Stochastic Simulation
The modelling process

Bo Friis Nielsen

Institute of Mathematical Modelling

Technical University of Denmark

2800 Kgs. Lyngby – Denmark

Email: bfni@dtu.dk

The modelling process

- Problem identification
- Goal/purpose
- System analysis and data gathering
- System syntesis - model formulation
- Estimation of model parameters
- Preliminary model validation
- Program development
- Final validation
- Experimental design
- Statistical analysis

Goal/purpose

- Describe the objective of the problem
- e.g. to design an inventory control system with stable production

Problem identification

- Define which part of reality which is to be modelled
- A company producing one product with an ingoing and outgoing inventory wants an adequate inventory control system

System analysis and data gathering

- Investigate the system identifying parts with direct impact on the goal. Provide data on these parts.
- Demand, relations between order, production and inventory. Insignificant: unemployment, weather.

System syntesis

- Define state variables. Describe dynamics and relations, determine distributions.
- Example: Inventory at time t, determine the type and form of the demand function.

Estimation of model parameters

- Determine parameter values, values for model constants/parameters.
- Example: Estimate mean and variance of the demand function.

Preliminary model evaluation

- Control of fundamental logical structures. Common sense control of parameters
- Does the model imply inventory sizes exceeding system capacity

Program development

- Translate state definitions into data structures. Formalise logical and physical relations. Prepare the program for debugging. Make a modular program which is easy to extend.
- Example: Inventory size is defined as an integer variable. Time is define integer or continuous depending on the context.

Final validation

- Run the program for input combination with known analytical solution. Run the program with extreme values of the parameters. Common sense control of output. Study animations. Compare with real world data if possible (existing system).
- Example: Choose exponential distribution. Reduce/simplify relations.

Experimental design

- Planning of sensitivity analyses.
- Realistic/interesting combinations of parameter values.
- Example: Periods of constant demand. Periods with highly varying demand.

Statistical analysis

- Estimation of systemparameters. Confidence intervals. Variance reduction techniques. Time series analysis.
- Example: Variance of number of orders.

Verification and validation of simulation models - L&K chapter 5

- *Validation* is the process of determining whether a simulation *model* (as opposed to the computer program) is an accurate representation for the particular objectives in study.
- *Verification* is concerned with determining whether the conceptual simulation model (model assumptions) has been correctly translated into a computer "program".
- A simulation model and its results have *Credibility* if the manager and other key project personnel accept them as "correct".

Validiation

- Conceptually, if a simulation model is “valid” then it can be used to make decisions about the system similar to those that would be made if it were feasible and cost-effective to experiment with the system itself.

Credibility

- The managers understanding and agreement with the models assumptions.
- Demonstration that the model has been validated and verified.
- The managers ownership of and involvement with the project
- Reputation of the model developers

What is simulation?

- Computer experiments with mathematical model
- General engineering technique
- Analytical/numerical solutions

Course goal

- Topics related to scientific computer experimentation
- Specialised techniques
  - ◇ Variance reduction methods
  - ◇ Random number generation
  - ◇ Random variable generation
  - ◇ The event-by-event principle
- Simulation based statistical techniques
  - ◇ Markov chain Monte Carlo simulated annealing
  - ◇ Bootstrap
- Validition and verification of models
- Model building

Project types

- Model a system (e.g., like the ferry example) in order to assess performance, under varying designs.
- Study a mathematical model, that is impossible or hard to analyze
- Study any one of the techniques we have been through, more closely. For example, generating random numbers with the Mersenne Twister.
- Come up with your own project type.

Simulation projects

- Post office (discrete event)
- Simulation and estimation in a Markov model of breast cancer (discrete event)
- Simulation of queueing system with input generated by interrupted Poisson processes (discrete event)
- Simulation of Levy processes (discrete event)
- Simulation of rainfall events (discrete event)
- Simulation of queues with Brownian motion input (discrete event, can be developed to something more advanced)
- How zeros affect chemical concentration data (general simulation exercise)
- How thresholds affect modelling sea level time series (discrete event + general simulation exercise)
- Your own suggestion to discuss

General guidelines

- Do not make model too complicated
- Clear objective
- Time to experiment with model
- Apply variance reduction techniques if possible

Deliverable 2: Project report

- Precision of objective
- Model validation
- Program verification
- Experimental design Standard report, the important issue though is to have some time to experiment with your model.
- Deadline Thursday June 23nd (Monday June 27th if you like)

Registering

- Register online. I have created an exercise for group hand in on Campusnet.

Plan for the next two weeks

- Oscar, and I will be available on a consultancy basis. The availability will be communicated through the web page. Some exercises have external teachers. You might be able to get a little more help here.

And remember

- Course evaluation (Campus net)
- Comments and suggestions, at any level of detail