% Computers
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% 15/03/2023

Definition

A computer is a machine that can be programmed to carry out sequences of arithmetic or logical operations (computation) automatically.

. . .

> Computer is a machine designed to solve problems automatically

Little story

Little story

Little story

Little story

> Jacquard machine (1804)

. . .

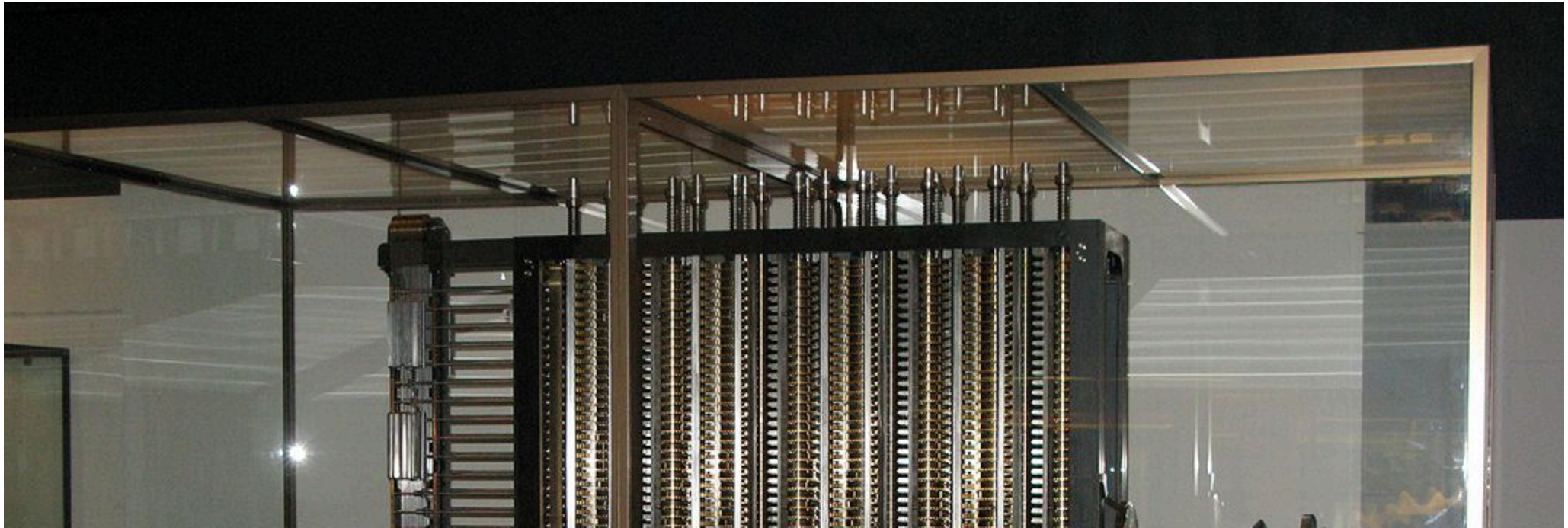
Simplifies the process of manufacturing complex textiles he machine.
Was controlled by a chain of punched cards;

Little story

> The differential engine (1820)

. . .

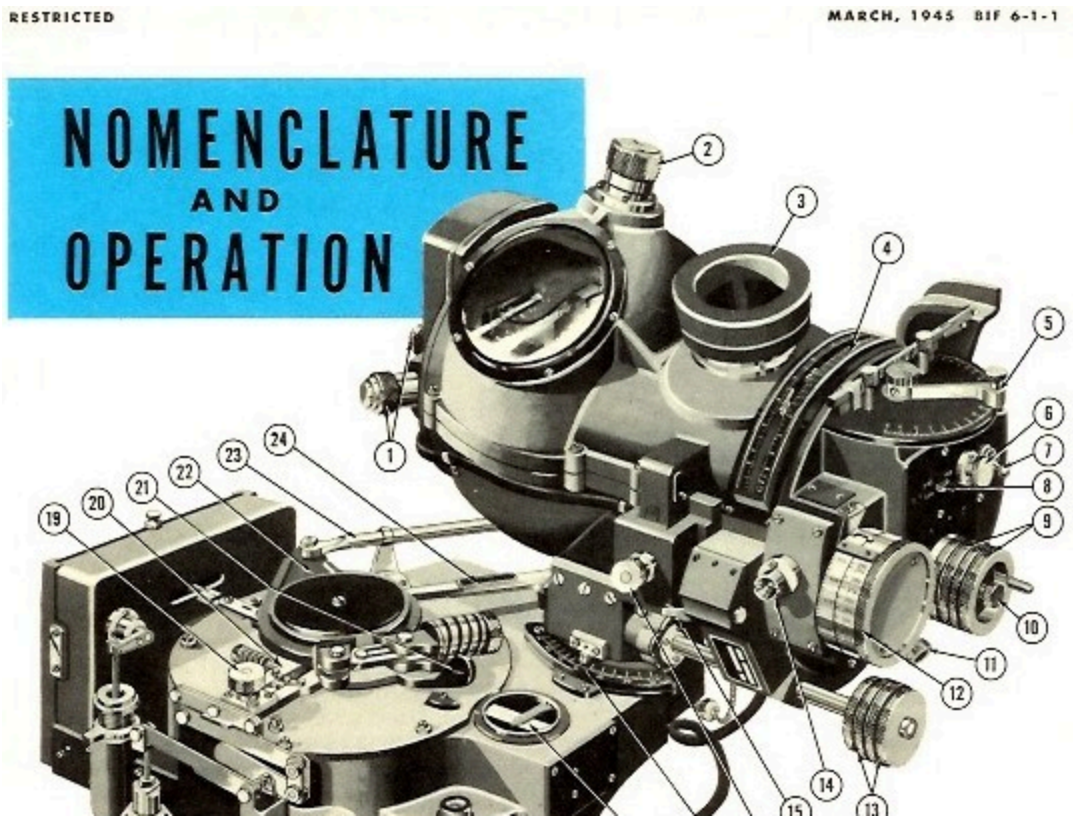
A mechanical calculator designed to tabulate polynomial functions. Was first created by Charles Babbage and is considered the first moder computer.



Analog computers

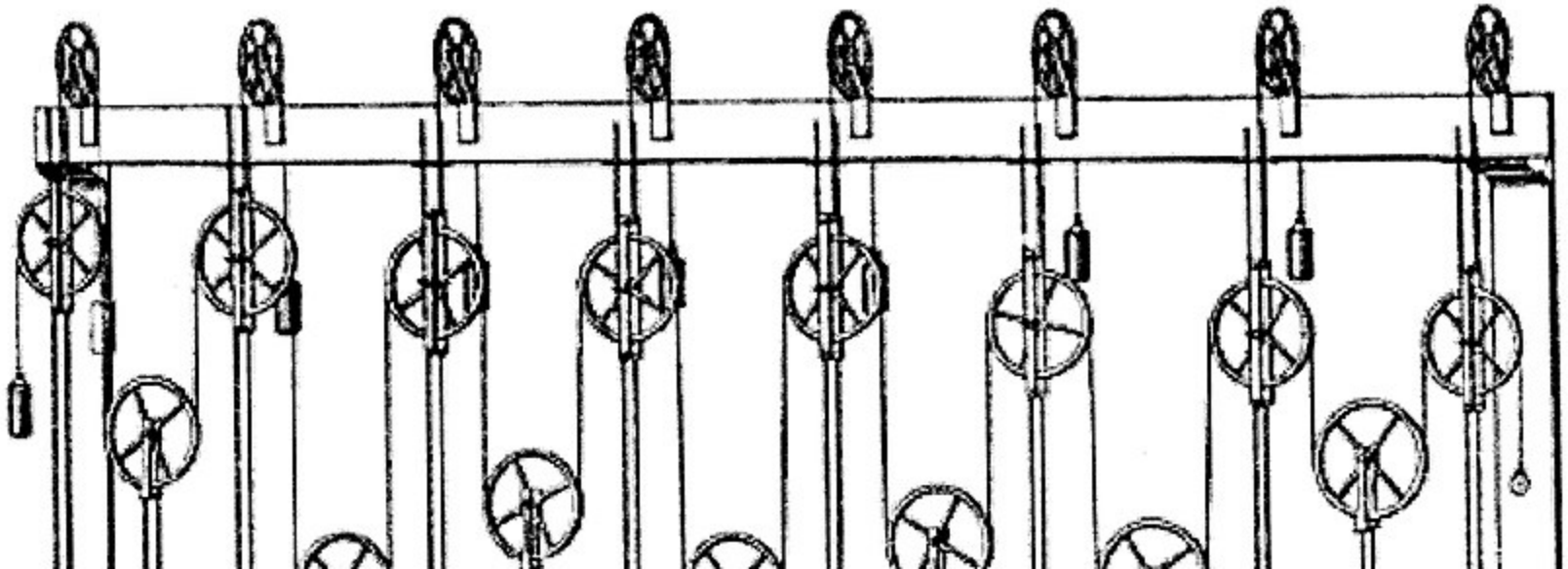
. . .

Is a type of computer that uses the **continuous** variation aspect `(analog signals)` to model the problem being solved.



Example of analog computer

Here is tide predictor machine that, using a sequence of pulley, can predict `(compute)` tides.
This is conceptually similar to the Antikythera mechanism.



Digital computers

. . .

Is a type of computer that uses the discrete form `(discrete inputs)` to model the problem being solved.

Example of Digital computer

The Lehmer sieve in 1926 was made using chains of varying length, with rods at appropriate points in the chains. As the chains turned, the rods would close electrical switches, and when all the switches were closed simultaneously a solution had been found

Hilbert Problems(1900)

Completeness of Math

. . .

1. **Is mathematics complete**? That is, can every mathematical statement be proved or disproved from a given finite set of axioms?

. . .

2. **Is mathematics consistent**? In other words, can only the true statements be proved?

. . .

3. **Is every statement in mathematics decidable**? There is a **definite procedure** that can be applied to every statement that will tell us in finite time if the statement is true or false?

Kurt Gödel

Kurt Gödel in 1930 answered to the first two stating shortly that
if the answer to question 2 above is “yes” (i.e., mathematics is consistent),
then the answer to question 1 (is mathematics complete?) has to be “no.”

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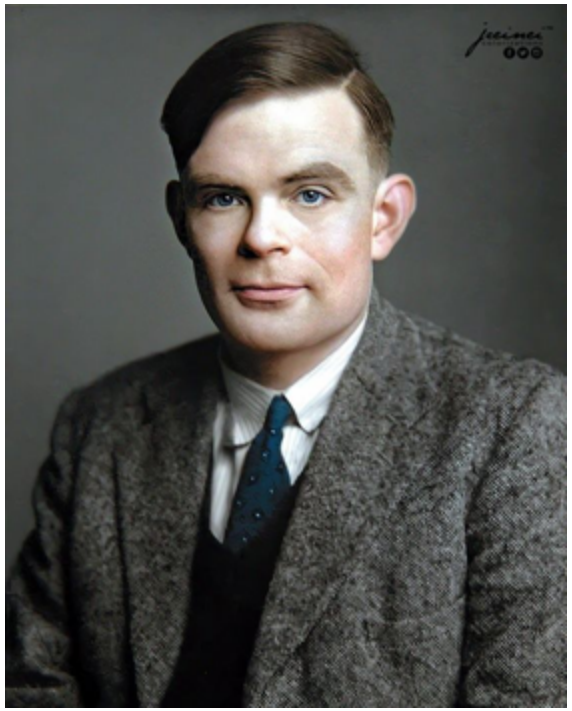
Entscheidungsproblem

The last question is known by its German name as the Entscheidungsproblem (“decision problem”), and goes back to the seventeenth-century mathematician **Gottfried Leibniz. Leibniz** actually built his own calculating machine, and believed that humans could eventually build a machine that could determine the truth or falsity of any mathematical statement.

Alan Turing

 {width=150}

The decision problem was answered by Alan Turing in 1935 and the answer was no, (the halting problem) but doing this he create the computer concept as we know it today.

. . .

Leibniz Legacy

Following the intuition of Leibniz of more than two centuries earlier, Turing formulated his definition by thinking about a powerful calculating machine that could not only perform arithmetic but also could `manipulate symbols` in order to prove mathematical statements.

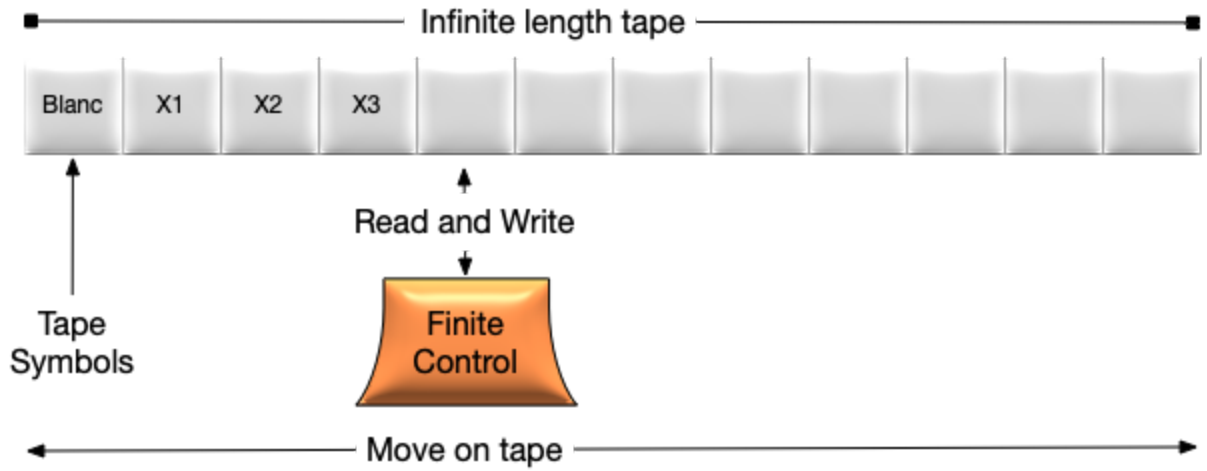
Thought Machine

By thinking about how humans might calculate, he constructed a **mental design** of such a machine

. . .

> `The Turing machine turned out to be a blueprint for the invention of the electronic programmable computer.`

Turing Machine



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. . .

is composed by a `tape` where an `head` can scroll in any direction and can read/write symbols on it. The `head` can use a finite control made up with **rules** eg: if `tape cell` read is (x) then move to next `tape cell` and write (y)

...

Limits!

. . .

1. This thought machine has set the definition of ***definite procedure,*** fixing an ill-defined notion,

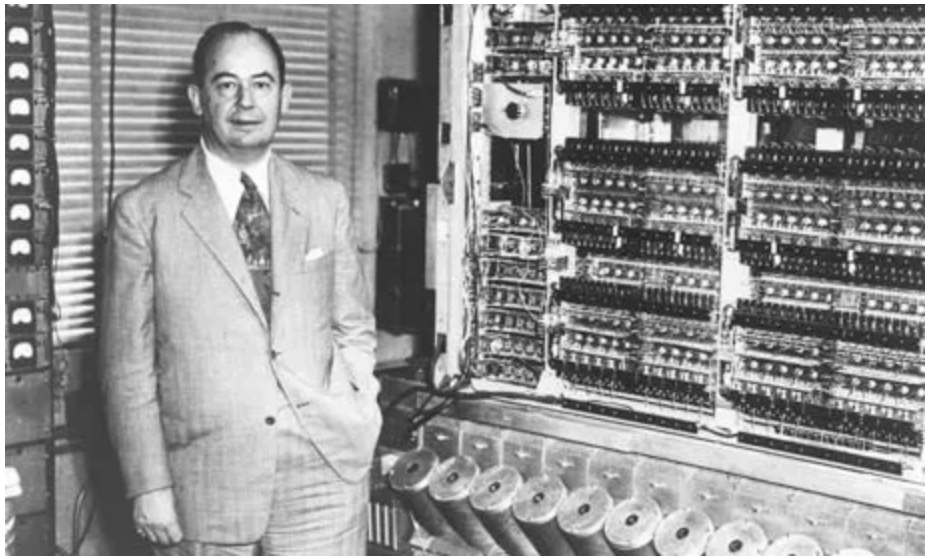
. . .

2. Has blueprinted and paved the way to modern computers

. . .

3. Has given bird to the *computer science*, exploiting the *halting problem* and demonstrating that `there are limits to what can be computed`.

von Neumann

 {width=300}

The **von Neumann architecture** consists of a `random access memory` (RAM) that stores both program instructions and data, and a central `processing unit` (CPU) that fetches instructions and data from memory and executes the instructions.

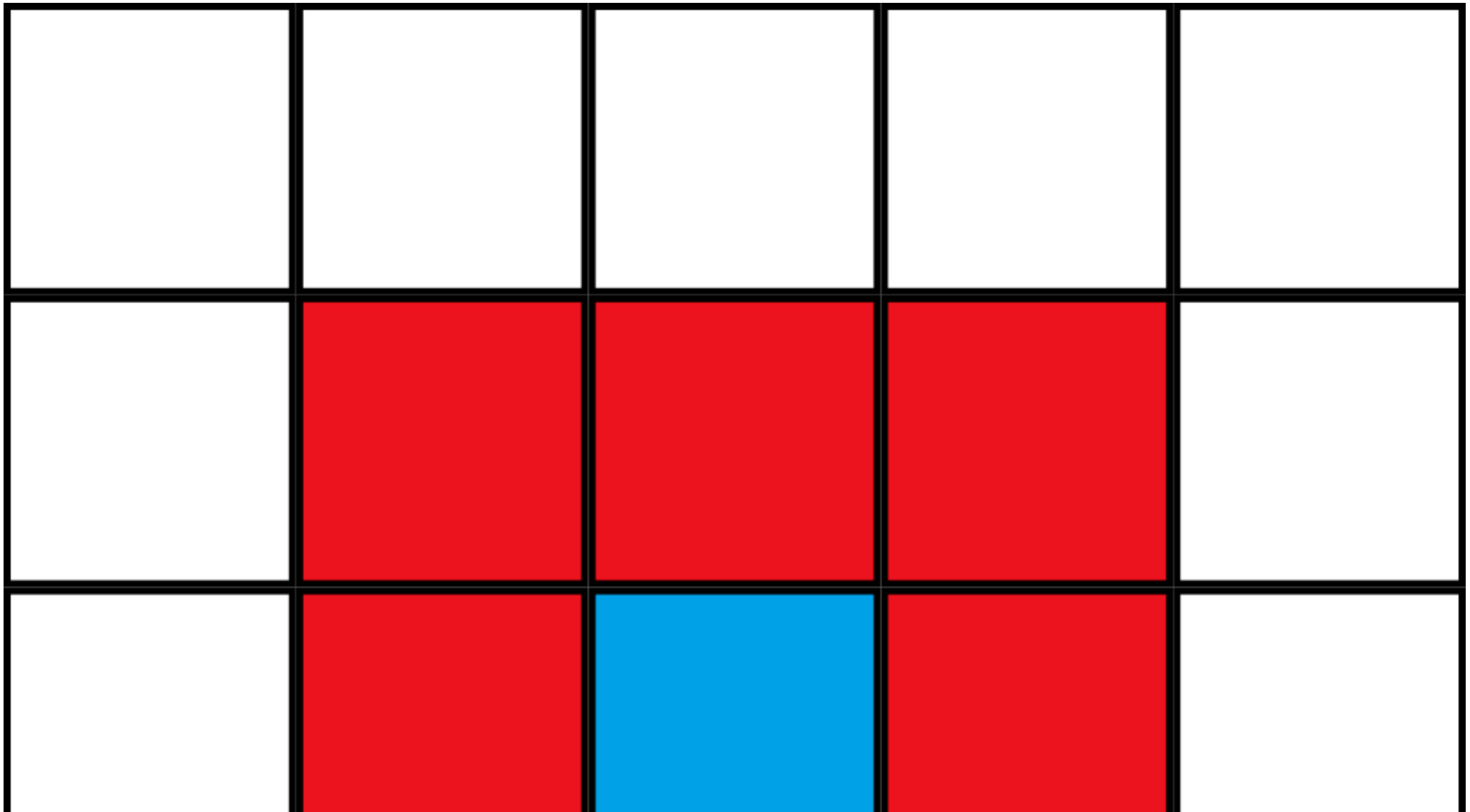
Cellular Automaton

A forward step

Definition

A cellular automaton consists of a regular grid of cells, each in one of a finite number of states, such as on and off.
An initial state `(time t = 0)` is selected by assigning a state for each cell. A new generation is created `(t = t+1)`, according to some **rules** that determines the new **state** of each cell in terms of the current state of the cell and the states of the cells in its neighborhood on grid.

cellular grids



Conway's Game of Life

Guns and Glider

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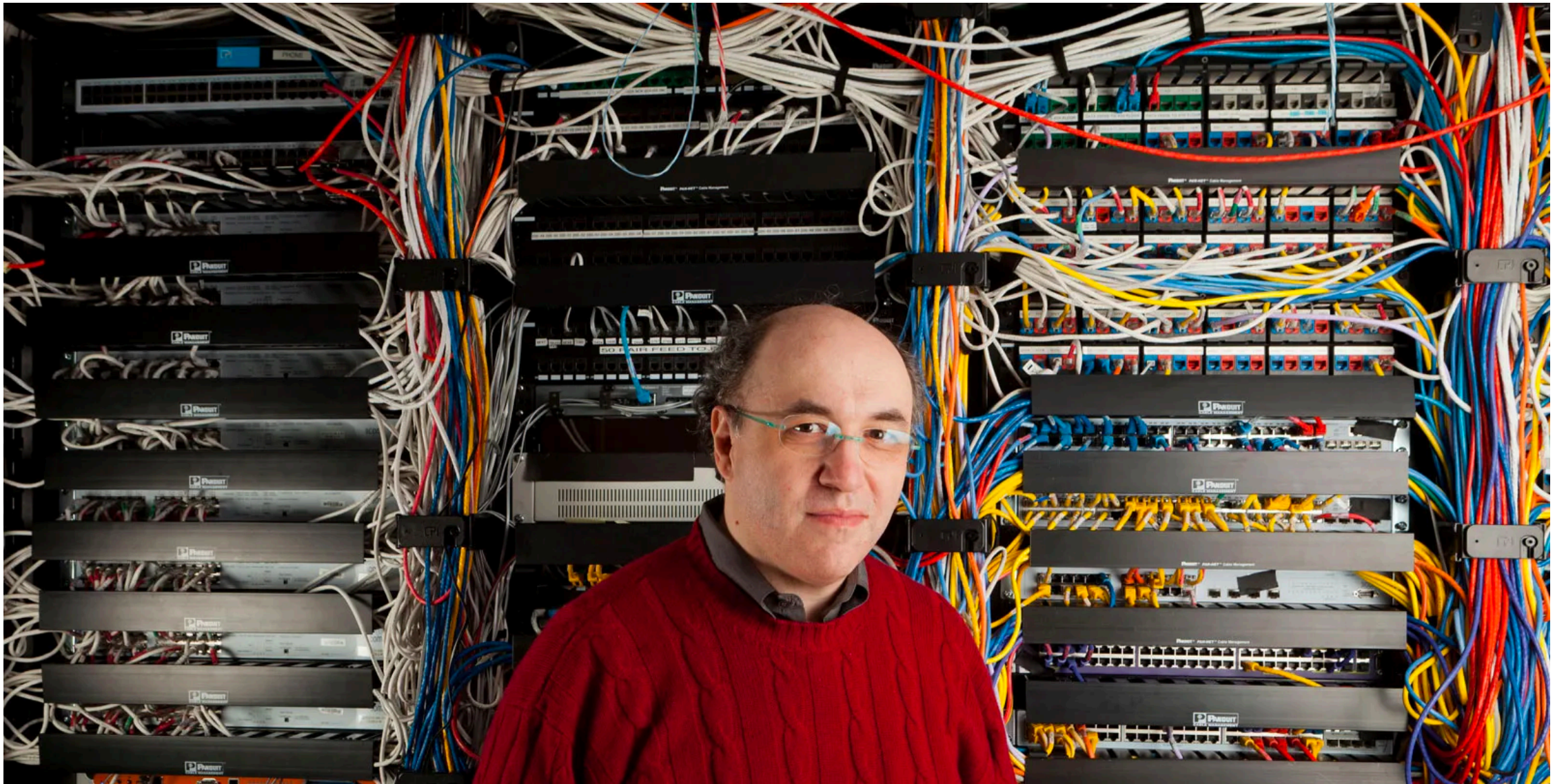
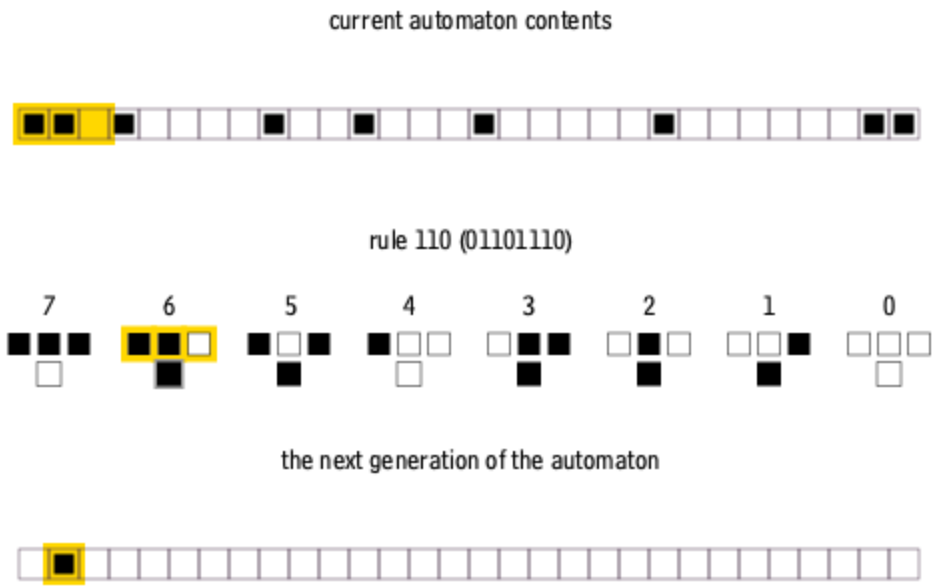
Wolfram Automaton



Rule 110



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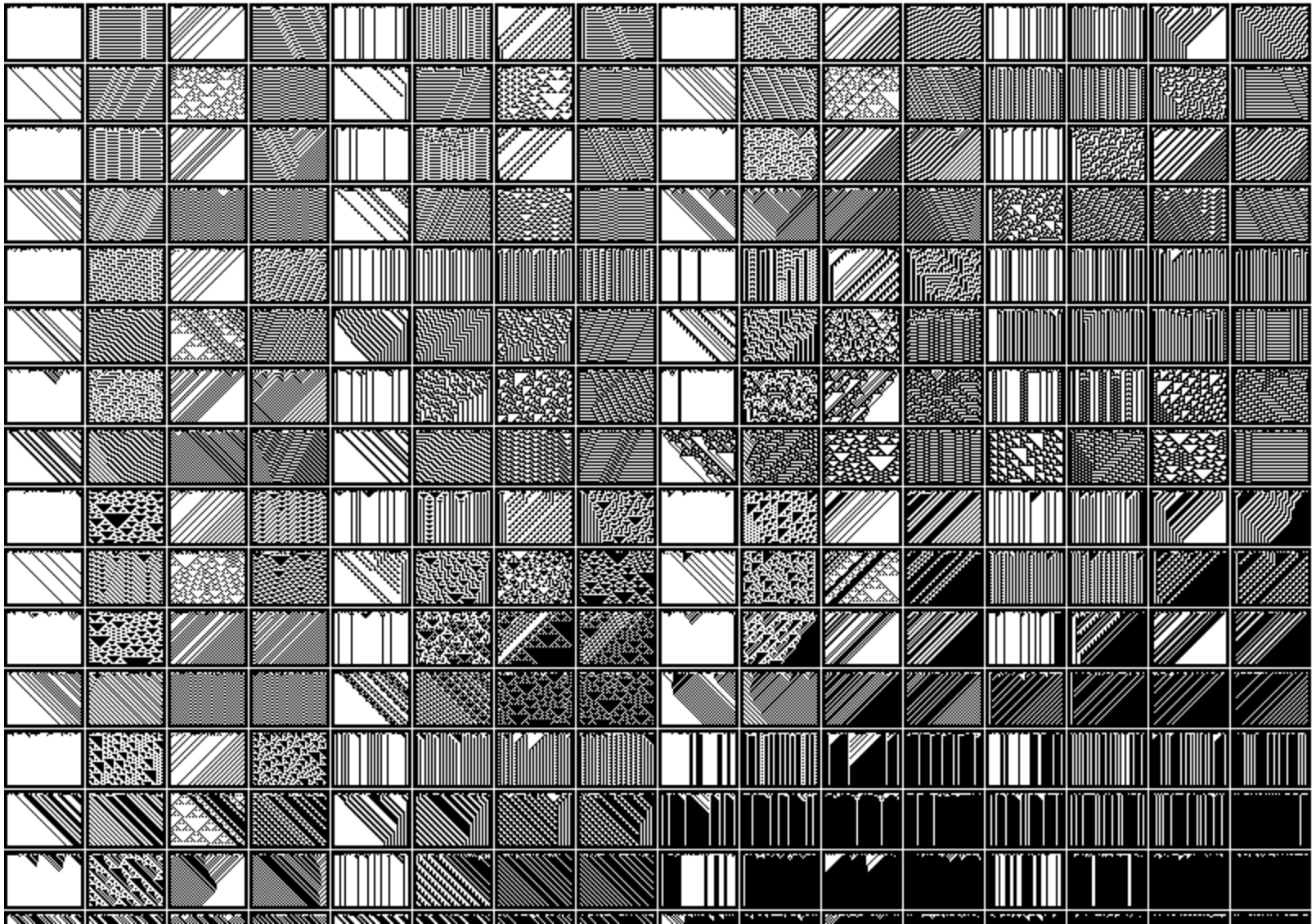
Automaton 256 rules

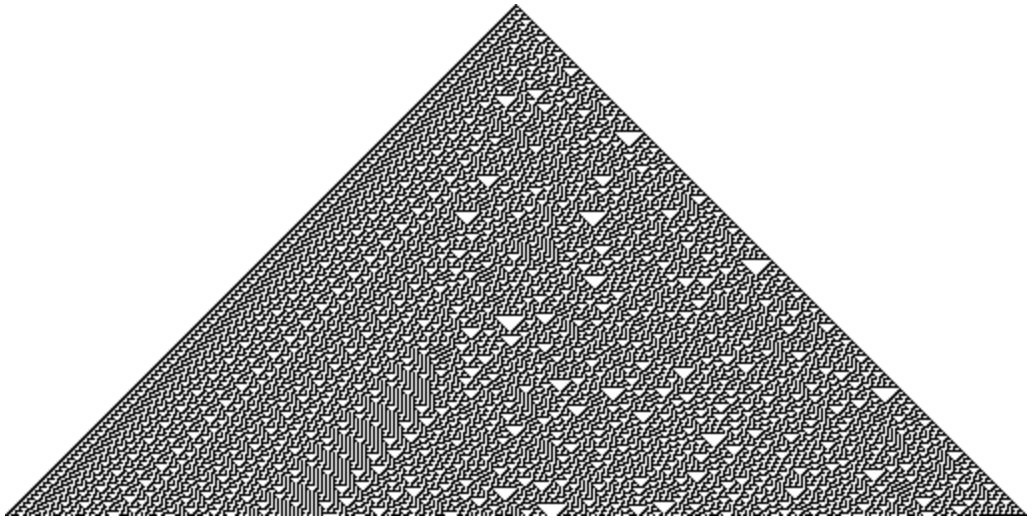


Universal computer

A universal computer in a cellular automaton is a system that can compute anything that a Turing machine can compute (another term for this is Turing-complete). A cellular automaton in which such a system exists is called universal. A universal computer may be either infinite or finite, but when combined with a universal constructor, it is assumed to be finite.

Chaos and Order

`Rule 110` was proved to be an **Universal Computer** but `Rule 30` seem to be hitting the edge from Chaos and Order in the field of complexity, leading to an idea of

 {width=650}

Complexity

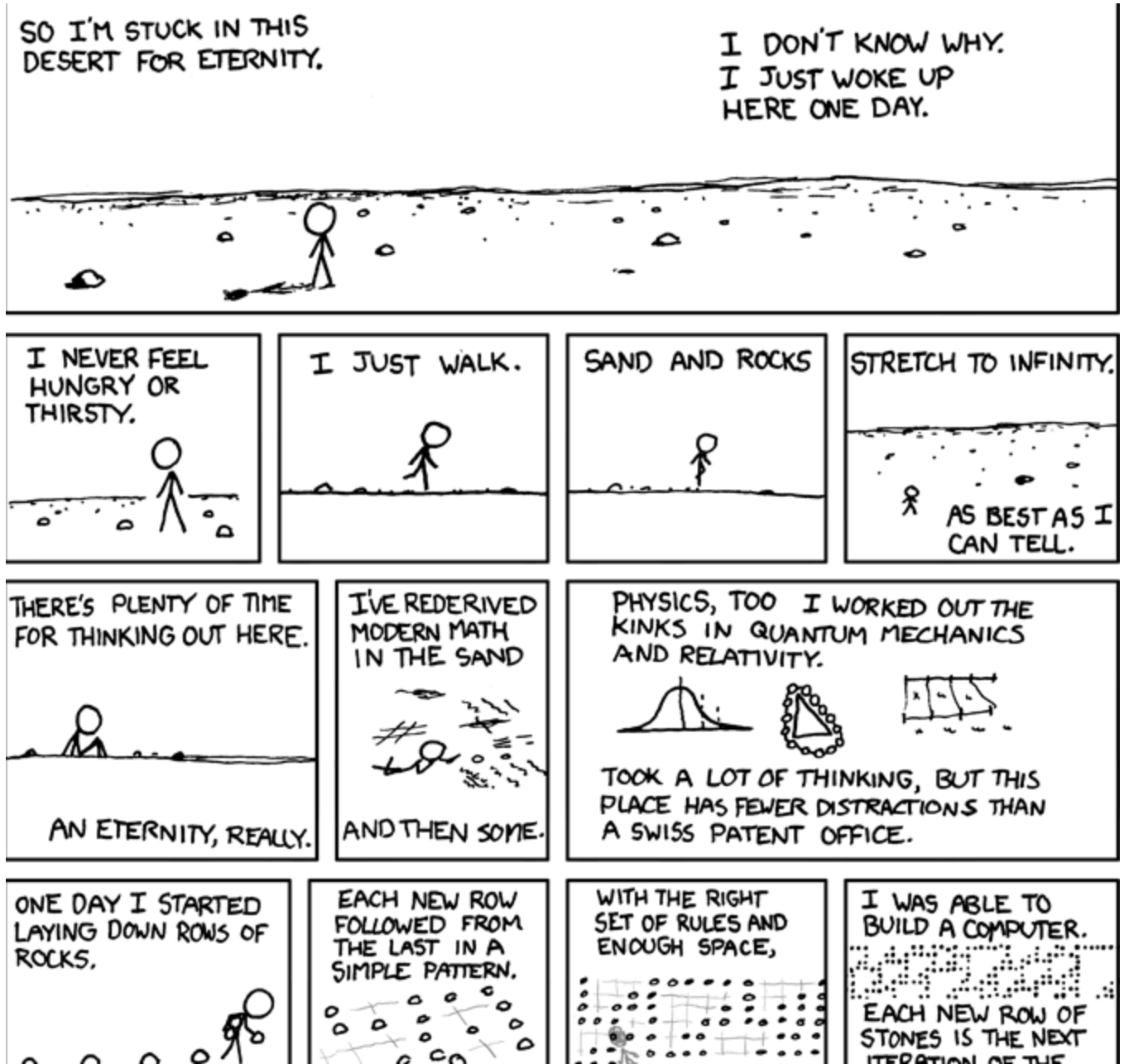
New Kind Of Science

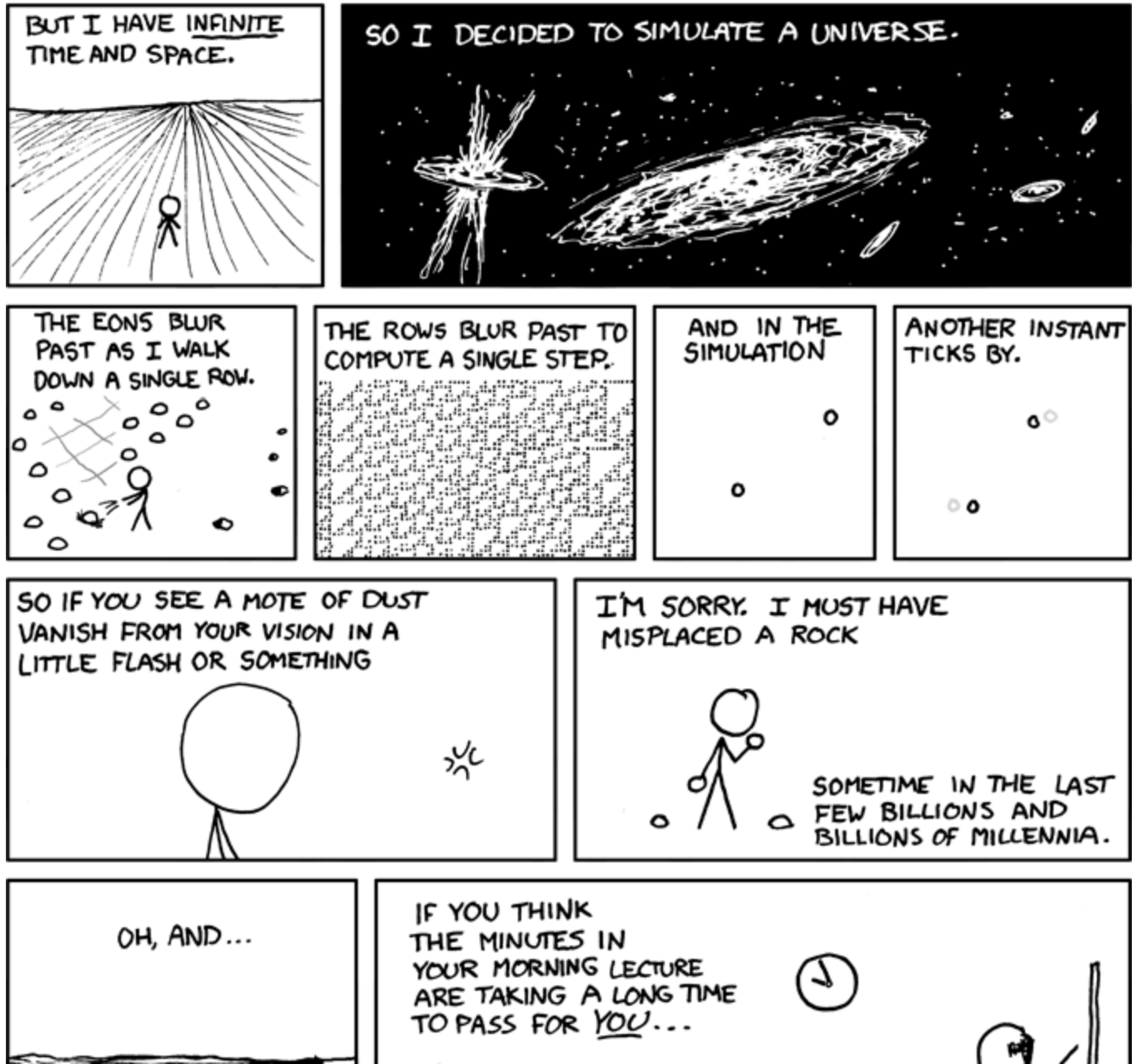
1. The proper way to think about processes in nature is that they are computing.
2. Since even very simple rules can support universal computation, the ability to support universal computation is very common in nature.

New Kind Of Science

3. Universal computation is an upper limit on the complexity of computations in nature. That is, no natural system or process can produce behavior that is “noncomputable.”
4. The computations done by different processes in nature are almost always equivalent in sophistication.

Conclusion


SO I'M STUCK IN THIS DESERT FOR ETERNITY.
I DON'T KNOW WHY. I JUST WOKE UP HERE ONE DAY.
I NEVER FEEL HUNGRY OR THIRSTY.
I JUST WALK.
SAND AND ROCKS
STRETCH TO INFINITY.
AS BEST AS I CAN TELL.
THERE'S PLENTY OF TIME FOR THINKING OUT HERE.
AN ETERNITY, REALLY.
I'VE REDERIVED MODERN MATH IN THE SAND
AND THEN SOME.
PHYSICS, TOO I WORKED OUT THE KINKS IN QUANTUM MECHANICS AND RELATIVITY.
TOOK A LOT OF THINKING, BUT THIS PLACE HAS FEWER DISTRACTIONS THAN A SWISS PATENT OFFICE.
ONE DAY I STARTED LAYING DOWN ROWS OF ROCKS.
EACH NEW ROW FOLLOWED FROM THE LAST IN A SIMPLE PATTERN.
WITH THE RIGHT SET OF RULES AND ENOUGH SPACE,
I WAS ABLE TO BUILD A COMPUTER.
EACH NEW ROW OF STONES IS THE NEXT


BUT I HAVE INFINITE TIME AND SPACE.
SO I DECIDED TO SIMULATE A UNIVERSE.
THE EONS BLUR PAST AS I WALK DOWN A SINGLE ROW.
THE ROWS BLUR PAST TO COMPUTE A SINGLE STEP.
AND IN THE SIMULATION
ANOTHER INSTANT TICKS BY.
SO IF YOU SEE A MOTE OF DUST VANISH FROM YOUR VISION IN A LITTLE FLASH OR SOMETHING
I'M SORRY. I MUST HAVE MISPLACED A ROCK
SOMETIME IN THE LAST FEW BILLIONS AND BILLIONS OF MILLENNIA.
OH, AND...
IF YOU THINK THE MINUTES IN YOUR MORNING LECTURE ARE TAKING A LONG TIME TO PASS FOR YOU...