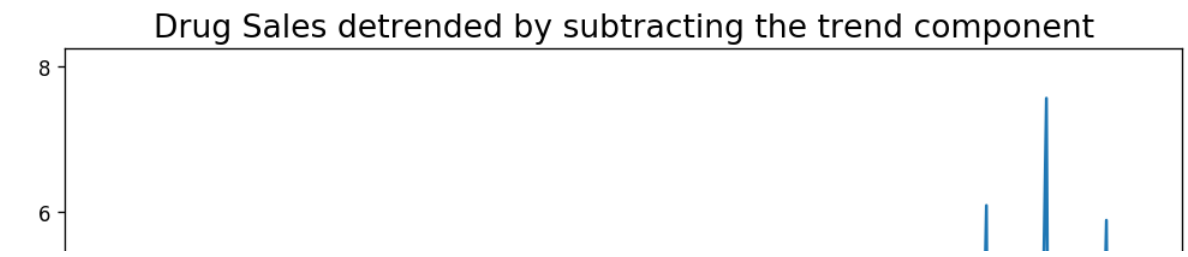

```
# Using scipy: Subtract the line of best fit
from scipy import signal
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'])
detrended = signal.detrend(df.value.values)
plt.plot(detrended)
plt.title('Drug Sales detrended by subtracting the least squares fit', fontsize=16)

```

```
Text(0.5, 1.0, 'Drug Sales detrended by subtracting the least squares fit')
```



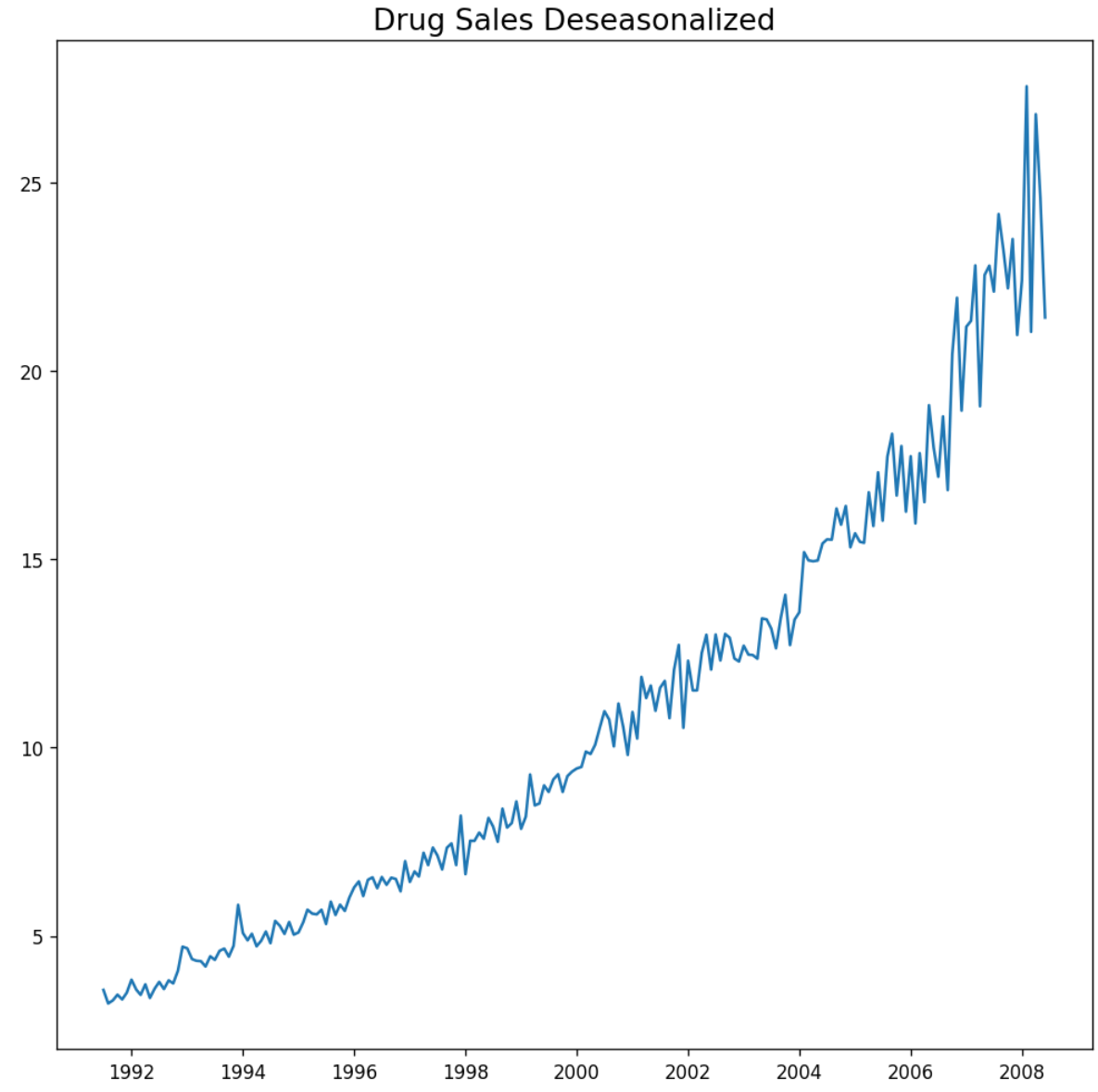

```
# Using statmodels: Subtracting the Trend Component.
from statsmodels.tsa.seasonal import seasonal_decompose
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')
result_mul = seasonal_decompose(df['value'], model='multiplicative', extrapolate_trend='freq')
detrended = df.value.values - result_mul.trend
plt.plot(detrended)
plt.title('Drug Sales detrended by subtracting the trend component', fontsize=16)
```

```
Text(0.5, 1.0, 'Drug Sales detrended by subtracting the trend component')
```



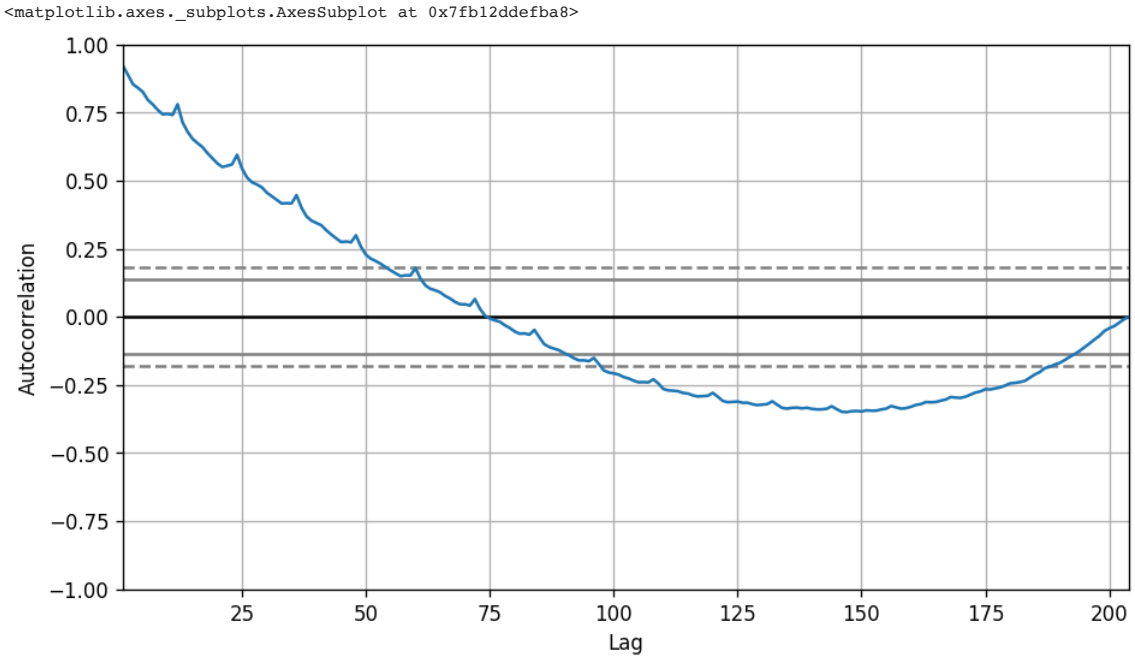

```
# Subtracting the Trend Component.
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'], index_col='date')

# Time Series Decomposition
result_mul = seasonal_decompose(df['value'], model='multiplicative', extrapolate_trend='freq')

# Deseasonalize
deseasonalized = df.value.values / result_mul.seasonal

# Plot
plt.plot(deseasonalized)
plt.title('Drug Sales Deseasonalized', fontsize=16)
plt.plot()
```

```
[]
```

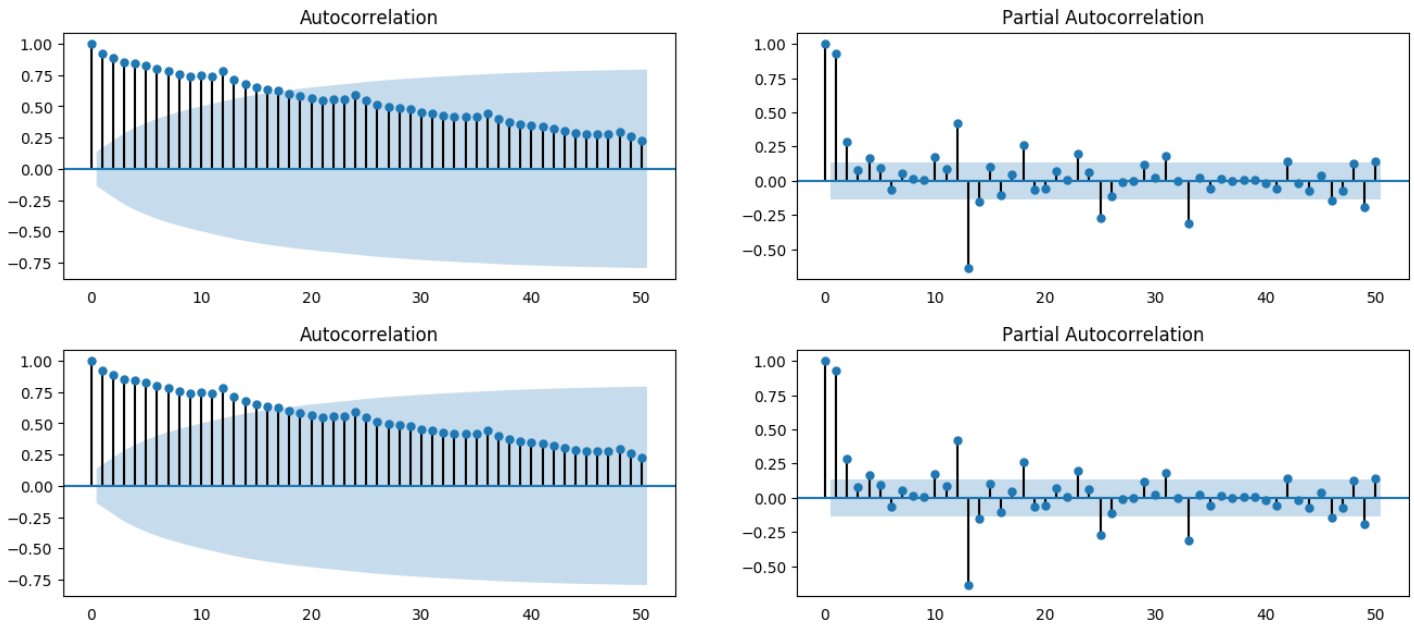



```
from pandas.plotting import autocorrelation_plot
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv')

# Draw Plot
plt.rcParams.update({'figure.figsize':(9,5), 'figure.dpi':120})
autocorrelation_plot(df.value.tolist())
```

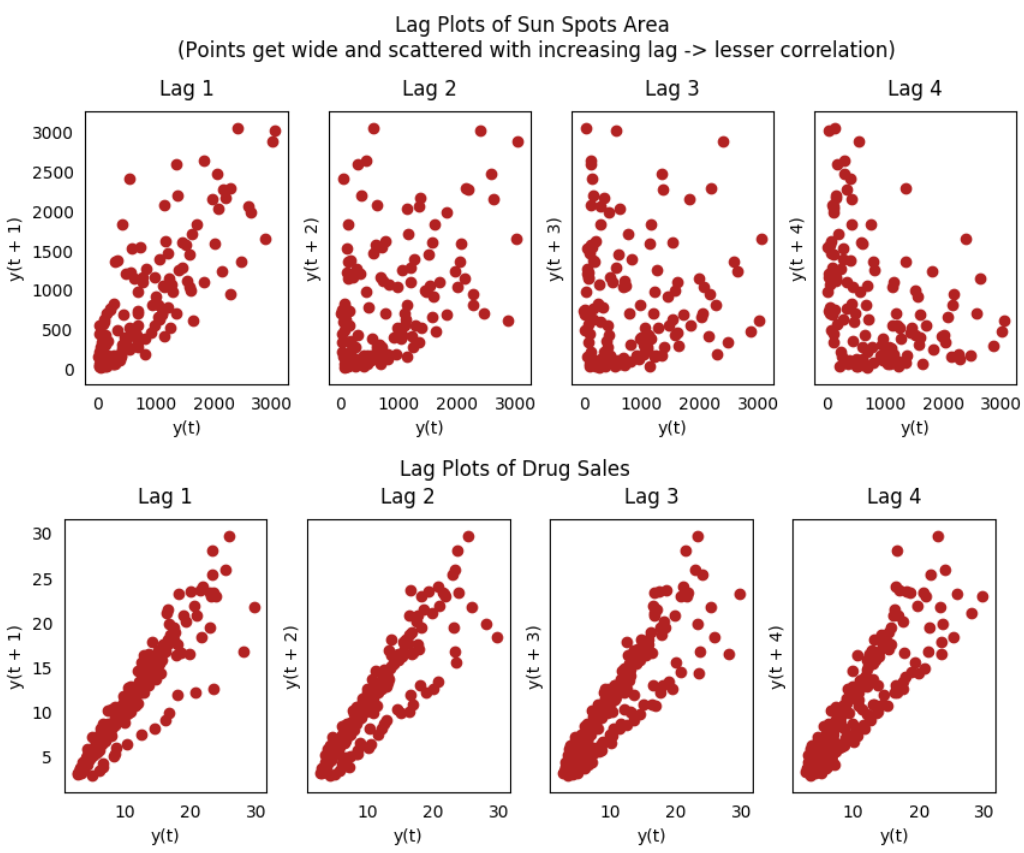
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fb12ddefba8>
```




```
from statsmodels.tsa.stattools import acf, pacf
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf

df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv')

# Calculate ACF and PACF upto 50 lags
# acf_50 = acf(df.value, nlags=50)
# pacf_50 = pacf(df.value, nlags=50)

# Draw Plot
fig, axes = plt.subplots(1,2,figsize=(16,3), dpi= 100)
plot_acf(df.value.tolist(), lags=50, ax=axes[0])
plot_pacf(df.value.tolist(), lags=50, ax=axes[1])
```




```
from pandas.plotting import lag_plot
plt.rcParams.update({'ytick.left' : False, 'axes.titlepad':10})

# Import
ss = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/sunspotarea.csv')
a10 = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv')

# Plot
fig, axes = plt.subplots(1, 4, figsize=(10,3), sharex=True, sharey=True, dpi=100)
for i, ax in enumerate(axes.flatten()[:4]):
    lag_plot(ss.value, lag=i+1, ax=ax, c='firebrick')
    ax.set_title('Lag ' + str(i+1))

fig.suptitle('Lag Plots of Sun Spots Area \n(Points get wide and scattered with increasing lag -> lesser correlation)\n', y=1.15)

fig, axes = plt.subplots(1, 4, figsize=(10,3), sharex=True, sharey=True, dpi=100)
for i, ax in enumerate(axes.flatten()[:4]):
    lag_plot(a10.value, lag=i+1, ax=ax, c='firebrick')
    ax.set_title('Lag ' + str(i+1))

fig.suptitle('Lag Plots of Drug Sales', y=1.05)
plt.show()
```




```
# https://en.wikipedia.org/wiki/Approximate_entropy
ss = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/sunspotarea.csv')
a10 = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv')
rand_small = np.random.randint(0, 100, size=36)
rand_big = np.random.randint(0, 100, size=136)

def ApEn(U, m, r):
    """Compute Aproximate entropy"""
    def _maxdist(x_i, x_j):
        return max([abs(ua - va) for ua, va in zip(x_i, x_j)])

    def _phi(m):
        x = [[U[j] for j in range(i, i + m - 1 + 1)] for i in range(N - m + 1)]
        C = [len([1 for x_j in x if _maxdist(x_i, x_j) <= r]) / (N - m + 1.0) for x_i in x]
        return (N - m + 1.0)**(-1) * sum(np.log(C))

    N = len(U)
    return abs(_phi(m+1) - _phi(m))

print(ApEn(ss.value, m=2, r=0.2*np.std(ss.value)))     # 0.651
print(ApEn(a10.value, m=2, r=0.2*np.std(a10.value)))   # 0.537
print(ApEn(rand_small, m=2, r=0.2*np.std(rand_small))) # 0.143
print(ApEn(rand_big, m=2, r=0.2*np.std(rand_big)))     # 0.716
```

```
0.6514704970333534
0.5374775224973489
0.0898376940798844
0.6725953850207098
```

```
# https://en.wikipedia.org/wiki/Sample_entropy
def SampEn(U, m, r):
    """Compute Sample entropy"""
    def _maxdist(x_i, x_j):
        return max([abs(ua - va) for ua, va in zip(x_i, x_j)])

    def _phi(m):
        x = [[U[j] for j in range(i, i + m - 1 + 1)] for i in range(N - m + 1)]
```

```
        C = [len([1 for j in range(len(x)) if i != j and _maxdist(x[i], x[j]) <= r]) for i in range(len(x))]
        return sum(C)

    N = len(U)
    return -np.log(_phi(m+1) / _phi(m))

print(SampEn(ss.value, m=2, r=0.2*np.std(ss.value)))      # 0.78
print(SampEn(a10.value, m=2, r=0.2*np.std(a10.value)))    # 0.41
print(SampEn(rand_small, m=2, r=0.2*np.std(rand_small)))  # 1.79
print(SampEn(rand_big, m=2, r=0.2*np.std(rand_big)))      # 2.42
```

```
0.7853311366380039
0.41887013457621214
inf
2.2721258855093374
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:12: RuntimeWarning: divide by zero encountered in log
  if sys.path[0] == '':
```

```
from statsmodels.tsa.stattools import grangercausalitytests
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/a10.csv', parse_dates=['date'])
df['month'] = df.date.dt.month
grangercausalitytests(df[['value', 'month']], maxlag=2)
```

```
Granger Causality
number of lags (no zero) 1
ssr based F test:         F=54.7797 , p=0.0000  , df_denom=200, df_num=1
ssr based chi2 test:   chi2=55.6014 , p=0.0000  , df=1
likelihood ratio test: chi2=49.1426 , p=0.0000  , df=1
parameter F test:         F=54.7797 , p=0.0000  , df_denom=200, df_num=1

Granger Causality
number of lags (no zero) 2
ssr based F test:         F=162.6989, p=0.0000  , df_denom=197, df_num=2
ssr based chi2 test:   chi2=333.6567, p=0.0000  , df=2
likelihood ratio test: chi2=196.9956, p=0.0000  , df=2
parameter F test:         F=162.6989, p=0.0000  , df_denom=197, df_num=2
{1: ({'lrtest': (49.14260233004984, 2.38014300604565e-12, 1),
   'params_ftest': (54.77967483557335, 3.661425871353419e-12, 200.0, 1.0),
   'ssr_chi2test': (55.6013699581072, 8.876175235021508e-14, 1),
   'ssr_ftest': (54.7796748355736, 3.661425871353102e-12, 200.0, 1)},
  [<statsmodels.regression.linear_model.RegressionResultsWrapper at 0x7fb12bcd05c0>,
   <statsmodels.regression.linear_model.RegressionResultsWrapper at 0x7fb12bcd06a0>,
   array([[0., 1., 0.]])]),
 2: ({'lrtest': (196.99559277182186, 1.6709003499116746e-43, 2),
   'params_ftest': (162.69891799873227, 1.9133235086857535e-42, 197.0, 2.0),
   'ssr_chi2test': (333.65666432227346, 3.5267600881280646e-73, 2),
   'ssr_ftest': (162.69891799873236, 1.9133235086857257e-42, 197.0, 2)},
  [<statsmodels.regression.linear_model.RegressionResultsWrapper at 0x7fb12bdf22b0>,
   <statsmodels.regression.linear_model.RegressionResultsWrapper at 0x7fb12bdf2eb8>,
   array([[0., 0., 1., 0., 0.],
          [0., 0., 0., 1., 0.]])])}
```