

Simulation

Introduction

Simulation

- Simulation ~ imitation
 - To describe the essential features of the studied system using a model.
 - The scope of study and the features of interests have to be defined before fixing the model and starting the simulation.
 - "Model" involves three models:
 - Observed properties of the output
 - (Modelled) input of the system
 - Functional model of the system

Models

- Models for different purposes
 - Explanatory models (for observation/understanding)
 - Predictive models (for prediction/what if)
 - Design models (for comparing alternatives)
 - Optimisation models (for maximizing performance)

Models

- Interactive simulators are left out of the scope
 - Different requirements for the input and output
 - Typically data streams instead of modelled processes/reported indicators
 - Emphasis on observation/visualization
 - Simulation in (fictive) real time

Models

- Models have different taxonomies
 - Concrete/abstract
 - Concrete scale model vs virtual computer model
 - Deterministic/stochastic
 - Exactly known vs statistical data
 - Analytic/Numeric
 - Closed form solution vs numerical procedure
 - Continuous/discrete
 - Infinite/finite number of states and changes

Examples

- "Throwing the ball"
 - Equations and initial conditions known, closed form solution (deterministic/analytic)

$$U_t = V, \quad V_t = -g, \quad W_t = 0,$$

$$U(0) = U_0, \quad V(0) = V_0, \quad W(0) = W_0,$$

$$U(t) = U_0 + tV_0 + gt^2/2, \quad W(t) = W_0$$

Example

- "Cannon ball"
 - More complex equations (drag, lift, wind to be taken into account), initial velocity and wind are imprecise
 - Requires numerical solution, stochasticity has a vital role (literally)

Examples

- Game of life
 - Deterministic rules, finitely many rules and states for the cells (deterministic, discrete time)
 - http://en.wikipedia.org/wiki/Conway%27s_Game_of_Life
- Cashiers queue
 - Discrete (finitely many states/events),
 - Stochastic (partly only statistical data available)
 - Sometimes analytical (for some properties)

Course synopsis

- Emphasis on finite (discrete event), stochastic models and their numerical simulation.
- Models for prediction/design purposes
- Requires basics of statistics/probabilities and object oriented programming.

Learning outcomes

- Knows main concepts of discrete event simulation
- Knows main simulation paradigms and their implementation strategies
- Can implement simple simulation models
- Manages systematic generation of pseudo random numbers
- Can analyze simulation experiments and their reliability
- Can design goal driven simulation experiments

Stages of simulation 1

- Recognition of the system/problem
 - What are the essential questions/where to focus modelling.
- Model design
 - System components and their interactions
- Data collection and parameter estimation
 - How to get realistic input data (hard work and lot of observation/measurement)

Stages of simulation 2

- Software design
 - Description model structures and interaction patterns
- Software implementation
 - Actual programming of the simulator
- Software testing
 - Debugging

Stages of simulation 3

- **Model validation**
 - Qualitative/quantitative analysis of the model (comparisons to observation, intuitive expectations, simplified test cases, dependency of uncertain parameters)
- **Model experimentation**
 - First production runs, evaluation of accuracy/confidence of results, design of full set of experiments.
- **Analysis of results**
 - Conclusions, risk/sensitivity analysis, decision making, model based optimisation

Course structure

- Three loosely coupled threads
 - Designing discrete event simulation models
 - Different paradigms and programming techniques
 - Modelling and model based decision making
 - Using modelling of randomness and Monte Carlo + hypothesis testing as sample cases
 - Designing and running simulation experiments
 - "real" experiments on "real" models

Synopsis

- Introduction
- Simulation paradigms
- Event based simulation
- Object oriented simulation
- Random numbers
- Monte Carlo
- Simulation experiments for equilibria
- Variance reduction
- Design of experiments
- Metamodelling

Simulation fundamentals

- Do not simulate unless you have to
 - Analytical and deterministic results are preferable
- Do not simulate before you understand the question
 - Changing the goal after/during model creation can be difficult
 - When computing starts, thinking stops!