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)

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

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

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

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!