Simulations

Systems Analysis

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Outline

1. Basic Concepts
2. Cellular Automata

Outline

1 Basic Concepts

2 Cellular Automata

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.

Events and Stochastic Processes

2 3 4

- 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 caos and Murphy's Law.

1st

$\sim t_j = 2\,min$

$1.5\,min$

σ

$\mu = 3$

$2\,min$

C1 C2 C3

object

random numbers

1st

random

white

Events and Stochastic Processes

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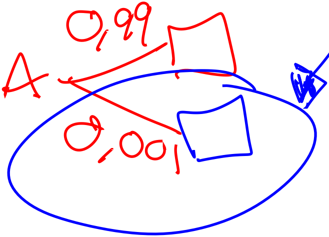

deterministic + stochastic } chaos

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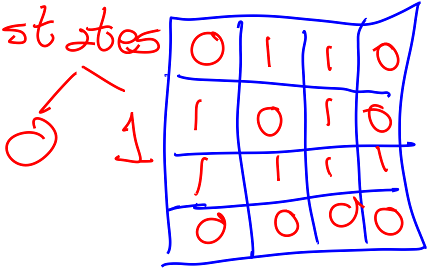
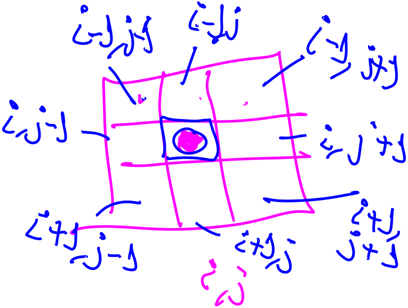
Celullar Automatas

- 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**.





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.

Social Dynamical

- 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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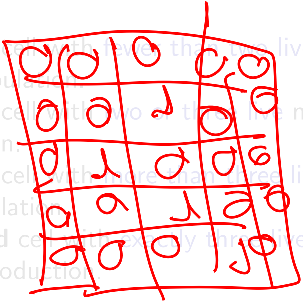
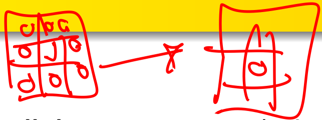


random

Game of Life



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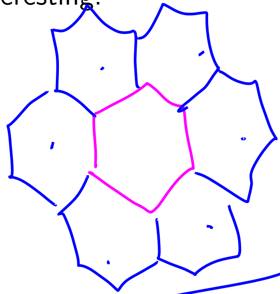
HoneyComb Cellular Automata

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

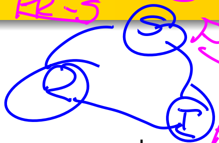


Sparse matrix

SIR Model

rate

PR-S



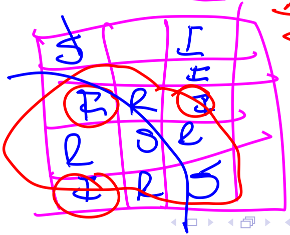
PS-I

PI-R

2003 ~ SARS

- 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:
  - $\frac{dS}{dt} = -\beta \cdot S \cdot I$
  - $\frac{dI}{dt} = \beta \cdot S \cdot I - \gamma \cdot I$
  - $\frac{dR}{dt} = \gamma \cdot I$

Infekta



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.

2D 3D $\frac{1}{2}$D $\frac{3}{4}$D

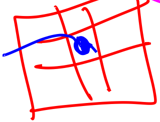
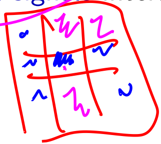
Fract

Mandelbrot

Turing Morphogenesis

The Basis of Morphogenesis

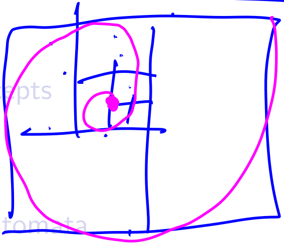
- Turing Morphogenesis is a theory of biological development that explains how patterns form in living organisms.
- The theory is based on the idea that chemical signals can interact to create patterns in a cellular automaton.
- The reaction-diffusion model is a common way to simulate **Turing morphogenesis**.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

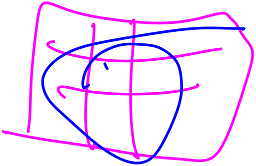




Outline

Fibonacci

0 1 1 2 3 5 8 13 21 . . . . .





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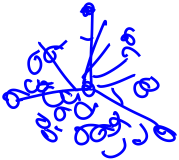
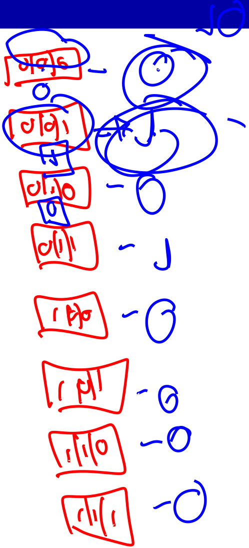
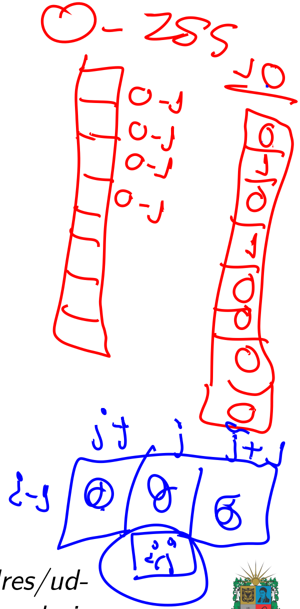




Thanks!

Questions?



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