Simulations

Systems Analysis

Author: Eng. Carlos Andrés Sierra, M.Sc.
cavirguezs@udistrital.edu.co

Lecturer
Computer Engineer
School of Engineering
Universidad Distrital Francisco José de Caldas

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Outline

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What is a simulation?

- **Simulations** are a sort of real-world representation, but rarely exactly the real world.
- Sometimes you need to **test** or **experiment** with expensive use cases. Simulations let play with different `inputs`, `conditions`, `hyper parameter optimizations`.
- Also, there are dangerous or hard to reach stages where **simulations** become the best option.
- You should define the **detail level** good enough to represent the expected behavior, without fail in both high complexity or lazy simplicity.

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Events and Stochastic Processes

- It is typical to play with **events probability**, creating stochastic behaviors. That is how *reality works*.
- One way to simulate a lot of systems is to use **event-based models**. Embrace the chaos and `Murphy's Law`.

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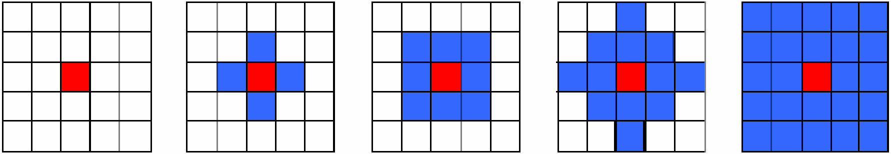
Celullar Automatas

- **Cellular Automata** are a discrete model defined by a grid of cells, each one with a state.
- The state of a cell is updated based on the state of its neighbors.



Celullar Automata Typical Neighborhoods

Game of Life

- **Game of Life** is a cellular automaton devised by the British mathematician John Horton Conway in 1970.
- It is a **zero-player game**, meaning that its **evolution** is determined by its initial state, requiring no further input.
- Rules:
  - Any **live** cell with fewer than two live neighbors **dies**, as if by underpopulation.
  - Any **live** cell with two or three live neighbors **lives** on to the next generation.
  - Any **live** cell with more than three live neighbors **dies**, as if by overpopulation.
  - Any **dead** cell with exactly three live neighbors becomes a **live** cell, as if by reproduction.

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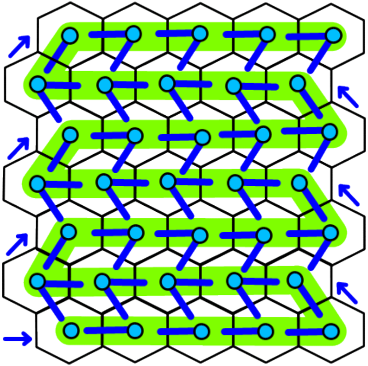
HoneyComb Cellular Automata

- **HoneyComb Cellular Automata** is a different topology where a cell has six neighbors.
- This representation has different dispersion properties, sometimes, more interesting.

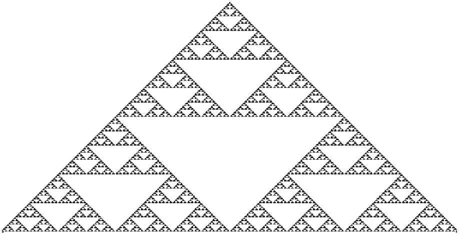


SIR Model

- **SIR Model** is a compartmental model used to represent the transmission of a contagious disease.
- The **model** divides the population into three compartments: **S** for the number of susceptible, **I** for the number of infected, and **R** for the number of recovered.
- The model is defined by the following differential equations where β is the transmission rate and γ is the recovery rate:
  - $\frac{dS}{dt} = -\beta \cdot S \cdot I$
  - $\frac{dI}{dt} = \beta \cdot S \cdot I - \gamma \cdot I$
  - $\frac{dR}{dt} = \gamma \cdot I$

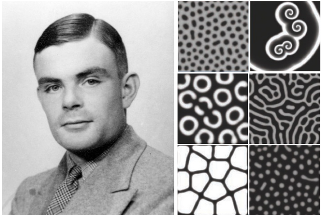
Chaotic Systems

- **Chaotic Systems** are a class of dynamical systems that exhibit sensitive dependence on initial conditions.
- This means that the future behavior of the system is **highly dependent** on the initial conditions.
- The **Lorenz System** is a well-known example of a chaotic system.
- Using **cellular automata** to simulate chaotic systems is a common practice. A lot of **fractals** can be created using something called chaotic rules.



Turing Morphogenesis

- **Turing Morphogenesis** is a theory of biological development that explains how patterns form in living organisms.
- The theory is based on the idea that chemical signals can interact to create patterns in a cellular automaton.
- The reaction-diffusion model is a common way to simulate **Turing morphogenesis**.
- The model is defined by a set of reaction and diffusion equations that describe how the chemical signals interact.



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Thanks!

Questions?

Repo: *https://github.com/EngAndres/ud-public/tree/main/courses/systems-analysis*

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