Time Series

Part I

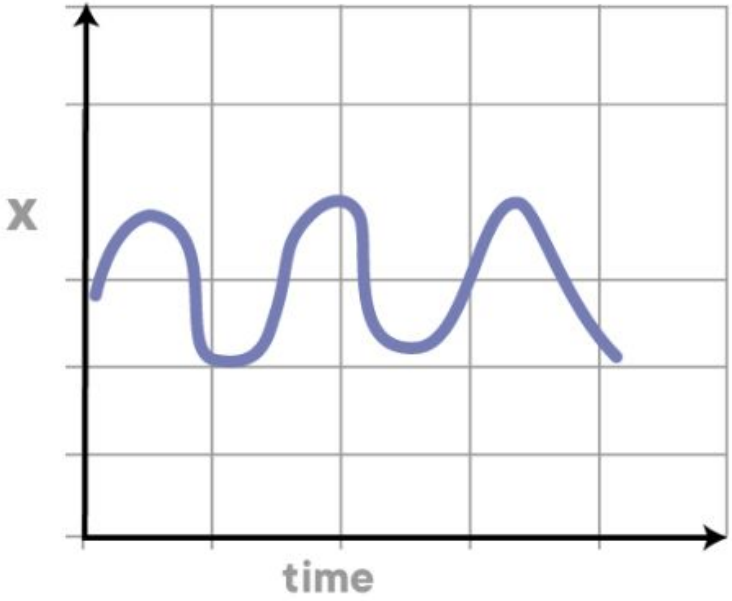
Jan 8th 2020

Stationarity

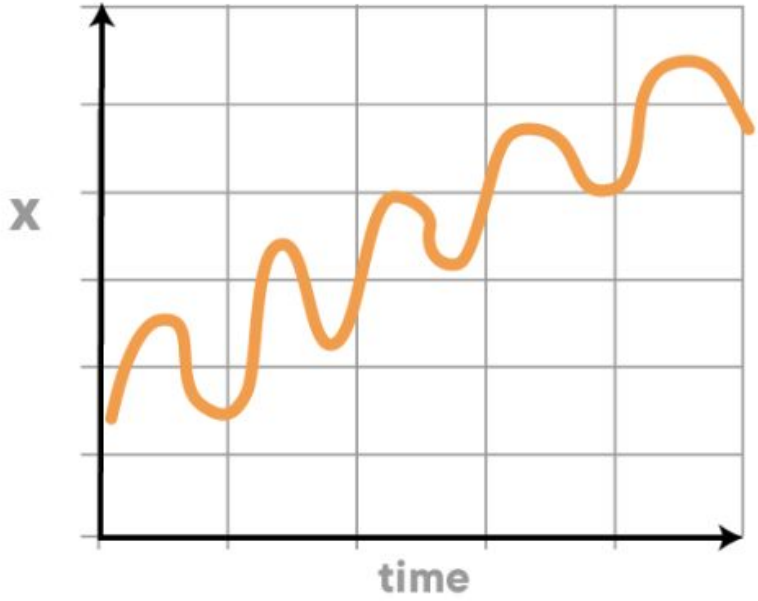
- Definition
- Mean
- Variance
- Autocorrelation

Stationarity

- The mean doesn’t change over time



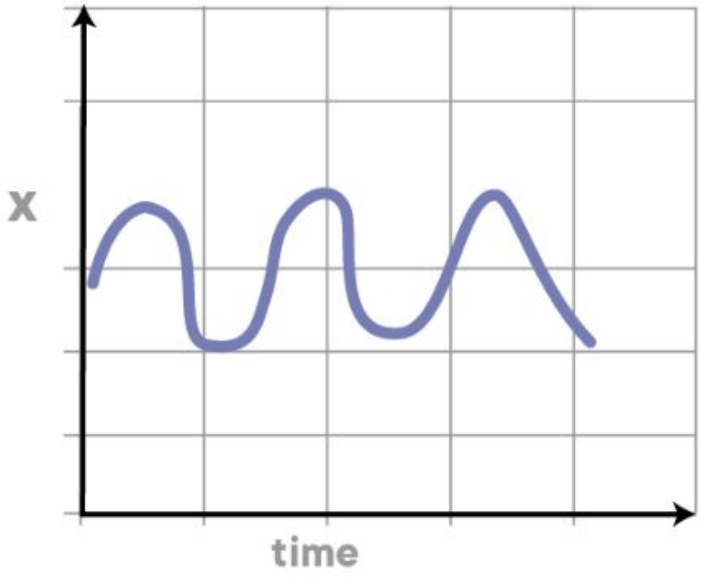
Stationary series



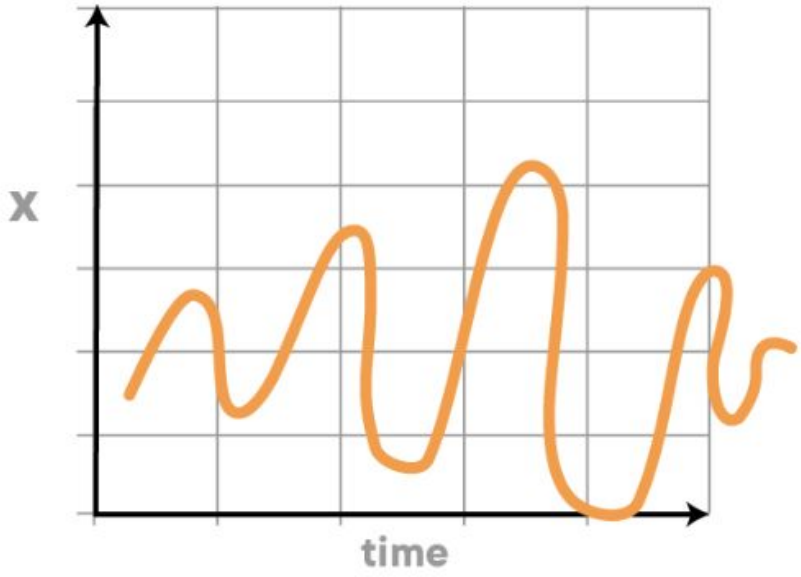
Non-Stationary series

Stationarity

- The variance doesn’t change over time

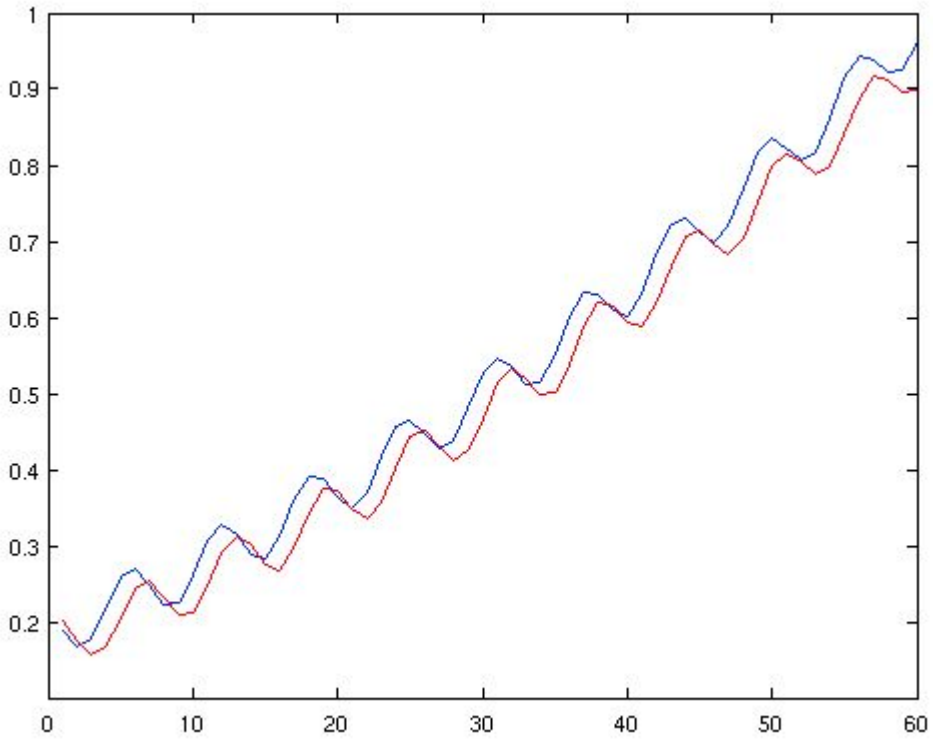


Stationary series



Non-Stationary series

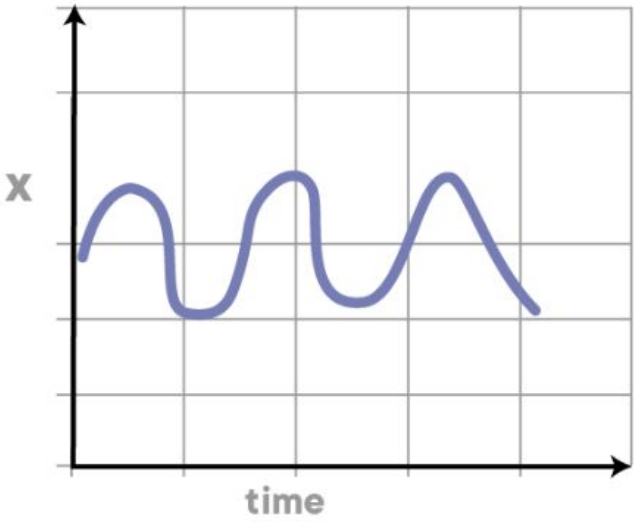
Autocorrelation



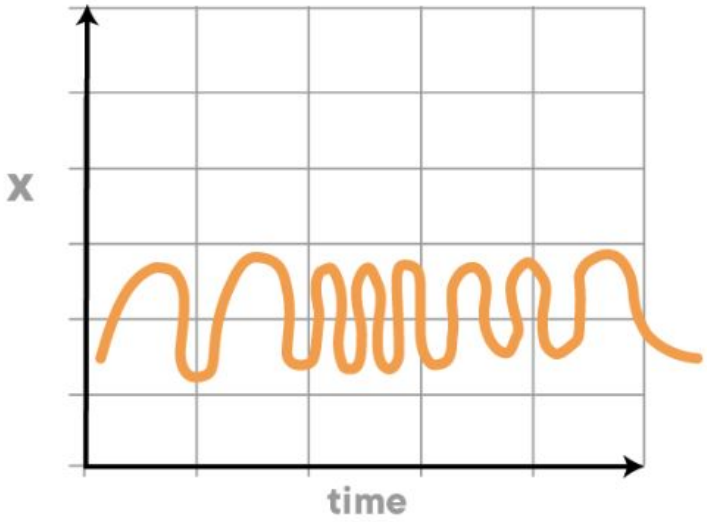
- If you create a copy (red) of your time series (blue) and move it forward in time: Would you be able to predict when the original one was going to go up /down?
- You can calculate the correlation of any period passed with the current one

Stationarity

- The autocorrelation doesn’t change overtime



Stationary series



Non-Stationary series

Dealing with non-stationary time series

- Log transformation
- Differencing
- Higher degree differencing
- Higher period differencing
- Time Series Decomposition

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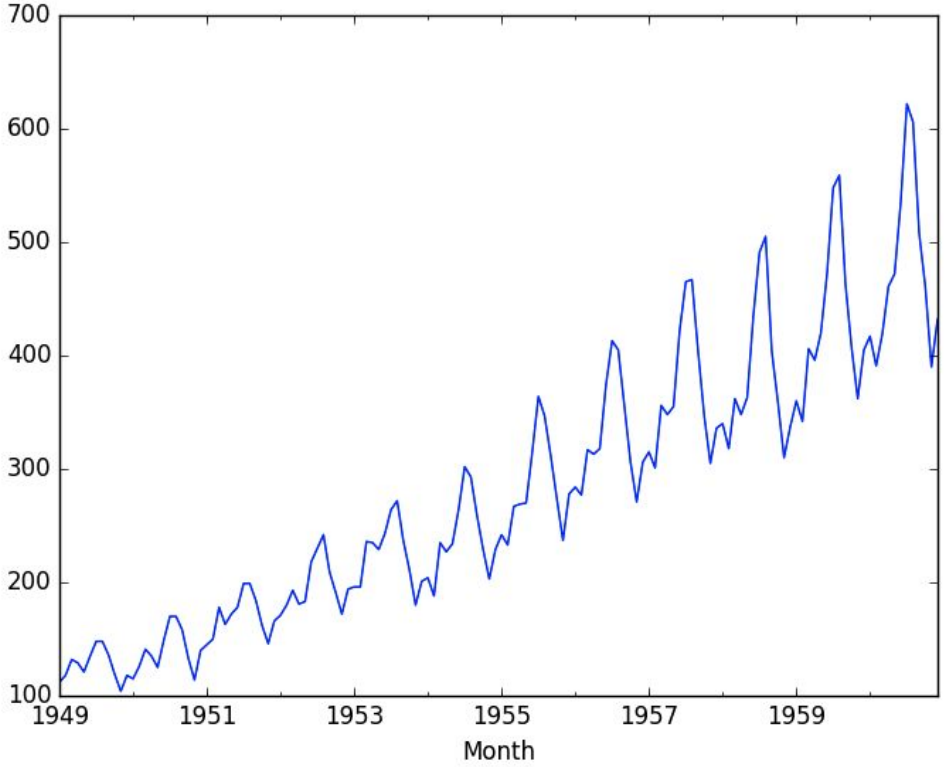
Log transformation

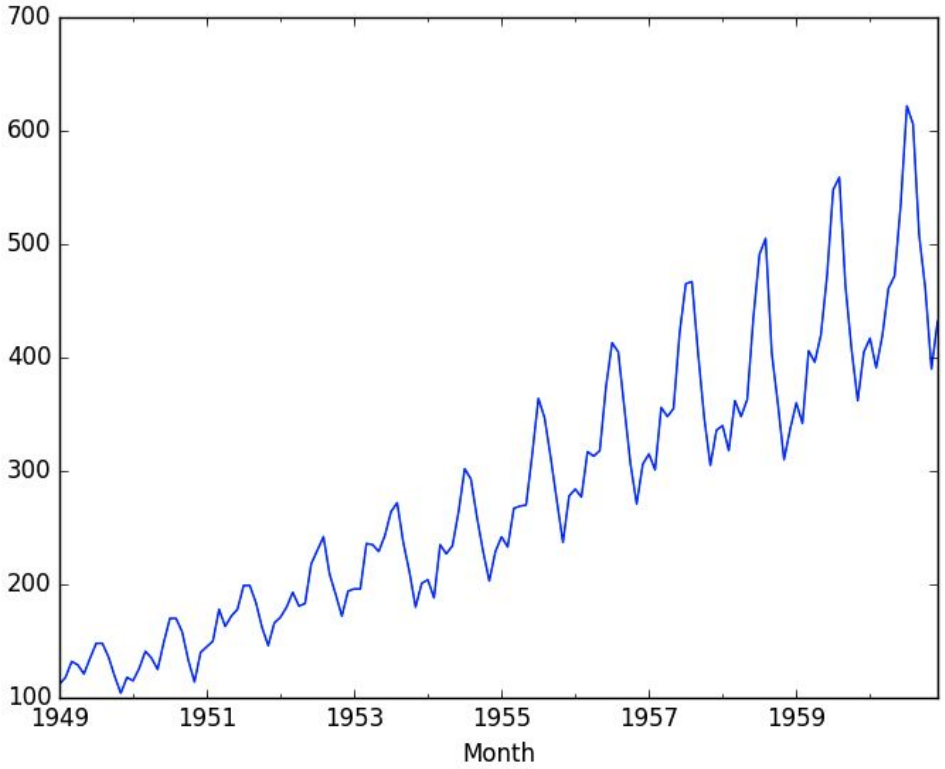
- When to use it:
  - Only positive values
  - Existing trend
  - Growing trend

- Results:
  - The time series will still have a trend but it will have a constant drift
  - If that's not the case you can repeat the process until it happens



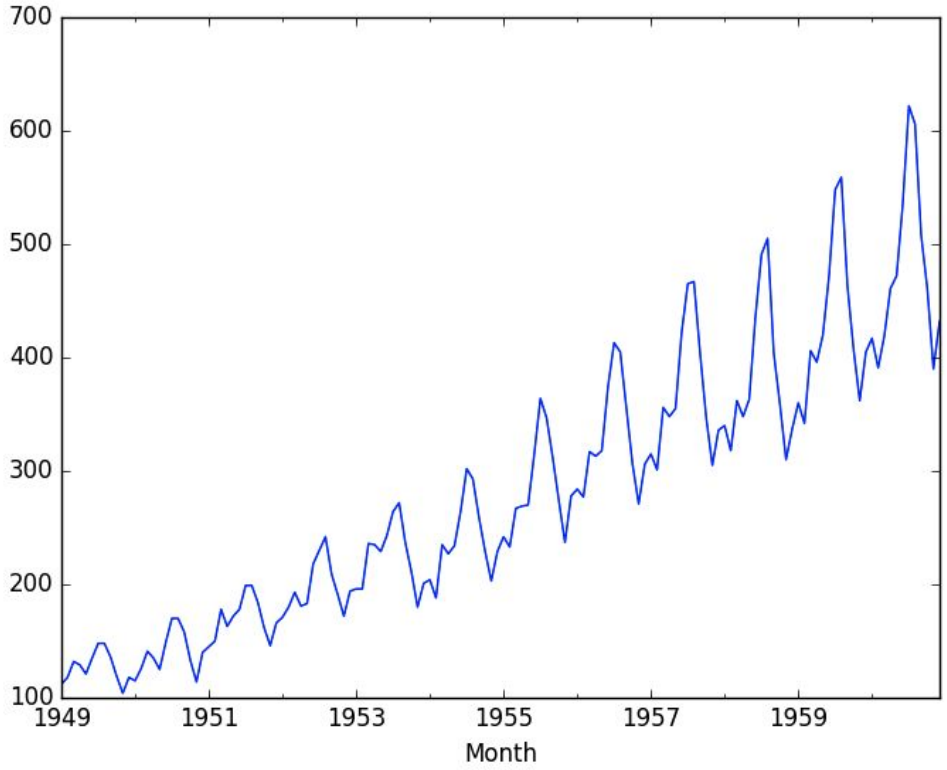
Differencing

- What is it:
  - $X_t - X_{t-n}$
- When to use it:
  - Existing trend
- Results:
  - The drift will become the average
  - If a trend still can be seen repeat the process until there is no trend



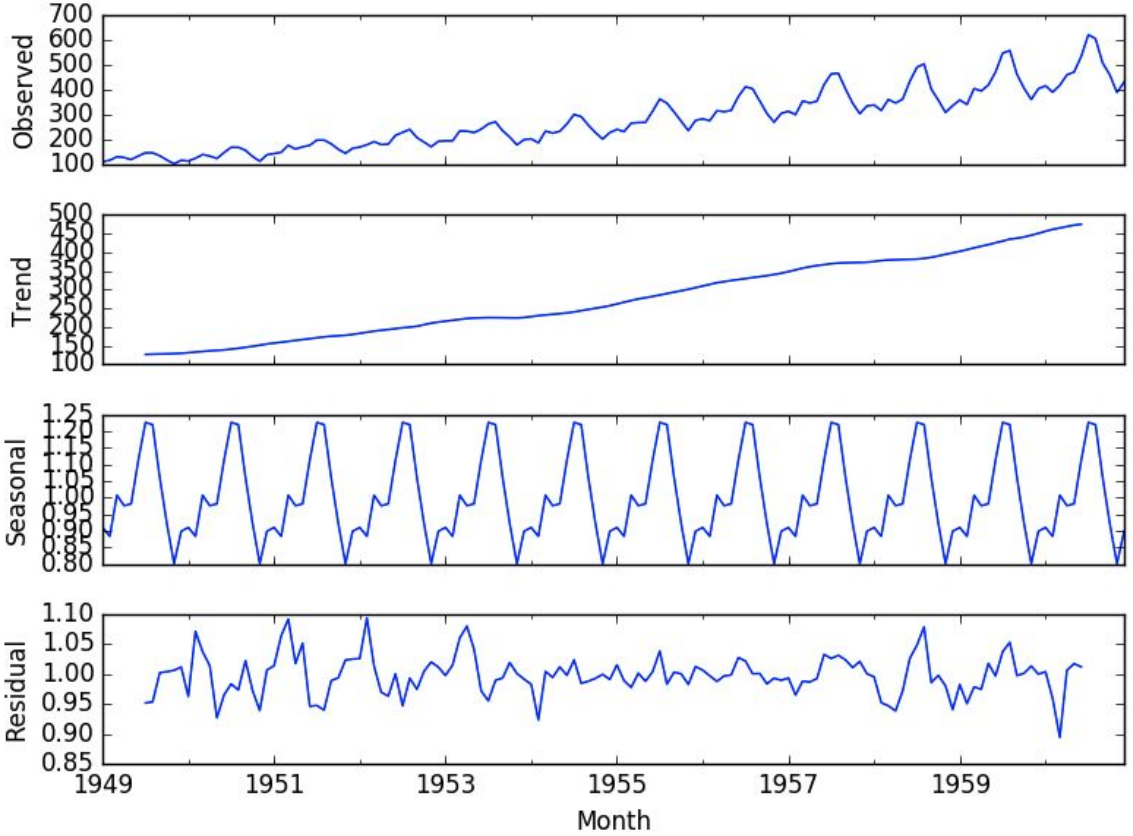
Seasonal Differencing

- What is it:
  - $X_t - X_{t-s}$
- When to use it:
  - You can see some periodicity/cyclicality in your data of period s
- Results:
  - The drift will become the average
  - If the seasonality still can be seen repeat the process until it goes away



Decomposing Time Series

- When to use it:
  - You can see trend and seasonality in your data
- Results:
  - It leaves data free of trend and seasonality
  - It still doesn't guarantee stationarity



Augmented DK Fuller Test

- When to use it:
  - You need to verify whether your time series is stationary

- Results:
  - No transformation
  - Just information

```
Augmented Dickey-Fuller Test Results:
ADF Test Statistic      -1.045848e+01
P-Value                  1.378722e-18
# Lags Used              0.000000e+00
# Observations Used      9.900000e+01
Critical Value (1%)     -3.498198e+00
Critical Value (5%)     -2.891208e+00
Critical Value (10%)    -2.582596e+00
dtype: float64
Is the time series stationary? True
```

Stationarity Recap

Task: Take turns with a neighbor, answering the questions below:

- How do you define stationarity?
- What methods can you use to enforce it?
- When do you apply each?
- How do you make sure your data is in fact stationary?

5 minutes

We will then come back to the large group and I'll pick some of you to share your answers with the rest of the class.

Modelling Time Series

- Autocorrelations and partial autocorrelations
- Interpreting correlograms
- AR and MA models
- Robust models

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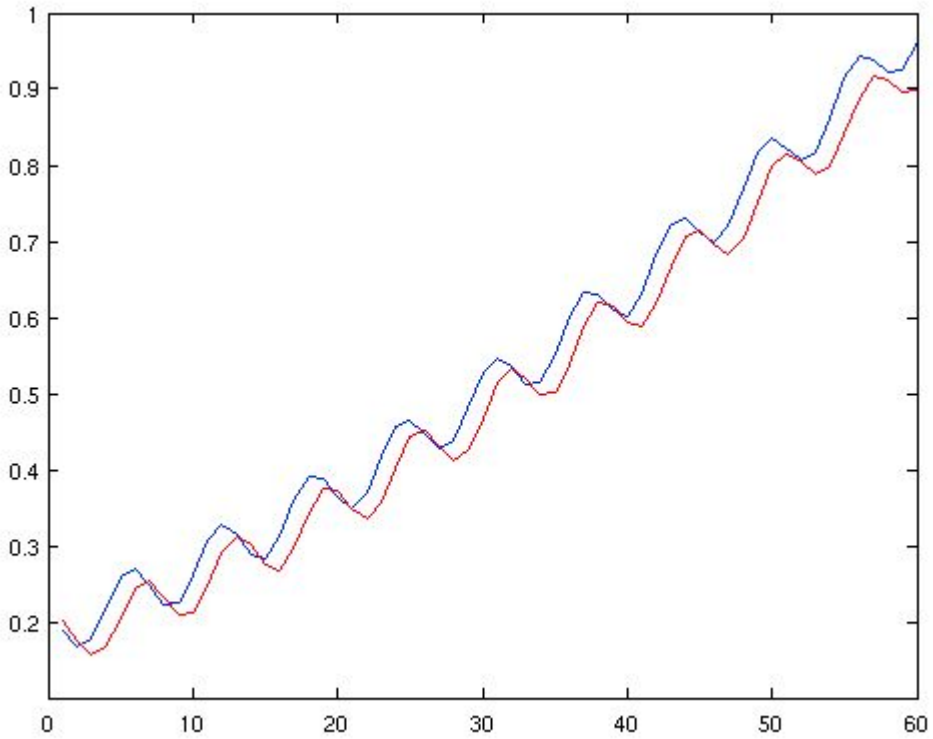
Autocorrelation (ACF)



- If you create a copy (red) of your time series (blue) and move it forward in time: Would you be able to predict when the original one was going to go up /down?
- You can calculate the correlation of any period passed with the current one

Partial Autocorrelation (PACF)

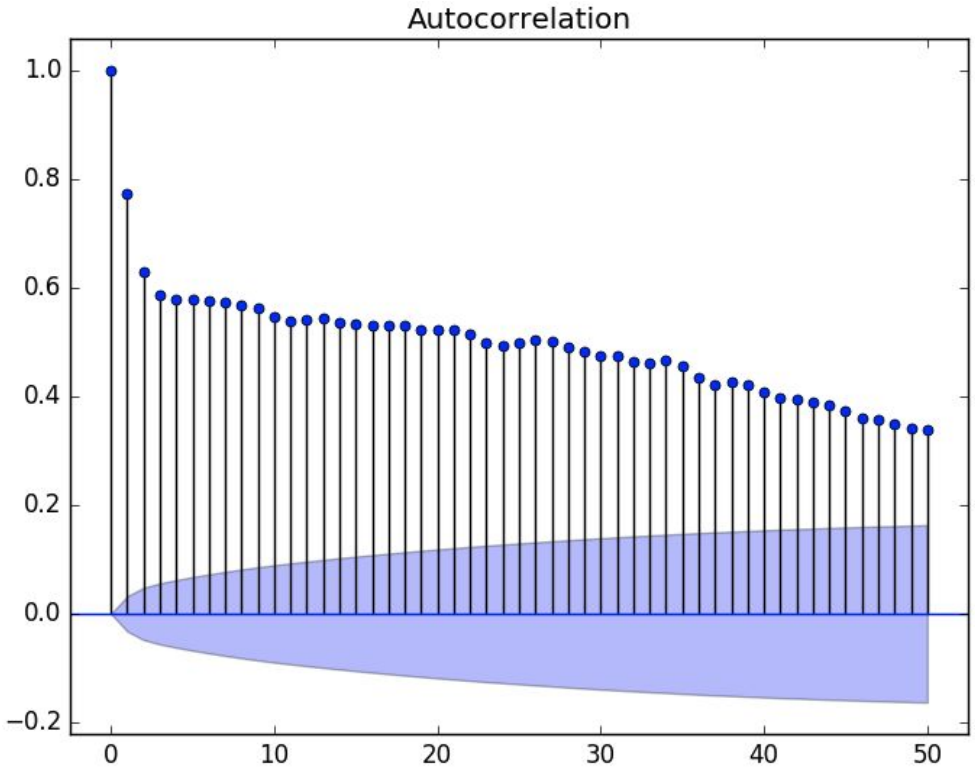
- You want to calculate the partial autocorrelation of X_t and X_{t-3}
- The intermediate periods are: X_{t-1} and X_{t-2}

- We run OLS to predict X_t using the intermediate periods as predictors
- We do the same but trying to predict X_{t-3} this time

- We take the residuals (error) from each

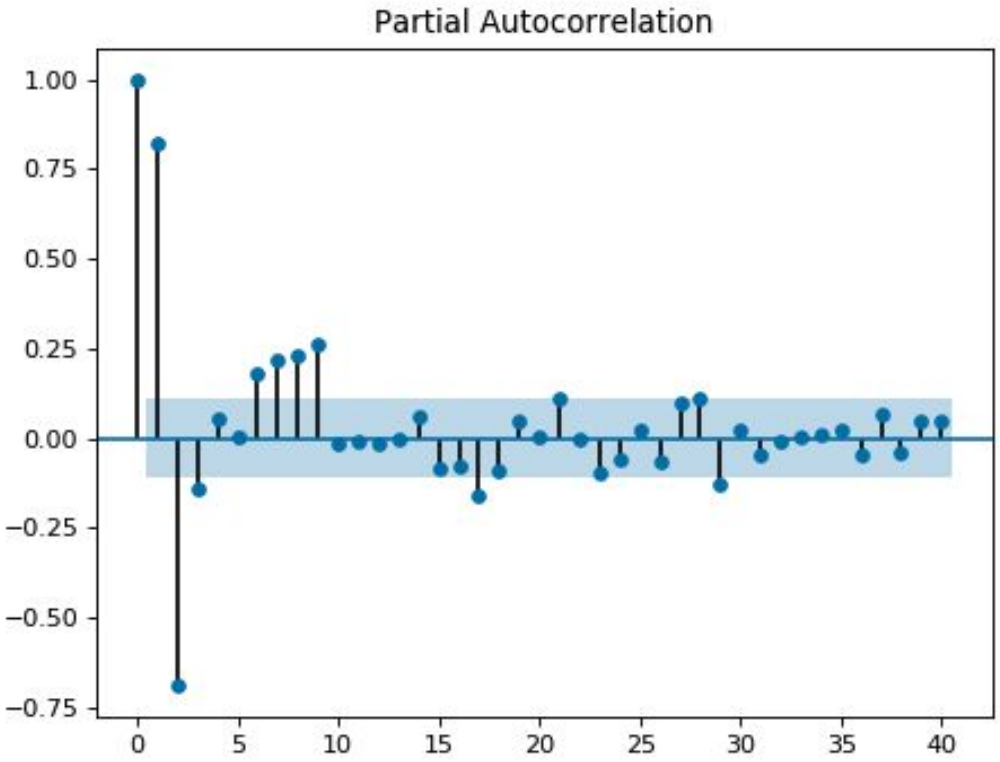
- We calculate the correlation between them

Autocorrelation plot



- Correlation of each lag with the original data
- Is typical to observed correlations tailing off but seasonality can affect this pattern
- Anything above the shadowed area is considered to be real correlation

Partial Autocorrelation plot



- Only the direct effects are shown
- Inversions can happen where there was a drop in correlation in the total autocorrelation
- Anything above the shadowed area is considered to be real correlation

Autoregressive models AR(p)

- Trying to predict current value based on a linear combination of previous terms

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-i} + \varepsilon_t$$

Moving Average models MA(q)

- Trying to predict current value based on the average of the time series and the linear combination of the error made in previous terms

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

ARMA(p,q) models

- Combines the previous two to generate a prediction

$$X_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}.$$

Robust models

- ARIMA(p,d,q) is able to do ARMA with models that have a trend
  - d will be 1 if the drift is constant or 2 if exponential (similar to the number of necessary differentiations

- SARIMA S(P,D,Q)x(p,d,q) is also able to work with seasonality
  - S is the period of the seasonality pattern

- SARIMAX allows you use eXogenous variables to help your prediction
  - Just like adding an OLS term (or more) to your time series model

$$X_t = \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \sum_{i=1}^{b} \eta_i d_{t-i}$$

Forecasting

- One-ahead forecasting
  - It predicts one period in the future always departing from your known data

- Multi-step-ahead forecasting
  - Predicts a long period in the future departing from the previous prediction

Forecasting

- Forecasting models performance decreases as you go into the future
- Always use error bands when giving forecasts to your stakeholders

- Update your models frequently so that your stakeholders have the best forecasts available to them
- Definitely update your model if you know that something unexpected happened in the reality that you are trying to predict and could impact your forecast

- Leave the latest periods of your time series out of your modelling so that you can use it for validation purposes

Forecasting models Recap

Task: Take turns with a neighbor, answering the questions below:

- What is autocorrelation?
- How do you calculate partial autocorrelation?
- What characterises each of the forecasting models we have covered?
- How do you validate a forecasting model?

5 minutes

We will then come back to the large group and I'll pick some of you to share your answers with the rest of the class.

Delivering Value

Your job is not to create high performance models

They pay you to **solve problems**

Summary + Exit Ticket

Presented by Dan Sanz

FLATIRON SCHOOL