Dynamic Modelling for Human-centered Systems

Lecture 1

Reader: chapter 1 and 2

Agenda for today

- What is a model?
- Why modelling?
- Designing models
- Growth model in Excel

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- **What is a model?**
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Model

- What is a model?
  - Describe the most important characteristics of model
  - With a neighbour, answer via menti.com: **61 71 84**

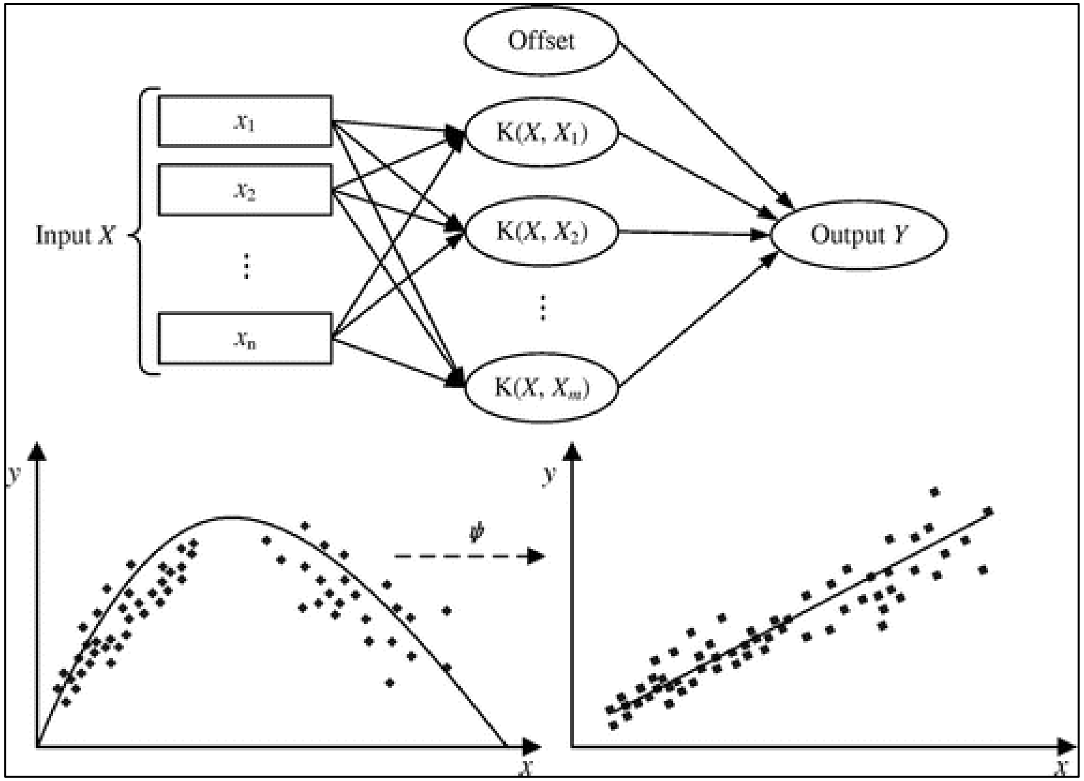
- Definitions:
  - *A representation of an object, system, or idea in some form other than that of the entity itself* **(R.F. Shannon)**
  - *A simplified representation of a system or phenomenon, as in the sciences, with any hypotheses required to describe the system or explain the phenomenon, often mathematically* **(Random House Unabridged Dictionary)**
  - *A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics* **(The American Heritage Dictionary)**

Example

- Planetarium:
  - Representation of *planets and their orbit*
  - Aim:
    - Show working of solar system
    - … and Eisinga: proof that the world will not disappear
  - Type
    - physical
    - *dynamic*

Another example

- Statistical / machine learning models
  - Representation of *correlation between input and output*
  - Aim:
    - predict output based on input
  - Type
    - numerical
    - *static*

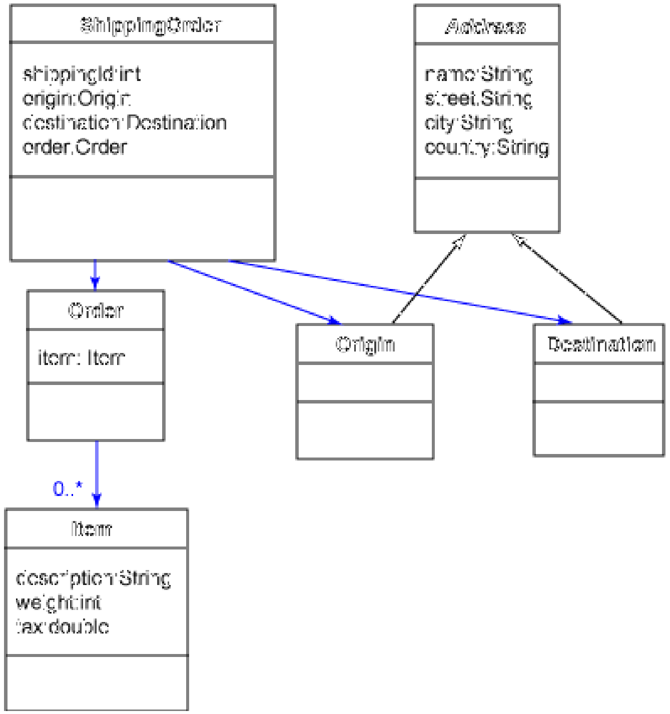


Yet another

- Marquette (scale model):
  - Representation of *spatial properties of between objects*
  - Aim:
    - study spatial aspects beforehand
  - Type
    - physical
    - *static*

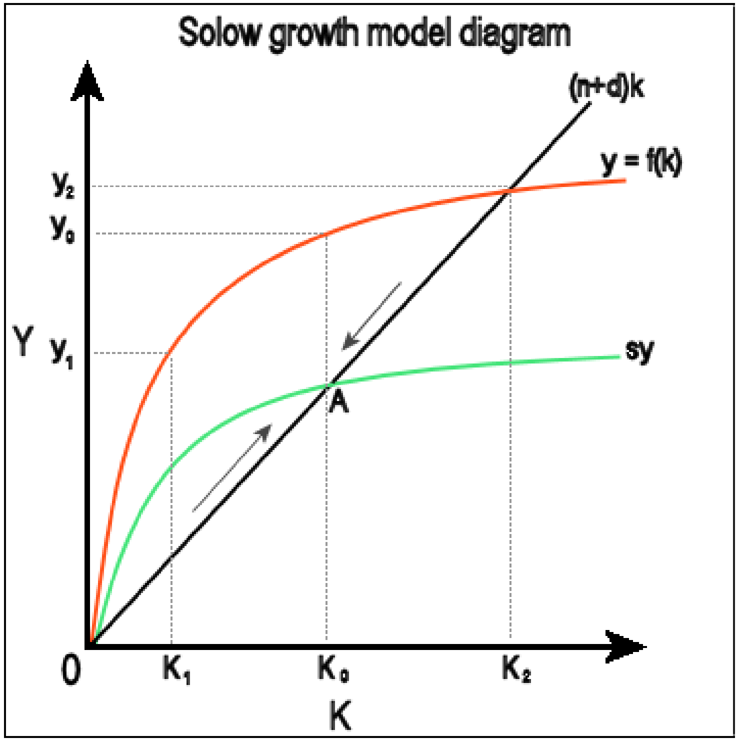
And again…

- Software model:
  - Representation of snippets of computer programs, their functions and relations
  - Aim:
    - verify program beforehand
    - simplify or automate programming
  - Type:
    - diagrams and semi-formal descriptions
    - static (or dynamic)



… another example

- Economic model:
  - Representation of economic processes
  - Aim:
    - predict aspects of economy
    - tool for determining economic policies
  - Type:
    - mathematical formuleas
    - dynamic



- Many other types exist…

Our focus in this course

- We restrict ourselves to **dynamic models**
  - what is the most important property? Via menti.com

- A **dynamic model**:
  - describes a specific phenomenon, theory or system (i.e. a process)
  - specifies **changes over time**
    - i.e. can simulate the process

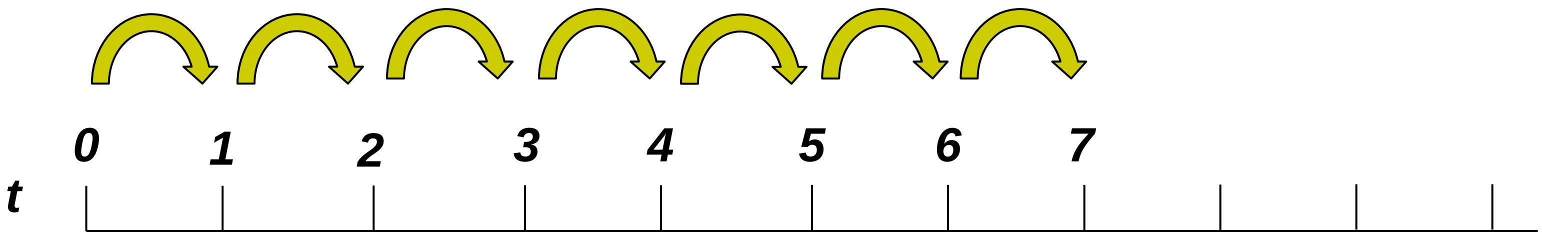
Risks of using models

- Which risks do you see risks in using models?

- Important observations
  - a model is a *simplification*
  - during the design of the models, *choices* have been made
    - assumptions
  - a model is not the same as reality!

What is a dynamic model?

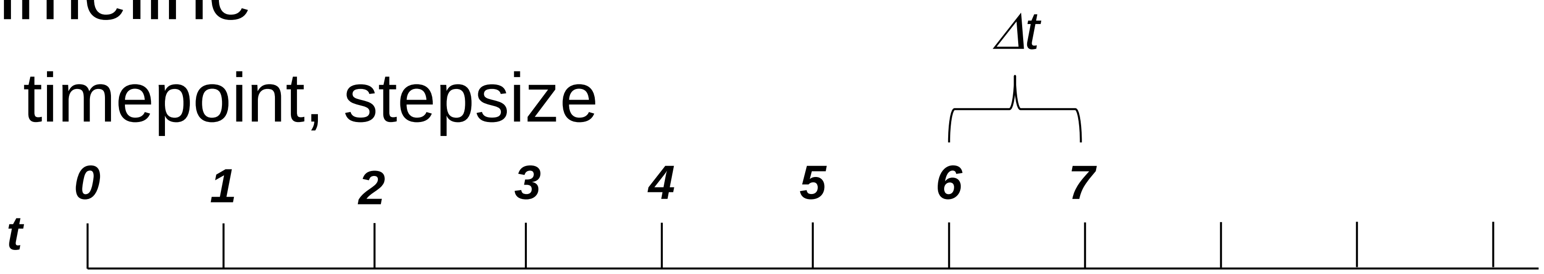
- Describes a **process** by defining how a next state is derived given the current state.



- At each point, only the current situation is considered, and the same rules are applied at every timepoint

Elements of a dynamic model

- Concepts
  - represented as variables
    - temperature of an egg: *TempEgg*
- Timeline
  - timepoint, stepsize



- Rules that describe how concepts change per time step
  - $TempEgg(\mathbf{t+\Delta t}) = \beta * TempWater(\mathbf{t}) + (1-\beta) * TempEgg(\mathbf{t})$

Additional elements

- Start values
  - *TempEgg(0) = 35*
- Optional parameters
  - $\beta = 0{,}33$
- Optional stochastic variables
  - random values

Model outcome

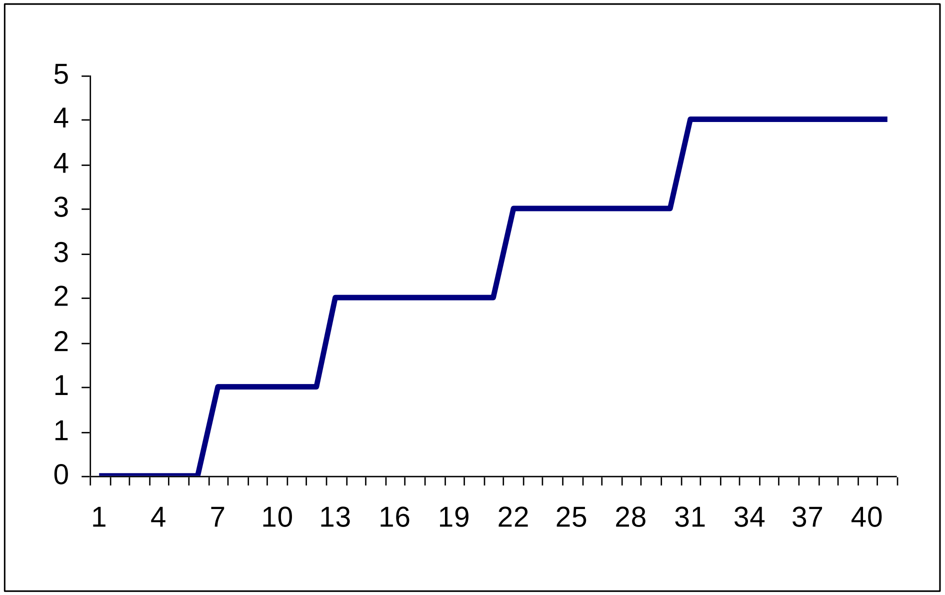
- How to describe the outcome of a *dynamic* model?

- List of states of a model at subsequent time points:
  - (simulation) trace
  - simulation run

- How can we show it?

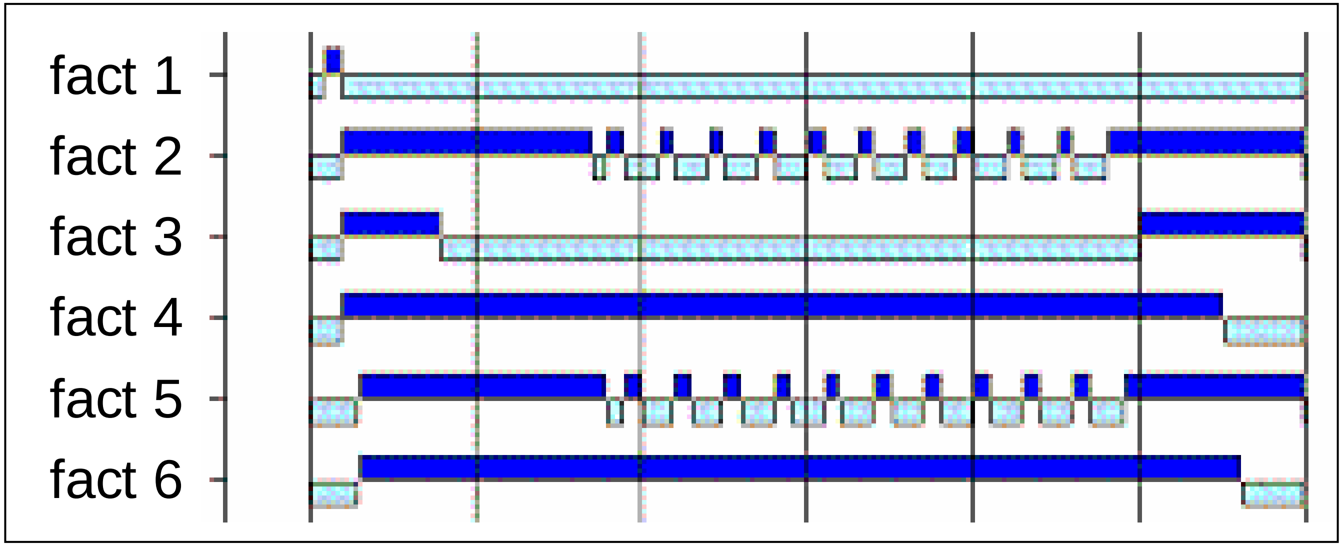
Visualisation of simulations

- Dependent on the representation of the model
  - graphical representation of values of model variables at subsequent time points



Visualisation - 2

- representation of truth values of model variables at subsequent time points (state trace)



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Why modelling?

- 1. Study a process to increase understanding:
  - study the behaviour of a process over time
  - performing “what if” simulations
- 2. Basis for intelligent systems
  - models are used to understand what is happening with humans (and what to do)
  - models can make systems behave human-like

Users of models

- People:
  - researchers
  - policy makers

- Systems:
  - adaptive systems
  - human-like systems
  - ⇒ *second half of the course*

Use of models for intelligent applications

- Ambient Intelligence:
  - Intelligent systems support humans in their daily environment
- Requirements:
  - Systems have *knowledge* about human functioning
  - This course: making dynamic models about human functioning and incorporate them in systems

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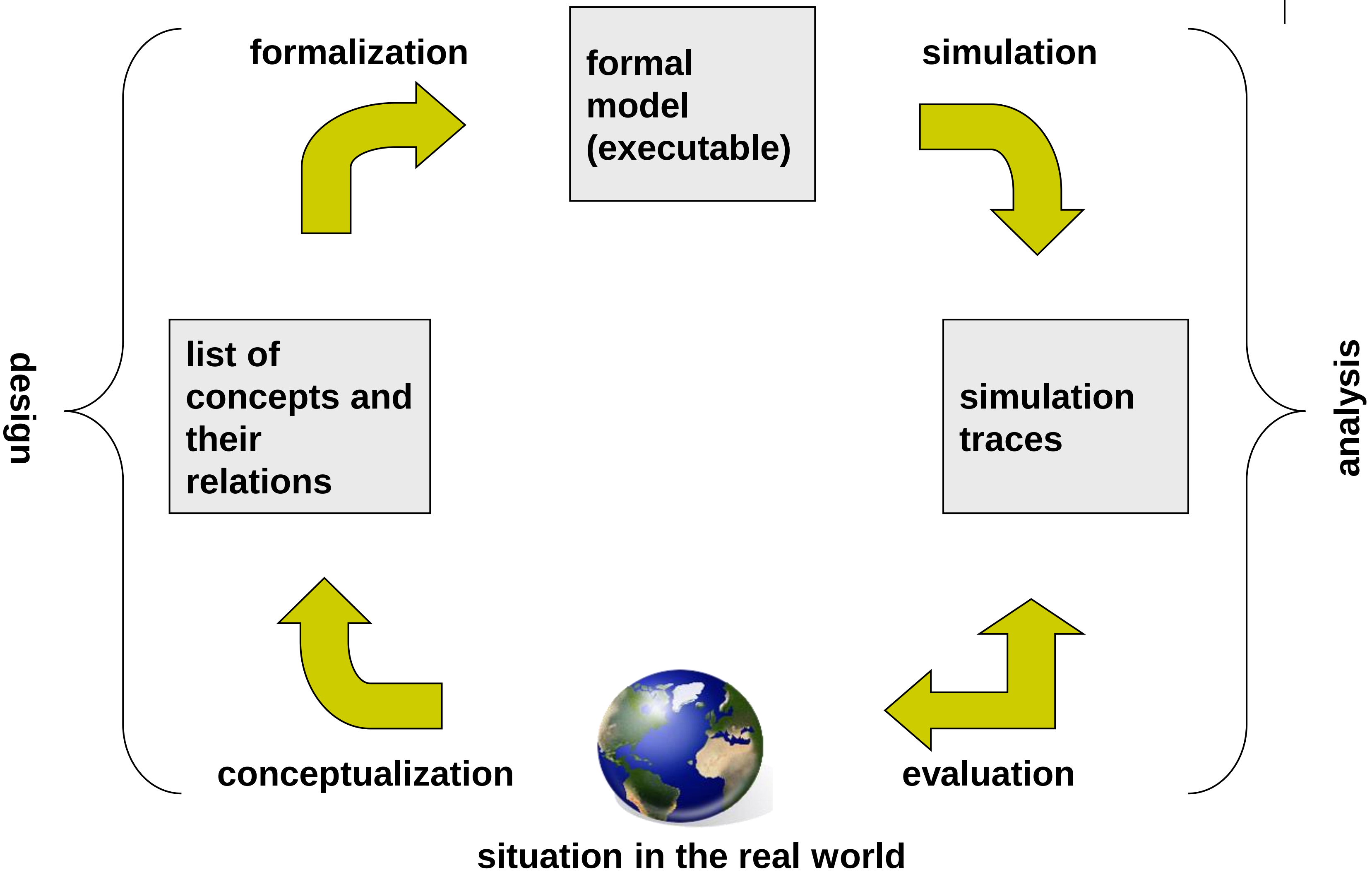
Designing models

- Quotes:
  - *"Make your theory as simple as possible, but no simpler."* (Albert Einstein)
  - *"For every complex question there is a simple and wrong solution."* (H.L. Mencken)
- Creative process!
  - requires choices and assumptions
  - not one correct solution
    - global / detailed; what to include / ignore
- Guideline provides structure to process

Modelling and Simulation Cycle



1. Conceptualisation

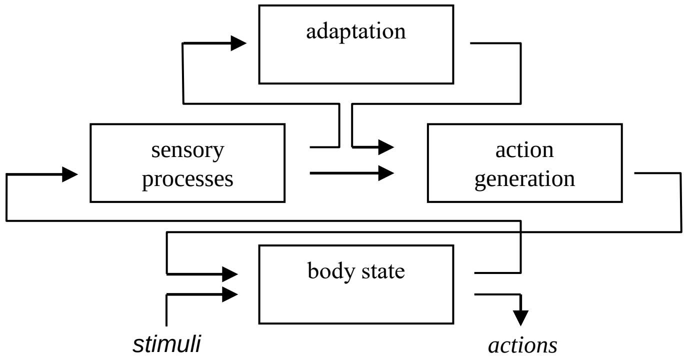
- Several steps
- Iterative process
  - outcome task can influence other choices

A. Characterizing the process
  - scope and boundaries
  - type of questions to answer with the model
  - expected behaviour (***characteristic patterns***)

Conceptualisation (2)

B. If necessary: describe sub processes

- identify sub processes
- determine order
- result: simple diagram with processes and arrows



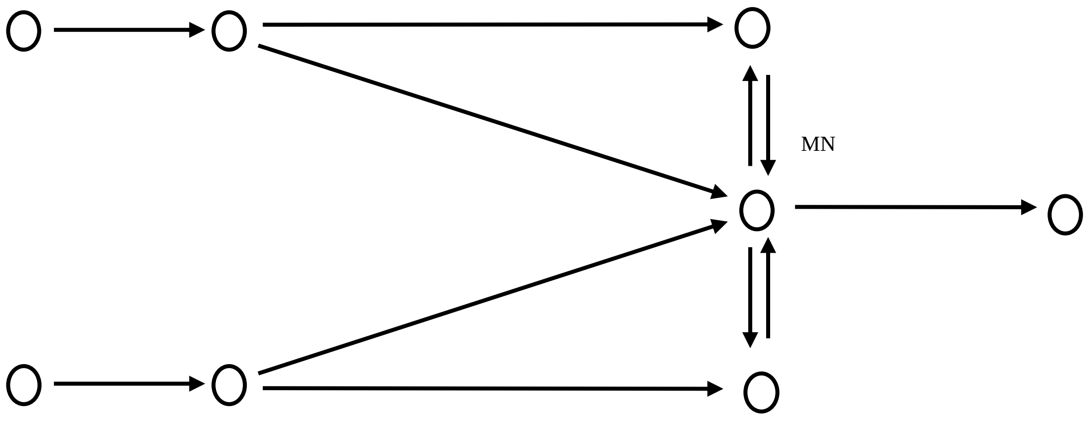
C. Identify important concepts

- which *factors* play a role in the process
  - objects, events, principles
- result: list of concepts

Conceptualisation (3)

D. Relations between concepts

- which concepts affect each other
  - whether, not how
- most relations occur within a sub process
- result:
  - list “A affect B”
  - diagram



2. Formalisation

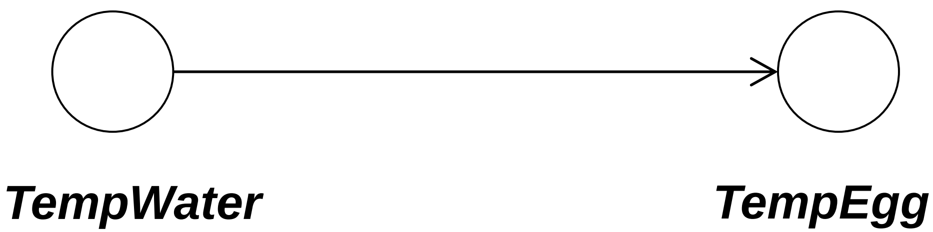
- Specification of the details of the conceptualization
  - concepts & relations
- Dependent on chosen representation
- Two main variant:
  - numerical representation
  - logical representation

Numerical representation

- Concepts:
  - variables met numerical value
    - integer, real, 0 of 1
    - example: concept “temperature” → “Temp: real”
- Relations:
  - calculation rules to determine value of concept at next time point based on values other concepts
    - in dynamic model values change over time
    - Δt (change in time) is time step between two states

Numerical representation (2)

- Suppose: model of the temperature of an egg that is boiled in a pot of water



- Example calculation rules:
  - $TempEgg(t+\Delta t) = TempWater(t)$
  - $TempEgg(t+\Delta t) = \beta * TempWater(t) + (1-\beta) * TempEgg(t)$

Logical representation

- Concepts:
  - statements (propositions) that can be *true* or *false*
    - example: medicine_taken(hiv_slowers)
- Relations:
  - Boolean rules that specify which combination of truth values is required for a concept to be true at next time point

Logical representation (2)

- Example rules:
  - $A \wedge B \rightarrow C$:
    - if A and B are true, C becomes true
  - $A \vee B \rightarrow C$:
    - If A or B or both are true, C becomes true
  - $A(X) \rightarrow B(X)$:
    - If A is true for argument value X, B becomes true for the same argument X
  - $\text{not}(A) \rightarrow B$:
    - If A is not true, B becomes true
  - $A(X) \wedge X > 52 \rightarrow B$:
    - If A is true for some value X larger than 52, B becomes true

3. Simulation

- Expected behaviour of correct model is specified as characteristic pattern $\Rightarrow$ property
  - already during conceptualisation
- Define different scenarios that should be able to show properties
  - different start values
  - parameters that are different
  - stochastic variables (random factors)

4. Evaluation

- Simulations results are compared to expectations
  - hypotheses about model behaviour
- Used to draw conclusions about correctness of model
  - validation

New term: model property

- A hypothesis about a model behavior (i.e. the outcome of a simulation given some input and parameter value) is called:

  a **model property**

- When formulated in the design phase, it is also called “characteristic pattern” of a model

Model properties

- Can be statements about
  - effects that happen over time
  - combination of inputs that lead to some output
- Examples:
  - *Jupiter and Pluto will not collide within two years*
  - *when taking a pill every 3 hours, the medication level is between 12 and 20 mg/l*
- What is essential for a property?
  - it can be tested in an unambiguous way

Validation of properties

- Run (several) simulations of the model and check the properties ⇒ scenarios
  - choose conditions / input parameters intelligently
  - be precise about what you can conclude
- Alternatively:
  - use logic / mathematics to (dis)prove the properties
    - usually quite complex

Steps in brief

1. **Conceptualisation**: identification of important concepts and relations
2. **Formalisation**: describe concepts and relations in an unambiguous way
3. **Simulation**: running experiments with models to generate simulations traces
4. **Evaluation**: verify whether the simulations are in line with expectations (properties about characteristics patterns)

Wrap up:

- What is a property of model?
- Which two use cases have we seen?

Reporting

- Structured reporting is important
  - many arbitrary choices in process
- Elements of report:
  - assumptions, choices, motivation
  - concepts, relations, expected patterns
  - scenarios used in simulation experiments
    - settings
    - input parameters
  - Verified properties, conclusions

Summary

- Dynamic models describe process in which factors change over time
- Models consists of:
  - concepts
  - rules
- Hypothesis / properties can be formulated and validated against simulation
  - for evaluating expected patterns
  - for studying the process