



8: EMERGENCE

GAM330 MAJOR GAME DEVELOPMENT PROJECT: PRODUCTION



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



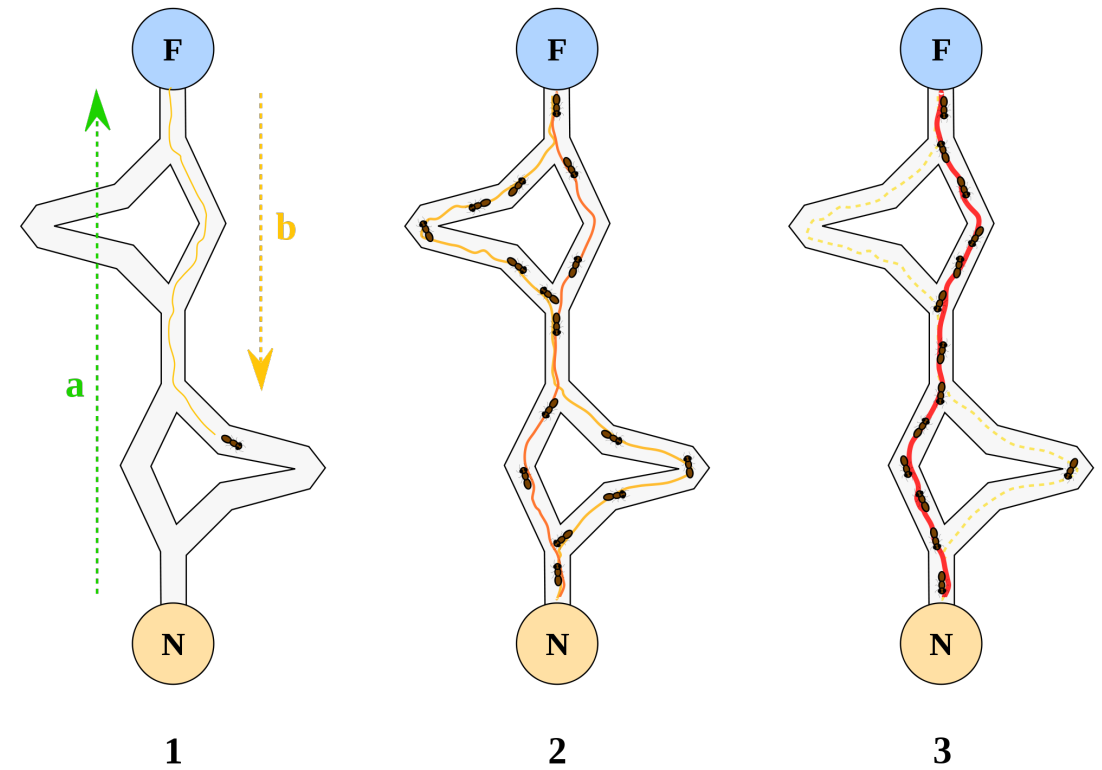
ANTS

- 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, ...

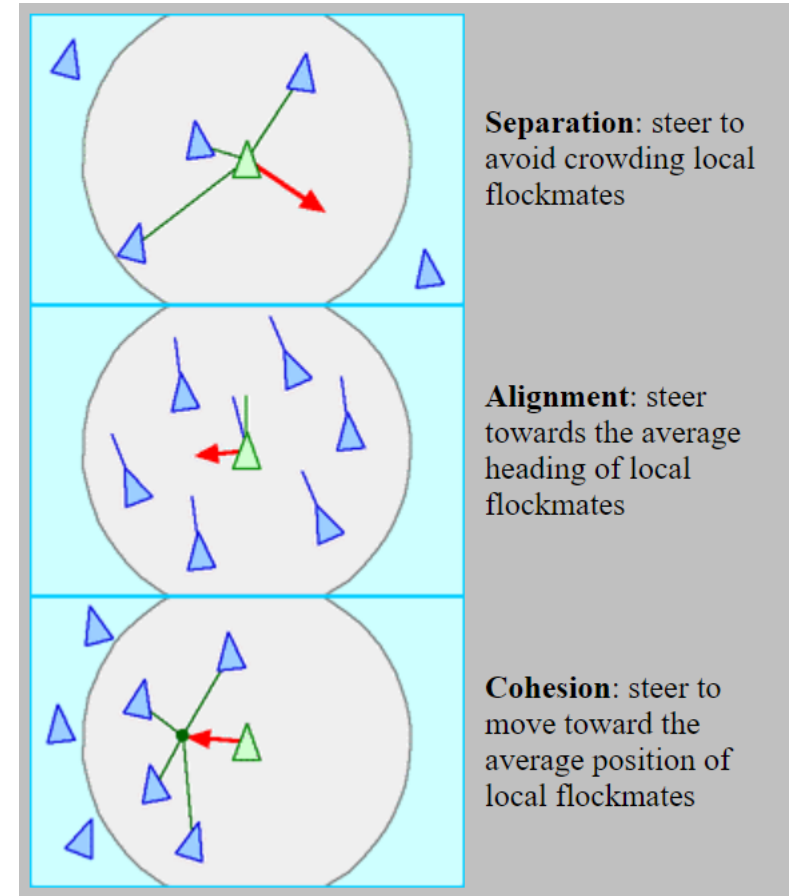


FLOCKING, SCHOOLING, HERDING

- 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”

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



STARLINGS

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



SIMULATED STAMPEDE IN THE LION KING (1994)

- <https://youtu.be/FbLA0LS67XE?t=74>
- <https://youtu.be/epd3mEpWjco?t=200>



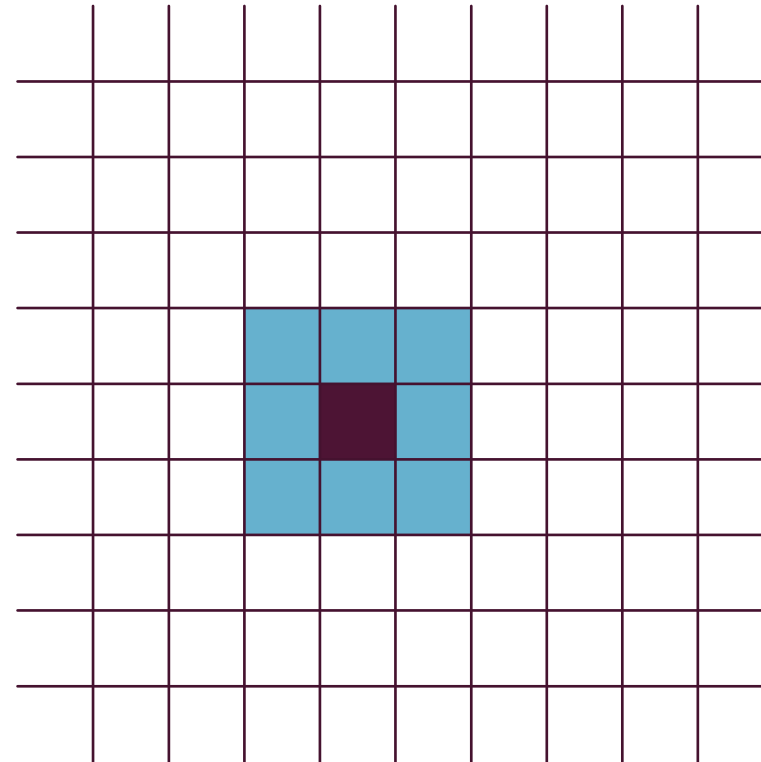
SIMULATED CROWDS IN HITMAN:ABSOLUTION (2012)

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



CELLULAR AUTOMATA

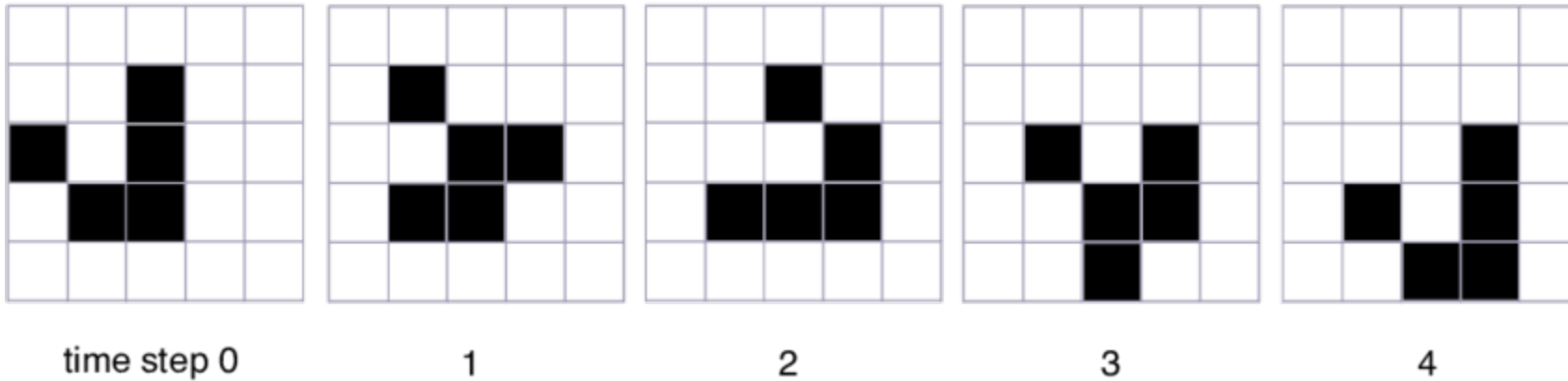
- A lattice of cells
- Each cell has a state
- Update rule applied to each cell every time step:
gives new state of the cell as a function of the
old state of the cell and its neighbours



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



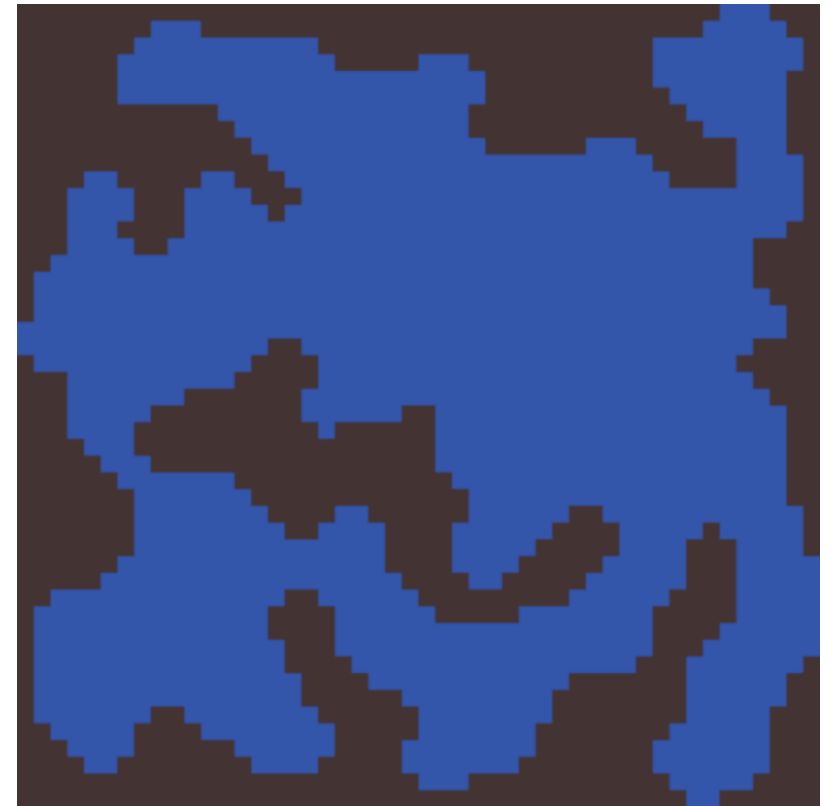
- This pattern of cells appears to move down and to the right every 4 time steps
- The cells themselves **don't move**
- The update rule just happens to give the **illusion** of movement

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!**

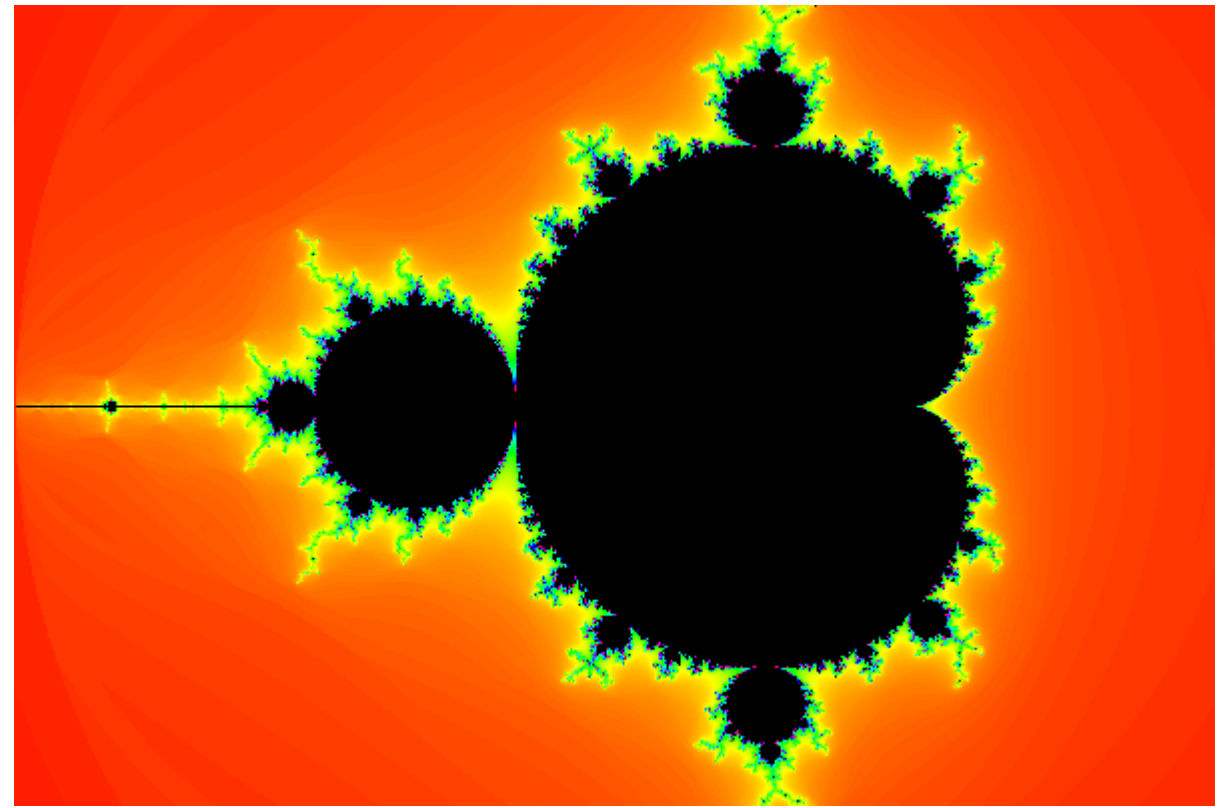
OTHER CELLULAR AUTOMATA

- 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>



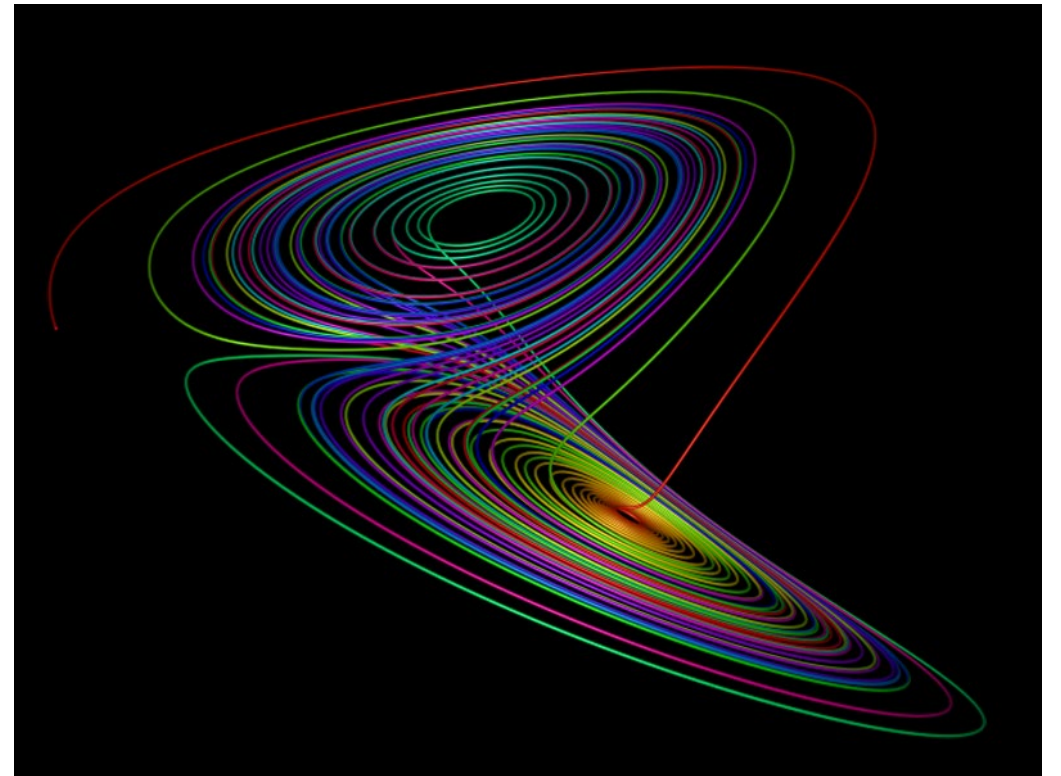
CHAOS

$$\frac{dx}{dt} = \sigma(y - x),$$

$$\frac{dy}{dt} = x(\rho - z) - y,$$

$$\frac{dz}{dt} = xy - \beta z.$$

- 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**
- **Emergent gameplay:** open-world games, RPGs, roguelikes, Deus Ex, System Shock
- **Emergent narrative:** simulation games, sandbox games, roguelikes, The Sims, Minecraft, Dwarf Fortress, Factorio
- This can be a **double-edged sword** in terms of game design
 - **Pro:** rich dynamics can emerge from relatively simple designs
 - **Con:** difficult to predict or design what will emerge
 - **Pro:** players can find their own creative solutions to problems
 - **Con(?):** it might be possible to break the game by finding unintended solutions
 - **Pro:** players “own” an emergent narrative
 - **Con:** emergent narrative can lack the emotional depth of traditional written narrative