Discrete-Event Simulation: Methodology and Practice

by

Prof., Dr.sc.habil.ing. Yuri Merkuryev
Lect., M.Sc. Jelena Pecherska

Department of Modelling and Simulation
Riga Technical University
Riga, Latvia

merkur@itl.rtu.lv
www.itl.rtu.lv/mik/ymerk
Riga Technical University

- The main technical university in Latvia
- Offers advanced study programmes in Engineering, Technology, Natural Sciences, Architecture, and Business Administration
- 8 faculties, 16900 students
- www.rtu.lv
Riga Technical University

- Faculty of Architecture and Urban Planning
- Faculty of Building and Civil Engineering
- Faculty of Computer Science and Information Technology
- Faculty of Electronics and Telecommunications
- Faculty of Engineering Economics
- Faculty of Materials Science and Applied Chemistry
- Faculty of Power and Electrical Engineering
- Faculty of Transport and Mechanical Engineering
Department of Modelling and Simulation

- Institute
  - Information Technology

- Study programme (Bachelor, Master, Doctoral)
  - Information Technology

- Main directions of activities:
  - Discrete-Event System Simulation
  - Logistics Management

- www.itl.rtu.lv/mik/english.php
Discrete-Event Simulation – What it is
Simulation (in general, by R. Shannon):

The process of designing a model of a real system and constructing experiments with this model for the purposes of understanding the behaviour of the systems and/or evaluating various strategies for the operations of the system.
Model \textit{(in general)} –

Abstract or material system that:
- describes essential features of the modelled system,
- describes the modelled system in a way that is convenient for a conducted study,
- could be used for solving problems, that could not be solved, using the modelled system itself.
Simulation:

- The computer-based imitation of the operation of a real-world process or system over time
- Allows modelling influences of random factors
- One of the most widely used and accepted tools in Operations research and Systems analysis

General aims of simulation:
- Better understanding operation of the simulated system
- Improving operation of the simulated system
Discrete - Event Simulation:
1. Deals with discrete - event systems, that change their state instantly, at discrete time moments.

Examples:
- Queuing Systems with
  - clients to be served (e.g., parts to be processed or assembled)
  - servers (e.g., processing or assembling parts)
  - queues, where clients wait for serving (e.g., buffers)
  - routing of served clients (e.g., to the next processing or to a warehouse)
• Reliability Studies
  - were breakdowns (e.g., of a technological equipment) are considered

2. Deals with complicated systems
   - of a large scale
   - with complicated relations between elements
   - influenced by random factors
   - when analytical models actually cannot be used

3. Is a computer-based abstract, mathematical, algorithmical modelling
Discrete - Event Simulation approach:

1. Describe how the modelled system operates
   (specify its operation algorithm – develop a conceptual model)

2. Develop a simulation model: computer programme
   that realises this algorithm
   (convert the conceptual model into a computer program)

3. Experiment with the simulation model (simulate) and analyse simulation results
November 21-22, 2005      Warsaw University of Technology Prof. Yuri Merkuryev

Development of a conceptual model

Development of a simulation model

Experimenting with a simulation model

Structure of a simulation study

- Problem formulation
- Setting of objectives and overall project plan
- Model conceptualization
- Data collection
- Model programming
- Experimental design
- Simulation runs and analysis
- Documentation and reporting
- Implementation
- Verified?
- Validated?
- More runs?
Typical simulated systems:

- service systems
- manufacturing systems
- transport systems
- inventory systems
- logistics systems
- communication systems
Typical simulation tasks:

- better understanding of MS behaviour
- analysis of MS operation in different situations ("what-if" analysis)
- analysis and removal of bottlenecks
- optimisation of MS parameters
- comparison of alternative scenarios (e.g., control algorithms)
- personnel training (e.g., managerial personnel)
Simulation in Manufacturing

A support tool for:
- designing a new production system
  (*optimisation of investments*)
- modernisation of already existing production
  (*meeting market demands*)
- scheduling a production process
  (*maximising throughput, minimizing performance time*)
- personnel training
  (*getting managerial skills*)
Simulation in Manufacturing

Sample application areas:
- as a design and analysis aid for factory layouts, equipment decisions, operating policies, etc.
- as a scheduling aid for production processes
- as a part of a real-time, on-line control system (e.g., generating a new schedule when a piece of equipment has broken down)
Simulation in Manufacturing

Typical questions, to be answered by simulation in a design mode:

- What will be the throughput of a particular design?
- Where are the bottlenecks? How can we remove them?
- How does the system performance change in a function of number and type of machines, number of workers, in-process storage and transportation, etc.?
- How will breakdowns affect the throughput?
Simulation in Logistics

Sample application areas:

- facility location decisions
  \textit{(comparison of alternative locations)}

- transportation planning
  \textit{(evaluation of different routes)}

- inventory management
  \textit{(evaluation of inventory policies, tuning their parameters)}

- supply chain management
  \textit{(evaluation of customer service, minimization of total inventories, minimization of lead times, analysis of supply chain dynamics)}
Advantages of simulation:

- Allows modelling of complex dynamic systems, influenced by random factors, that cannot be modelled analytically.
- Wide visualisation possibilities.
- Provides a more realistic replication of a system than mathematical analysis.
- Allows simulation experiments similar to experimenting with real-world systems.
- Time control possibilities, allowing both a speed up or slow down of the phenomena under investigation.
- Convenient analysis of bottlenecks.
- Efficient training tool (e.g., simulation-based business games).
Disadvantages of simulation:

- Simulation is a resource-consuming approach:
  - time
  - finances
  - hardware and software
- A specific knowledge on simulation methods and tools is necessary
- Simulation is both art and science
- Necessity to educate customers of simulation studies
Cost efficiency of Simulation

Costs:
– software
– hardware
– labour

Average relation of costs to savings:
– between 1:6 and 1:10

(Solvers, Ltd.: 1:9)
Sample simulation model:

Simulation of a Manufacturing System:

A sample simulation model developed with the

Arena Simulation System

(Rocwell Software, http://arenasimulation.com/)
Discrete-Event Simulation –
How it works
A brief insight into the simulation world

*Simulated System* – Collection of entities

*Entity* – An object of interest in the system:
- *dynamic*, e.g., customers to be served
- *static (resources)*, e.g., servers to serve customers

*Attribute* – Characteristic of an entity,
e.g., customer priority

*Variable* – Characteristic of the system,
e.g., number of customers being served

*System State* – Collection of variables
A brief insight into the simulation world

*Event* – Change of the system state

*Discrete system* – Variables change instantaneously at separated points in time, e.g., changes of the number of customers in a shop

*Simulation* – Following changes in the system state during its operation
A shop: Entities and events

- 1st customer
- 2nd customer
- 3rd customer
- Seller
- Queue

$t_1(E_1) \quad t_2(E_2) \quad t_3(E_3) \quad t_4(E_4) \quad t_5(E_5)$
A shop: Entities and events

Attributes:
R – No of customers in the queue
P – seller’s state: 0 – idle, 1 - busy

System state changes:

<table>
<thead>
<tr>
<th>t</th>
<th>S(t) = {R(t), P(t)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – t₁</td>
<td>0, 0</td>
</tr>
<tr>
<td>t₁ – t₂</td>
<td>0, 1</td>
</tr>
<tr>
<td>t₂ – t₃</td>
<td>1, 1</td>
</tr>
<tr>
<td>t₃ – t₄</td>
<td>0, 1</td>
</tr>
<tr>
<td>t₄ – t₅</td>
<td>0, 0</td>
</tr>
<tr>
<td>t₅ – ...</td>
<td>0, 1</td>
</tr>
</tbody>
</table>
Modelling the progress of time

*Time-slicing approach:* Advancing time with a permanent step - Very inefficient!

*Event-scheduling:* Three-phase simulation approach

- B-events: scheduled for a particular point in time, e.g., arrival of a current customer; generally: *arrivals* and *completing of activities*
- C-events: dependent on the conditions in the model, e.g., servicing could start if the server is idle; generally: *starting an activity*
- Event list: List of future events, ordered by time of their occurrence
Modelling the progress of time

The three-phase simulation approach:

*Initialise simulation* - Determine initial states and schedule initial events

*A-phase*: Find time of the next event and advance the clock to that time

*B-phase*: Execute all B-events due now

*C-phase*: Attempt all C-events and execute those for which the conditions are met

During A- and B-phases, future events are scheduled
The three-phase simulation approach