Simulation

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1 What is simulation?

Simulation The production of a model of something, with the purpose of study. The main goal of simulation is to replicate the behavior of a certain entity or system to understand something about it.

Simulation is usually limited and closed in the engineering field, while in computer science the represented system can be really complex and not deterministically defined.

Descriptive model A descriptive model can be defined as some form of formalism that represent the behavior of a system. It could be an equation, a system of equations, a probability distribution and so on.
A descriptive model can be then used by a computer, to study what would happen in the real system or to replicate its behavior.

Remark. *Parameters are part of a model whereas the values represent a particular instance of it.*

Reasons to simulate The main reasons to do simulations are:

1. cheaper then real worlds simulations
2. they can test particular or even extreme *what if* scenarios
3. visualization of results

When to skip simulation When a problem has closed forms solutions, they are better than simulations. Also, when *what if* scenarios are too complex, it's better to use prescriptive models.

Simulation paradigms There are three main simulation paradigms:

1. *discrete event*: the focus is not on individuals but on the process, there is the idea of events that can trigger other ones
2. *agent-based*: each entity is an agent with its own logic that can interact with others via messages
3. *system dynamics*: basically a system is represented by states and individuals can change states according to some probabilistic transitions

These three paradigms are used for different contexts and choosing the right one is a crucial part of simulation.

For instance, the first two approaches model fine grain details, while the in the third we can only define coarse grain specifications.

1.1 Game of Life example

Let's now consider an example, *Game of Life by Conway*, the games maps a certain region with individuals, and there are some rules:

1. any individual with less than two neighbors dies
2. any individual with more than three neighbors dies
3. an individual lives if it has two or three neighbors
4. if an empty space have exactly three individuals, a new one comes to live there

Remark. *The exact definition of empty space can be fuzzy, indeed, descriptive modeling models the exact definition. If we see the region as a boolean matrix, a cell could be empty if its value is false.*

Individuals Each individual can be an agent, they interact with each others with messages.

Region For the sake of simplicity, our region can be a two dimensional matrix, each cell contains at most one agents, the concept of neighbors is in this case trivial.

Implementation The model can be implemented using anything that models a matrix, for each cell, we need to recalculate its value according to the rules, and by iterating we obtained the simulation.

1.2 Pharmacist example

Another example can be a situation where a pharmacist wants to simulate the pharmacy behavior.

Parameters The problem needs some parameters to create an instance on the situation:

- the opening time is set from 9 a.m. to 5 p.m.
- on average there are 32 prescriptions per day
- the time to fill a prescription is between 4 and 10 minutes
- he will remain in the shop after 5 p.m. if a prescription is in the making

Events We can simulate the scenario by considering a queue of events where each one of them is picked from a normal distribution, and then starting the prescription process by keeping the pharmacist busy for a random interval of time.