Cellular automata approaches to biological modelling

Hjalmar Karlsson

Chalmers University of Technology

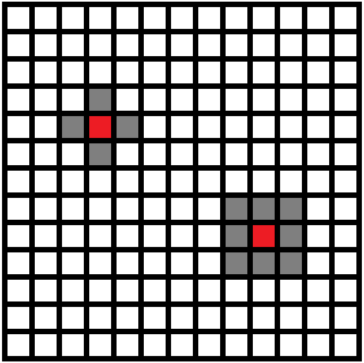
January 29, 2015

Introduction

Table of contents

Basic properties

- Discrete in time, space and state
- Small state space
- Acts locally and with finite speed



Benefits of using cellular automata

- Highly parallelizable
- Fast and easy to implement
- Visual feedback
- Good first step in formalizing a theoretical mechanism in computational terms.

Biological cellular automata

Three broad classes:

- Deterministic automata
- Lattice gas
- Solidification models

Deterministic cellular automata

The state of the automaton at next time step is determined solely by the earlier states of its neighbours.

- Waves in excitable media
- Coupled oscillators
- Predator-prey models

Lattice gas models

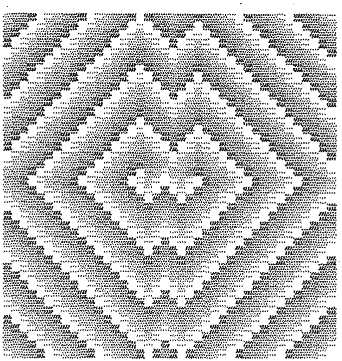
- Particles move in a medium over a discrete lattice
- State change when particles collide
- Steady spatial patterns
- Ant systems

Growth models

- Only sites adjacent to existing cells can be populated by new cells
- Once occupied, a site remains occupied
- Similar to diffusion-limited aggregation
- Fungal branching

Belousov-Zhabotinsky reactions

- Three states:
  1. Rest
  2. Excited
  3. Refractory
- Cells go from rest to excited if they are adjacent to an excited cell
- Excited cells goes automatically to refractory
- Refractory cells go back to rest



Belousov-Zhabotinsky reactions

- Three states:
  1. Rest
  2. Excited
  3. Refractory
- Cells go from rest to excited if they are adjacent to an excited cell
- Excited cells goes automatically to refractory
- Refractory cells go back to rest

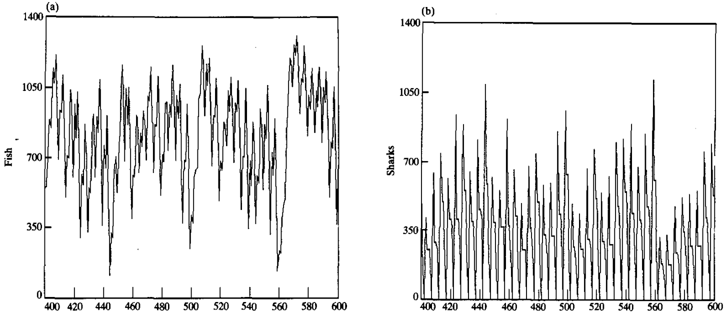
Coupled oscillators

- Study two-dimensional oscillatory medium
- Locally coupled oscillators
- Kuramoto model

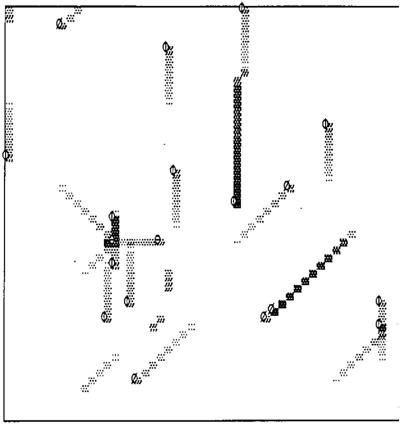
Predator prey model

- WATOR
  1. Fish and sharks move on a torus
  2. Fish reproduce to adjacent, empty cells after T_F generations
  3. Fishes are destroyed if adjacent to sharks
  4. Sharks reproduce after T_R generations if they find fish
  5. Sharks starve after T_S generations unless they find fish
- Behaves like the Lotka-Volterra model

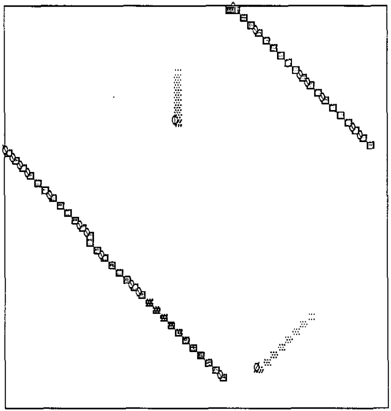
Predator-prey model



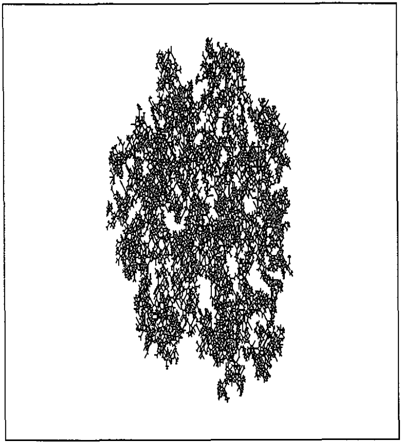
Ant trails



Ant trails



Fungal branching



Final remarks

- How to use CA
  1. Mechanism
  2. CA rule
  3. Validate, go back to 2 or
  4. Try to formulate a mathematical rule for the mechanism
- First step in going from verbal and non-rigorus statement of mechanisms to a formal model
- Current state of cellular automata usage