Cellular Automaton: *'The Roulette Wheel'* and the Landscape Effect

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Abstract. The project presented here aims at exploring the evolution of Cellular automata. Starting from previous genetic algorithms (GA) experiments, we faced the need of finding chromosomes with better performances. Exploring the universe of CA, we arrived at a notion similar with the landscape effect from GA

Keywords: cellular automata, randomness, prediction, the landscape effect, genetic algorithms, experimental mathematics

1 Presentation of the Project

This paper is a follow-up of papers [1]-[3]. In [3] we were presenting a project which aims at exploring the possibility of using the CA as random number generators. We made simulation with linear CA, with 256 cells, and used genetic algorithms for obtaining better chromosomes from the older ones. In [1] and [2], the part connected to CA it treated in more detail, from the standpoint of behavior.

In this paper we are exploring a different direction. A classic dilemma in GA is the following: offspring vs. parents. Otherwise put, the amount of new, better, material than that we already have obtained through crossings and mutations. One of the major problems experimenters have met is the landscape effect. The notion is not formalized, and it is intuitively associated with the experimenter's chance: starting from close solutions' spaces, the results differ a lot. It appears thus **the notion** (effect) **of landscape** (valley-hill): *an initially good solutions' space can lead us to much better solutions (hill), while a bad space leaves us in a pit (valley).*

The present paper is adapting the notion for cellular automata (CA). During the experiment [1], we have generated chromosome colonies and have applied GA techniques. Starting from a series of searches, we have arrived at a similar notion to that of the landscape effect (valley-hill) from GA. We have performed systematic chromosome generation, altering only one bit. The results were extremely dispersed [1]. Intuitively, if we have an initial generation (parents) with better performance, there is a better chance of having better offspring. The normal question which arose was: which is the apparition frequency of chromosomes with good performance in the total mass of experiments. This is the adaptation of the landscape concept for CA.

2 Cellular Automata

2.1 Definitions

An ‘elementary’ **cellular automaton** (CA) consists of a sequence of *elementary cells* carrying a number of predefined values, arranged on a line. The cells’ possible values are memorized in a **look-up table**.

The **configuration** of the CA is the distribution of the cell’s values (the sequences of values). Generally, the cells of a CA may be arranged on a regular lattice.

They **evolve** in a series of time steps. At each step, *the value of each site is updated* according to a **specific rule**. The value of each cell evolves deterministically with time according to the rule, involving the values of the cell and of its nearest r neighbors. Different rules (lookup tables) generate different types of dynamics of CA, when the rules are iterated in time ([4]-[6]). The evolution cycle of a CA is called also **life-cycle**.

2.2 Randomness and Prediction

G. Chaitin established in a large set of papers [7]-[11] a complete theory of randomness, connected with the capacity of programs for computing finite binary sequences. In short, he defines a string as being random if its shorter representation is the string itself. In other words, a string of bits is random as long as it does not repeat itself. When it starts repeating itself, it can be represented by an algorithm, and becomes predictable.

We adopt here the same functional point of view for CA: when it starts repeating itself, it becomes predictable. **Automaton’s evolution is random** *until it starts cycling.* We decide to stop the automaton in the moment it starts cycling, and *to consider its evolution as complete*.

2.3 Experimental Mathematics

Experimental Mathematics is a paradigm appearing in association "with the exploratory use of a computer" [12], especially "when one attempts to analyze experimentally algorithms" [13].

In our case, we have used the computer for simulating CA. The space of the solutions is of the 2^{256} dimension.

3 The Experiment

3.1 Setting of the Parameters

We used **256 cells chromosomes** with **binary values** (binary strings of length 256).

As a look-up table we have used the binary code transcription of the numbers 0-255.

As an accessing rule for the look-up table we have used a random numbers generator (it is for this reason that we named the experiment '**the roulette wheel'**).

There is one more parameter, conclusive for the experiment. The CA structure is given by the initial distribution of 0/1 cells. For the statistic experiment, it is conclusive too *the number of 1 cells in the initial structure of the CA*. We will name this parameter **initial density** of the CA.

CA were systematically generated, altering each time a bit from the preceding structure. The experiment was made with 5 initial densities: 5, 127, 128, 129, 250. These densities were chosen for the following reasons:

- The 127-128-129 group was selected because, in the CA space of dimension 256, they represent the group with the most possible cases.
- 5 and 250 are densities with a small space of possible distribution; they were selected as a 'witness', group, in order to see whether there is a sensible difference as compared with the 127-128-129 group.

The experiment was resumed with 3 automatic halting lengths of time (number of iterations after which we considered the CA as cyclic): 500, 1000 and 2000 de cycles.

3.2 The Results

The main objective is finding CA with longer life cycle. For each experiment, the simulations were made in 10 'slices' of 100.000 cases each, monitoring the results after each 'slice'.

The first surprise was that no automaton 'reached' 500 life cycles. In fact, none has reached 300! It is for this reason that the performances were counted into 3 categories: CA with a life cycle under 100 cycles, between 100 and 200, and above 200 cycles.

The synthesis of the distribution of the cases is that in table 1 (complete results are available by direct contact). We retained in this tables only the CA's with life cycles greater that 100.

'Slices'	Density **5**		Density **127**		Density **128**		Density **129**		Density **250**	
	100< 200	200+	100< 200	200+	100< 200	200+	100< 200	200+	100< 200	200+
1 – 100.000	750	7	839	4	8200	79	70	0	810	9
100.001 – 200.000	2887	22	1570	13	0	0	1526	16	7189	76
200.001 – 300.000	0	0	0	0	0	0	6491	59	0	0
300.001 – 400.000	0	0	3255	33	0	0	0	0	0	0
400.001 – 500.000	0	0	0	0	0	0	0	0	0	0
500.001 – 600.000	3532	41	0	0	0	0	0	0	0	0
600.001 – 700.0000	0	0	0	0	0	0	0	0	0	0
700.001 – 800.000	0	0	2473	31	0	0	0	0	0	0
800.001 – 900.000	0	0	0	0	0	0	0	0	0	0
900.001 – 1.000.000	0	0	0	0	0	0	0	0	0	0
Total	7169	70	8137	81	8200	79	8087	74	7999	85
Total over 100 cycles	7239		8218		8279		8162		8084	

Table 1

The synthesis of the distribution of the cases

But after all, we are looking for ’champions’. So, in Table 2 we sinthesize the aparition of the better performances.

Initial density	Maximum life cycle	Number of experiment
5	257	500.834
127	269	301.761
128	271	28.521
129	257	100.164
250	258	100.172

Table 2
The distribution of best performers

Conclusions

The objective of the paper was to explore the landscape effect for the CA’s. Lookig into Tables 1 and 2 and in [2] and [3], we fiind severat conclusions:

The first one: the notion of randon generally associated with CA is very valid from two points of vue:

- we experimented different parametters, but the statistic are rather similar (arroud 8% of performers),
- the frecvency of apparition of ’champions’ is drastically different!

The second one: Eiben A.E. et alii [14] makes a comparison between various crossover operators. In [1]-[3] we used as operator the sum. We there obtained CA’s with performances less than 100. Using the ‘the roulette wheel’ and extending the number of experiments, we have obtained here CA’s with over 200 life cycles.

We retain the idea of resuming our experiments, using ‘the roulette wheel’ as operator, and extending the number of experiments.

It becomes clear that we cannot win time with selected parameters and ‘oriented’ experiments. The only way is to obtain performers is to continue the simulations.

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