CITS4403
Computational Modelling

Week 7 Lecture: Agent-based Modelling I

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Semester 2, 2024
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LECTURE PLAN

W7 Lecture: Agent-based Modelling I

1. **Agent-based Model**
2. Schelling’s Model
   - Implementation
3. Sugarscape model
   - Implementation
4. Project Specification Released

Agent-based Model

Agent-based Model (ABM) is a computational model for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organisations or groups) to understand the behaviour of a system and what governs its outcomes.

ABMs are stochastic models that include randomness.

The three elements in Agent-based Model

1. Agent

people and other entities that gather information about the world, make decisions, and take actions.

The agents are usually situated **in space or in a network** and **interact** with each other locally.

Agent has autonomous behaviour which means it can change its behaviour in adapting to its surrounding.

They may be the same as their neighbours (homogeneous) or different to them (heterogeneous).

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The three elements in Agent-based Model

Compared to Cellular Automata:

- Cells in Cellular Automata can be considered as the representation of agents without spatial movement.
- What makes ABM different from CA is that ABM allows the agent to **roam** in spaces whereas in Cellular Automata, the cell (agent) remains in a fixed spatial coordinate.

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The three elements in Agent-based Model

2. Environment

The environment is the encompassing system in which the agents exist. Environment can be characterised by the types of interactions that are allowed.

- **Spatial environments** allow agents to directly interact with each other. This environment can be as simple as a **2D grid**. Agents occupy a position and can interact with nearby agents (neighbours as defined in the model) or even with the environment itself.
- **Abstract environments** are generally used when agents do not directly interact with other agents, rather they interact with the environment.

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The three elements in Agent-based Model

3. Interaction

In ABM, the agent and environment interact towards themselves and towards each other’s. There are two main types of interaction:

- **Agent-to-Environment:** the Agent influences the Environment by changing the state of the cell in the Environment. Likewise, the changing state of environment influences the agent.

- **Agent-to-Agent:** query or obtaining information for the agent from other agents holds the most basic interaction in ABM.

Model of Segregation

Thomas Schelling proposed “Models of Segregation”, a simple model to simulate racial segregation.

- The Schelling model of the world is a grid where each cell represents a house. The houses are occupied by **two** kinds of agents (labelled by red and blue), in roughly equal numbers. **About 10% of the houses are empty**.
- Depending on the other agents in the neighbourhood (**8 neighbours**), agents are happy if they have at least two neighbours like themselves, and unhappy if they have one or zero.
- Choose an agent at **random** and check to see whether the agent is happy. If so, nothing happens; if not, the agent chooses one of the unoccupied cells (empty houses) at **random** and moves.

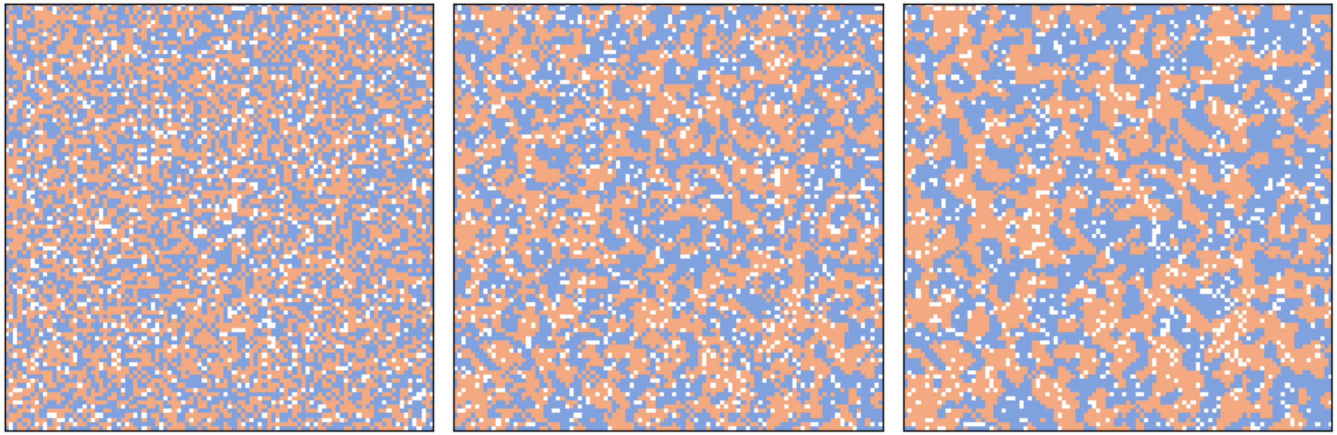
Implementing Model of Segregation

What pieces of machinery do we need?

- Initialise a grid randomly with 3 possible states
- Determine neighbourhood situation for each cell
- Assess whether happy or unhappy by comparing neighbourhood ratio with some defined model parameter
- Find unhappy agents
- Find empty locations
- Select (randomly) an unhappy agent and move it to a randomly selected empty location.
- Update neighbourhood, agent states, empty locations
- Repeat the process

Implementing Model of Segregation

We can watch the evolution of our simulation and observe snapshots in time:



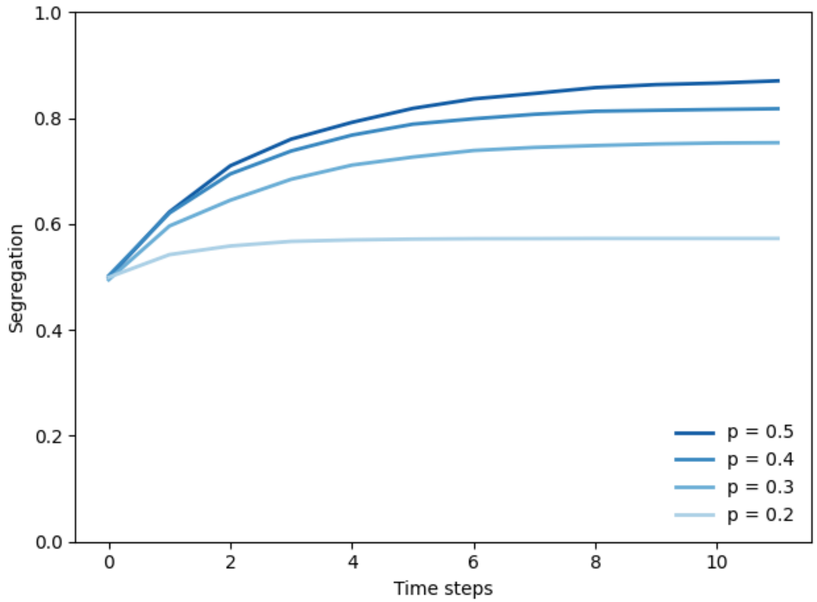
Initial configuration | After 2 steps | After 10 steps

Clusters form almost immediately and grow quickly, until most agents live in highly-segregated neighborhoods.

2 Implementing Model of Segregation

To Quantify the Segregation:

we can compute the degree of segregation, which is the average, across agents, of the fraction of neighbors who are the same color as the agent.



What we can conclude:

- If you did not know the process and only saw the result, you might assume that the agents were racist, but in fact all of them would be perfectly happy in a mixed neighbourhood.
- This is a very good demonstration of the unpredictable relationship between individual decisions and system behaviour.
- Schelling's model demonstrates a possible cause of segregation but says nothing about actual causes.

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Sugarscape

In 1996 Joshua Epstein and Robert Axtell proposed Sugarscape, an agent-based model of an “artificial society” intended to support experiments related to economics and other social sciences.

Agents move around on a 2-D grid, harvesting and accumulating “sugar”, which represents economic wealth. Some parts of the grid produce more sugar than others, and some agents are better at finding it than others.

This version of the model is used to explore and explain the distribution of wealth, particularly the tendency toward inequality.

Model of Wealth Distribution

The Sugarscape World (environment):

- Each cell in the 2D grid has a capacity (maximum amount of sugar it can hold).
- There are two high-sugar regions, with capacity 4 (peaks), surrounded by concentric rings with capacities 3, 2, and 1.

The Agents: 400 agents are placed at random locations. Each agent has there randomly-chosen attributes.

- Sugar: how much sugar they start with;
- Metabolism: how much sugar they consume per time step;
- Vision – how far they can see (radius of k).

Model of Wealth Distribution

During each time step, agents move one at a time in a **random** order. **Each agent follows these rules:**

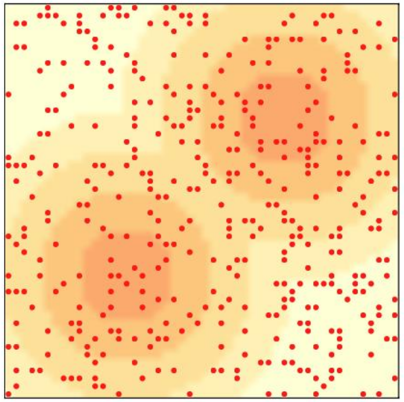
- The agent surveys k cells in each of the 4 compass directions, where k is the range of the agent's vision.
- It chooses the unoccupied cell with the most sugar. In case of a tie, it chooses the closer cell; among cells at the same distance, it chooses randomly.
- The agent moves to the selected cell and harvests the sugar, adding the harvest to its accumulated wealth and leaving the cell empty.
- The agent consumes some part of its wealth, depending on its metabolism. If the resulting total is negative, the agent "starves" and is removed.

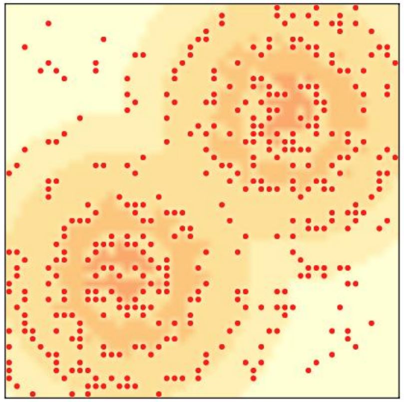
World (environment) update rules:

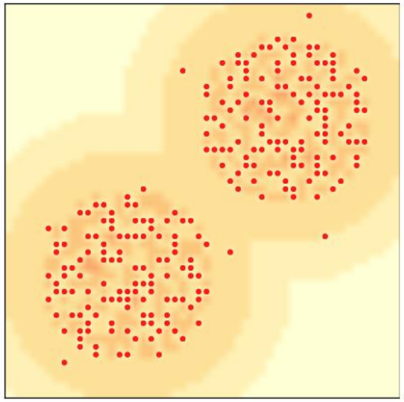
- After all agents have executed these steps, the cells grow back some sugar, typically 1 unit, but the total sugar in each cell is bounded by its capacity.

Model of Wealth Distribution

We can watch the evolution of our simulation and observe snapshots in time:


Initial configuration

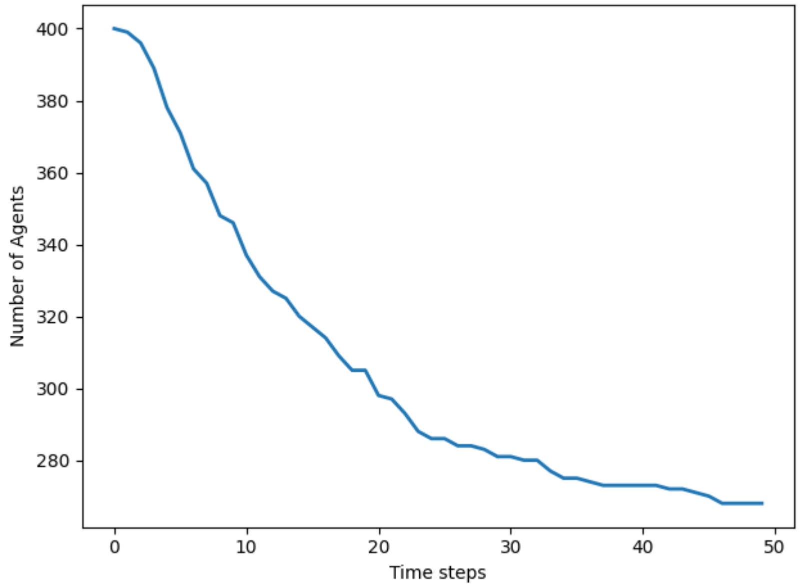

After 2 steps


After 10 steps

- Most agents are moving toward the areas with the most sugar.
- Agents with high vision move the fastest; agents with low vision tend to get stuck on the plateaus, wandering randomly until they get close enough to see the next level.

Model of Wealth Distribution

We can watch the evolution of our simulation and observe snapshots in time:



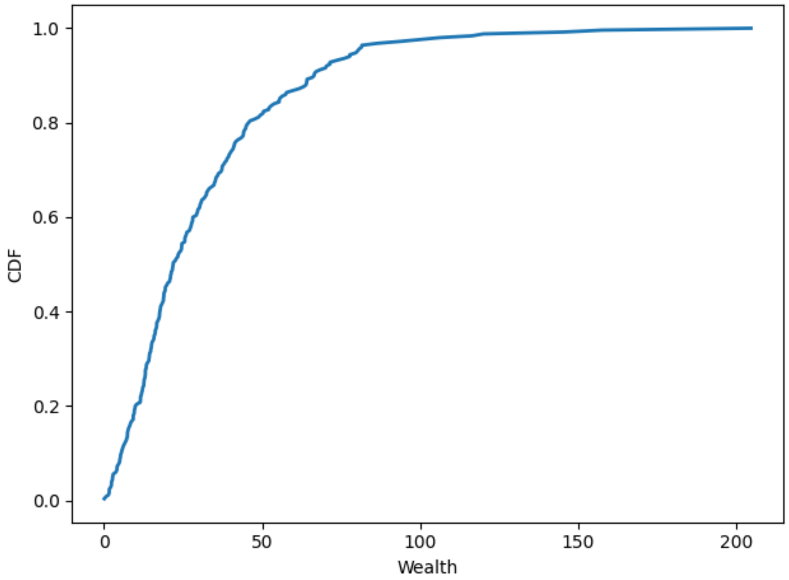
- Agents born in the areas with the least sugar are likely to starve unless they have a high initial endowment and high vision.
- The population will drop because when sugar grows back at 1 unit per time step, there is not enough sugar to sustain the 400 agents we started with.

Some other factors can be involved into the model?

- Agent’s age can increase at each time step
- Agents have finite lifespan
- New agent can be added to the environment if an existing agent died, to make the population unchanged.

Model of Wealth Distribution

if we give the agents finite lifespans, the model produces a stationary distribution of wealth. Then we can see what effect the parameters and rules have on this distribution.

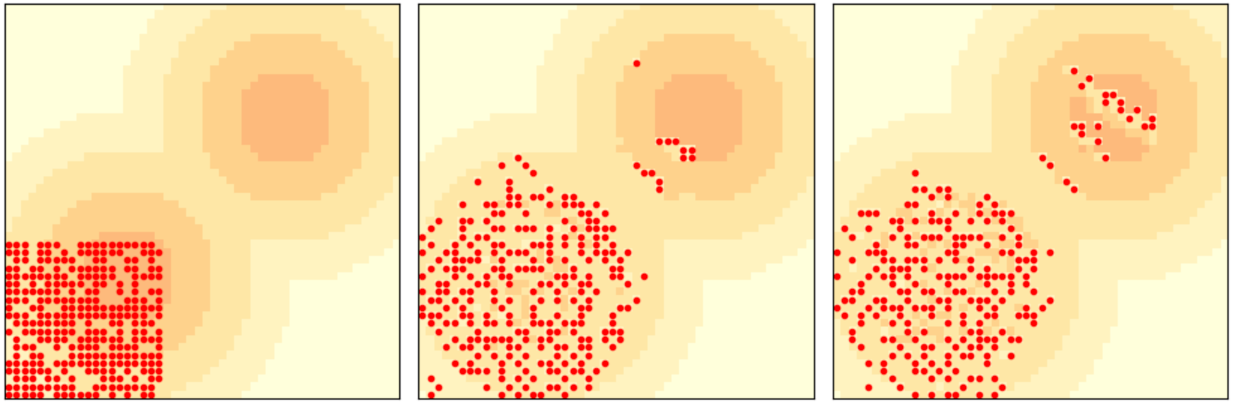


The cumulative distribution function (CDF) of sugar accumulated by the agents after 100 steps.

Cumulative Distribution Function (CDF), which maps from a value, x, to the fraction of values less than or equal to x.

Model of Wealth Distribution

Simulation outcome changes with different initial configuration, and new discovery found.



Initial configuration | After 6 steps | After 12 steps

- Start with all agents in the lower-left corner, they quickly move toward the closest "peak" of high-capacity cells, sugar are quickly exhausted, and agents are forced to move into lower-capacity areas.
- The agents with the longest vision cross the valley between the peaks and propagate toward the northeast in a pattern that resembles a wave front.

Emergence

An **emergent property** is a characteristic of a system that results from the interaction of its components, not from their properties.

Emergent properties are surprising — it is hard to predict the behavior of the system even if we know all the rules.

- The segregation we see in Schelling's model is an emergent property because it is not caused by racist agents. Even when the agents are only mildly xenophobic, the outcome of the system is substantially different from the intention of the agent's decisions.
- Sugarscape model with all agents start in the lower-left corner of the grid shows the outcome that — groups or "aggregates" with properties and behaviours that the agents don't have.

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The Project Specification can be found on LMS Unit Content Page!

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Project Specification

Submission Deadline: 14 October 2024, 11:59PM AWST

1 General Project Information

This project is to be completed in **a group of 2 students (maximum)**. We recommend you to come to the lecture and the lab, where you can meet others, find a group member and form a group. Individual submission is allowed for this project but please note **NO bonus mark will be given for individual submission**.

We strongly encourage healthy collaboration (please see the University of Western Australia Working in Groups Guide, and an early start on this project, so that you will have ample time to discover stumbling blocks.

Every group is required to submit the Group Registration Form (following this link) before **23 September 2024** even if you're doing the project individually. *Only ONE group member needs to submit the form for the group. Please do not submit the duplicated group registration.*