3: AUTHORED BEHAVIOURS II: EMERGENCE

COMP702: CLASSICAL ARTIFICIAL INTELLIGENCE

EMERGENCE

WHAT IS EMERGENCE?

- When something has a **property** that its **parts** alone do not have
- The whole is **different from** the sum of its parts

A PILE OF SAND

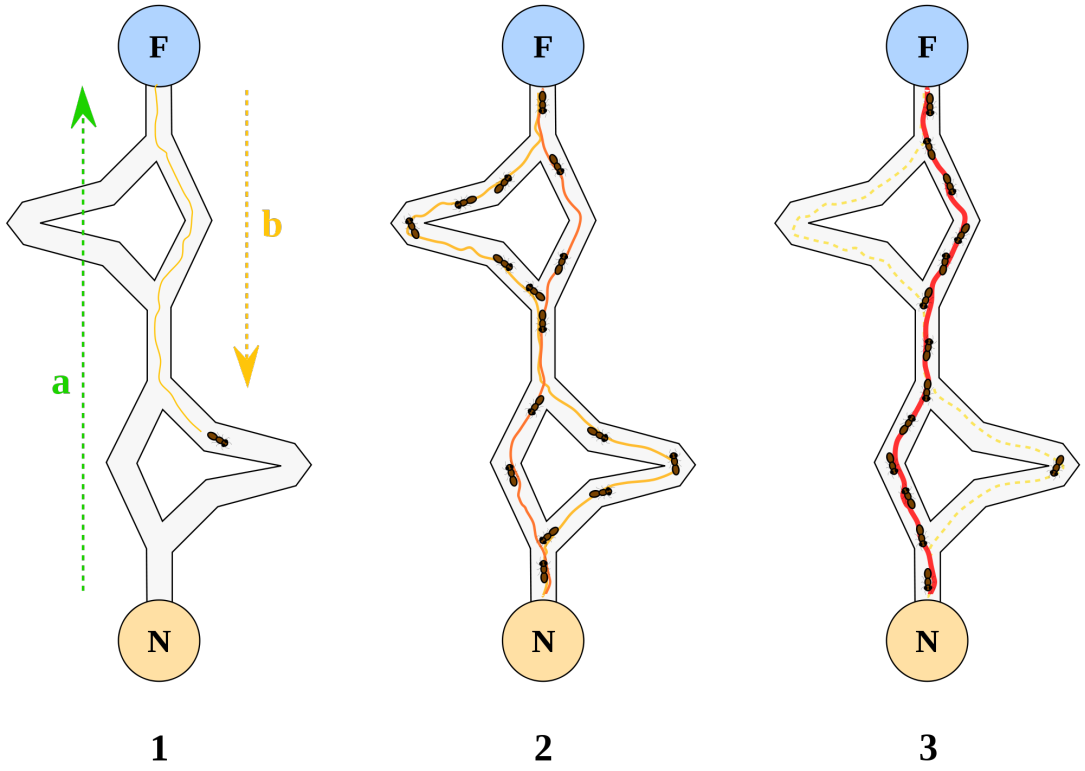
- Composed of many thousands of grains
- The size and weight of the pile comes from the sum of the individual grains → not emergent
- The slope of the pile comes from interaction of the grains with friction and gravity → emergent

ANTS

- The ant queen is not in charge!
- Individual ants react to **stimulus** (scent)
- Ants "coordinate" through **stigmergy**
  - Coordination by altering the **environment**
  - Ants lay **pheromones**, which other ants react to
- Complex behaviours (building nests, finding food, removing waste) emerge from simple behaviours by individual ants

ANT COLONY OPTIMISATION

- How real ants find food:
  - Wander randomly
  - On finding food, return to the nest (laying pheromones)
  - If there is a pheromone trail, follow it (but not perfectly)
- Algorithms inspired by this can be used for pathfinding, travelling salesman problems, network routing, …



FLOCKING, SCHOOLING, HERDING

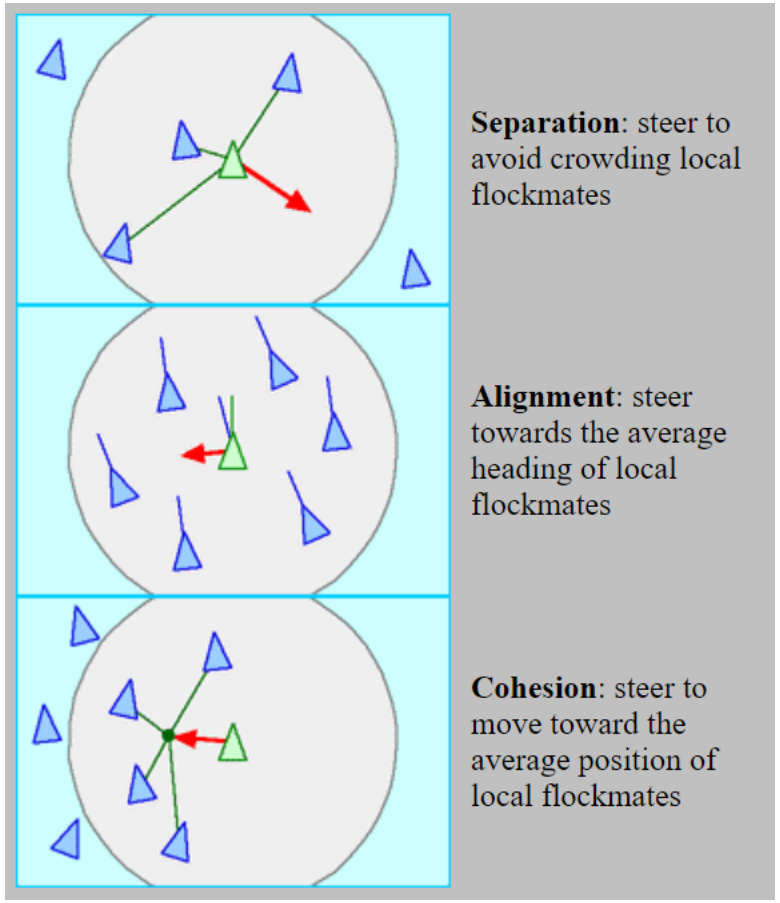
- Many animals exhibit complex group behaviours
  - Flocking in birds
  - Schooling in fish
  - Herding in land mammals
- Arising from simple behaviours
- There is no “leader” or “commander”

STARLINGS

- https://www.youtube.com/watch?v=eakKfY5aHmY

BOIDS

- Developed by Craig Reynolds in 1986
- Based on three simple rules: separation, alignment and cohesion
- Can also add obstacle avoidance, danger avoidance, goal seeking



SIMULATED STAMPEDE IN THE LION KING (1994)

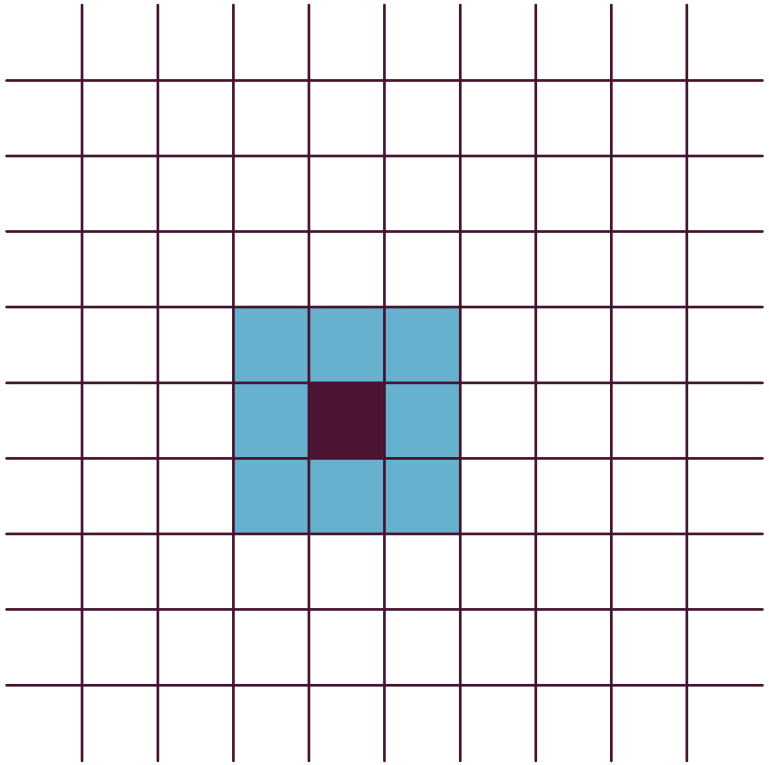
- https://youtu.be/FbLA0LS67XE?t=74
- https://youtu.be/HLmAT6t5kL0

SIMULATED CROWDS IN HITMAN: ABSOLUTION (2012)

- https://www.gdcvault.com/play/1016443/Crowds-in-Hitman

CELLULAR AUTOMATA

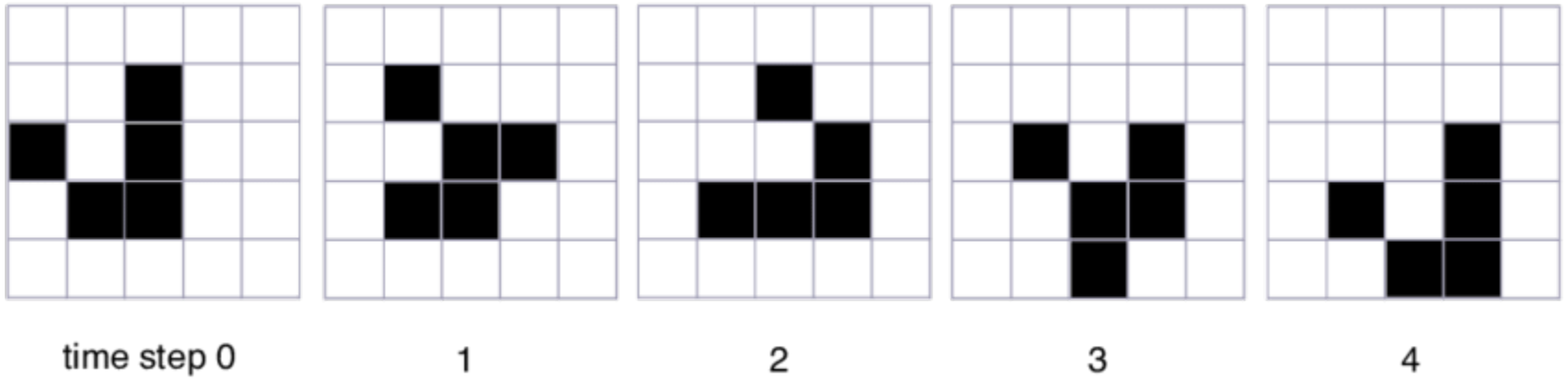
- A lattice of cells
- Each cell has a state
- Update rule applied to each cell every time step: gives new state of the cell as a function of the old state of the cell and its neighbours



CONWAY'S GAME OF LIFE

- Each cell has state 0 or 1
- A cell enters state 1 if:
  - Its state is 0 and exactly 3 of its neighbours are in state 1
  - Its state is 1 and exactly 2 or 3 of its neighbours are in state 1
- Otherwise it enters state 0
- https://www.samcodes.co.uk/project/game-of-life/

GLIDERS



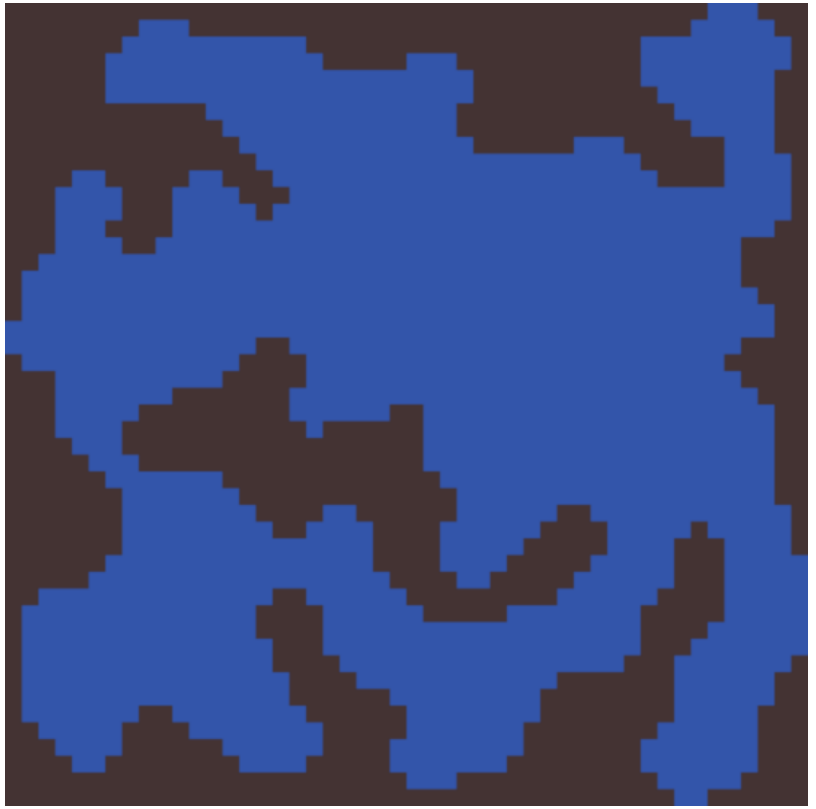
- This pattern of cells appears to move down and to the right every 4 time steps
- The cells themselves **don't move**
- The update rule just happens to give the **illusion** of movement

CONWAY'S GAME OF LIFE

- Many interesting emergent behaviours come from the simple rules of Conway's Game of Life
- It is possible to construct **logic gates** from interactions of gliders
- Conway's Game of Life is **Turing complete**!

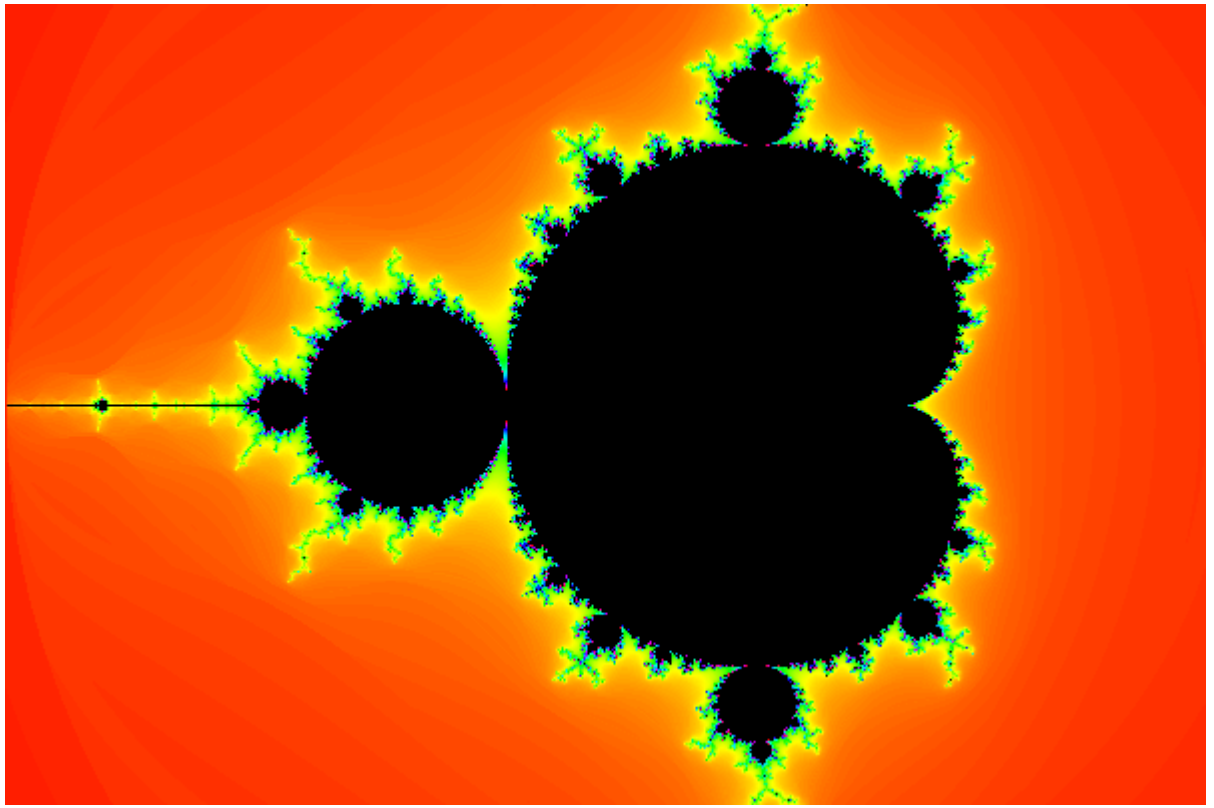
OTHER CELLULAR AUTOMATA

- Cave erosion (useful for PCG)
- Traffic simulation
- Fluid simulation
- …



FRACTALS

- Mathematical forms which exhibit self-similarity
- Typically generated by simple mathematical formulae, rules or transformations
- E.g. the Mandelbrot set: points on the complex plane for which the iteration $z = z^2 + c$ does not diverge
  - https://youtu.be/PD2XgQOyCCk



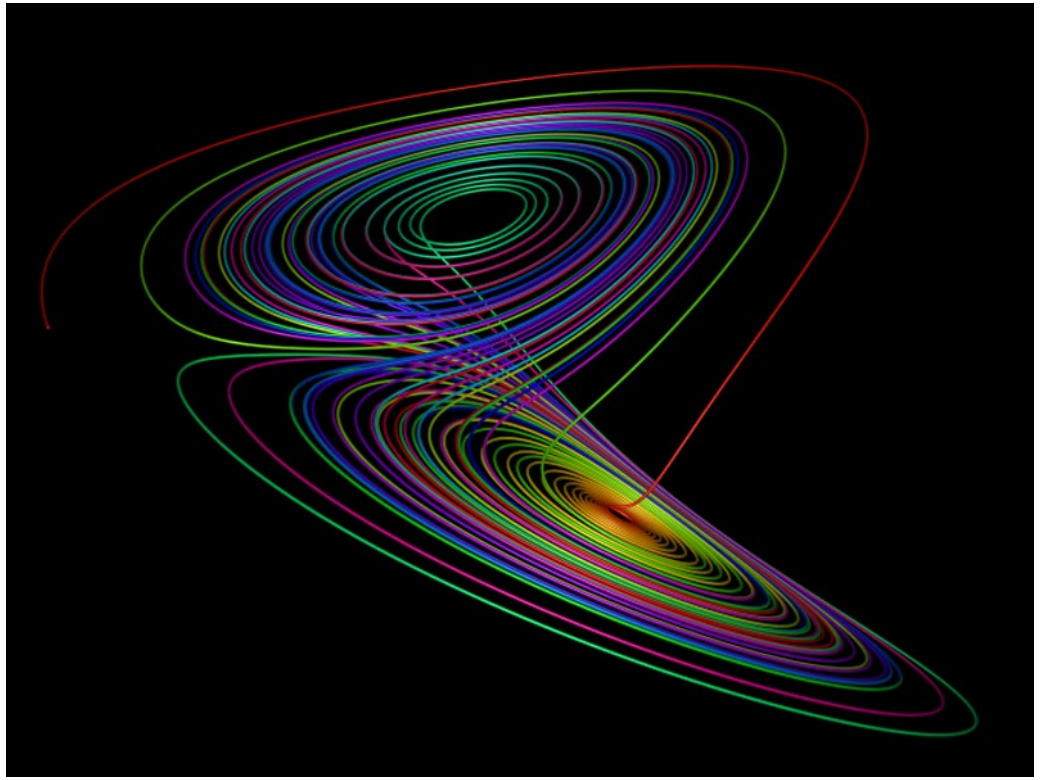
CHAOS

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \sigma(y - x),$$

$$\frac{\mathrm{d}y}{\mathrm{d}t} = x(\rho - z) - y,$$

$$\frac{\mathrm{d}z}{\mathrm{d}t} = xy - \beta z.$$

- Systems with emergence tend to be chaotic
- Sensitive dependence on initial conditions
- Unpredictable, even if deterministic (i.e. not random)



THE ULTIMATE EMERGENCE?

- The human brain is composed of billions of neurons
- A neuron is a relatively simple electro-chemical cell
- From them emerge intelligence, creativity, consciousness, …

USING EMERGENCE

- Emergence can mean that simple systems combine to give complex properties
- This can be a double-edged sword in terms of AI design
  - Pro: rich behaviours can emerge from relatively simple designs
  - Con: difficult to predict or design the behaviour that will emerge

WORKSHOP