Simulation (ST2006)

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Class hours:

<table>
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<tr>
<th>Day</th>
<th>Time</th>
<th>Location</th>
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<tbody>
<tr>
<td>Monday</td>
<td>14:00–15:00</td>
<td>ICT Lab 2</td>
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<tr>
<td>Tuesday</td>
<td>14:00–15:00</td>
<td>LB08</td>
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<tr>
<td>Wednesday</td>
<td>12:00–13:00</td>
<td>LB01</td>
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Location of on-line resources:

Computer Laboratory Sessions

- Alongside lectures there will be computer laboratory sessions.
- These are scheduled for Monday 14:00–15:00 in ICT Lab 2.
- The software used for this course will be R (http://www.r-project.org/).
Homework

• There will be one course assignment.

• This will be compulsory and will count 20% towards this part of the course so 10% towards your total mark for ST2006.

• This will require knowledge of the statistics software that will be taught in the laboratory sessions.
Books

- There is no compulsory textbook for this course, but the following cover some (or all) of the material:
  - J. Banks *et al.*, *Discrete-Event System Simulation*;
  - A.F. Seila *et al.*, *Applied Simulation Modeling*;

Any additional suggestions are welcome.
What is examinable?

Unless expressly stated otherwise:

- All material presented in class including:
  - Material in handouts.
  - Anything additional that is written on the blackboard.
  - Anything else additional that is said verbally during lectures or labs.
Simulation

The topics we will cover include (in no particular order):

• Motivation for Simulation.

• Random Number Generation and Pseudo-Random Numbers.

• Drawing samples from distributions.

• Simulating Processes.

Objectives include understanding:

• the concepts and terminology;

• different kinds of simulation techniques;

• how and when it is used and to be familiar with a range of application examples;

• how to apply a simulation in practice;

• the limitations.
What is a Simulation?

• A simulation: imitation of the operation of a real-world process or system over time:
  – Involves generation of an artificial history of a system.
  – Observes that history and draws inferences about system characteristics.

• Can be used as:
  – Analysis tool for predicting the effect of changes to existing systems.
  – Design tool to predict performance of new systems.

• Many real-world systems are very complex and cannot be readily solved mathematically:
  – Hence, numerical, computer-based simulation can be used to imitate the system behaviour.
When to use Simulation?

- Simulation can be used for the purposes of:
  - Study and experiment with internal interactions of a complex system.
  - Observe the effect of system alterations on model behaviour.
  - Gain knowledge about the system through design of simulation model.
  - Use as a pedagogical device to reinforce analytic solution methodologies, also to verify analytic solutions.
  - Experiment with new designs or policies before implementation.
  - Determine machine requirements through simulating different capabilities.
  - For training and learning.
  - Model complex systems.
When NOT to use Simulation?

- Simulation should not be used when:
  - Problem can be solved by common sense.
  - Problem can be solved (easily) analytically.
  - If it is easier to perform direct experiments.
  - If the costs exceed the savings.
  - If the resources or time to perform simulation studies are not available.
  - If no data, not even estimates, are available.
  - If there is not enough time or personnel to verify/validate the model.
  - If managers have unreasonable expectations: overestimate the power of simulation.
  - If system behaviour is too complex or cannot be identified.
Advantages and Disadvantages of Simulation

• Simulation is frequently used in problem solving:
  – It mimics what happens in a real system.
  – It is possible to develop a simulation model of a system without dubious assumptions of mathematically solvable models.

• In contrast to optimization models, simulation models are ‘run’ rather than solved.

• Advantages:
  – Explore new policies or procedures without disrupting ongoing operations of the real system.
  – Test new hardware or physical systems without committing to acquisition.
  – Test hypotheses about how or why certain phenomena occur.
  – Study speed-up or slow-down of the phenomena under investigation.
Advantages and Disadvantages of Simulation

● Advantages (cont.):
  – Study interactions of variables, and their importance to system performance.
  – Perform bottleneck analysis.
  – Understand how the system operates.
  – Test ‘what if’ questions.

● Disadvantages:
  – Model building requires special training.
  – Simulation results can be difficult to interpret.
  – Simulation modeling and analysis can be time consuming and expensive.
  – Simulation is used in some cases when an analytical solution is possible (or even preferable).
Areas of Application

• The applications of simulation are vast.

• Some areas of application include:
  – Manufacturing.
  – Construction engineering and project management.
  – Military.
  – Logistics, supply chain, and distribution.
  – Transportation modes and traffic.
  – Business process simulation.
  – Healthcare.
Areas of Application

• Some general trends:
  – Risk analysis, *e.g.*, pricing or insurance.
  – Call-center analysis.
  – Large-scale systems, *e.g.*, internet backbone, wireless networks.
  – Automated material handling systems as test beds for the development and functional testing of control-system software.
• A system is a group of objects joined together in some regular interaction or interdependence to accomplish some purpose:
  – *e.g.*, a production system: machines, component parts and workers operate jointly along an assembly line to produce a vehicle.
  – Affected by changes occurring outside the system.

• System environment: ‘outside the system’, defining the boundary between system and its environment is important.
Components of a System

• An entity: an object of interest in the system, *e.g.*, customers in a bank.

• An attribute: a property of an entity, *e.g.*, balance of their accounts.

• An activity: represents a time period of a specified length, *e.g.*, customers making deposits.

• The state of a system: collection of variables necessary to describe the system at any time, relative to the objectives of the study, *e.g.*, the number of busy tellers, the number of customers in line.

• An event: an instantaneous occurrence that may change the system state, can be endogenous or exogenous.
Discrete and Continuous Systems

- Discrete system: in which state variable(s) change only at a discrete set of points in time.
  - *e.g.*, the number of customers in a bank only change when a customer arrives or when service is completed.

- Continuous system: in which state variable(s) change continuously over time:
  - *e.g.*, the head of water behind a dam.
Model of a System

• Studies of systems are often accomplished with a model of a system.

• A model: a representation of a system for the purpose of studying the system:
  – A simplification of the system.
  – Should be sufficiently detailed to permit valid conclusions to be drawn about the real system.
  – Should contain only the components that are relevant to the study.
Types of Models

• Two types of models: mathematical or physical.

• Mathematical model: uses symbolic notation and mathematical equations to represent a system:
  – Simulation is a type of mathematical model.

• Simulation models:
  – Static or dynamic.
  – Deterministic or stochastic.
  – Discrete or continuous.

• Our focus: discrete, dynamic, and stochastic models.
Discrete Event System Simulation

- We focus on discrete-event system simulation.
- Simulation models are analyzed by numerical methods rather than by analytical methods:
  - Analytical methods: deductive reasoning of mathematics to ‘solve’ the model.
  - Numerical methods: computational procedures to ‘solve’ mathematical models.
Steps in a Simulation Study

1. Problem formulation
2. Setting of objectives and overall project plan
3. Model conceptualization
4. Data collection
5. Model translation
6. Verified?
   - No
   - Yes
7. Validated?
   - No
   - Yes
Steps in a Simulation Study (cont.)

1. Experimental design
2. Production runs and analysis
3. More runs?
   - Yes: Go back to 2
   - No: Go to 4
4. Documentation and reporting
5. Implementation
Steps in a Simulation Study

- Four phases:
  - Problem formulation, and setting objective and overall design (steps 1 and 2).
  - Modeling building and data collection (steps 3 to 7).
  - Running of the model (steps 8 and 10).
  - Implementation (steps 11 and 12).

- An iterative process.