Different Types of Simulation Models

Outline

Learning Objectives

By the end of this video, we hope that you will be able to:

- Understand how to use probability distributions to re-create simulation models of the real world
- Understand the different types of simulation models used.

Types of Simulation Models

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Simulation Models Definition

A simulation model imitates the operation of a real-world process. We use computers to run the simulation over time to describe, explain and predict real world behaviour.

Requirement 1

Simulations require the use of models; the model represents the key characteristics of the real-world process.

Requirement 2

Simulations require a certain level of abstraction of the real-world process.

Types of Simulation Models

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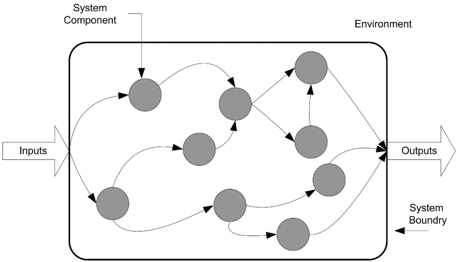
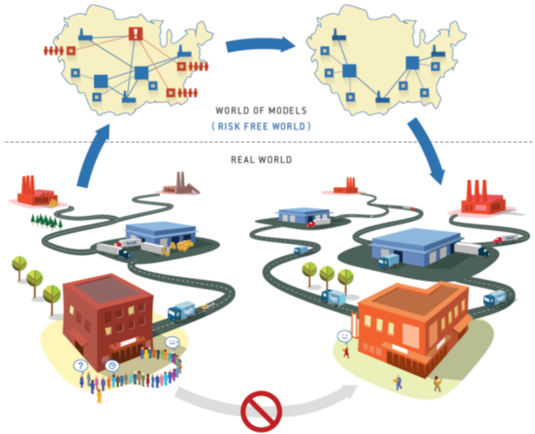
A simulation model is a system that requires inputs runs a series of procedures and produces an output. By varying the inputs on a computer, we can see how the output changes.

- By varying the inputs on a computer, we can see how the output changes.
- We then use this understanding to guide our decisions.



Types of Simulation Models



1. One reason simulation models are used so widely is because they are inexpensive; they do not require us to experiment with real world objects. The simulation environment is, in a sense, risk-free.
2. Another situation where simulation models are useful is when the system is too complex to figure out through reason or analytical derivations.

Some reasons for using simulation models

Summary

- Understanding how complex interactions in the system affect performance.
- Understanding how randomness affects performance.
- Comparing a fixed set of design alternatives to determine which design meets the performance goals under which conditions.
- Training people to prepare them for dealing with events that may be disruptive to the actual system.
- When the decision associated with the problem has a high cost, so that the cost of building the model and evaluating the design is worth its development.
- When the current system does not yet exist and you need to ensure that the chosen design will meet specifications.

Types of simulation models

The models that we create are affected by how we conceptualize the real-world process, or system. Hence it is useful to look at some general system classifications.

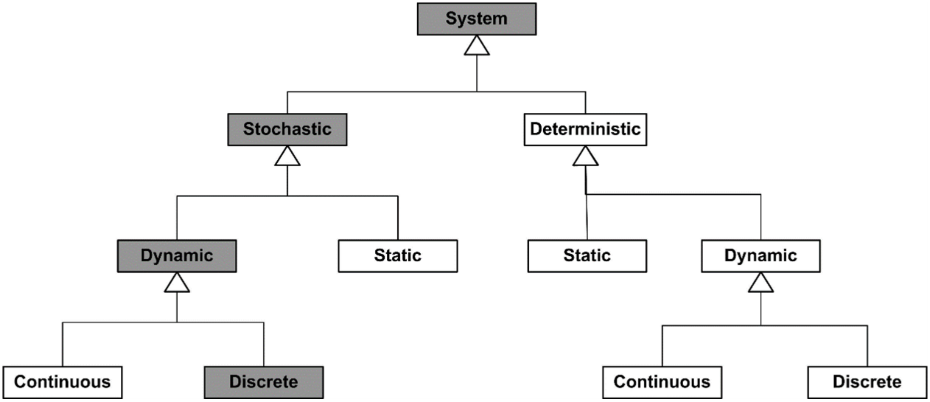
General System Classifications

- Man-made (e.g., manufacturing system) or natural (e.g., solar system)
- Physical (e.g., an airport) or conceptual (e.g., a system of equations)
- Random (stochastic) behaviour or deterministic behaviour.
- Changes significantly with time (dynamic) or is relatively constant (static).

A dynamic system is said to be discrete if the state of the system changes at discrete points in time. A dynamic system is said to be continuous if the state of the system changes continuously with time.

Types of Simulation Models

In this module, we are going to focus on systems that have stochastic elements, which is why we spent time to learn about probability distributions.



Abstraction levels

Abstraction

- Simulation Modelling can be grouped into 3 categories.

Lowest abstraction level

At this level, we are concerned about the physical interaction of the variables. (e.g., how the traffic lights timing affects the flow of traffic, and how individual customers evacuate from a shopping centre during an emergency.)

Medium abstraction level

At this level, we consider things at a more aggregate level. In a transportation problem, we would no longer represent traffic on the individual routes - we would just represent the departure and arrival times of delivery trucks.

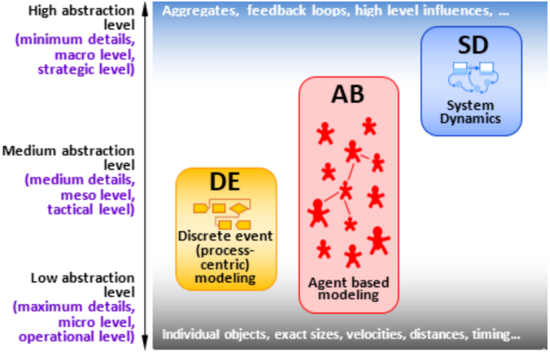
Highest abstraction level

At this level, we are concerned about aggregates such as consumer populations and employment statistics rather than individual objects.

- Choosing the right abstraction level is critical to the modelling project's success.

Types of Simulation Models

The three levels of abstraction are simply a guide, but they do correspond to three main paradigms of simulation modeling.



These three paradigms can be used in combination with one another, but for now, let's look at some examples in each of these methods.

System Dynamics Modelling

System Dynamics Modelling

- System dynamics models are usually used in long-term, strategic models, and it assumes high levels of object aggregation. (e.g., individual properties of people, products, or events)
- It is usually used to model nonlinear behaviour of complex systems over time using stocks, flows, internal feedback loops and time delays.

Feedback Loops

The feedback loop is a basic concept of system dynamics. For example, the more money you invest in marketing, the bigger revenues you have, and so, the more money you can spend on marketing.

- A contemporary example of a system-dynamics model would simulate the number of people infected every month and modify the number of people in each compartment accordingly.
- With repeated simulations, we would be able to tell when the entire population becomes infected.

Discrete Event Modelling

Discrete Event Modelling

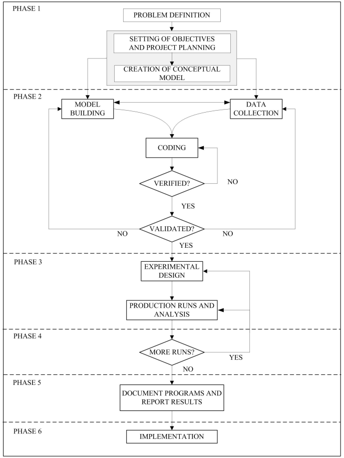
- A discrete-event simulation models the operation of a system as a sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system.
- Discrete event modelling simply means modelling a process or a sequence of operations for someone or something to perform. The operations can include actions, delays, use of resources or even locations/services dependent.

Examples of Discrete Event Modelling

- A customer goes into a supermarket, picks up an item, goes to the cashier, pays for it and leaves the supermarket.
- Driving a car from point A to point B. With discrete event simulation modelling, we only consider the departure and the arrival. Specific details, such as the speed of the car, the type and even the acceleration are not represented.

Discrete Event Modelling

This type of modelling can also be presented as a flowchart where blocks and shapes represent the different operations.



- Discrete models are mostly stochastic in nature and such models will need to run for a specific amount of time before they can generate some meaningful output.
- Discrete event simulation modeling is widely used in the manufacturing, logistics, and healthcare fields.

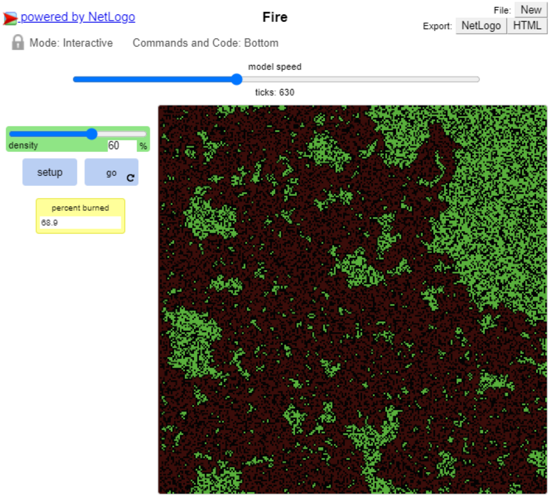
Agent-based modelling

Agent-based modelling

- In agent-based modelling, the agents may represent many different things. (e.g., people, vehicles, or products) Connections between them are established, environmental variables set, and simulations run.
- We define their behaviour, connect them, and then let them loose in an environment.
- The global dynamics of the system then emerge from the interactions of the many individual behaviours. Behaviours are the processes to perform upon specific events.

Agent-based modelling: Forest fires

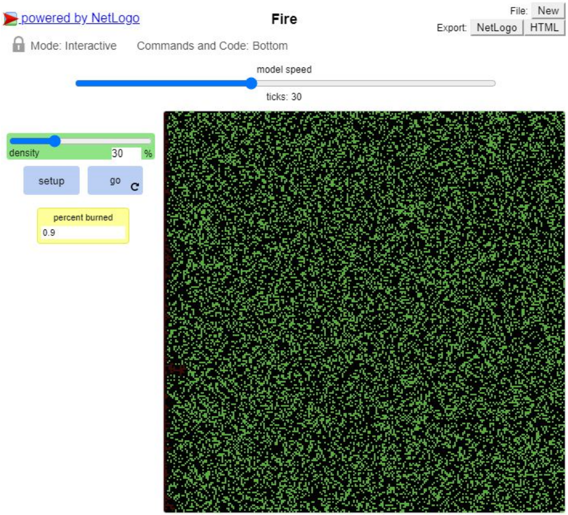
- Suppose that we consider trees in a forest to be agents, and we would like to study how the speed of forest fires is affected by the density of a forest.
- In the image on the right, green pixels represent trees within a square forest region.



Agent-based modelling: Forest fires

cont'd

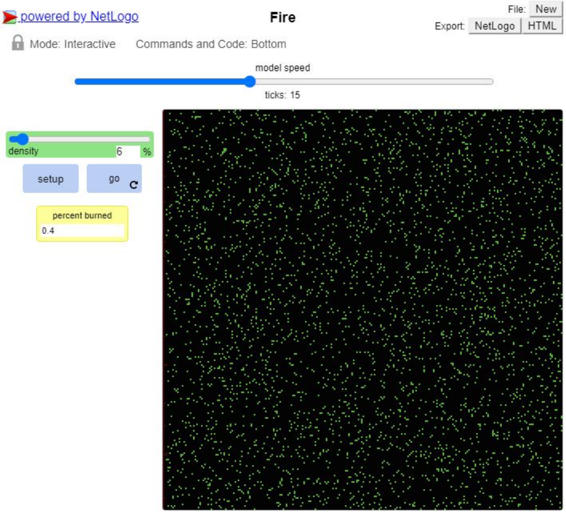
- In our model, the fire is going to begin on the Western edge; our goal is to study how, if at all, the fire spreads all the way to the eastern side.
- The density of the forest can be controlled with a slider. Let's take a look at how the simulation proceeds if the density is 30%.



Agent-based modelling: Forest fires

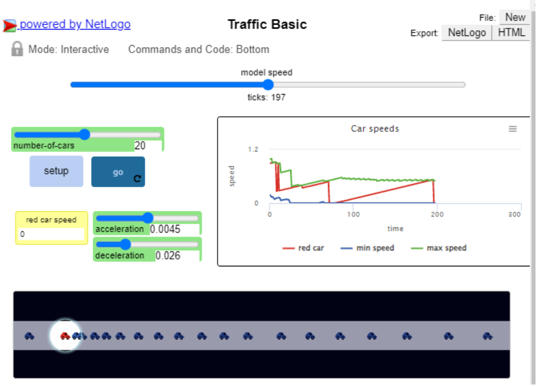
cont'd

- In our model, the fire is going to begin on the Western edge; our goal is to study how, if at all, the fire spreads all the way to the eastern side.
- The density of the forest can be controlled with a slider. Let's take a look at how the simulation proceeds if the density is 30%.
- Now let's look at the spread when the density is 6%.



A second example on agent-based models

Another common domain in which agent-based models are applied is traffic. In this model, individual agents are drivers, and we parameterize their behaviour through their acceleration and deceleration. Traffic scientists can study how quickly traffic jams evolve and dissipate with a model such as this one.



Extracted from Netlogo`https://ccl.northwestern.edu/netlogo/`

Summary

Learning Outcomes

- In this video, we talked about the different types of simulation models. Namely Discrete Event simulation, agent-based simulation and system dynamics modelling. We also looked at the different uses of modelling. However, for this module, we will be focusing on discrete event simulations only.
- Below are some links you can use to try your hands at modelling.

References

Book Reference:

- Rossetti, M. (2015). *Simulation Modelling and Arena.* John Wiley Sons.
- Wilensky, U. Rand, W. (2015). Introduction to Agent-Based Modeling: Modeling Natural, Social and Engineered Complex Systems with NetLogo. Cambridge, MA. MIT Press.

Model Reference:

- Wilensky, U. (1997). NetLogo Fire model. http://ccl.northwestern.edu/netlogo/models/Fire. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
- Wilensky, U. (1997). NetLogo Traffic Basic model. http://ccl.northwestern.edu/netlogo/models/TrafficBasic. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Software Reference:

- Netlogo https://ccl.northwestern.edu/netlogo/
- EpiModels https://www.epimodel.org/ This is an R package that provides tools for simulation.