

Advanced Practical 2022/2023 *Operations Research Case*¹

Lecture: Introduction

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¹ all the materials on simulation are provided by Professor Ad Ridder

Organisation








- ▶ Contact hours:
Tuesday 6, 13, 20, 27 June 11:00-12:45 in 9A24
Thursday 8 June on academic writing
- ▶ Teams of three persons.
- ▶ Simulation project.
- ▶ Model and program a discrete event simulation (DES).
- ▶ Academic writing assignment due Thursday 15 June.
- ▶ Report due Tuesday 27 June.
- ▶ Team presentations: 28 June.

Sufficient should be

- ▶ Slides
- ▶ Supporting documents in Canvas

Also many books on simulation (containing DES) are available, next slide

Relevant Simulation Books

-  Jerry Banks, John Carson, Barry Nelson and David Nicol. *Discrete-Event System Simulation*, Fourth edition, Pearson 2005; Fifth edition 2009.
-  Christos Cassandras and Stéphane Lafortune. *Introduction to Discrete Event Systems*, Second edition, Springer 2009.
-  George S. Fishman. *Discrete-Event Simulation: Modeling, Programming, and Analysis*, Springer 2001.
-  Averill M. Law. *Simulation Modeling and Analysis*, Fourth edition, McGraw-Hill 2007; Fifth edition, 2015.
-  Lawrence Leemis and Steve Park. *Discrete-Event Simulation: A First Course*, Pearson, 2006.
-  B.L. Nelson. *Foundations and Methods of Stochastic Simulation*, Springer 2013.
-  H. Perros. *Computer Simulation Techniques: The definitive introduction!*, 2009, available from <https://people.engr.ncsu.edu/hp/files/simulation.pdf>

The OR Modelling Approach

1. Define the problem of interest.
2. Gather relevant data.
3. Formulate a mathematical model that represents the problem.
4. Validate the model [redefine when needed].
5. Develop or construct solution methods, or techniques and algorithms for solving the problem from the model.
6. Write computer code and/or use computer solvers.
7. Verify the computer program.
8. Run the program.
9. Report and present the results.

Hence, data and data analysis are also elements of an OR process.

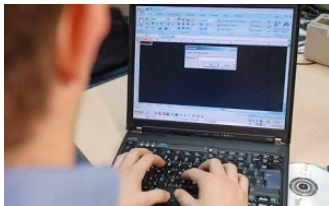
Rather to look for patterns, the data are used to construct and validate the mathematical model by statistical methods, such as MLE, GoF, two-sample comparison, etc.

This Course

Main focus on

- ▶ Considering operational processes (from business, economics or finance) with uncertain components.
- ▶ Providing efficient or optimal solutions to decision problems.
- ▶ Using computer simulation techniques.

What is Stochastic Computer Simulation?



- ▶ Computer simulation is a computer program that mimicks (or reproduces) a system with the purpose to experiment the system and to obtain estimates of system performance measures.
- ▶ We call it stochastic computer simulation when the system contains probabilistic entities.
- ▶ Also known as Monte Carlo simulation (or methods or computing).

Why Simulation?

Several reasons why one might decide to execute a simulation study.

- ▶ The system cannot be described by an analytic or numerical model.
- ▶ Able to evaluate the performance of an existing system under other operating conditions.
- ▶ Comparison of system behaviour and performance for a range of alternative proposed system designs.
- ▶ Study of the system in the “long run” is feasible via simulation.

Motivating Example

Boarding an Airplane



- ▶ People arrive in a random order at the gate and wait to enter the airplane.
- ▶ In the airplane they go to their designated seats.
- ▶ It takes a random time before a passenger is seated.

What is the Problem?



- ▶ Small aisles in the airplane so people cannot pass.
- ▶ People stuff their stuff into the overhead bins before seating, meanwhile the line get stuck.
- ▶ Boarding a whole airplane randomly is inefficient and takes too long.
- ▶ Are there smart boarding strategies?

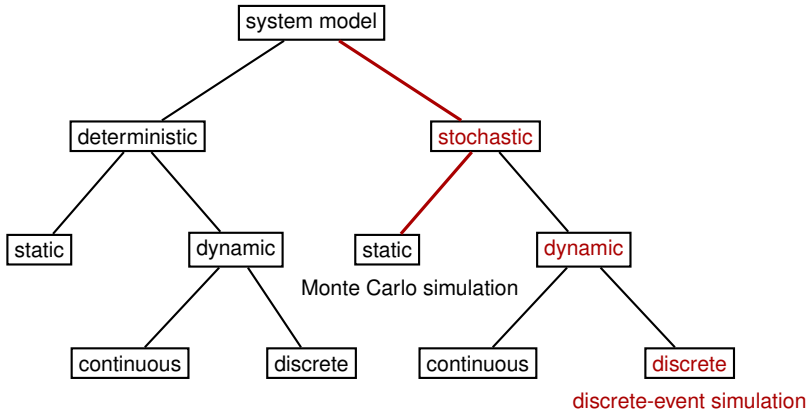
Proposals

For example, row by row? Per block of rows? First window seats?

- ▶ Objective: minimal time until all passengers are seated.
- ▶ No analytic formulas available.
- ▶ Alternatives: physical simulation; computer simulation.

Types of Simulation

A Simulation Taxonomy



Various Types of Stochastic Simulation

- A.* Static, for estimating expectations or probabilities.
- B.* Monte Carlo integration, for computing areas or integrals (usually in multi dimensions).
- C.* Markov chain Monte Carlo, for sampling from complex distributions (typically in multi dimensions).
- D.* Discrete-event simulation, for computing performance measures of dynamic systems, e.g., the boarding problem.
- E.* ...

Discrete Event Simulation

What is Discrete Event Simulation (DES)?

- ▶ It is a computer simulation program that mimicks
- ▶ a system that evolves dynamically in time,
- ▶ with changes (updates) of state information at discrete time epochs.
- ▶ These changes are triggered by the occurrences of events.
- ▶ The duration of events follow known probability distributions from which samples can be drawn/.

Applications of DES

In business process of operational, financial, business, logistical, technological, etc, nature.

For instance,

- ▶ Bike sharing in a large city.
- ▶ Elevators in a large building.
- ▶ Traffic lights management at busy crossroads.
- ▶ Large call centers.
- ▶ Supply chains, transport and distribution.
- ▶ Patient flows in hospitals.
- ▶ Intensive care capacity planning.
- ▶ Airline schedule planning and control.
- ▶ ...

Your Task

- ▶ Model and analyse such a system.
- ▶ Write a computer simulation program of the operations.
- ▶ Languages: preferably Python but Matlab/Octave, or R, and also Java, C/C++ are allowed.
- ▶ NB, no usage of specific simulation packages such as Arena, FlexSim, Enterprise Dynamics, ProModel, Simul8, etc.

- ▶ Probability Theory
- ▶ Statistics
- ▶ Markov chains
- ▶ Sampling from distributions (invers transform; accept-reject)
- ▶ Programming skills

Study the slides on

- ▶ Monte Carlo Simulation (basic simulation principles)
- ▶ Discrete Event Simulation
- ▶ Steady State Analysis
- ▶ Ingredients of a Simulation Study
- ▶ Design of Experiments