TPT09 - Emergence in Complex Systems (Athens week at Telecom-Paristech)
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Implementation of a Langton's Ant simulator in Evolife

The project

This project consisted in the implementation of a simulator for the Langton's Ant cellular automaton, with which some experiments were performed to observe its emergent behaviour. Accompanying this report is a folder *LangtonAnt* containing the different files needed in order to utilise the simulator with Evolife (in particular, the LangtonAnt.py source file, the LangtonAntConfig.xml configuration file and the start/starter.bat files).

Langton's Ant is a two-dimensional cellular automaton introduced by Chris Langton in 1986 [1]. It is based around an agent (the ant) in a grid of black and white squares. At the beginning of every step of the automaton's operation, the ant is on a particular square cell of a grid and has a one of four orientations (up, down, left and right). The ant then performs the following algorithm (an animated version may be consulted in [2]):

1. If the current cell is white, turn 90 degrees right and paint it black. Alternatively, if the current cell is black, turn 90 degrees left and paint it white.
2. Advance one cell in the current orientation and repeat from 1.

The simulator implemented in Evolife is based on a simple extension to this basic model, presented by Greg Turk and Jim Propp in 1995 [3]. Said extension allows for more than two possible colors for square cells. The colors have are organized in a cyclic sequence, and each one has an associated rotation (either "90 degrees left" or "90 degrees right"). The algorithm followed by the ant then becomes.

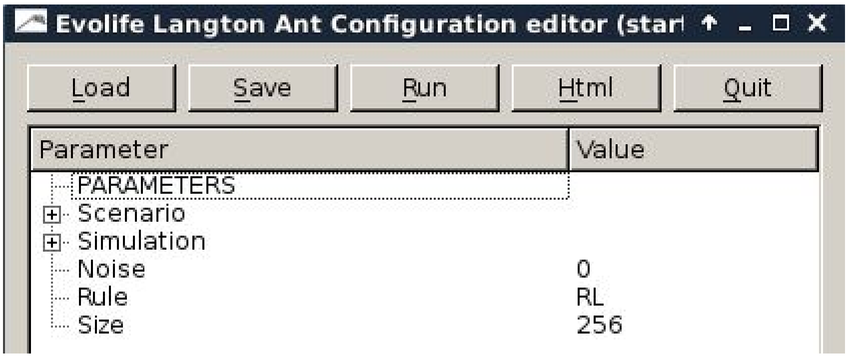
1. Turn in the direction corresponding to the color of the current cell.
2. Paint the current cell with the color that follows the current cell's color in the cyclical sequence.
3. Advance one cell in the current orientation and repeat from 1.

The original Langton's Ant is a particular case of this extended model with a 2-color cyclical sequence (black → white → black …) and the associated rotations are "90 degrees right" for white and "90 degrees left" for black. The video in [4] shows several animated examples of multi-color Langton's Ant automata.

As a further feature for the simulator, a parameter "Noise" was added, which is the likelihood (per million turns) that the ant rotates in the wrong direction. With

“Noise” = 100, for instance, the ant will take a turn in the direction opposite to that corresponding to the color of the current cell every 10000 steps, on average.

Thus, the Evolife configuration editor for the simulator has the following project-specific parameters:



→ **Size:** The grid is a square of Size x Size cells. In the current implementation, if the ant goes beyond one of the sides of the square it reappears on the opposite side. The grid is initialized to all white squares.

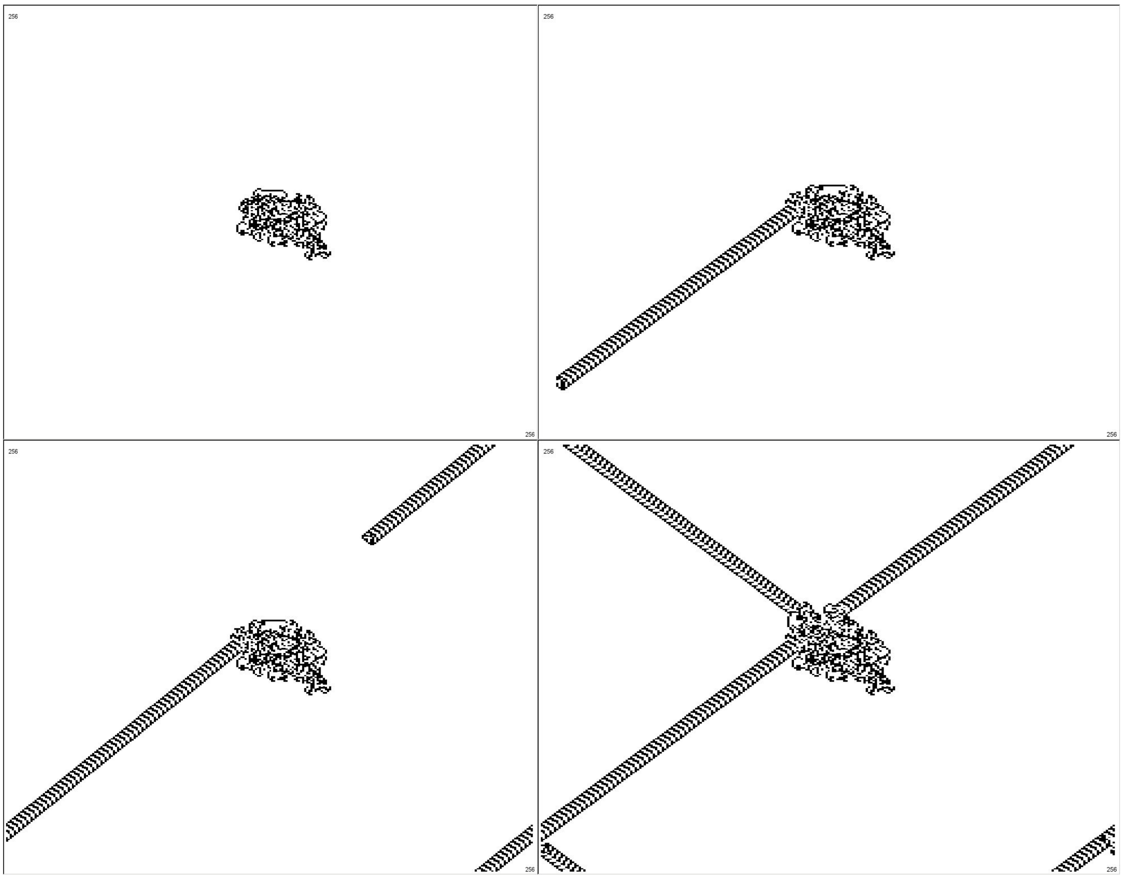
→ **Noise:** as described above.

→ **Rule:** A string of “L” and “R” letters describing the automaton. The length of the string is the number of colors: the colors are predefined (white, then black, then grey, then blue …) and up to 12 are currently supported. The N-th letter in the string is the rotation direction (Left or Right) of the N-th color in the sequence (the first letter is the rotation for color white, and so on).

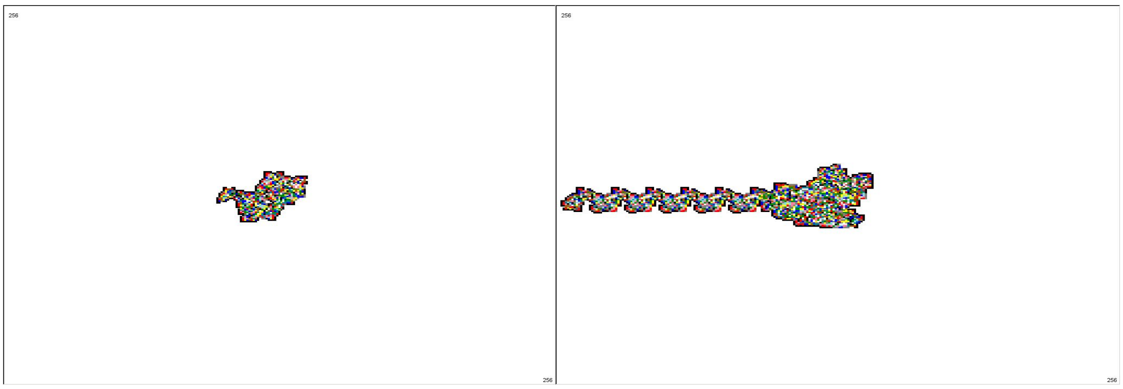
The different automaton's emerging behaviour take several thousand steps to appear, thus it is interesting to execute the simulation with 500~1000 steps per refresh. Additionally, for reasons I was not able to determine, the simulation always halt every 10000 steps, it being necessary to press again the “Run” button on the control panel again for it to continue.

Simulations without noise

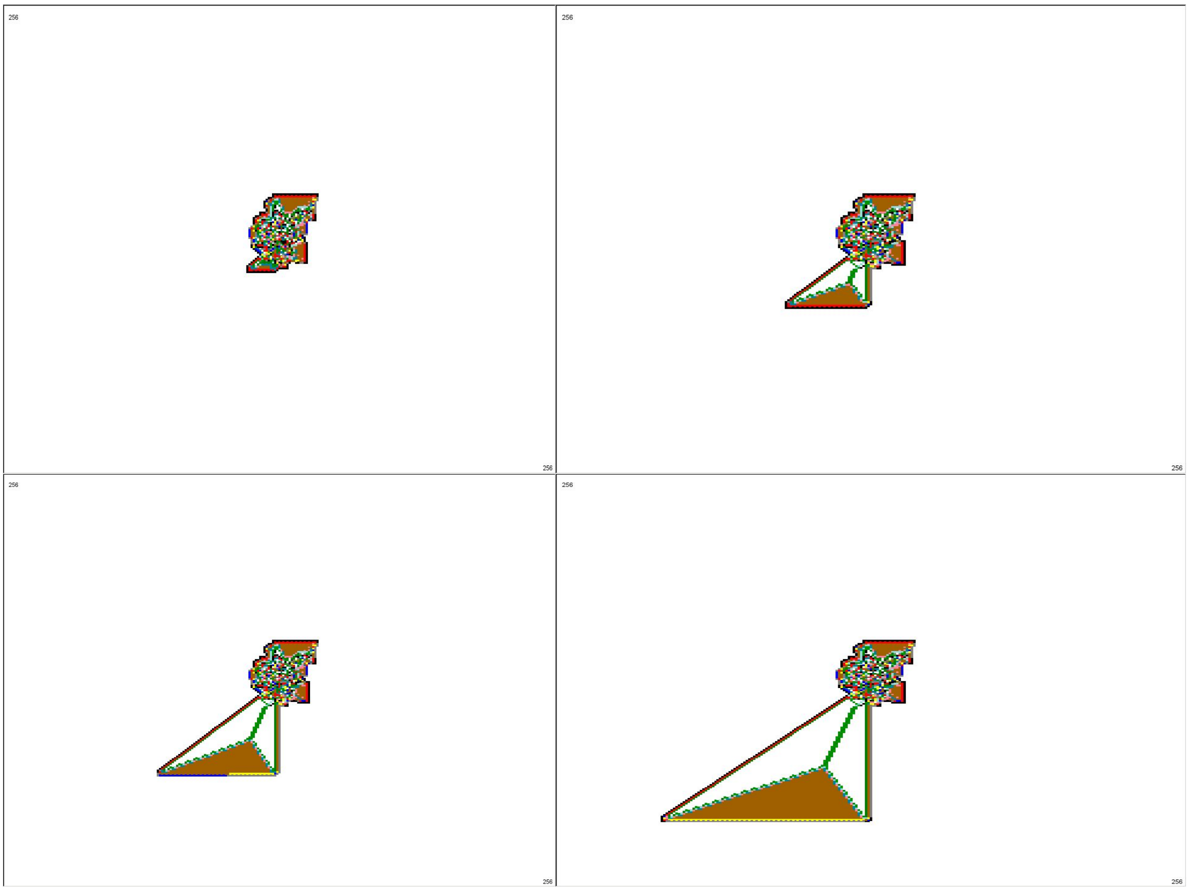
The original Langton’s Ant automaton corresponds to the rule “RL”. The images below, captured after 12761, 14951, 20001 and 29831 simulation steps in the Evolife simulator show the emergent behaviour of the ant: it first produces an irregular pattern up until about 13000 steps, when it starts producing highways, a highly regular pattern that allows the ant to move away from the starting point. Even when the highway collides with the initial structure due to wrapping around the grid’s limit, it eventually emerges again in another direction.



The 12 color rule “LLRRRLRLRLLR” also creates a (more complex) highway. The images were captured after 10291 and 40001 steps in the Evolife simulator.

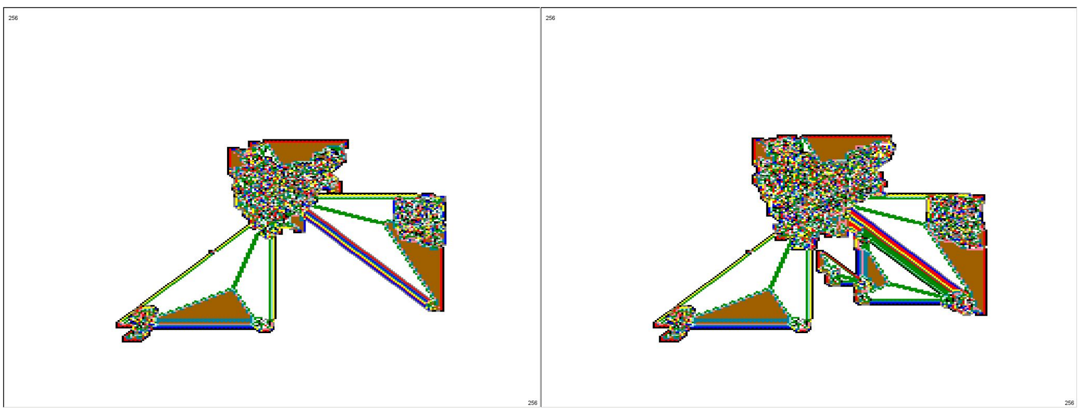


The 12 color rule “RRLLLRLLLRRR” creates a triangular structure that grows away from the starting point (images captured after 14293, 20001, 30001 and 50001 steps in the Evolife simulator).

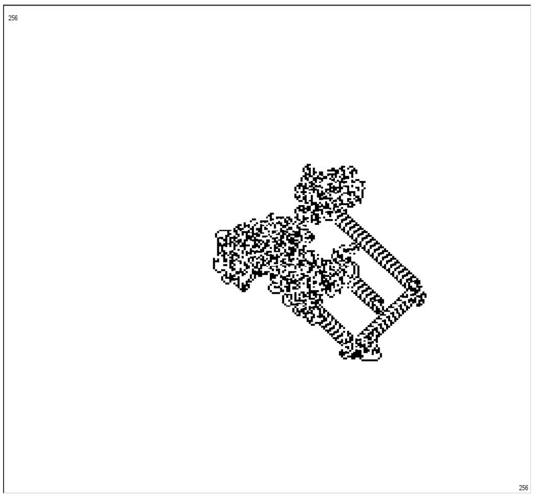


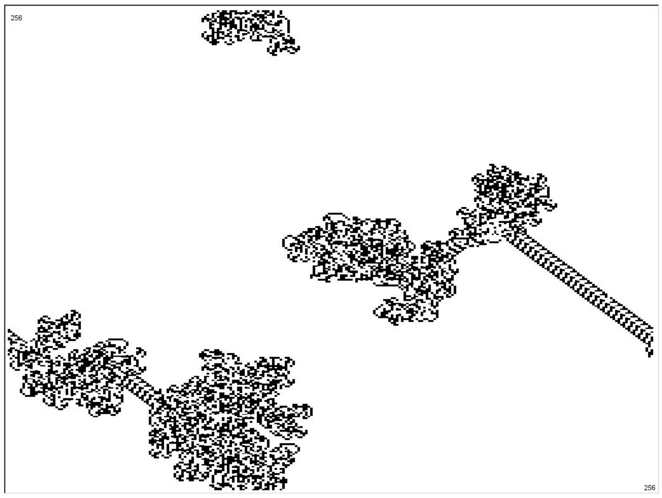
Simulations with noise

The addition of the noise parameter allows us to verify the robustness of the emerging patterns for the automata. An example of an interesting result obtained in a simulation with noise is that, with Noise up to ~75 and Rule = “RRLLLRLLLRRR”, the triangular structure still emerges. In fact, multiple triangles with various orientations may appear instead of a single one:



For noise as high as 2000, the highways of the pattern “LR” still emerge, but not necessarily in the same orientation as in the noiseless version. The highways are eventually interrupted when a wrong turn is taken, but tend to emerge again.





Conclusion and ideas for further development

The fact that the patterns in the simulation with may emerge in orientations different from the ones of the noiseless version appears to be the most interesting observation that may be derived from the experiments realized. Some further features that could be added to enhance the simulator are multiple ants and some way to specify a initial configuration for the grid.

References

[1] Langton, Chris G. (1986). "Studying artificial life with cellular automata". Physica D: Nonlinear Phenomena. 22 (1-3): 120–149. doi:10.1016/0167-2789(86)90237-X. hdl:2027.42/26022.

[2] http://mathworld.wolfram.com/LangtonsAnt.html

[3] http://www.math.stonybrook.edu/cgi-bin/preprint.pl?ims95-1

[4] https://www.youtube.com/watch?v=1X-gtr4pEBU