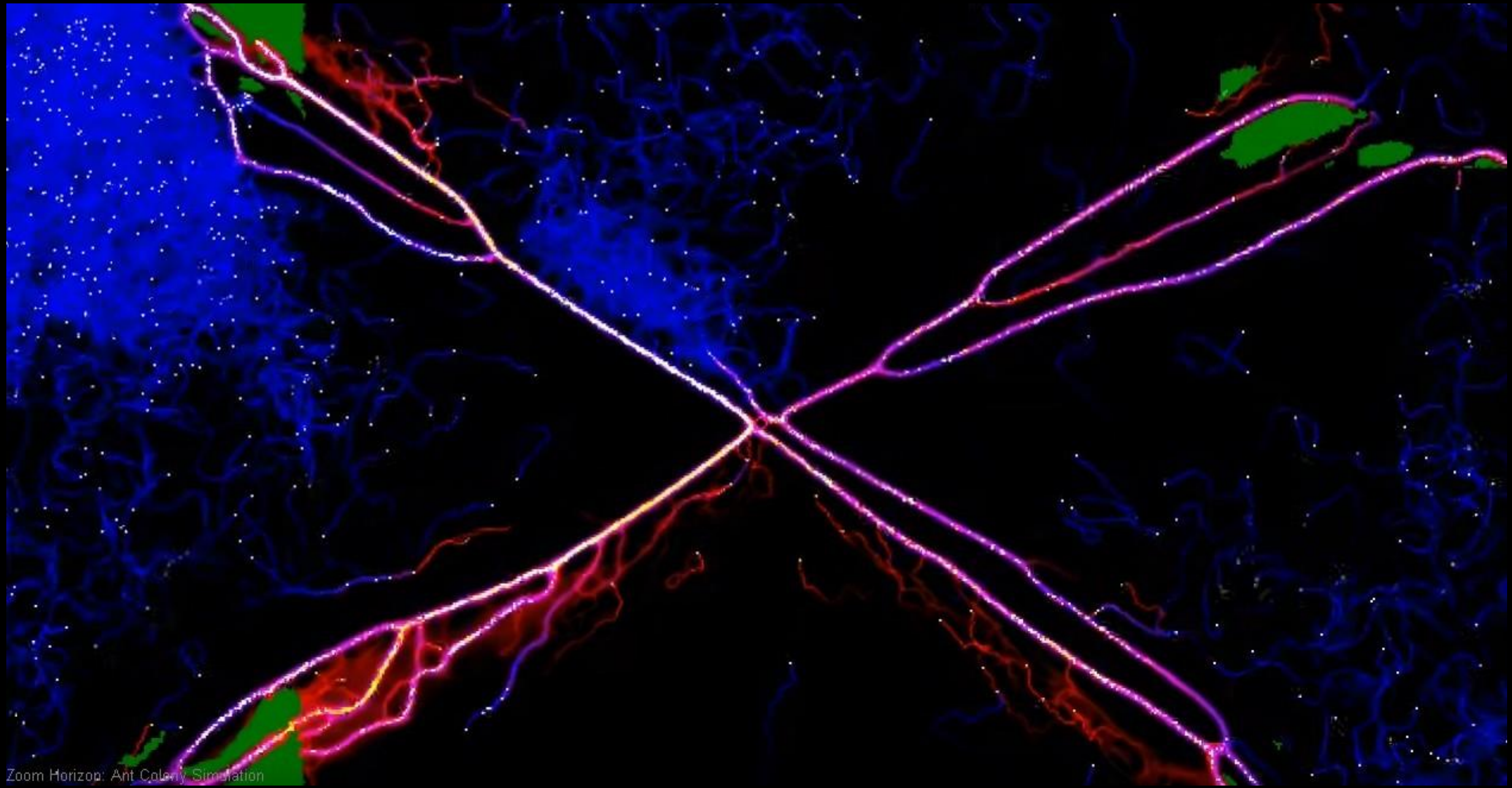
Computer modeling of physical phenomena



Karol Łukanowski & Tomasz Szawełło & Jakub Tworzydło

Rules

Schedule

- lecture part (45min – 1h)
- break (15 min)
- lab part (until completing the task or the end of classes)

Grading

- 0-1 point
- part finished during the classes – multiplied by 1
- part finished at home and graded on next classes – multiplied by 0.8
- extra task (optional) – 0.2 point, both when graded during current classes and during the next

Rules

Assessment

- lab score (where the maximum score is calculated without the extra tasks – it is possible to score more than 100%) – 80% of the total score
- final exam (11-12.06) – 20% of the total score

To pass the course it is necessary to meet all of the following conditions:

1. achieve at least 50% of the total score,
2. achieve at least 50% in the final exam,
3. prepare a short presentation summarizing one topic from the lectures.

The best presentations will be awarded an additional point!

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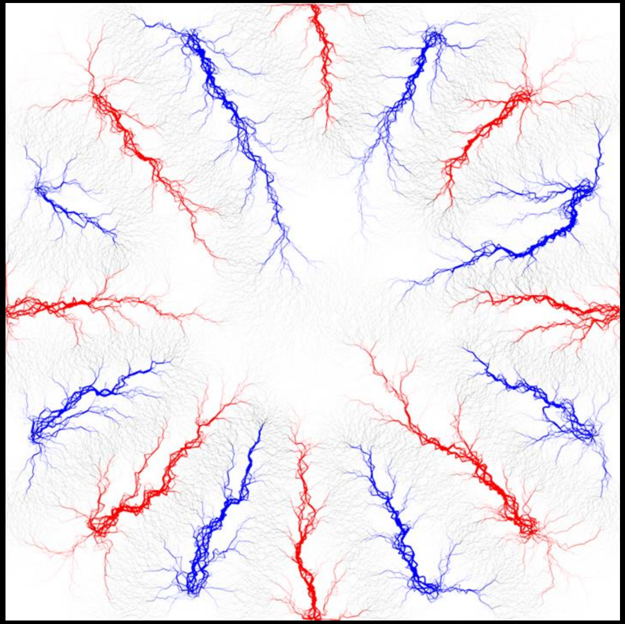
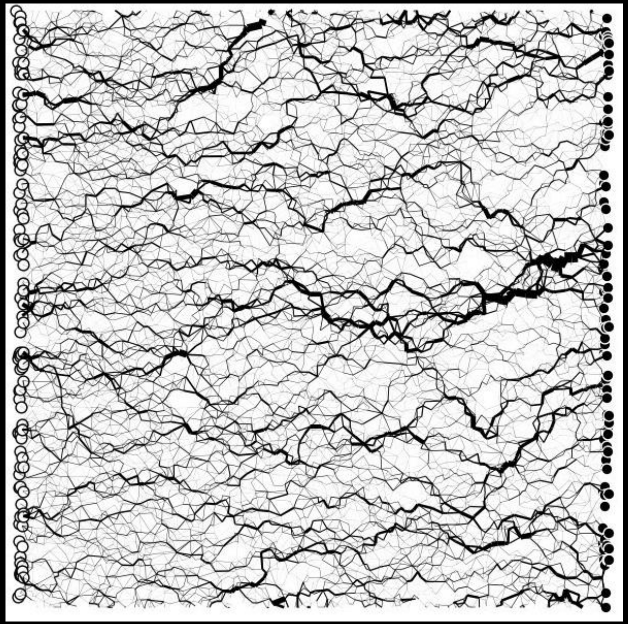
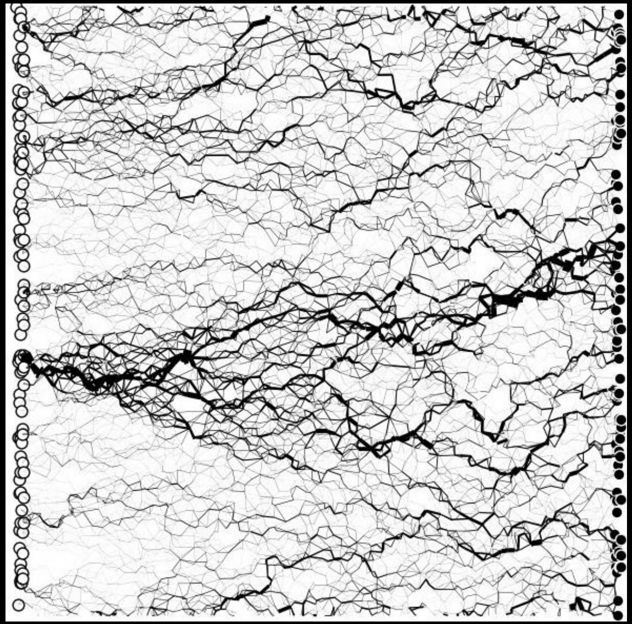
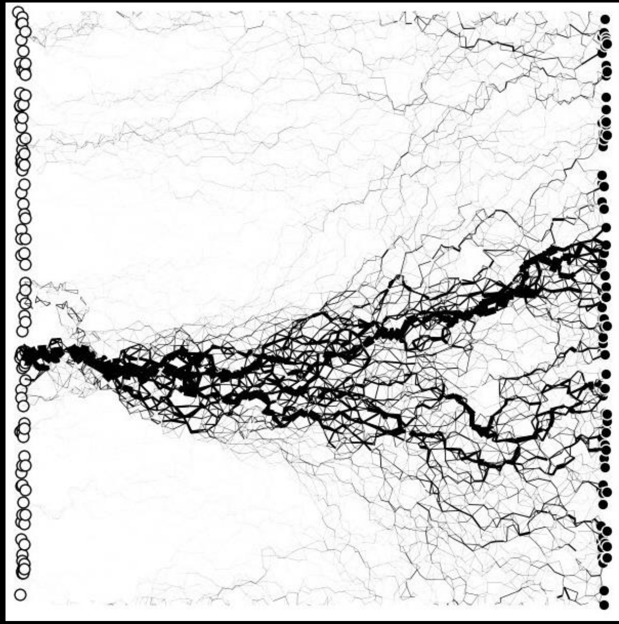
Consultation: Monday 11.15-13.00









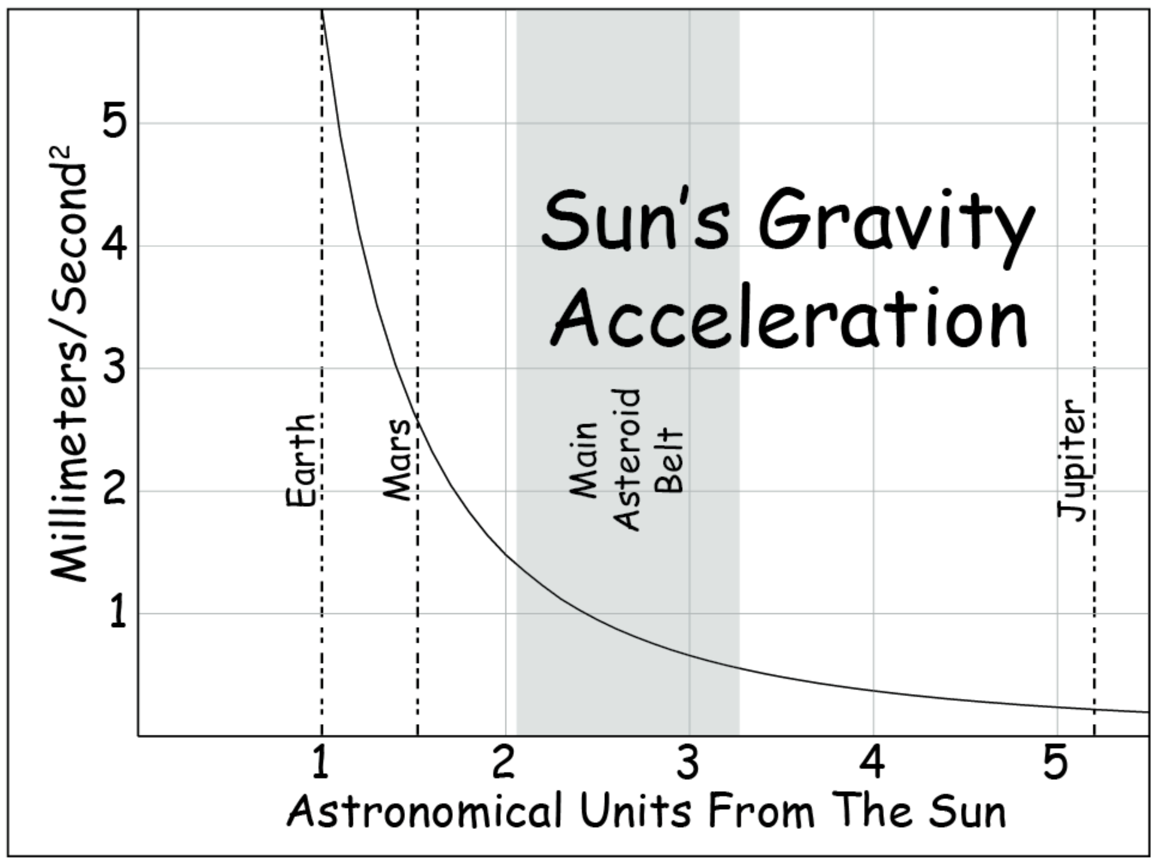
Computer modeling of physical phenomena

27-28.02.2024

Lecture 1: Modeling reality…
…a 2D discrete reality

Reality is complex…

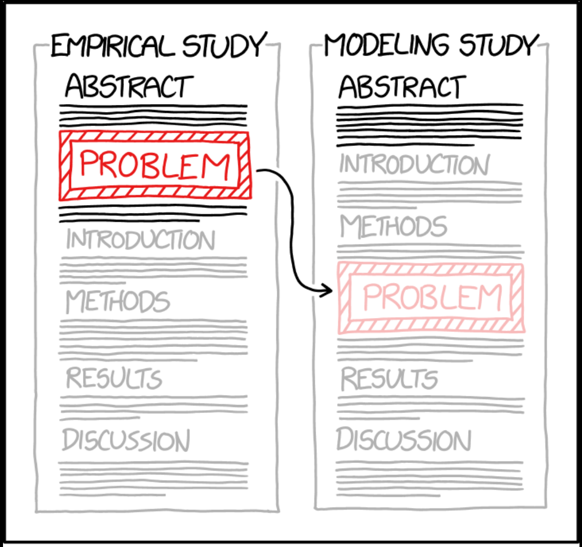
Reality is complex…



Modeling reality

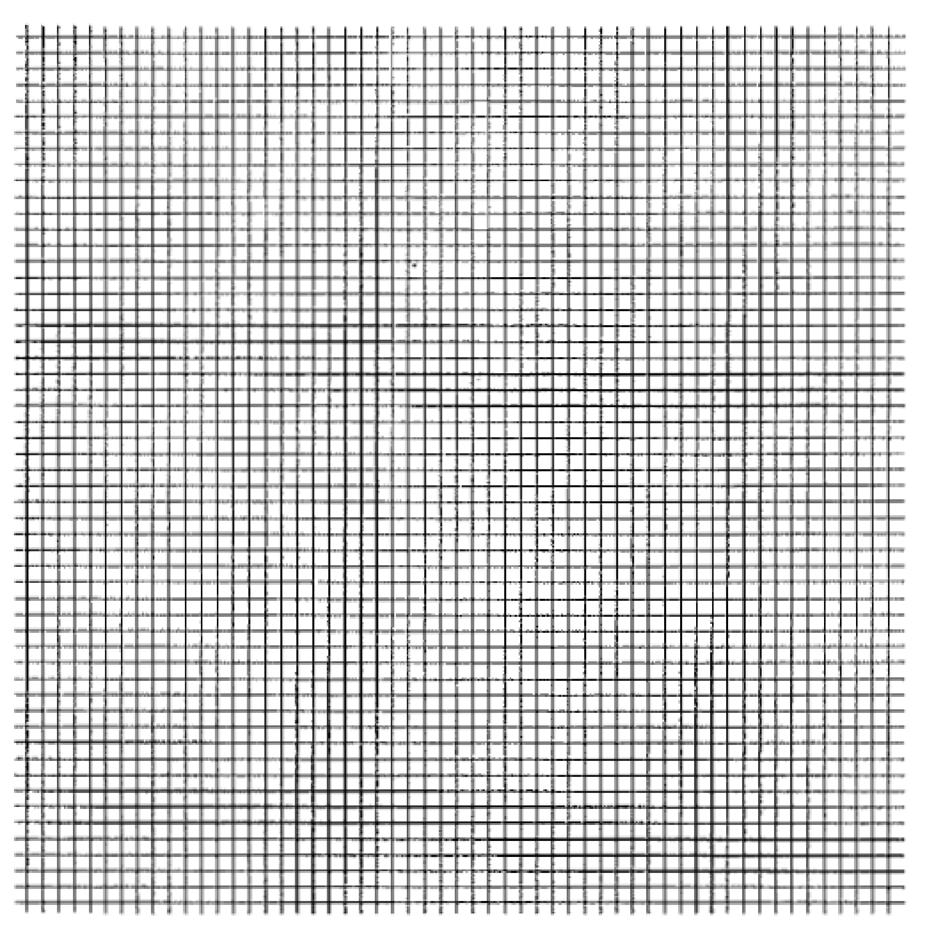
3 phases

1) Choosing a model for a given fraction of reality.
2) Building an algorithm to simulate the model.
3) Analyzing the results and making conclusions…



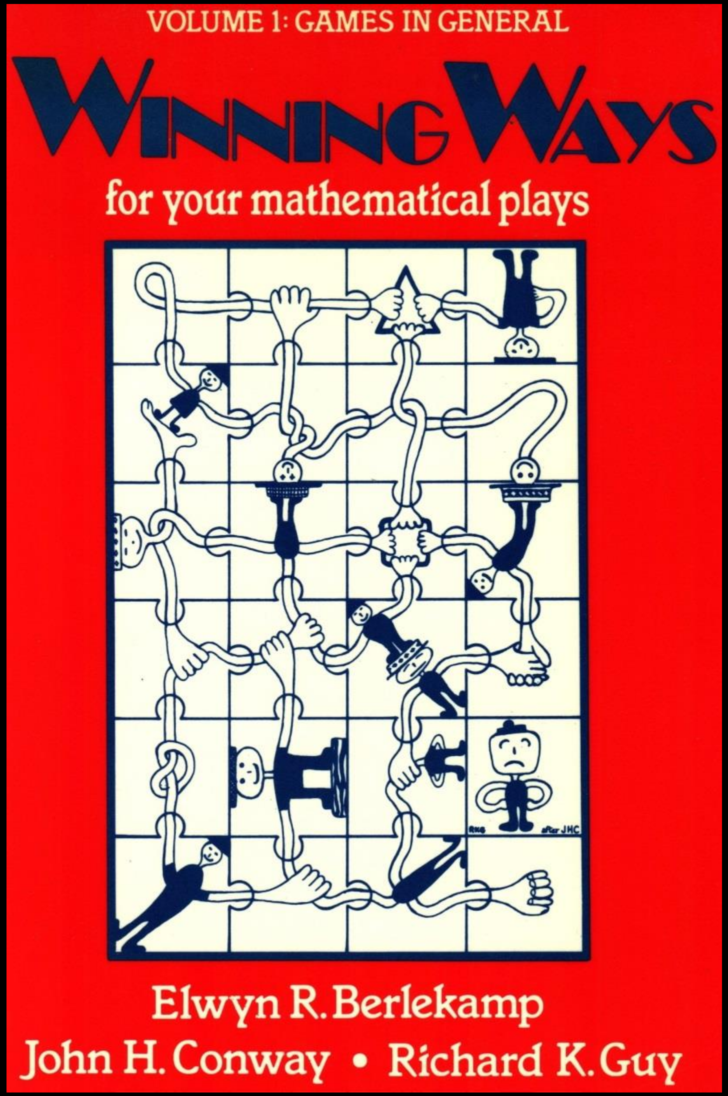
A MATHEMATICAL MODEL IS A POWERFUL TOOL FOR TAKING HARD PROBLEMS AND MOVING THEM TO THE METHODS SECTION.

Game of Life

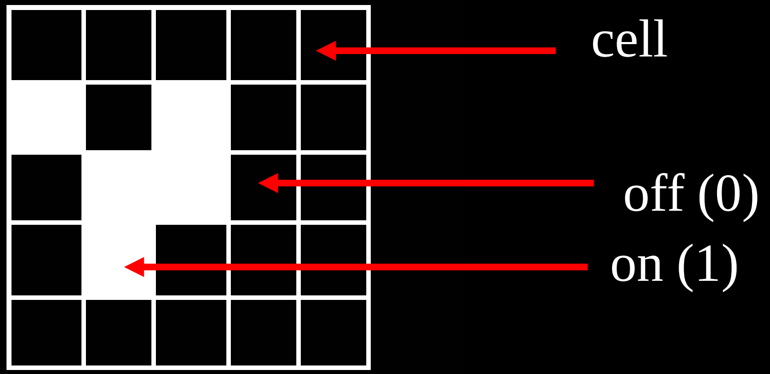


John Horton Conway

The rules first appeared in the October 1970 issue of Scientific American, in Martin Gardner's "Mathematical Games" column.

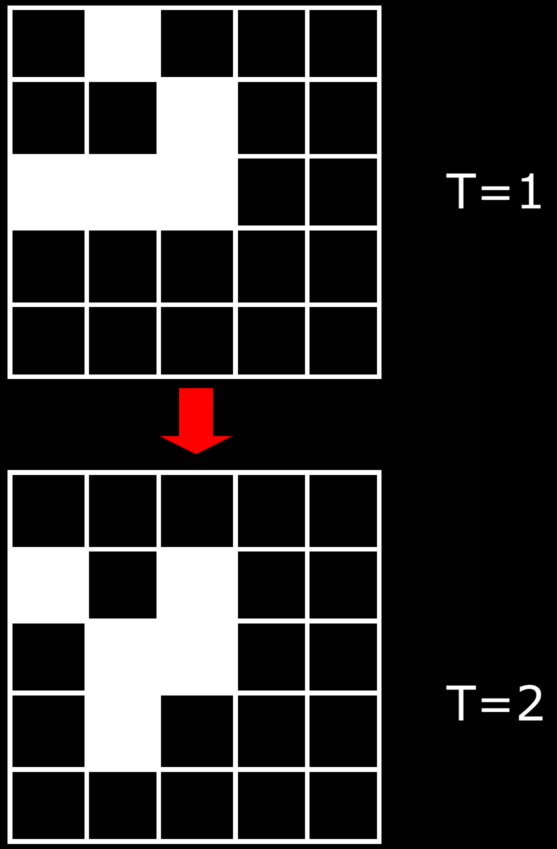


Cellular Automata



Automaton consists of a regular grid of cells,
each in one of a finite number of states.

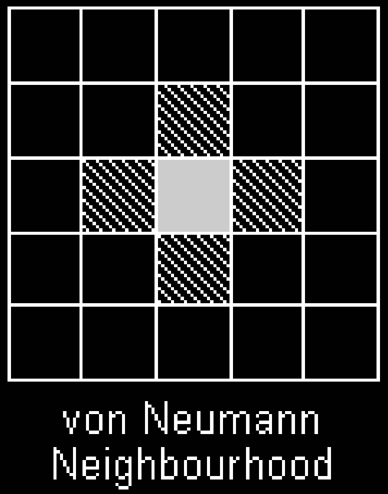
Evolution

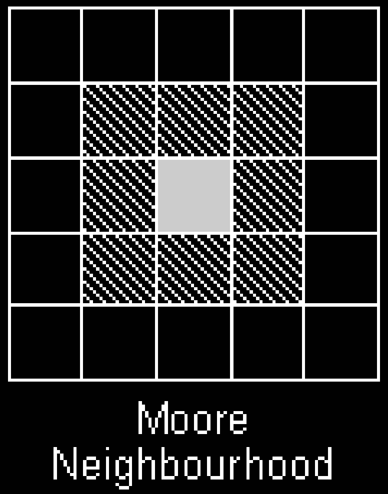


Cellular Automata evolve by changing the states of their cells according to transition rules, which set the future state of the cell based on the current state of it and its neighbours.

Neighbourhood

- defines the coupling between cells in the grid
- two typical neighbourhood types (in 2D):





Conway's criteria

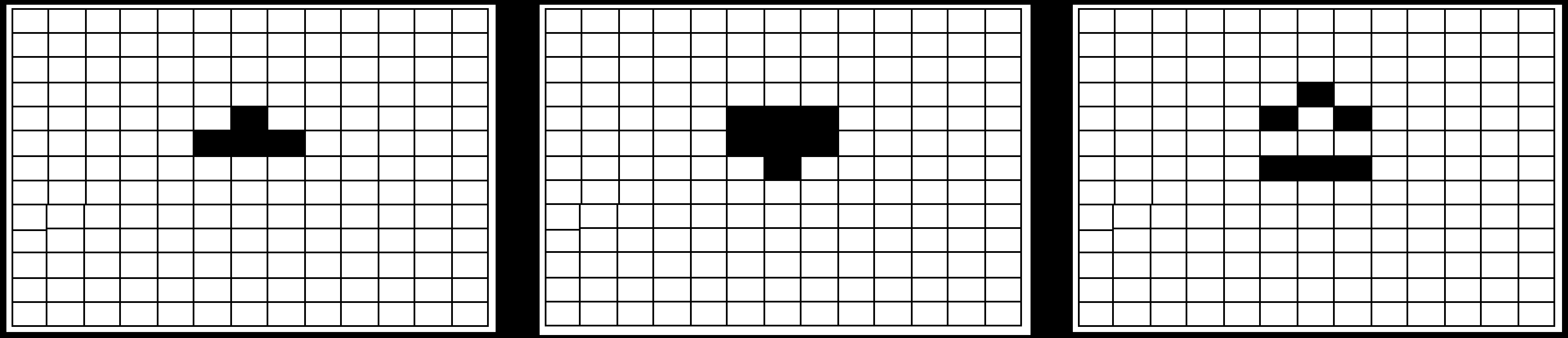
The rules should lead to interesting and unpredictable behaviour, i.e.:

1) There should be no initial pattern for which there is a simple proof that the population can grow without limit.
2) There should be initial patterns that apparently grow without limit.
3) There should be simple initial patterns that grow and change for a considerable period of time before coming to an end.

Conway's Game of Life

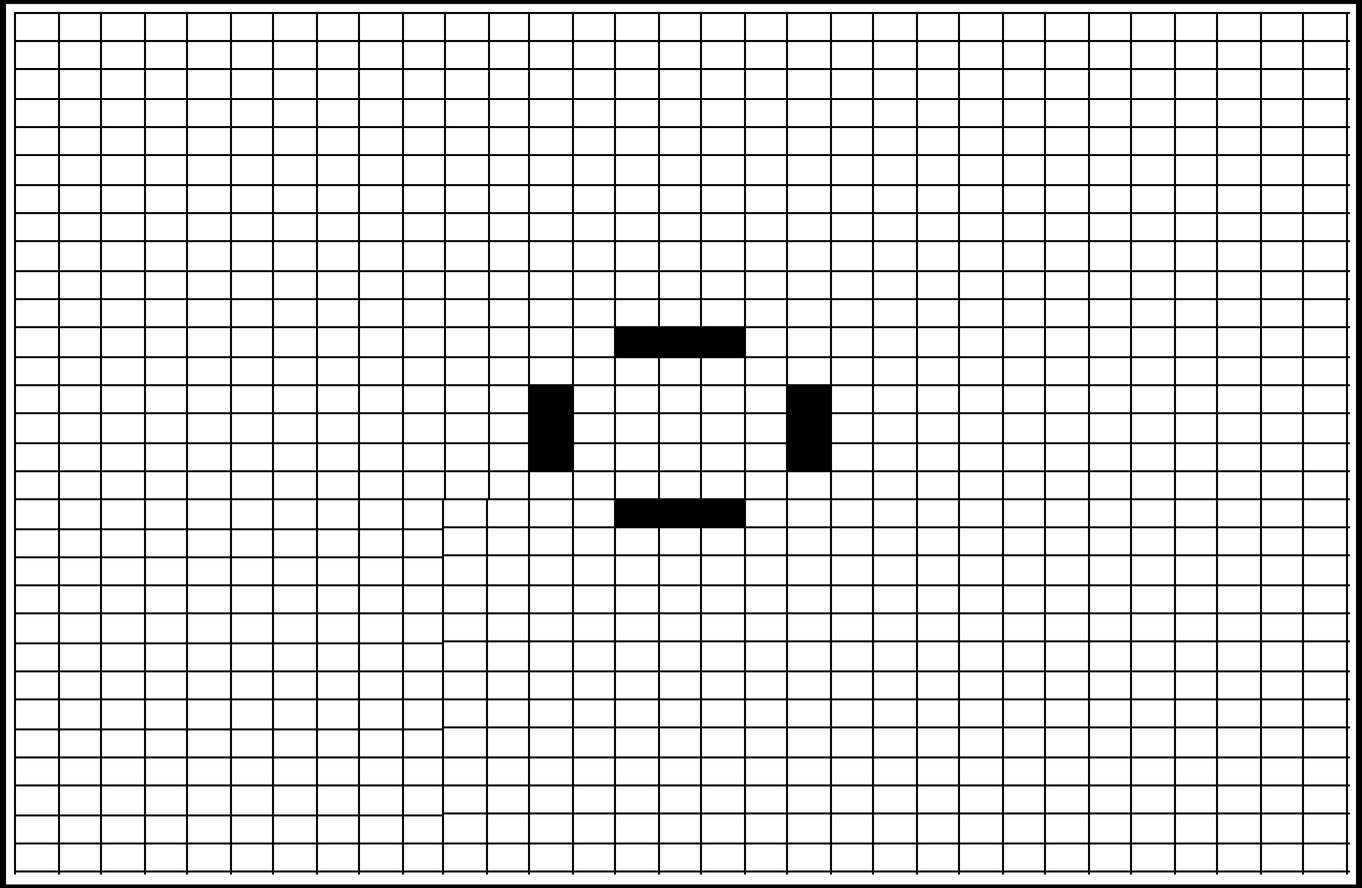
1) A dead cell becomes alive at the next generation if exactly three of its (Moore) neighbors are alive.
2) A live cell at the next generation remains alive if either two or three of its neighbors are alive but otherwise it dies.

Totalistic – rules depend only on the numer of live cells in a neighbourhood.

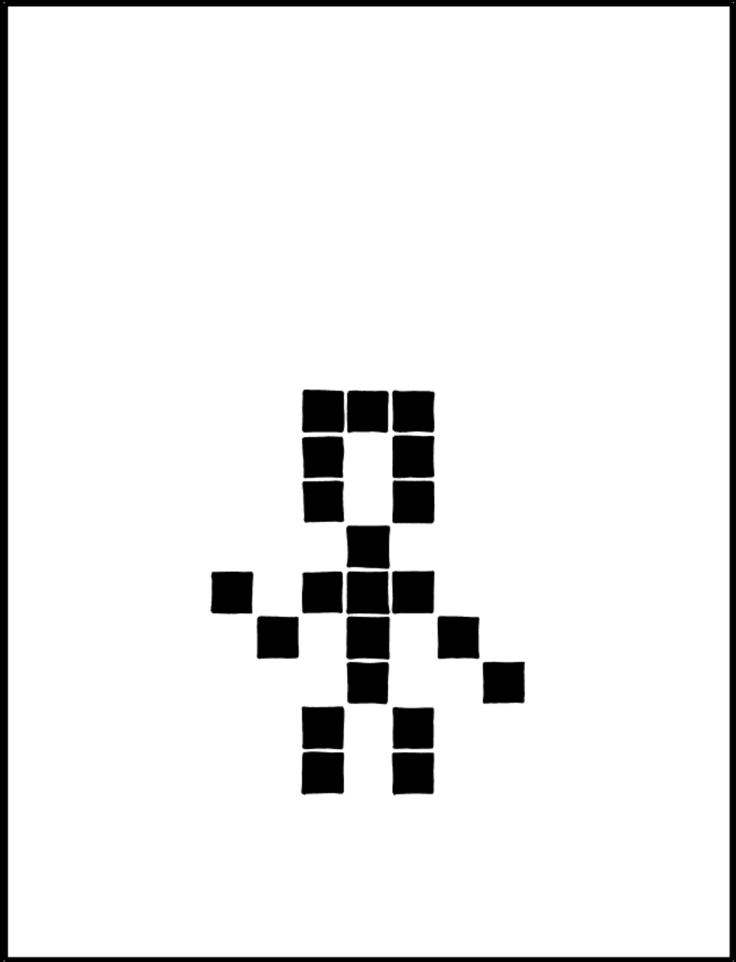


initial state step 1 step 2

Evolution...



Evolution...



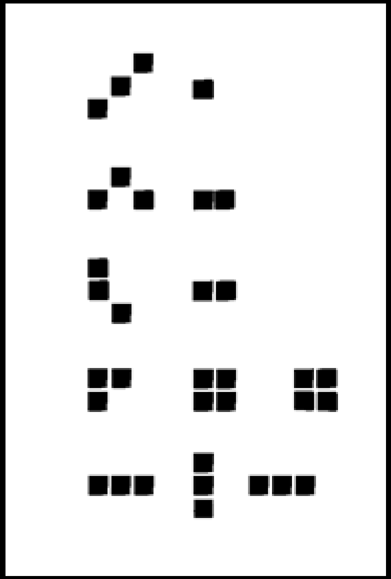
Modeling life?

It is probable, given a large enough 'Life’ space, initially in a random state, that after a long time, inteligent self-reproducing animals will emerge and populate some parts of the space.

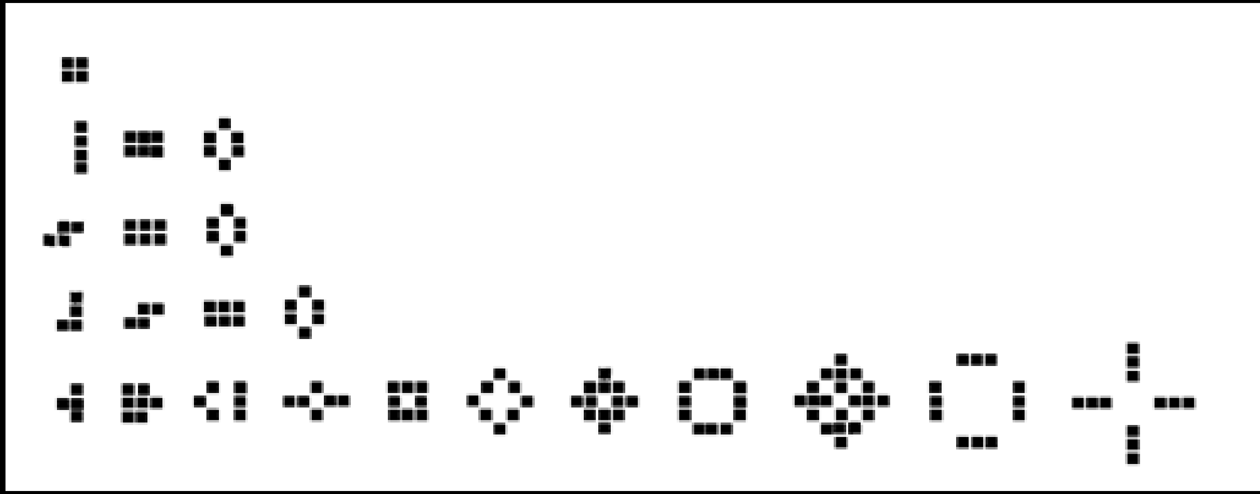
Life forms

N<3 cells always die out

triplets:

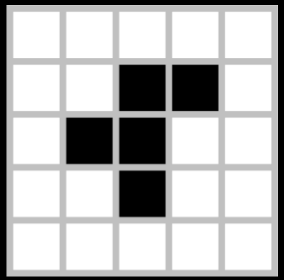


quadruplets:

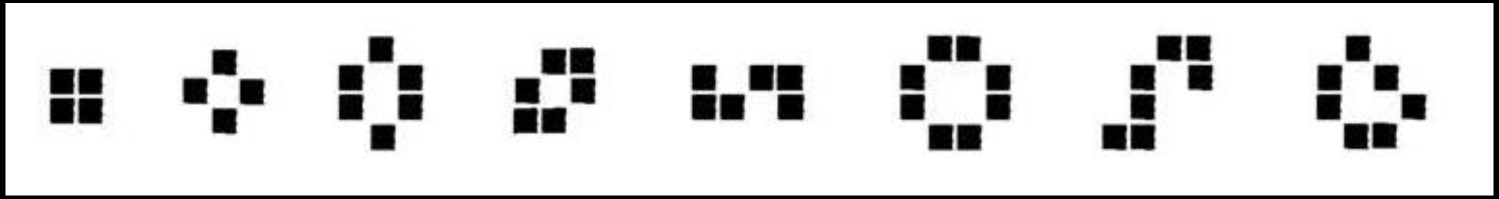


Conway set up a prize (50$) for a person who will prove, before the end of 1970, that no initial 'cell culture' will continue to extend without bounds…

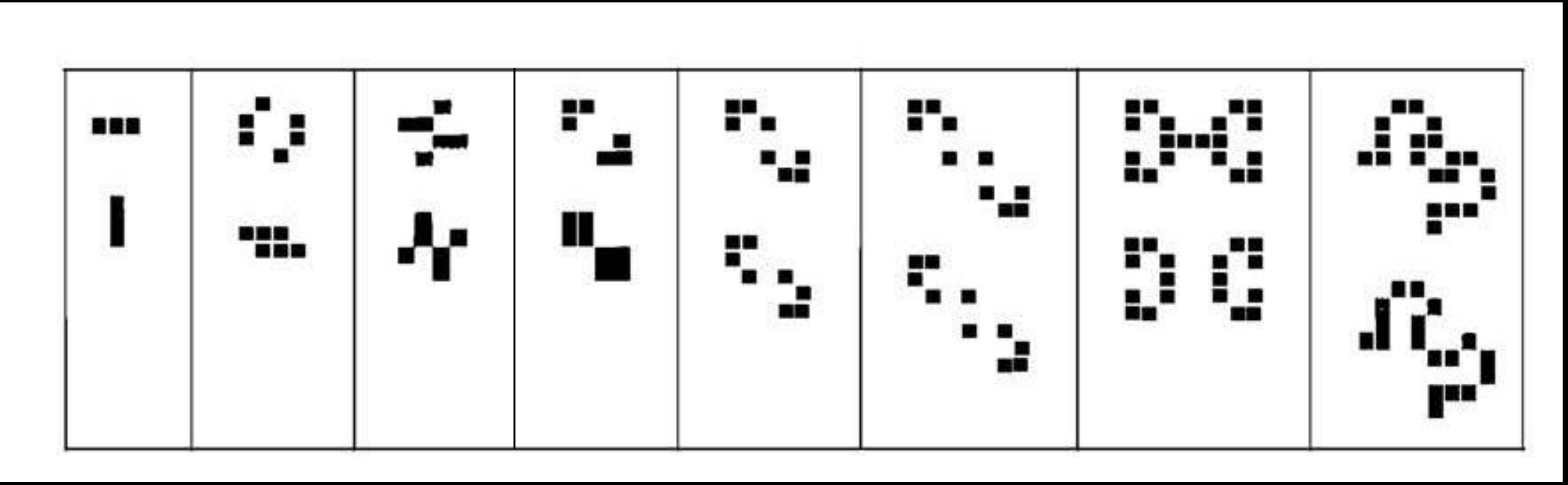
R-pentomino



Invariant forms and oscillators



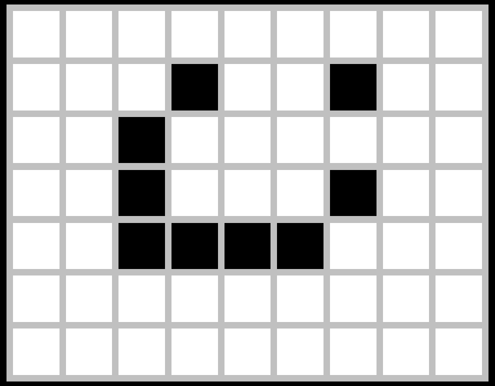
block tub beehive ship snake pond fishhook loaf



period-2 oscillators

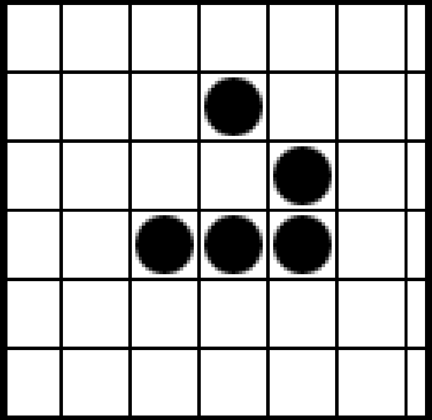
Spaceships

The maximal speed of information transmission in GoL universe c=1 (in grid lengths per unit time). Conway has shown that the maximum speed with which a form can move is equal to c/2; he called the forms moving with such a speed 'spaceships'.

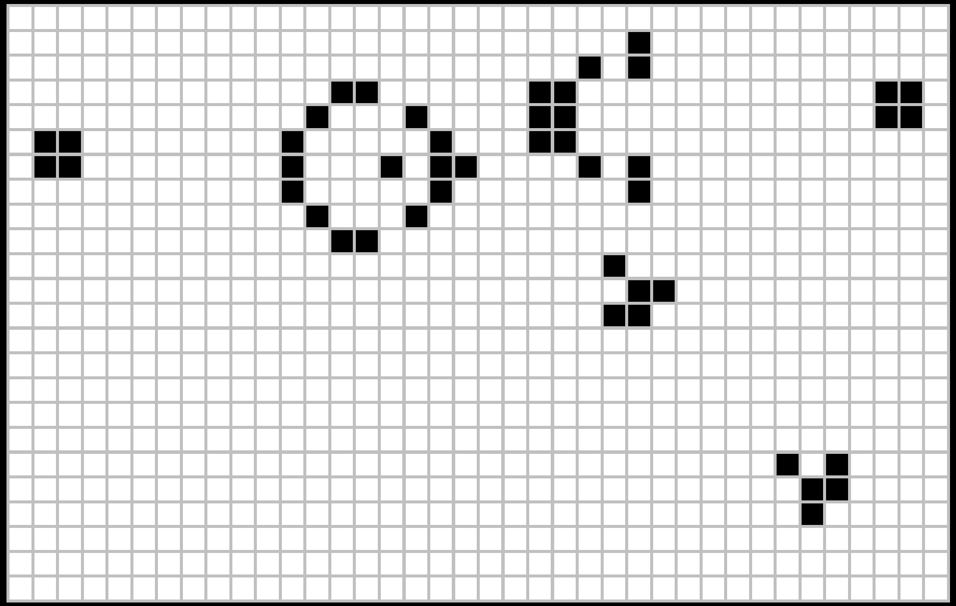


Gliders

Important life forms, moving with velocity c/4. Gliders are important because they are easily produced and can be collided with each other to form more complicated objects and can be used to transmit information over long distances.

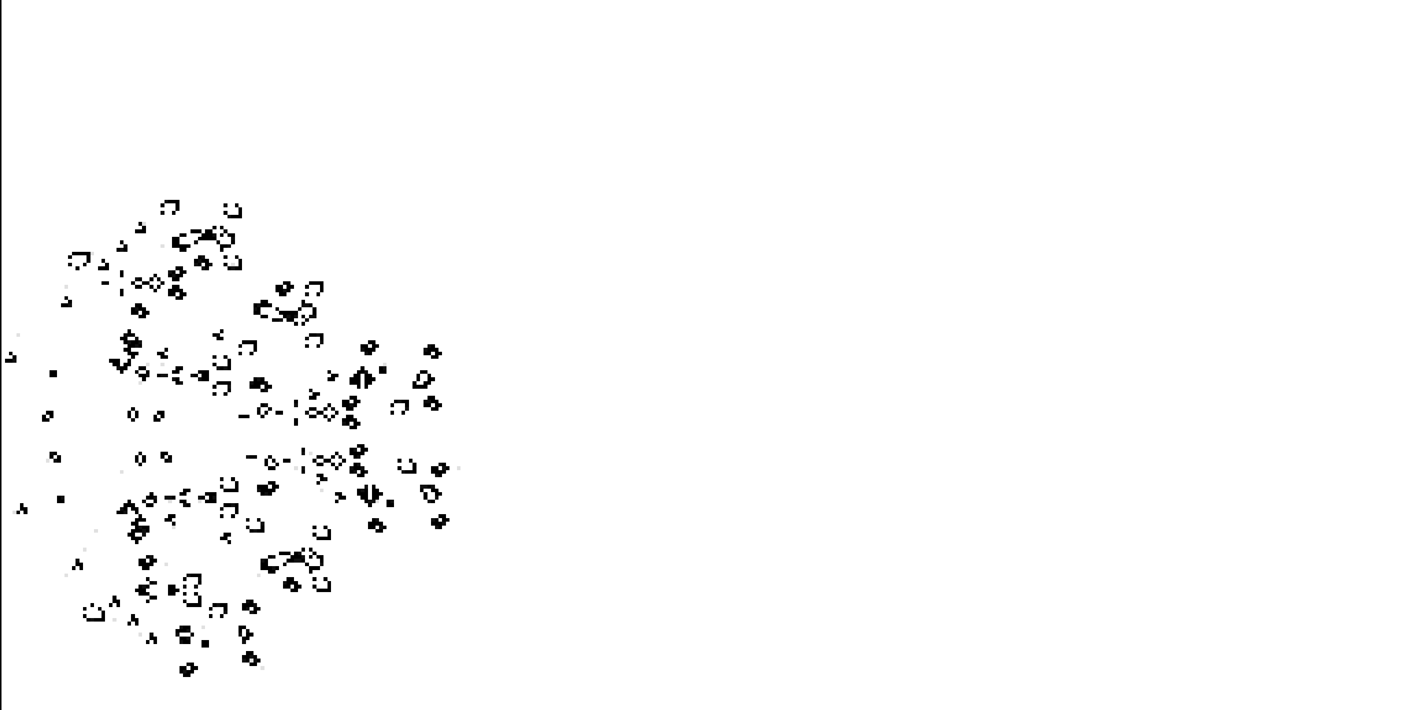


Glider gun



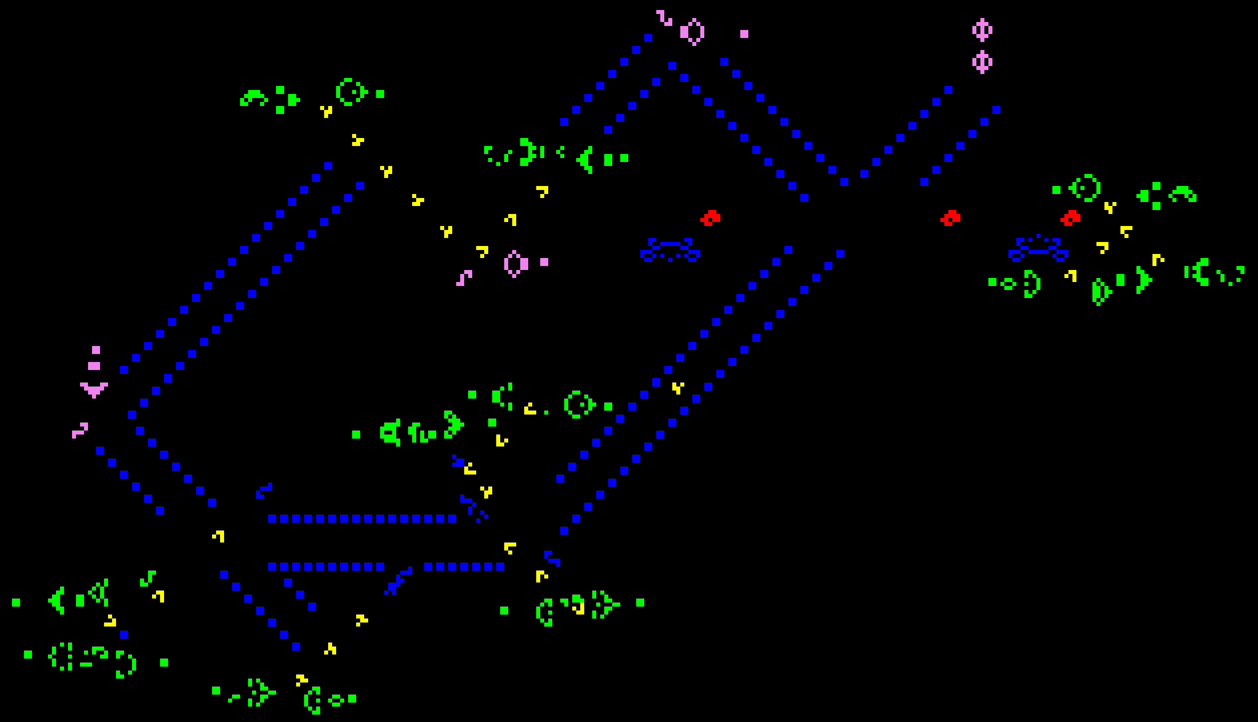
Discovered in 1970 by April, Beeler, Gosper, Howell, Schroeppel and Spenciner (they split Conway’s 50$ between themselves).

Breeder

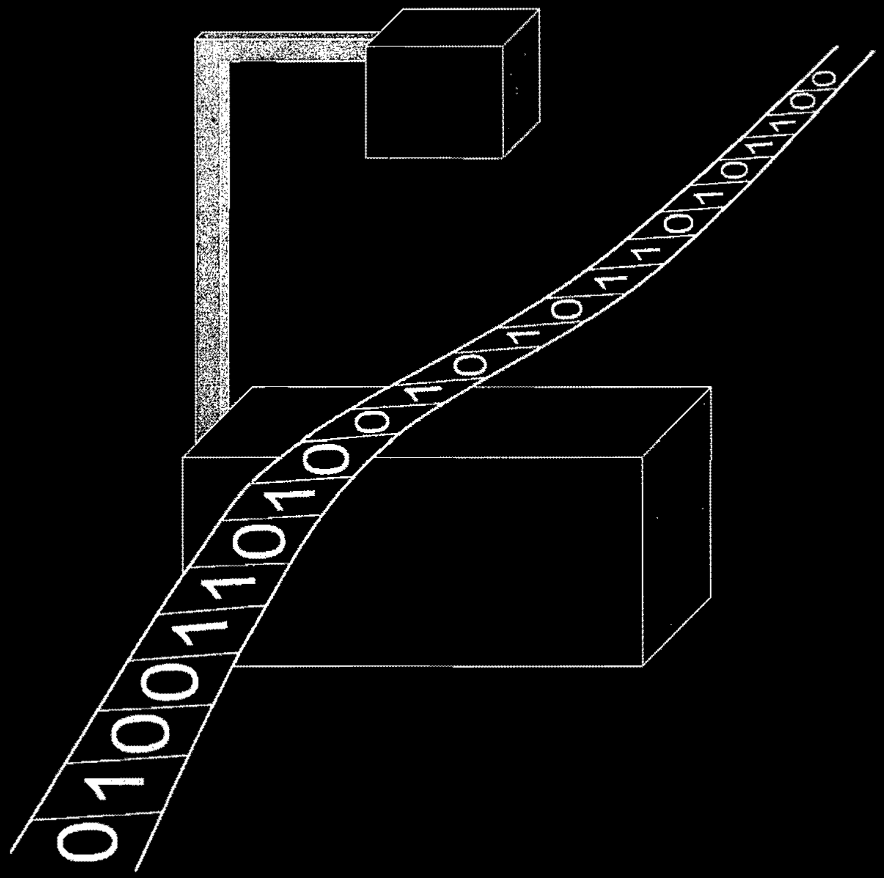


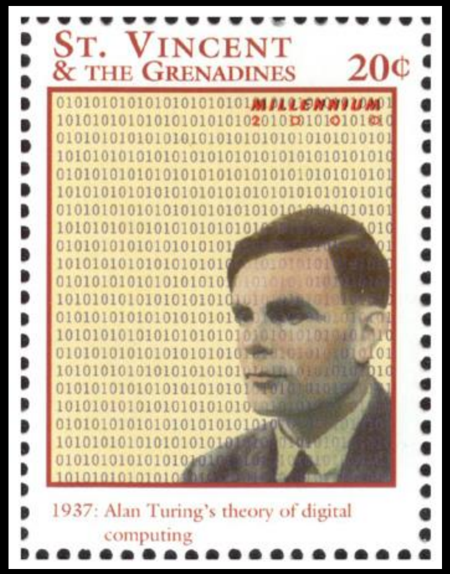
breeds the glider guns...

Everything together...



Turing machine

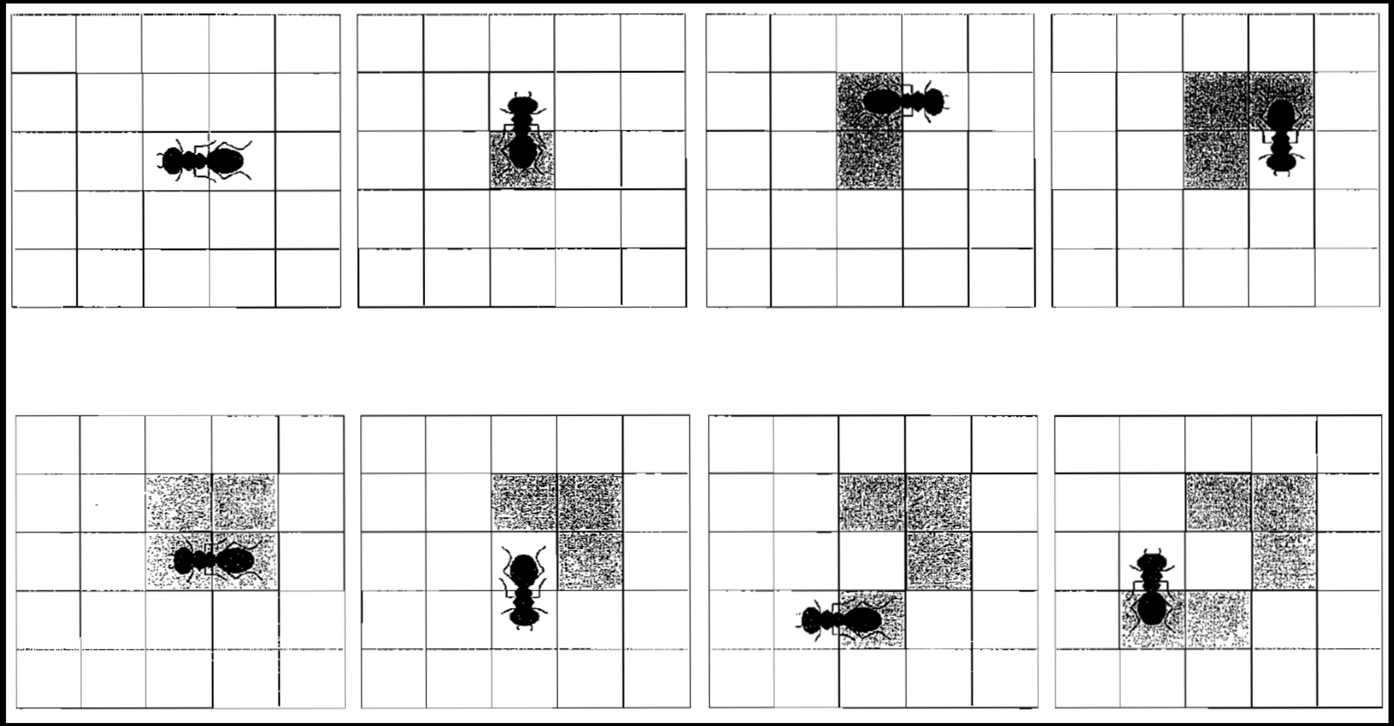




- a head in one of M states
- a tape divided into cells, each in one of N states
- given combination of head and cell states may change the state of the cell, change the state of the head and move tape one cell left or right

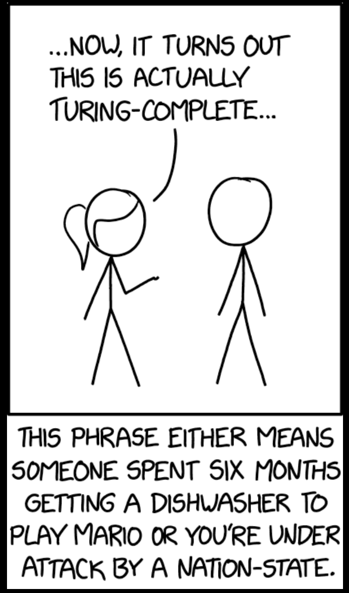
Langton's Ant

1) The ant changes any white cell it lands on to black, then turns 90º to the right and moves one cell forward.
2) The ant changes any black cell it lands on to white, then turns 90º to the left and moves one cell forward.



Universal Turing machine

is a Turing machine, which can emulate any other Turing machine; it is capable of computing any computable sequence – with a long enough program...

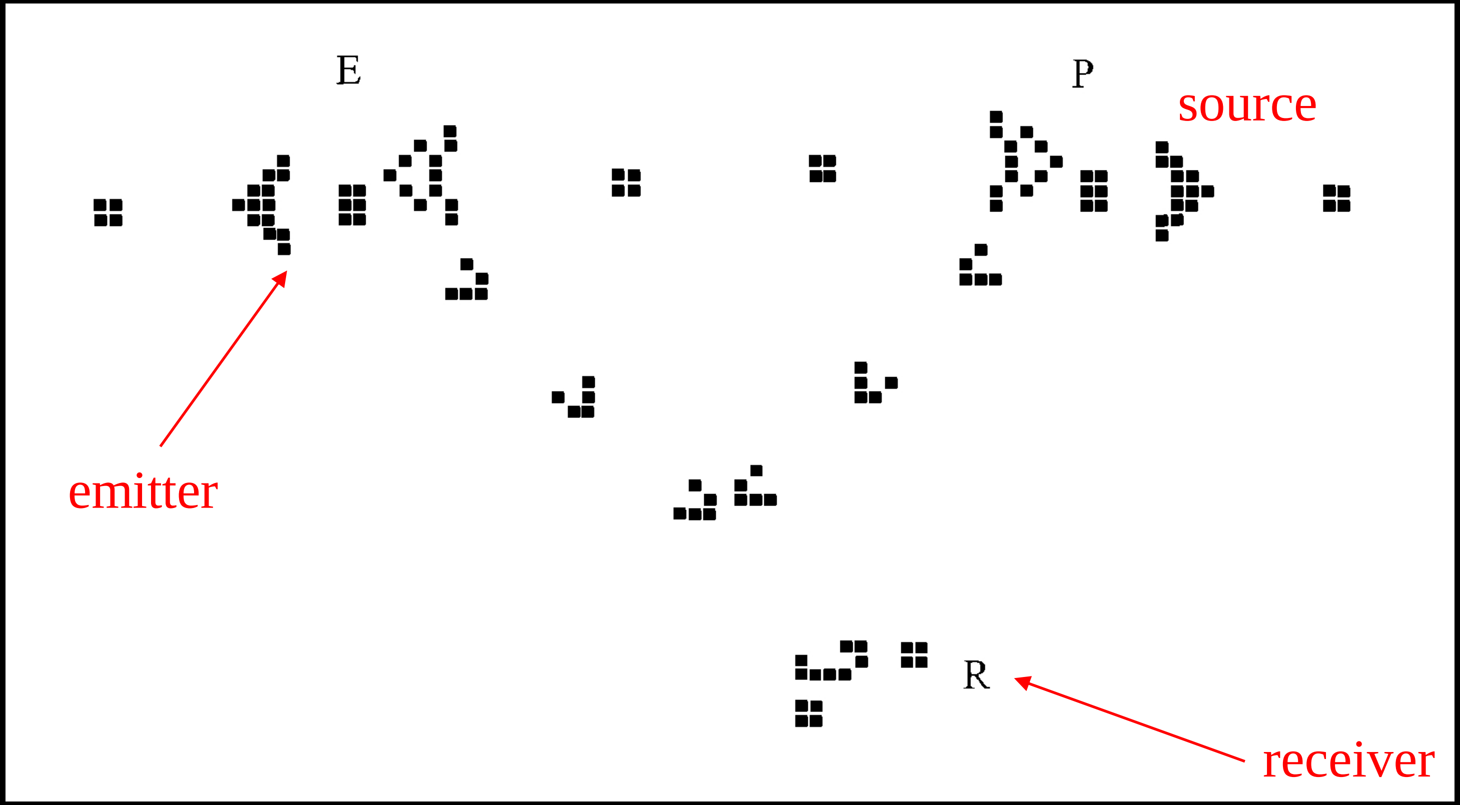


"It is possible to invent a single machine which can be used to compute any computable sequence. If this machine **U** is supplied with a tape on the beginning of which is written the action table of some computing machine **M**, then **U** will compute the same sequence as **M**”

Turing, 1936

Universal computations

In 1982 John Conway and independently William Gosper have shown that GoL is a universal Turing machine. The proof was based on the construction of logical gates NOT, AND i OR with the use of gliders.



NOT

Life in life