The Self-Replication Page: Accompanying Figures lslwww.epfl.ch/∼moshes/selfrep/

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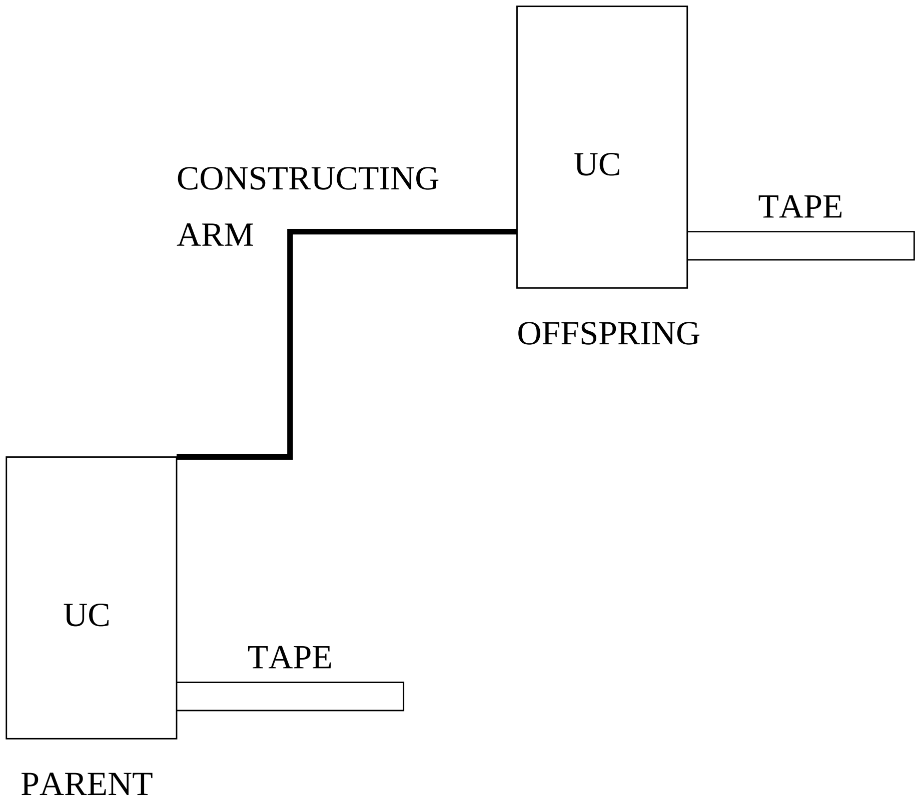


Figure 1: A schematic diagram of von Neumann's self-replicating cellular automaton. The system is a universal constructor (UC), namely, a machine capable of constructing, through the use of a "constructing arm," any configuration whose description can be stored on its input tape. This universal constructor is therefore capable, given its own description, of constructing a copy of itself, i.e., of self-replicating.

```
  . . . . . . . .
. 1 7 0 1 4 0 1 4 .
. 0 . . . . . . 0 .
. 7 .         . 1 .
. 1 .         . 1 .
. 0 .         . 1 .
. 7 .         . 1 .
. 1 . . . . . . 1 . . . . .
. 0 7 1 0 7 1 0 7 1 1 1 1 1 .
  . . . . . . . . . . . . .
```

(a)

```
  . . . . . . . .         . . . . . . . .
. 7 0 1 7 0 1 7 0 .   . 1 4 0 1 4 0 1 1 .
. 1 . . . . . . 1 .   . 0 . . . . . . 1 .
. 1 .         . 7 .   . 7 .         . 1 .
. 1 .         . 0 .   . 1 .         . 1 .
. 1 .         . 1 .   . 0 .         . 7 .
. 1 .         . 7 .   . 7 .         . 0 .
. 0 . . . . . . 0 . . . 1 . . . . . . 1 .
. 4 1 0 4 1 0 7 1 0 7 5 0 6 1 0 7 1 0 7 .
  . . . . . . . . . . . . . . . . . . .
```

(b)

Figure 2: Langton's self-replicating loop. The structure, embedded within an 8-state CA space (i.e., each cell can be in one of 8 possible states) consists of a looped pathway, containing instructions, with a construction arm projecting out from it. Upon encountering the arm junction, the instruction is replicated, with one copy propagating back around the loop again and the other copy propagating down the construction arm, where it is translated as an instruction when it reaches the end of the arm. Note that the loop lacks any computing and constructing capabilities, its sole functionality being that of self-replication. (a) Time step 0. (b) Time step 126.

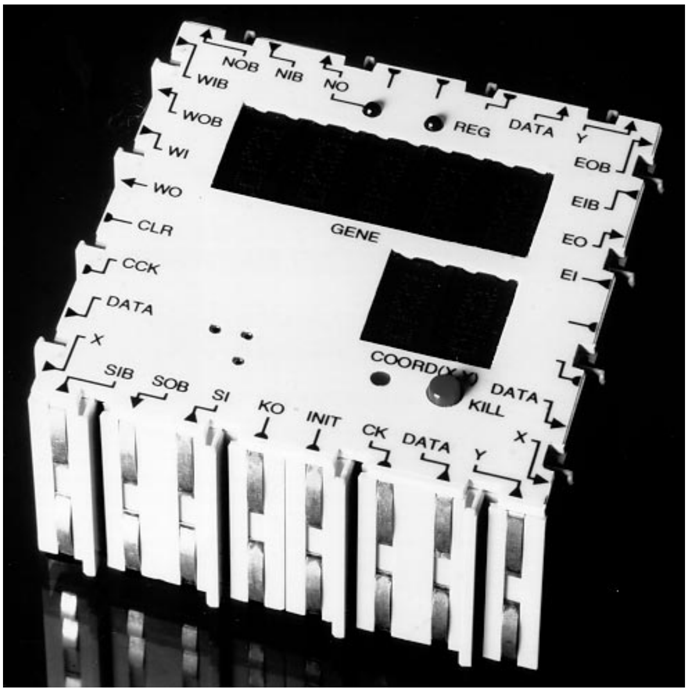


Figure 3: Embryonics project: an artificial cell – the biodule. A processor responsible for interpreting the genome constitutes the cytoplasm, in analogy to a ribosome, along with a random access memory (RAM) acting as the cell's nucleus, containing a copy of the entire genetic makeup, i.e., the genome. Displayed on the top cover are the cell's coordinates, as well as the specific gene within the genome that determines its functionality; these are acquired during cellular differentiation. The KILL button is used to induce the self-repair (regeneration) mechanism.

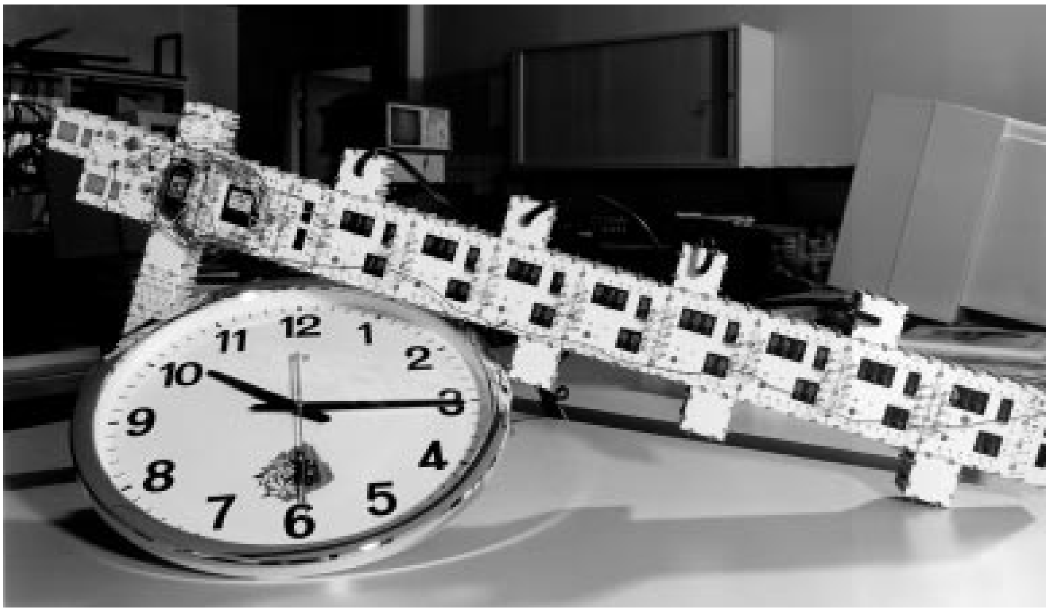


Figure 4: Embryonics project: the biowatch. An artificial "organism" designed to count minutes (from 00 to 59) and seconds (from 00 to 59), comprising in effect a modulo-3600 counter that is able to *self-replicate* and *self-repair*. It is implemented using eight biodule cells of Figure 3.

```
11
111

time = 0
```

```
11
1110

time = 1
```

```
11
11100

time = 2
```

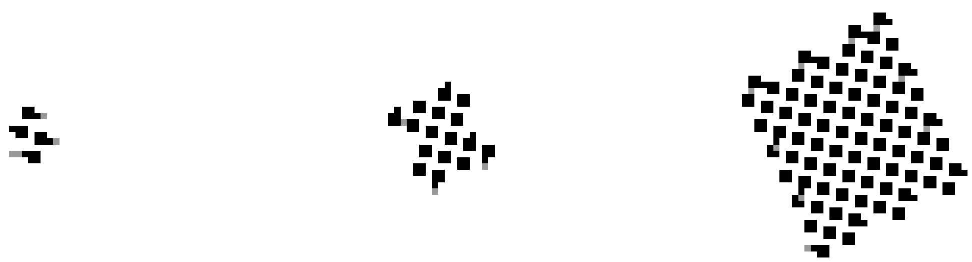
```
11
11101
    1
time = 3
```

```
11
11101
   11


time = 4
```

```
11
11011
   11
   1

time = 5
```

```
 1
11
11 11
   11
   1
   0
time = 6
```

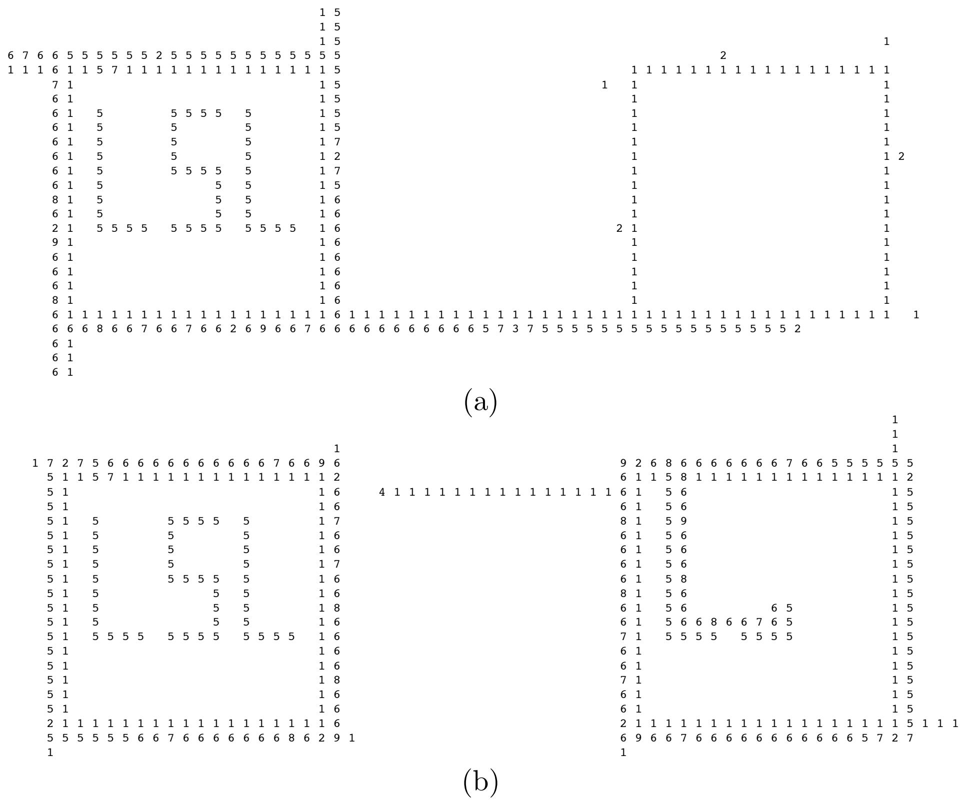
(a)



time = 12 time = 28 time = 66

(b)

Figure 5: Sipper's self-replicating loop. In (b), black squares represent cells in state 1, non-filled squares represent cells in state 0, and white squares represents cells in state *b*.

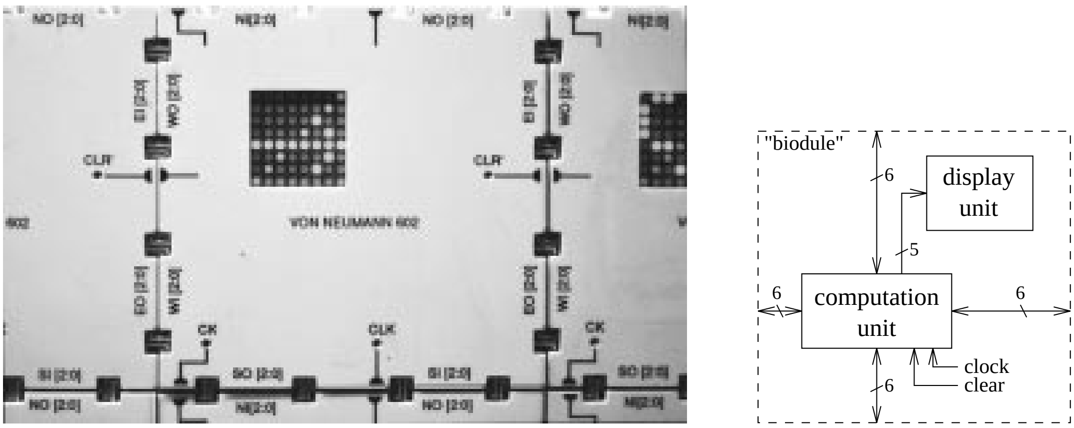


(a) (b)

Figure 6: Tempesti's loop is a self-replicating automaton, with the added capability of attaching an executable program which is duplicated and executed in each of its copies. This is demonstrated above for a simple program that writes out (after the loop's replication) LSL, acronym of the Logic Systems Laboratory. (a) Time step 240: the program is being copied into the daughter loop. (b) Time step 341: the program is being executed in the daughter loop.

```
  . . . . . . . .
. 7 0 1 7 0 1 7 0 .
. 1 . . . . . . 1 .
. 1 .         . 7 .
. 1 .         . 0 .
. 1 .         . 1 .
. 1 .         . 7 .
. 0 . . . . . . 0 . . . .
. 4 1 0 4 1 0 7 1 0 7 1 1 .
. A . . . . . . . . . . .
. P .         . D .
. P .         . D .
. P .         . D .
. P .         . D .
. P .           .
. P .
. P .
  .
```

Figure 7: Perrier, Sipper, and Zahnd: a self-replicating loop with programmable capabilities. The system consists of three parts, loop, program, and data, all of which are replicated, followed by the program's execution on the given data. `P` denotes a state belonging to the set of program states and `D` denotes a state belonging to the set of data states.



(a) (b)

Figure 8: Beuchat and Haenni: hardware implementation of the von Neumann cell. (a) Top face of the von Neumann module, including connection points to other cells and a LED display showing the current state of the cell. (b) General schema: the module is composed of two units, a *computation unit*, computing the cell's next state, and a *display unit*, handling the dot-matrix display.

Figure 9: Beuchat and Haenni: hardware implementation of one of the organs of von Neumann's universal constructor, known as a pulser, using the module of Figure 8. The above pulser P(11001) generates at the output cell (top right) the sequence of excitations (signals) 11001 a fixed number of time steps after receiving an excitation (i.e., a 1 signal) at the input cell (bottom left). Note that the 25 von Neumann modules are not arranged as a 5×5 square – in fact, the arrangement is that of a 7×7 square, where unused cells are simply not implemented. This allows for the construction of a larger organ for the price (literally) of a smaller one.