# **Definitions**

01:

1. **Life/living** – metabolism, growth, reproduction, response to environmental stimuli, adaption and evolving, complex, highly organised, able to take energy from environment, regeneration of body parts, existance in space and time, decay/death, storage of information about oneself, autonomy. Robots typically don't have metabolist or evolve.
2. **Systems of Artificial Life** – CA, Game of Life, Langton's self-replicating loop, ...

02:

1. **Goal of Artificial Life** - „Life made by man, rather than nature“.
2. **Strong / Weak Artificial Life** – in Strong Artificial Life non-living material is used to construct „real“ life. Weak Artificial Life, however, means that life is only simulated (conditions, behaviour)
3. **Cellular Automata** – discrete (space, time, value) and deterministic (non-random) model of information processing. Consists of: grid of cells, each cell has a state (finite set), an initial state of cells, transition rules for determining next state (that cell+neighbourhood).
4. **Initialising CA** – (1) by random, (2) as a seed, (3) as an initial pattern

03:

1. **4 classes of behaviour for CA**:
   1. Homogenous - settling of states over time to one stable state (typically silent).
   2. Periodic – a repetitive pattern in time (eg. every 3 steps), incl. stable patterns.
   3. Chaotic – a recognisable pattern is not observable to the human
   4. Complex, Patterns, „Self Organisation“ - despite seeming randomness, a human can observe a pattern. Interesting structures evolve, persist, seem to interact and generate new structures (eg. gliders).
2. **Conway's Game of Life** – CA of d=2, r=1 Moore neighbourhood, k=2 binary states. The rule is legal. Was based on population dynamics (survival, birth, death from overcrowding (>3 neighbours) or loneliness (<2 neighbours)).

04:

# **Revision of Artificial Life Systems**

## ***Cellular Automata***

|  |  |
| --- | --- |
| **1-dim** | **2-dim** |
| Grid/lattice  Neighbourhood (r=radius, d=dimension) |  |
| Rule example: | eg.   * Conway's Game of Life: * Majority voting CA * Non-deterministic CA (transition to next state is probability bound) * Forest Fire CA (ashes, tree, fire) non-deterministic |
| Size of neighbourhood: n=2\*r+1  No. of allowed states: k  No. of lines per rule / size of 1 rule: L = kn  No. of diff. rules possible: Z = kL  *(see task 7)* |  |

**Rule properties**:

Legal rule = symmetric rule + silent state.

|  |  |
| --- | --- |
| Silent state | Symmetric rule |
| Totalistic rule:  (only sum of set cells determine the next state) | Peripheral rule:  (the state of the cell itself is not influencing the result) |

*see Task 11*

**Wolfram number** (for d=1, r=1, k=2): eg. Rule 30

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  | **↓** | | 111  110  101  100  011  010  001  000 | 0  0  0  1  1  1  1  0 | |

**Conway's Game of Life (CA d=2)**

23/3, ie survival/birth:



Interesting patterns:

|  |  |
| --- | --- |
| * Oscillating class II patterns with periodicity 2 |  |
| * Longlasting patterns (Methuselah) |  |
| * Glider (exact shape reproduced but pattern is not periodic because it moves), class IV. Consists of 5 cells and in 4 steps moves one cell in diagonal. It is possible to construct Game of Life structures that act as AND, OR, NOT, NOR, XOR, ... via Gliders. Colliding Gliders are universal tools to construct/destroy other structures. |  |
| * Glidergun – implements a pattern that grows infinitely. Cycle length of 30 steps sends off a glider. Glidergun = motor, glider = 1 bit of information. |  |

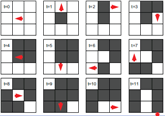
**Boundaries in CA Grids**

Boundary size depends on r. Grid boundaries are used often for special effects (structures bouncing off the closed boundary, objects absorbed at open boundary.

* Infinite (enlarging it on the go)
* Periodic (wrap-around grid)
* Fixed boundary (either resetting states to predefined values - typically silent state – or not applying update rules to these cells)
* Random
* Adiabatic (copy, mirror - „copy“ the cells into the grid behind the boundary) – used for diffusion process simulation
* Open (absorbs)
* Closed (reflects)

**Example applications of CA:**

* Growth of crystals
* Population dynamics
* Modelling and predicting traffic situations
* Modelling diffusion process
* Modelling forest fires
* Data mining algorithm testing that are looking for patterns in data

**Langton's Ant**

CA – like system, a kind of 2 dimensional Turing machine. The ant is an agent working on a d=2 grid of cells with binary content. The ant has a spatial position and a heading (NESW). The ant can move one cell, turn 90deg. and change the state of the cell.

* At a white cell – turn right, flip cell, move forward one step
* At a black cell – turn left, flip cell, move forward one step

Langton's ant tends to follow the following macroscopic behaviour when started on a uniform white grid: 

a) symmetic growth pattern (first ca 420 steps)

b) chaotic growth (no observable structure till ca step 10.000

c) highway (structured, repetitive pattern)