Conway's Game of Life

Discover the world of cellular automata

What is the Game of Life?

- Created by John Horton Conway in 1970
- Cellular automaton
- Zero-player game

Rules

1. **Any live cell with fewer than 2 live neighbours dies (underpopulation)**
2. **Any live cell with 2 or 3 live neighbours survives to the next generation**
3. **Any live cell with more than 3 live neighbours dies (overpopulation)**
4. **Any dead cell with exactly 3 live neighbours becomes live (reproduction)**

The Halting Problem

- Some patterns can grow forever or behave unpredictably

Patterns

- Still life: unchanging patterns
- Oscillators: patterns that cycle through states and eventually return to their original shape
- Spaceships: patterns that move across the grid over time
- Methuselahs: small patterns that take a long time to settle down into stable forms

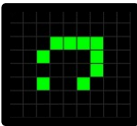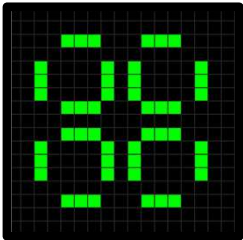| Class	Type	Size	Period
Glider	Spaceship	5	4
Exploder	Oscillator	13	8
10 Cell Row	Oscillator	10	2
LWSS	Spaceship	9	4
Pulsar	Oscillator	48	3
Pentadecathlon	Oscillator	12	15
Beacon	Oscillator	4x4	2
Gosper Glider Gun	Oscillator	36	30
R-Pentomino	Methuselah	5	1103
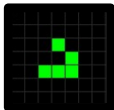
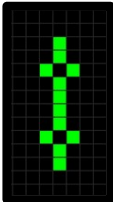Glider
(Spaceship)
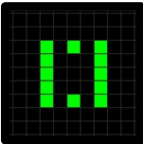
Exploder
(Oscillator)

10 Cell Row
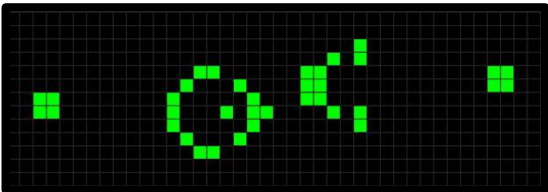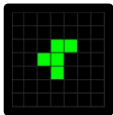(Oscillator)

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(Oscillator)

R-Pentomino
(Methuselah)

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The Bigger Picture

Significance

- Model for emergence: the concept which states that a complex system can arise from small simple interactions

- Turing-complete: it can simulate any computation, just like a real computer.

- The foundation for many research topics and areas.

Variants

- Highlife: a cell is born if it has 3 or 6 neighbours and survives if it has 2 or 3 neighbours (rule B36/S23)
- 3D life: the game of life in 3D space
- Lenia: continuous cellular automaton that generates evolving creatures
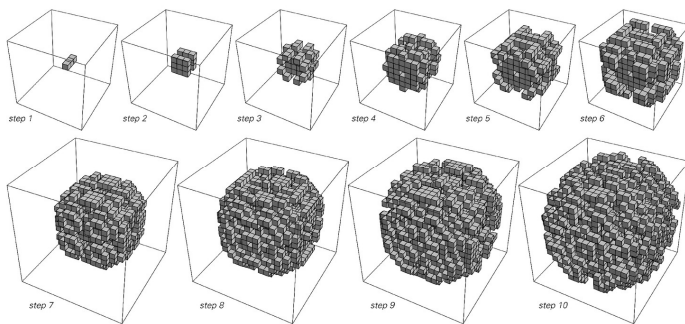
3D Life evolution over time

Image Sources

Highlife:
CA-NN: a cellular automata neural network for handwritten pattern recognition

3D Life:
A New Kind of Science by Stephen Wolfram (Chapter 5)

Lenia:
Lenia and Expanded Universe

Applications

- Evolutionary computation: used to test ideas about evolution, mutation, natural selection, and emergent behaviour (A-Life research)

- Chaos theory: the game of life demonstrates how local rules lead to global order in a self-organising system.

- Theoretical computer science: Turing-completeness allows us to study the limits of computation using the game of life

- Mathematics and logics: the game of life can be applied to explore combinatorics, number theory, recursion, and proofs.
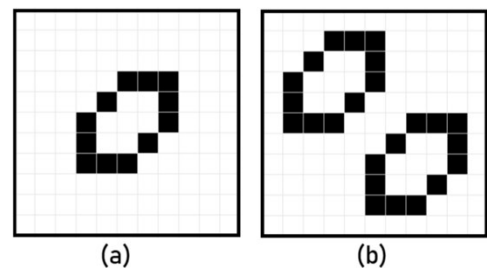
Highlife: (a) shows the initial state, (b) shows the resulting replicated pattern
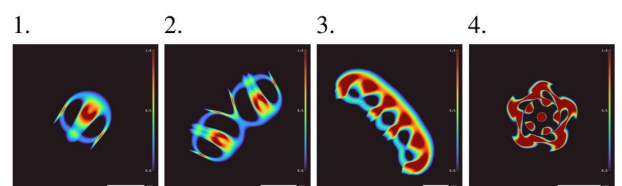
(a) Original Lenia: 1. *Orbium*; 2. *Orbium* individuals in elastic collision; 3. long-chain *Pentaptera*; 4. rotating *Asterium* with 5-fold rotational symmetry.
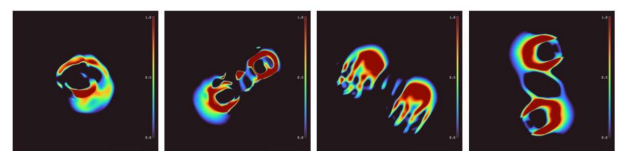
(b) Multi-kernel Lenia: 1. the first replicator discovered; 2. right after its self-replication; 3. solitons in parallel pair; 4. solitons in elastic collision, repulsive forces hinted by electricity-like lines.

Lenia Variants