

# A Complex Systems Approach to Study Human Nature

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## Chapter 1

# An introduction to the analytical toolbox of Complexity Science

This workshop will provide an introduction to some of the formal models, research methods and analytical techniques that allow for the study of human behaviour from a complex systems perspective. Complexity research transcends the boundaries between the classical scientific disciplines and is a hot topic in physics, mathematics, biology, economy and psychology. Its focus is a description and explanation of behaviour based on interaction dominant dynamics: Many processes interact on different temporal and spatial scales and behaviour emerges out of those interactions through physical processes such as self-organization or soft-assembly.

Contrary to what the name might suggest, complexity research is often about finding simple models or collective variables with which a wide range of different behavioural modes can be described. This approach differs fundamentally from the more classical approaches in which behaviour is considered the additive result of many independent, component processes (component dominant dynamics) and the goal of research is to identify efficient causes of behaviour.

The main focus of the workshop will be hands-on experience with data-analysis using the R statistical computing environment. No special background knowledge is required to participate.

## 1.1 Tentative program

**I. Introduction to the mathematics of change** \* Modelling (nonlinear) growth and Deterministic Chaos \* Predator-Prey dynamics \* Basic timeseries analysis

**II. Quantifying Recurrences in State Space** \* Takens' Theorem and State-Space reconstruction \* Recurrence Quantification Analysis of continuous and categorical data \* Cross-Recurrence Quantification Analysis of dyadic interaction

**III. Fractal Scaling, Network Topology and Early Warning Signals** \* Scaling phenomena in time and trial series of human behaviour and physiology \* Small-world and Scale-free networks \* Early Warning Signals in clinical interventions

## 1.2 Using R!

I recommend installing the latest version of **R** and **RStudio**. Rstudio is not strictly necessary, but especially new users will have a somewhat more comfortable experience. If you are completely new to R you might want to check these notes

### Packages needed for the assignments

You'll need to install the following packages, just copy and paste the command in R. Depending on your computer and internet connection, this might take a while to complete. If you run into any errors, skip the package and try the others, e.g. by adding them through the user interface of **RStudio** (Tools >> Install Packages...).

```
install.packages(c("devtools", "rio", "plyr", "tidyverse", "Matrix", "ggplot2", "lattice", "latticeExtra"))
```

NOTE: Sometimes R will ask whether you want to install a newer version of a package which still has to be built from the source code. I would suggest to select NO, because this will take more time and might cause problems.

### Files on GitHub

All the files (data, scripts and files that generated this document) are in a repository on Github. Github keeps track of all the different versions of the files in a repository.

- If you want to download a file that is basically a text file (e.g. an R script), find a button on the page named `raw`, press it and copy the text in your browser, or save it as a text file.
- For non-text files, a download button will be present somewhere on the page.

First, download from Github and type `source('nlRtsa_SOURCE.R')`, or, source it directly from Github if you have package `devtools` installed.

```
library(devtools)
source_url("https://raw.githubusercontent.com/FredHasselmann/DCS/master/functionLib/nlRtsa_SOURCE.R")
```

### Plotting Timeseries

There are many different ways to plot data in R, I summarised some of them in the notes

### This document

This text was transformed to HTML, PDF or ePUB using `bookdown(?)` in **RStudio**, the graphical user interface of the statistical language **R** (?). `bookdown` makes use of the R version of markdown called `Rmarkdown` (?), together with `knitr` (?) and `pandoc`.

We'll use some web applications made in `Shiny` (?)

Other R packages used are: `DT` (?), `htmlTable` (?), `plyr` (?), `dplyr` (?), `tidyr` (?), `png` (?), `rio` (?).





## **Part I**

# **Assignments**



# How to ...

These assignments were designed to prepare you for “real world” modelling and data analysis problems. That is, after completing the assignments you should be able to decide whether the phenomenon you study could benefit from a complex systems approach and which type of analyses would be a good place to start. The models and techniques discussed here are **not** a definite collection of available techniques, this is really just the tip of the iceberg.

## General Guidelines

- Read the instructions carefully.
- Do not skip any of the steps.
- Do not copy-paste from the assignment text into a spreadsheet or syntax editor (except for text in code blocks).
- Study the solutions and lecture notes.



## **Part II**

# **Introduction to the mathematics of change**



## Chapter 2

# Modelling (nonlinear) growth

In this assignment you will build two (relatively) simple one-dimensional maps in R, based on an example in a spreadsheet. Go to the following GoogleSheet and save a copy on your computer, you can use your favourite spreadsheet software (e.g., Excel, Numbers), or, copy it to a new GoogleSheet if you prefer Google.

We will start with the *Linear Map* and then proceed to the slightly more complicated *Logistic Map* (aka *Quadratic map*).



Be sure to check the solutions of the assignment and the examples of different ways to visualize the time series in R