Verification and Validation

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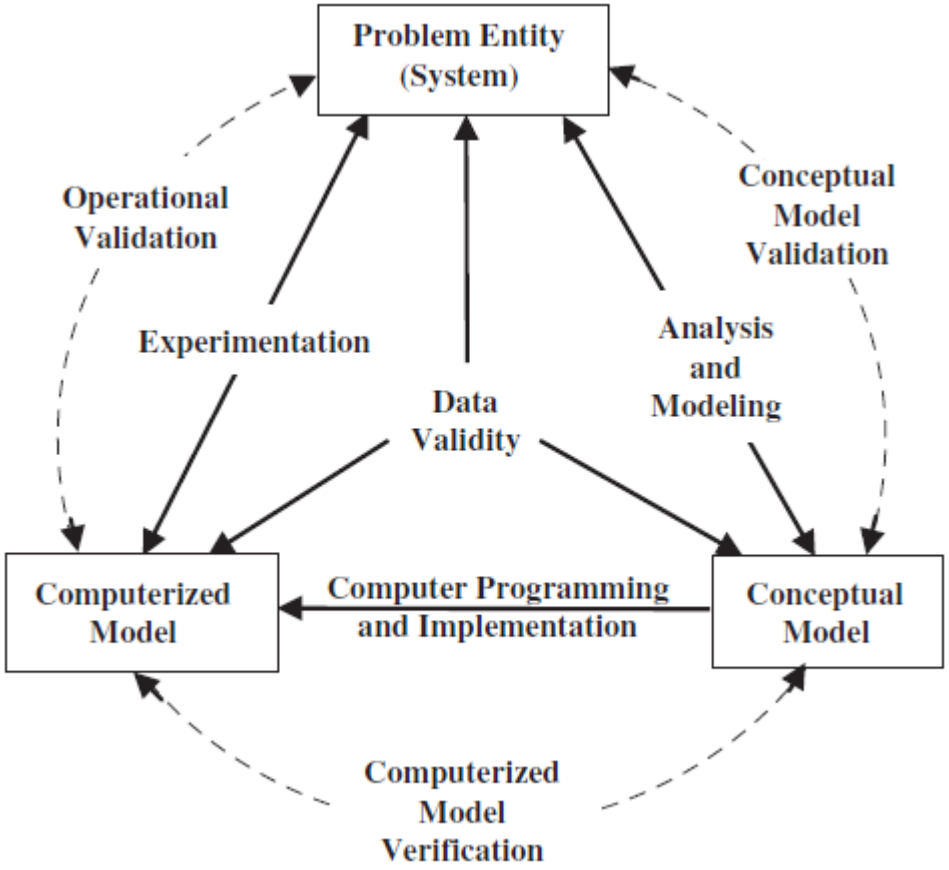
Model Verification & Validation

- Verification: building the model right
  - comparing a computer program with the conceptual model to see if the program implements the model correctly

- Validation: building the right model
  - comparing the model with the system to be simulated to build confidence that the model is adequate for its intended use

Simulation modelling



Sargent (2012)

Verification

- Conceptual model and its implementation
  - Conceptual model representation/specification
  - We assume the conceptual model is valid
- Depends on the simulation tool
  - General purpose language: essentially software testing
  - Simulation language: software testing – libraries are correctly used
  - VIMS: less effort – tools are used correctly

Verification techniques

- Static
  - Structured walkthrough
  - Proof of correctness, formal specification (DEVS)

- Dynamic
  - Traces/animation
  - Remove stochastic elements: test input-output and compare it with simple analytic solutions

Validation

- Simulation model versus real world
  - Careful interpretation, H0:Model=Real World?
  - Assume the simulation model is verified/correct
- Simulation models cannot be shown to be valid in absolute sense but
  - Valid for some predefined purpose under certain specific assumptions
    - Model documentation is important
    - Complete model re-use can be challenging

Analogy

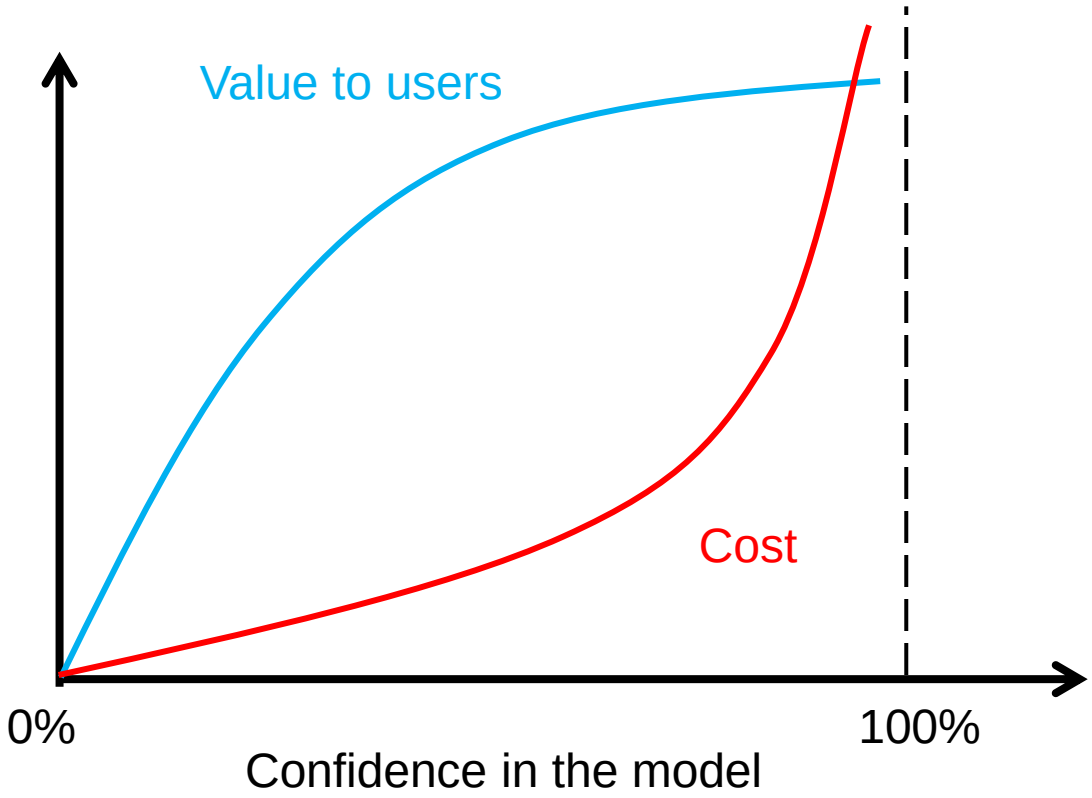
Theorem

- All swans are white
- It is not possible to observe all swans – use sample
- What if all swans in the sample are white?
- What if one swan in the sample is black?

Simulation

- My model is valid in an absolute sense
- It is not possible to test all possible conditions
- What if the chosen tests cannot invalidate my model?
- What if one of the tests invalidate my model?

Value versus Cost



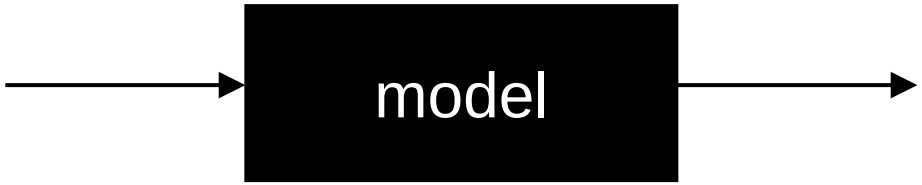
Sargent (2012)

Validation errors

- Type I
  - Good model wrongly rejected (modeller's risk)
  - Controlled by α
- Type II
  - Bad model wrongly accepted (user's risk)
  - Depends on sample size and α
- Type III (or type 0)
  - Model simply addresses the wrong issues

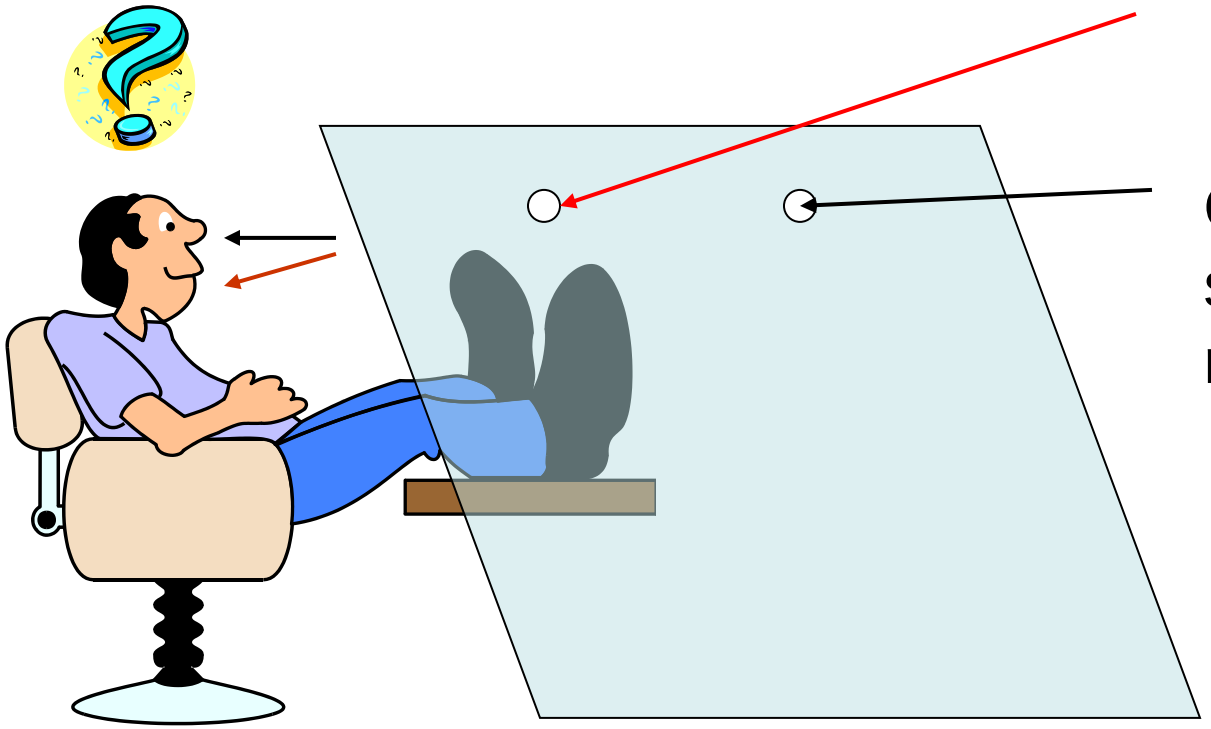
Black box validation

- internal workings of the model & 'real' system ignored
- collect observations from model
- collect observations from 'real' system under same conditions
- use appropriate statistical methods to compare the two sets of observations



Analogy

Which one is the real system



Output from real system

Output from simulation model

Examples

- Compare simulation output
  - Output of other models, such as analytic models
  - Output data from the real system
  - Output data from a similar real system
- Assess simulation output under extreme condition
- Assess the reasonableness of simulation output
  - Sensitivity analysis

Examples – comparing

- Occurrences of simulation events with the occurrences of real world events (*)
- Process flows in simulation with the process flows in the real world (*)
- Real-time performance measures in simulation with the ones in the real world (*)
- (*) Face validity
- Animation may help

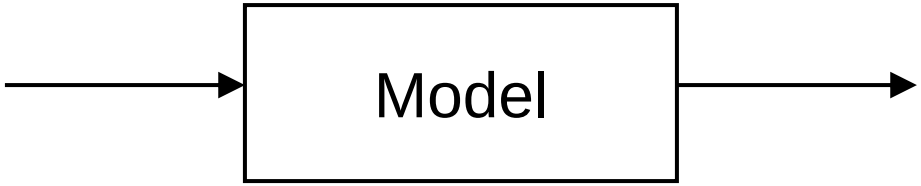
Practical session

- Output analysis using Excel

White (transparent) box validation

KEY ASSUMPTION: modeller knows the internal workings of the model

NEED TO EXAMINE detailed internal structure



Examples

- Assessing the validity of assumptions
- Assessing the validity of internal components
  - Recursively, use another white box method until a black box model is used
- Compare the internal components with theories or data
- Trace a sample of entities

Other issues

- Validation is an integral part of modelling
  - It is not an extra step after modelling
- Use two sets of data (input and output)
- Validate model components
  - Beware of system effect
- Consider the practical aspect
  - Not just the statistical significance
  - Depends on tolerance of errors and CI

Conceptual model validation

- How well does conceptual model match real world?
- Closely related to white-box validation
- Sufficient scope and level of detail?
- Involve client / domain experts
- Think about the data requirement

Data validation

- Data quality and availability is a common issue in practice
- It is difficult to guarantee data validity
  - Involve clients/domain experts
  - Follow good procedure for data collection
  - Follow standard data analysis process (descriptive statistics, identify outliers, missing values, etc)

Why bother with validation?

- A tool to make decision
  - changes to the ‘as is' system
  - new modes of operation
  - build new system
- A tool to understand a system – exploration / learning
- A tool for prediction
  - needs good quality data

Validation of your model

- Consider the research/project you have chosen
- Think of how you would like to validate your model
- Do you need data for the validation?

Further reading

- Pidd (2004) Chapter 12

- Sargent (2012) Verification and validation of simulation models. Journal of Simulation (2013) 7, 12–24.