



Master of Cognitive Science

Data Science Course

Time-Series analysis

Professor: Moran Steven

Lecturer: Maiolini Marco

Lecture 6: 6/April/2022

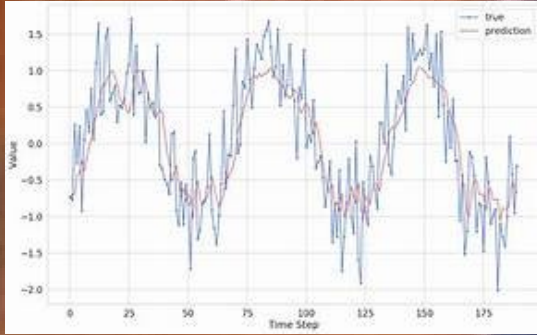
Outline

- Part 1: Book report & discussion (15 minutes)
- Part 2: Understand Time-series analysis (45 minutes)

Break (15 minutes)

- Part 3: Practical
- Part 4: Start the report

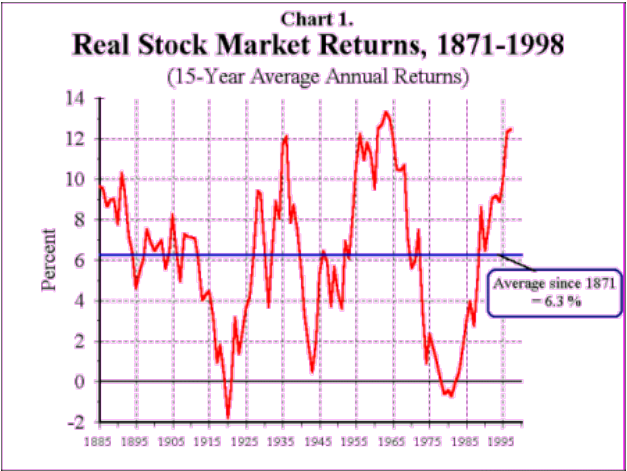
What is a Time-Series ?



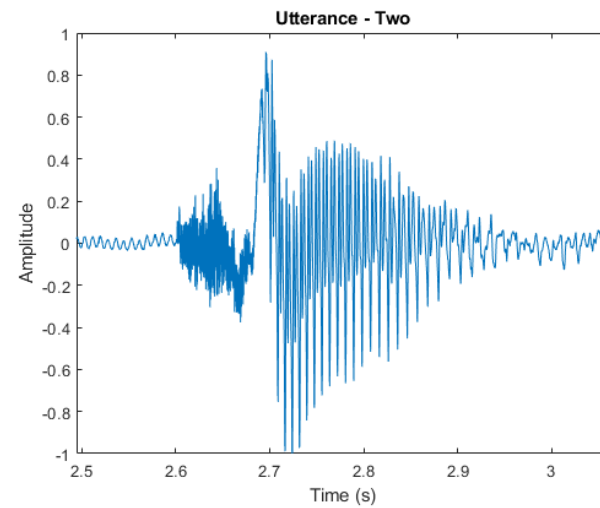
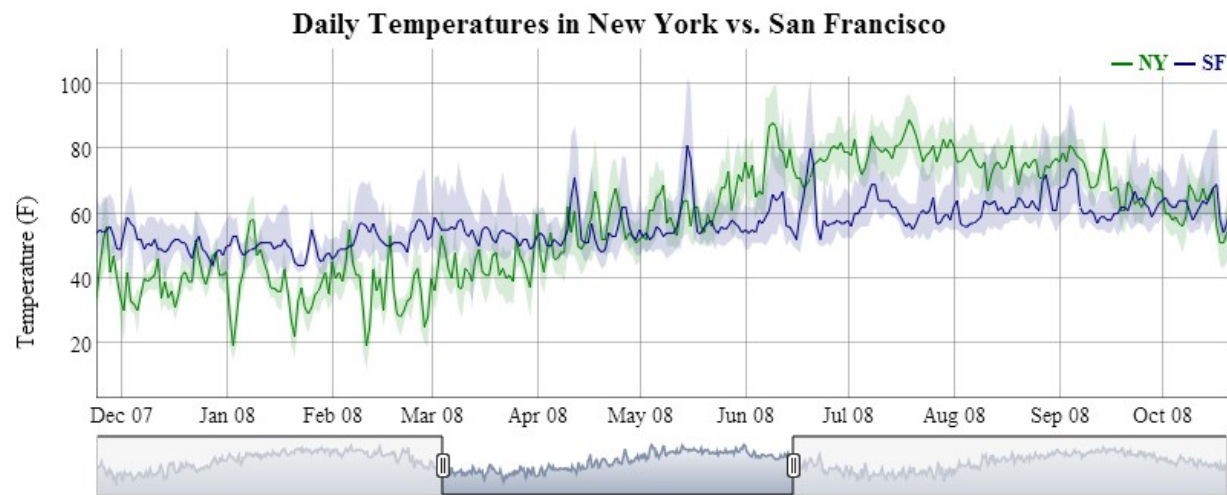
Time-Series

“Collection of observation made sequentially through time”

Economic & Finance



Physic

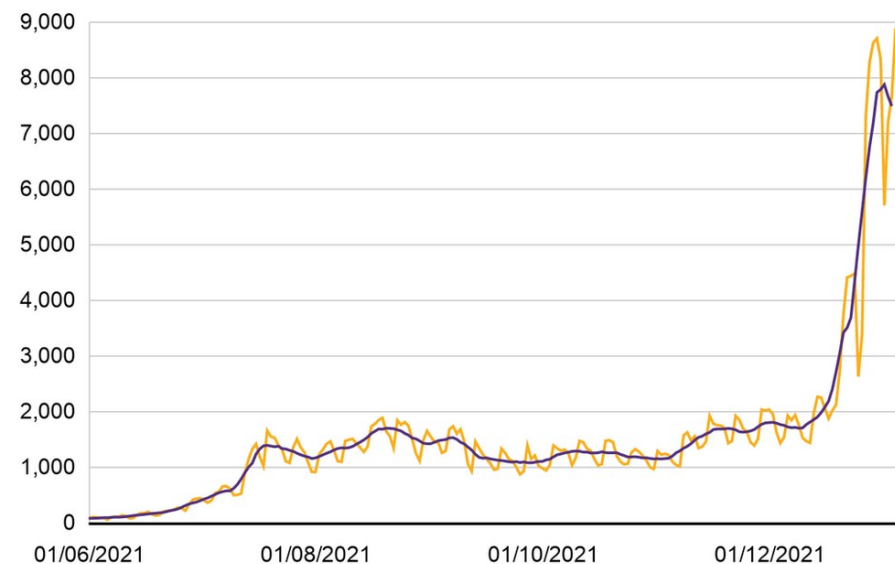


Biological

Coronavirus in Northern Ireland

Reported new daily confirmed cases

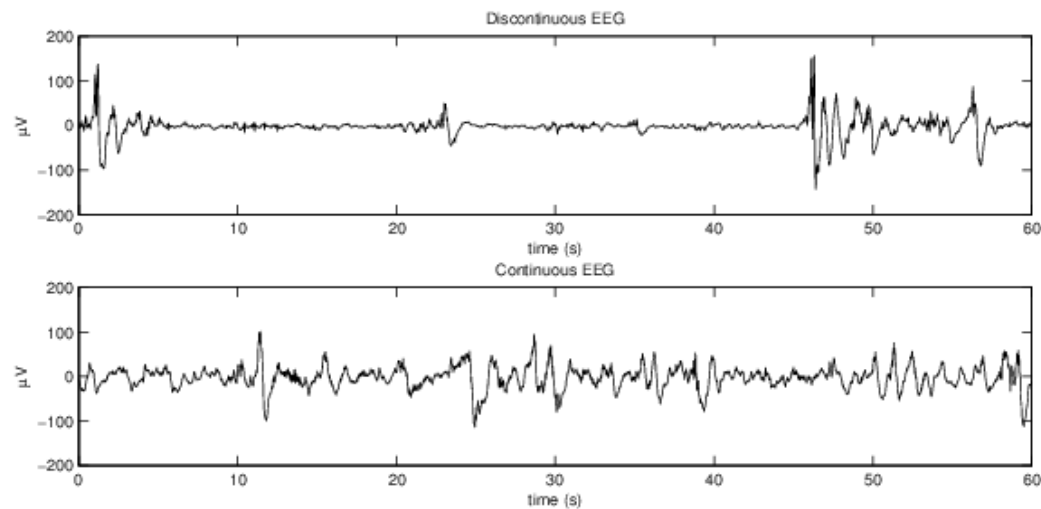
— Positive cases — Seven day average



Data from 1 June 2021

Source: Department of Health as of 7 January 2022

BBC



Types of time-series

- *Discrete*: Data taken only in specific fixed time
- *Continuous*: Data taken continuously through time
- *Deterministic*: Predicted exactly by previous values
- *Stochastic*: Only partially predicted by past values

What are we use to?

Describe

Explain

Predict

Control

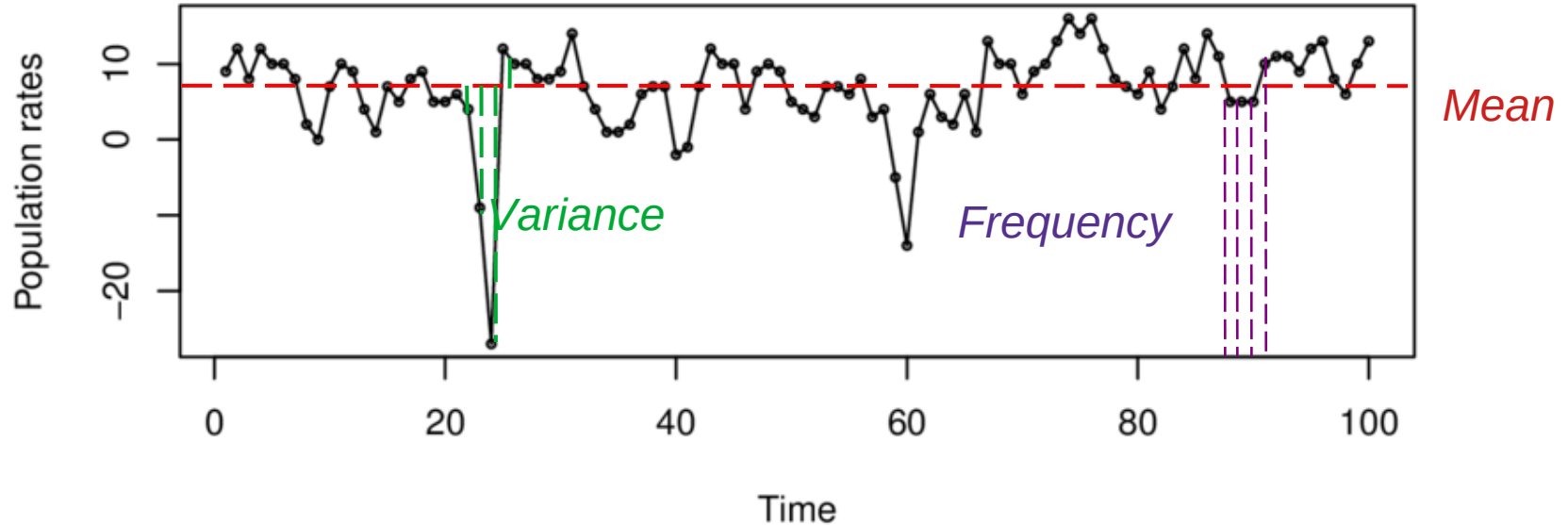


Describe a time-series

- *Mean*: The central value of a finite set of numbers
- *Frequency*: Sampling frequency
- *Variance*: Expectation of the squared deviation of a random variable from its mean
- *Autocorrelation*: Correlation among neighbouring observations

Describe a time-series

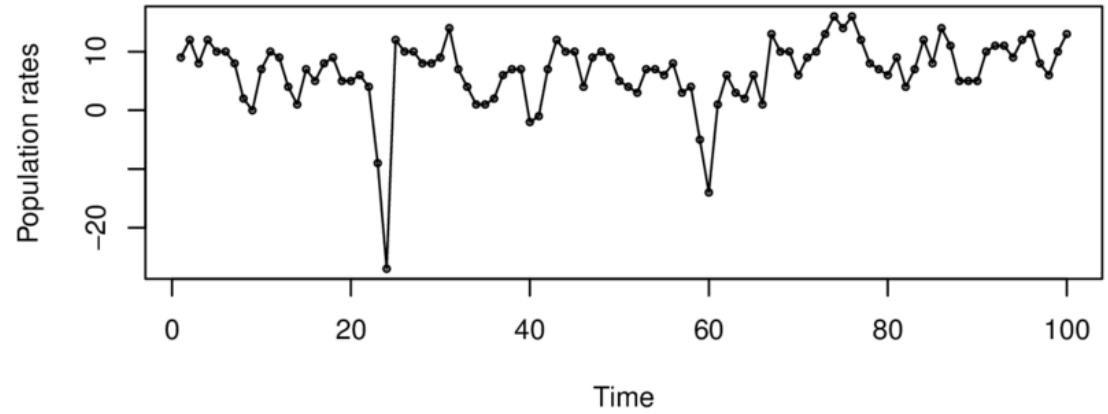
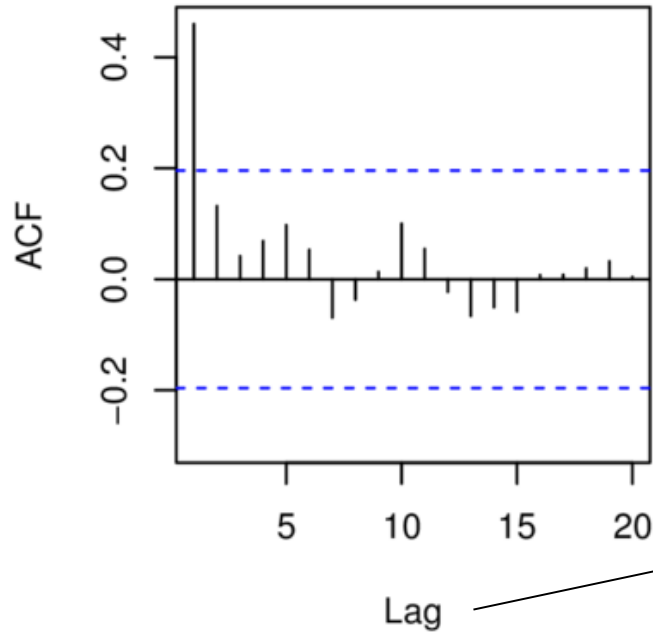
Population growth rate:



How to plot a time-series in R: `plot.ts(x, xlab, ylab, main)`

Describe a time-series

Autocorrelation plot



Lag: Delay of the observation is taken

How to do an autocorrelation plot for a specific time-series in R: `acf(x, main)`

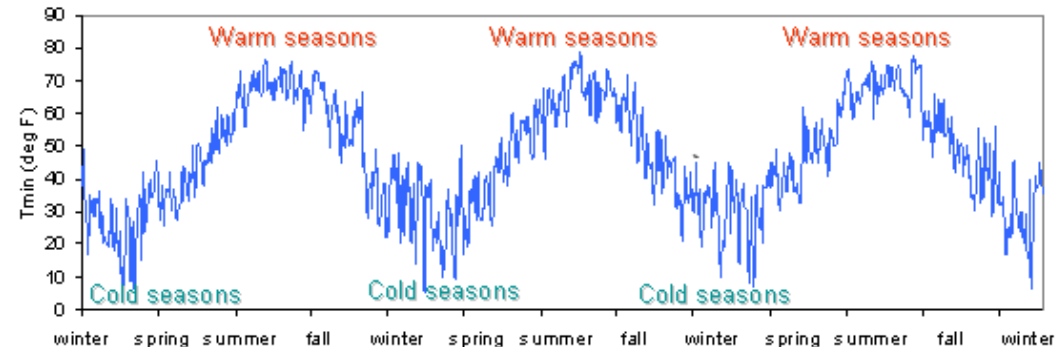
Describe a time-series

Trend: General development of a feature over time

Relation between your data and time



Linear trends



Periodic trends

In R you can remove the linear trend with: `diff()`

Models of time-series

- White Noise model (WN)
- Random walk model (RW)
- Simple moving average model (MA)
- Autoregressive model (AR)

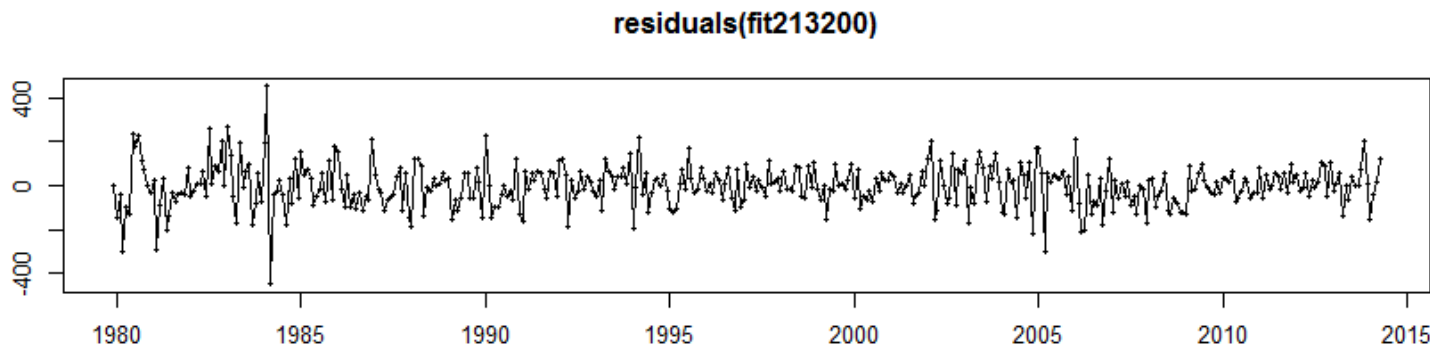
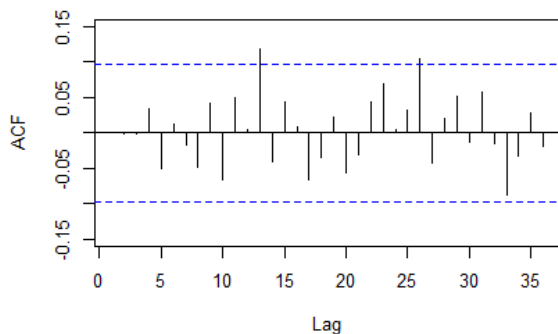
White Noise model (WN)

The simplest model of time-series

- A fixed, constant mean
- A fixed, constant variance
- No correlation over time

In R you can fit your data in a WN model using this code:

```
arima(x, order=c(0,0,0))
```



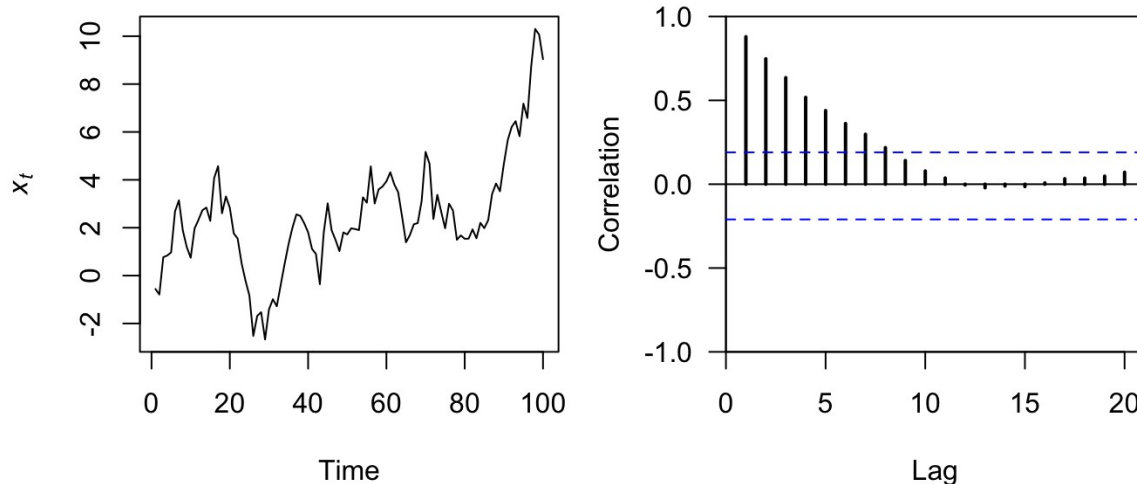
Random walk model (RW)

Defined as: $\text{Today} = \text{Yesterday} + \text{Noise}$ \longrightarrow $\text{Today} - \text{Yesterday} = \text{Noise}$

White noise

- No specific mean
- No specific variance
- Strong dependence over time

$\text{diff(RW)} \rightarrow \text{WN model}$



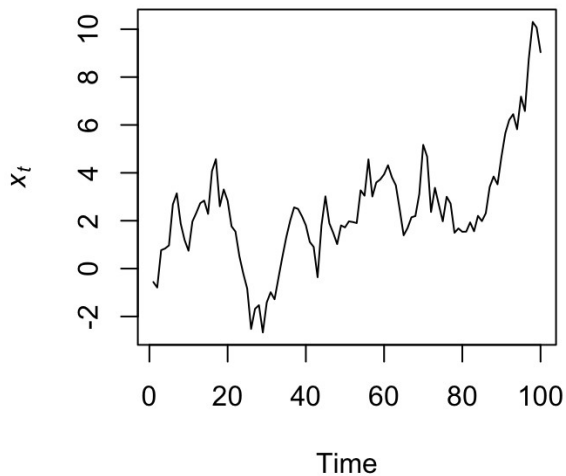
In R you can fit your data in a RW model using this code:

```
arima(x, order=c(0,1,0))
```

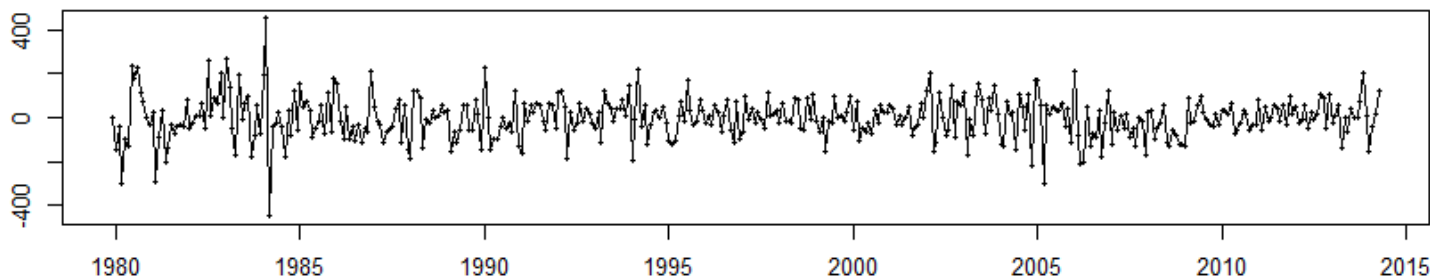

Stationarity

Parsimonious models with distributional stability over time

Random walk model



White Noise model



Stationary models can be modelled with fewer values, however few time series are stationary

Autoregressive models (AR)

Linear trend where each observation is regressed on the previous observation

Slope = 1 & Mean = 0

Today = Yesterday + Noise

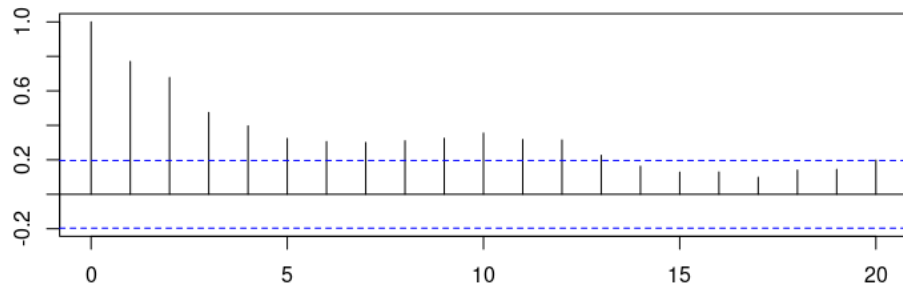
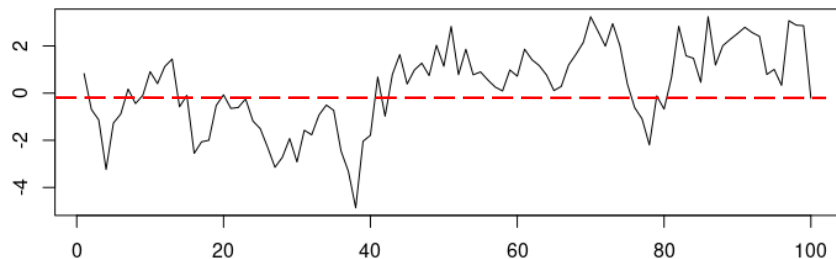
$$(\text{Today} - \text{Mean}) = \text{Slope} * (\text{Yesterday} - \text{Mean}) + \text{Noise}$$

Slope = 0

(Today - Mean) = Noise

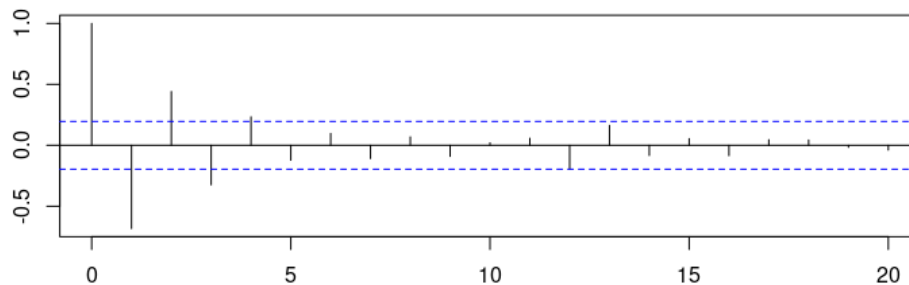
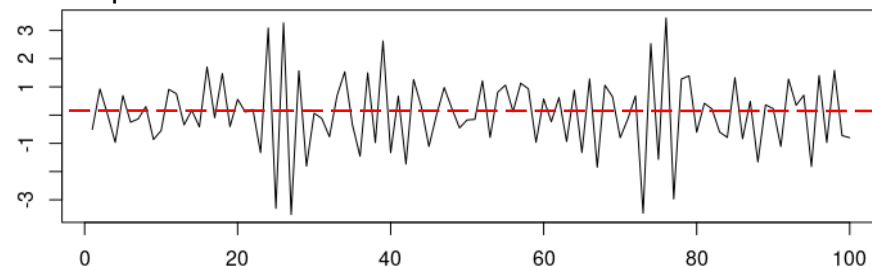
Slope = 0.7

AR model



Slope = -0.7

AR model

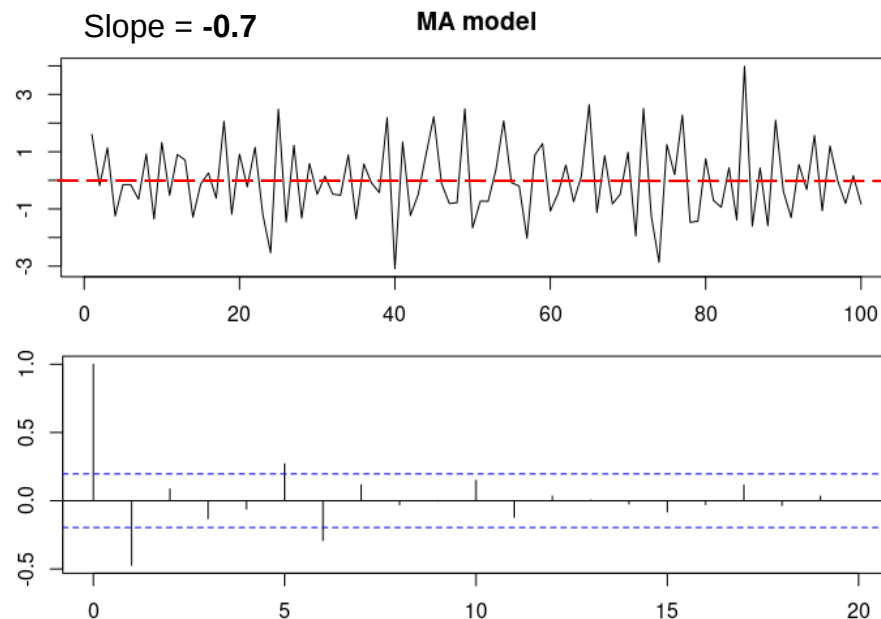
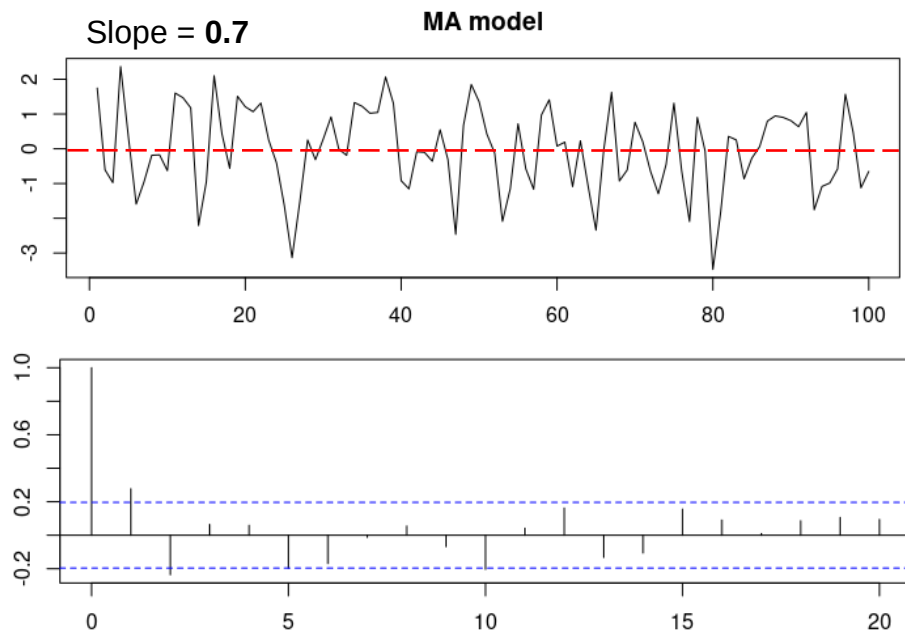


Simple Moving Average models (MA)

Linear trend where each observation is regressed on the previous innovation, which is not actually observed

Slope = 0 — Today = Mean + Noise

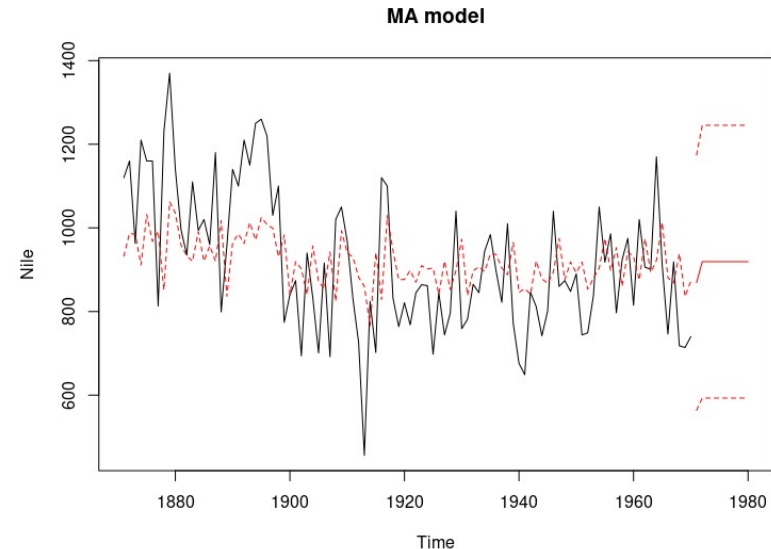
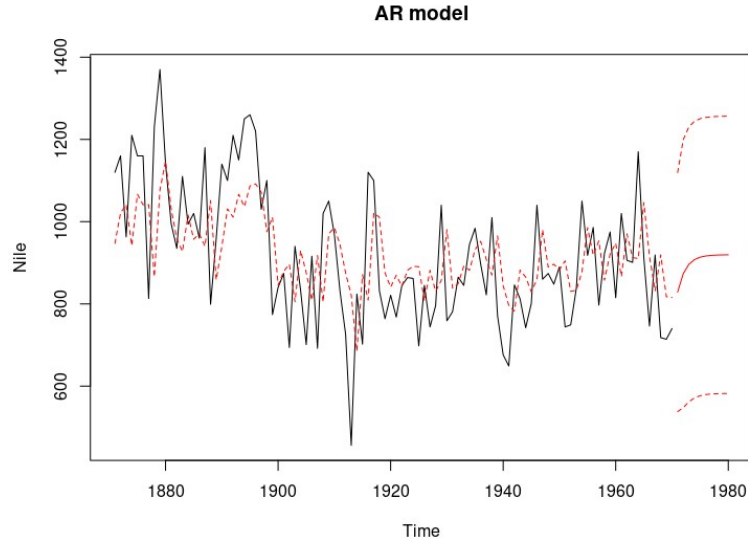
Today = Mean + Noise + Slope * (Yesterday's Noise)



Forecast

We can use the Autoregressive models (AR) and the Simple Moving Average models (MA) models to fit our data and try to forecast our time-series

- *Fitted values*: Forecast (estimation) of an observation using all previous ones
- *Residuals*: Difference between the observation and the corresponding fitted values



Forecast in R

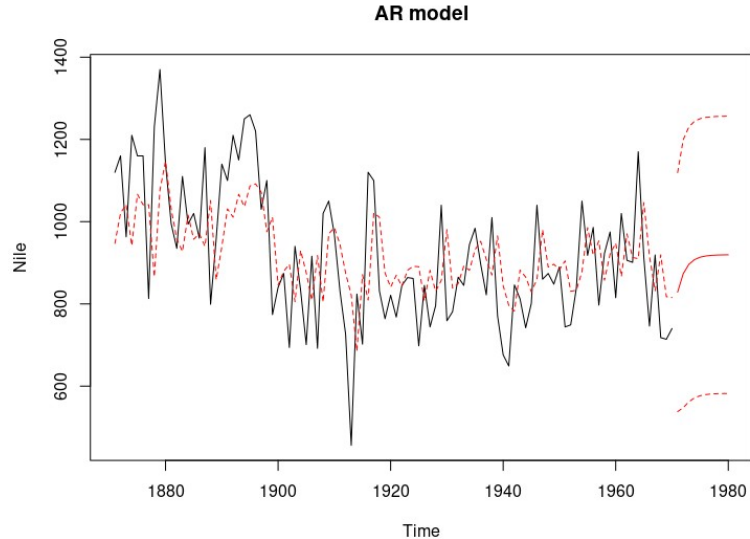
To fit our time-series on AR model:

```
AR model ← arima(x, order=c(1,0,0))
```

```
Fitted values ← x - residuals(x)
```

```
Forecast ← predict(x)$pred
```

```
Forecast SD ← predict(x)$sd
```



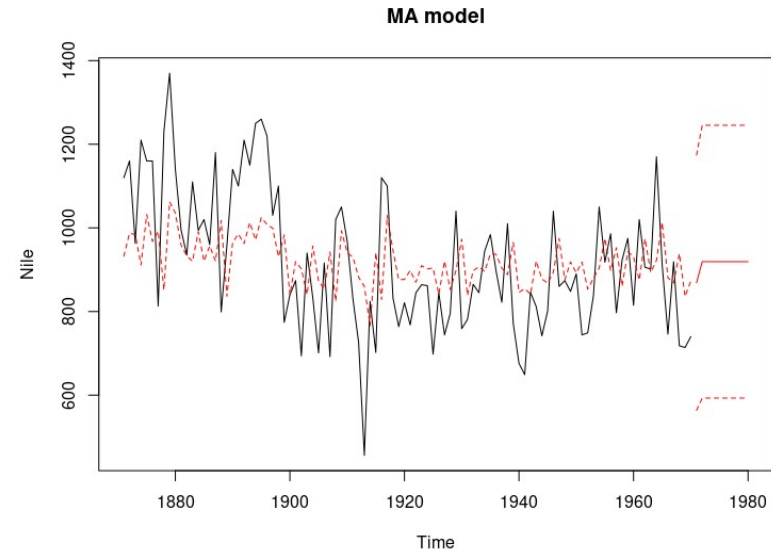
To fit our time-series on MA model:

```
MA model ← arima(x, order=c(0,0,1))
```

```
Fitted values ← x - residuals(x)
```

```
Forecast ← predict(x)$pred
```

```
Forecast SD ← predict(x)$sd
```



Compare different models

When comparing different models we want to find out which model explain better my data regardless the **Individual independent variables** in the model.



It doesn't mean that there is a right and a wrong model!

Akaike's information criteria (AIC):

AIC estimates model complexity. It works estimating the expected performance of model's predictions, for that scope it use observed data and hypothetical sample generated by the same model.

The best model show the smallest value; a difference within **4 - 7** units indicate less support, a difference over **10** indicate that the worse model can be omitted

Limits of time-series

- Limited to previous observations
- Seriously affected by NAs values
- When forecasting doesn't take into account variables

