A Sequential Cellular Automata Model of Information Processing: A Preliminary Investigation

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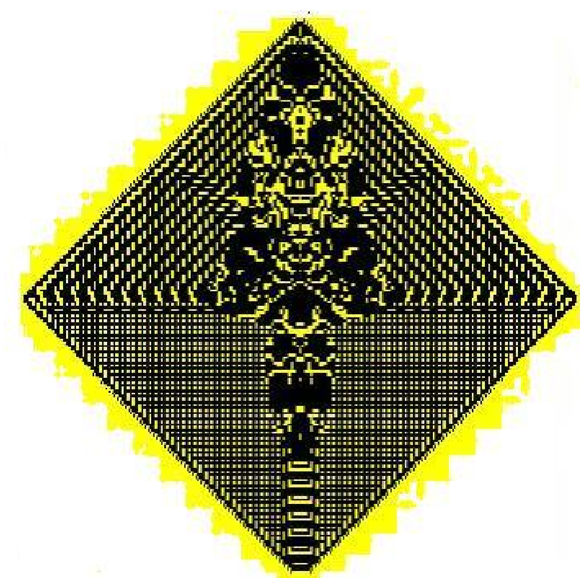


Overview & Method Summary:

With these investigations I have begun to characterize the sequential, 2-D Cellular Automata as they interact with images culled from the popular meme-space and the history of the image processing field.The images used include the famous ‘ Lena photograph , a close-up of the moon’ s surface, a standard non-smoking sign, and a seashell icon. My technique involves updating bivalent (two-color) Cellular Automata sequentially in a spiralling pattern, as opposed to simultaneous one-dimensional updating. This updating process occurs on a black and white, pixelated image which provides the initial condition for the rule at each step of the updating process. Then, the sequential CA is run again on the processed image, repeatedly for up to 10 iterations.

I hypothesize that the degree of complexity generated by a rule, either independently or using a background image, is not directly related to the rule's efficacy in processing an image. Furthermore, I extrapolate that in future investigations, the condition of global control will not significantly affect the degree of complexity or efficacy in image processing that is found in the rule space. Exhaustively investigating the various rule spaces, and drawing correlations between the simplicity of initial conditions and the complexity of outcomes are the principal ways this research reflects the New Kind of Science.

Results:

Several patterns are observed with the sequential spiral processing model. In this model, two-dimensional Cellular Automata that update each cell sequentially in an outwardly spiraling pattern, operate over an image. Each pixel in the image provides the initial condition for the spirally roving active cell. Using recursive

[NestList-based] processing feedback, once a distorted image is produced, the rule then operates again, in a spiral sequential fashion, on this processed image, 'n' times.

Under these conditions, some rules preserve salient aspects of the image, while trivially tinkering with the background texture. This might be analogous to the substrate of attention, i.e. figure/ground focusing processes. Interestingly, these rules tend to show uninteresting and simple behavior on their own, i.e. when given the simplest initial conditions, not an image. Therefore, the minimally distorted image suggests that the rule was less interactive.

Some rules preserve salient aspects of the image, while introducing non-trivial shapes and patterns into the image. This might be more analogous to imagination and other modifications to basic image processing. Some of these rules actually appear to create situations of "white wash" when given the simplest initial condition (1 black cell).

Third, there are some rules that act specifically at the sites of the image that are crucial to its identity (i.e. the edges and shapes), and begin to introduce variation and mutation at these sites first. Many times these rules decay the image quickly (i.e. after 1 order of recursion), but occasionally the image is modified only slightly over several levels of processing.

Fourth, there are rules that tend to annihilate the image’ ssalient characteristics almost immediately, either by washing the image black or white, or by creating a field of noise.

Conclusions:

It appears that the rules which most interestingly combine image preservation and novel form generation (complexity) are not necessarily the rules which exhibit the most interesting behavior on their own (when provided with the simplest initial conditions). Thus, I am inclined to tentatively confirm my hypothesis that the difference in complexity of 'higher-order' processing and 'lower-order' processing is trivial. My goal is to continue these investigations in order to more firmly extrapolate the conclusions to mental processes. In theory, I will be attempting to demonstrate the Principle of Computational Equivalence, with regards to these two supposed tiers of consciousness.

This first question arises: what are the rubrics for evaluating this model? How do we compare the information processing efficacy of global control with non-global control, and should we correlate these assessments of efficacy with assessments of complexity? It seems that obvious preservation of the image, as well as a qualitatively apparent level of complex form generation are the basic assays involved in this model. My next step is to perform an exhaustive search of the sequential and global-control rule spaces to compare them regarding these variables. One possibility is to compare the ratio of rules that exhibit complex behavior to rules that do not, within each of the categories of Cellular Automata I have investigated (and within each type/permutation of global control). Then these ratios will be compared to how the CA categories perform with respect to information processing efficacy. I am inclined to believe that those rules and rule combinations which manage to preserve salient aspects of the image-at-hand, while also introducing non-trivial modifications to the image, best represent the complexity and efficaciousness of mental information processing. It is my suspicion that situations of both global and non-global control include comparable numbers of rules that exhibit these two behaviors.

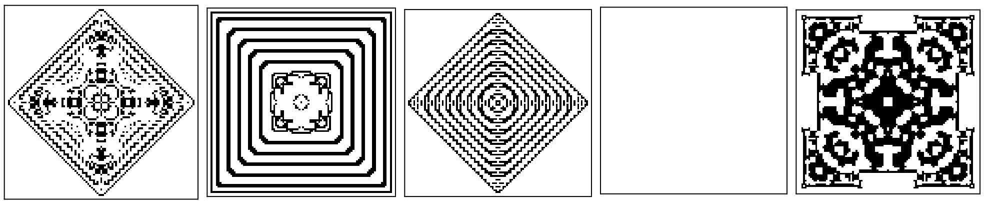
In upcoming investigations, I will investigate the effect of global control on processing efficacy and complexity. To create the condition of global control, I will determine at each step the mean value of the previous 100 cells, and assign a rule to be applied to the active cell based on whether that mean was in one of three normalized thirds (under 0.45 black/white; 0.45 to 0.55; or over 0.55).I will also have to explore the permutations of global control more fully. As of now I have simply taken core samples of the 2-D totalistic and sequential CA rule spaces. In part due to technical difficulties, the full NKS-style of exhaustive rule-space searching was not possible for me within the scope of the Summer School's three-week itinerary.

As Colleague Nochella has pointed out, this iterative, recursive process most directly reflects the one-glance information processing situation. In this case, the image is captured in one glance and then subject to the preservative or not-so-preservative processes of memory and interpretation. To get the model to correspond more to the situation in which an image remains stably in front of the viewer, we will have the CA update the "negative" and "positive" spaces of the image separately. Additionally, starting the sequential CA at multiple locations in the image would a potential extension of this technique. Furthermore, an initial parallel-processing sweep could be introduced, prior to the sequential update process, to capture the difference between what the retina does to an image and what the cortex and midbrain does with the information the retina provides.

Figures and Faces

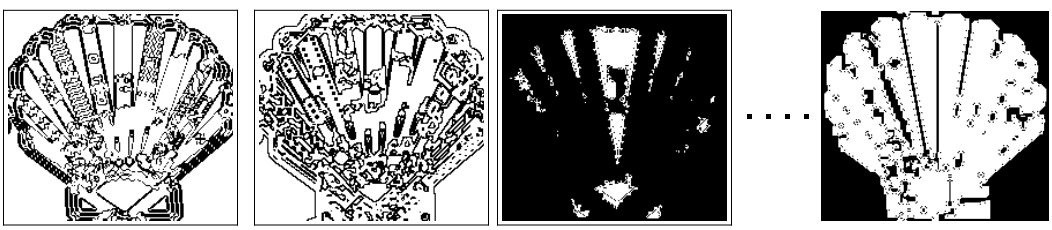
2-D Cellular Automaton With Simplest Initial Conditions, to 50 steps

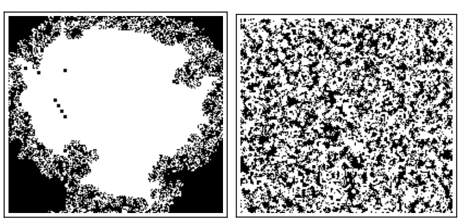
Rule 12 Rule 30 Rule 60 R. 135 etc. Rule 1010



2-D CA Rules, after 9 steps on a seashell . . . . 2-D CA Rules, after 100 steps on a seashell.

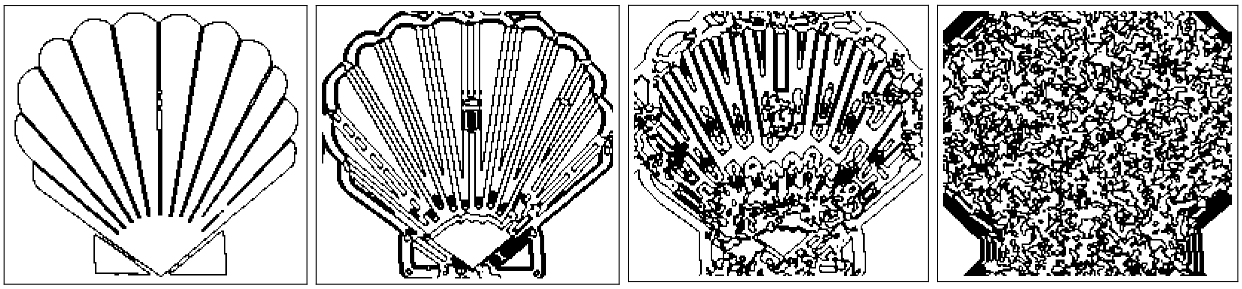
Rule 12 Rule 30 Rule 1010 Rule 135 Rule 351
Rule 523





2-D CA Rule 60, on a seashell, at...

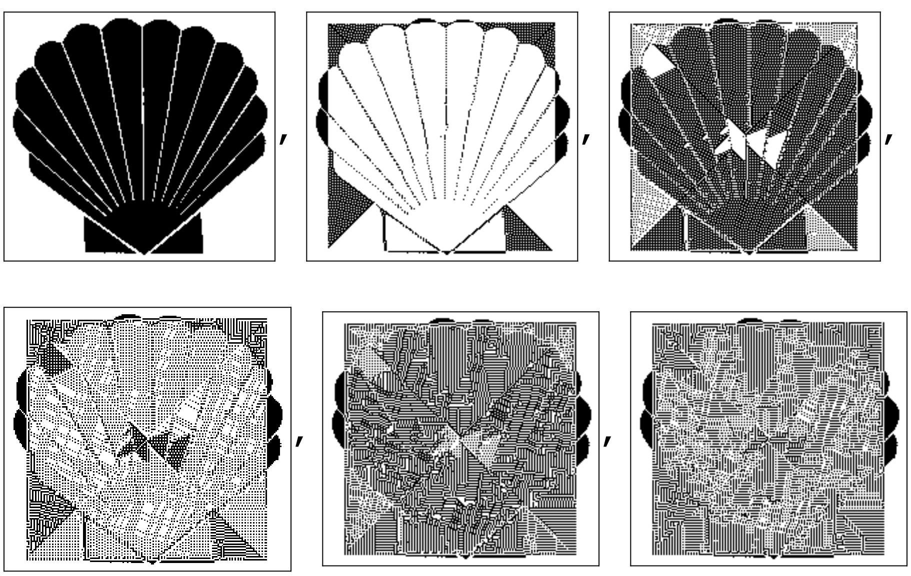
1 step..............6 steps......... 13steps............32 steps



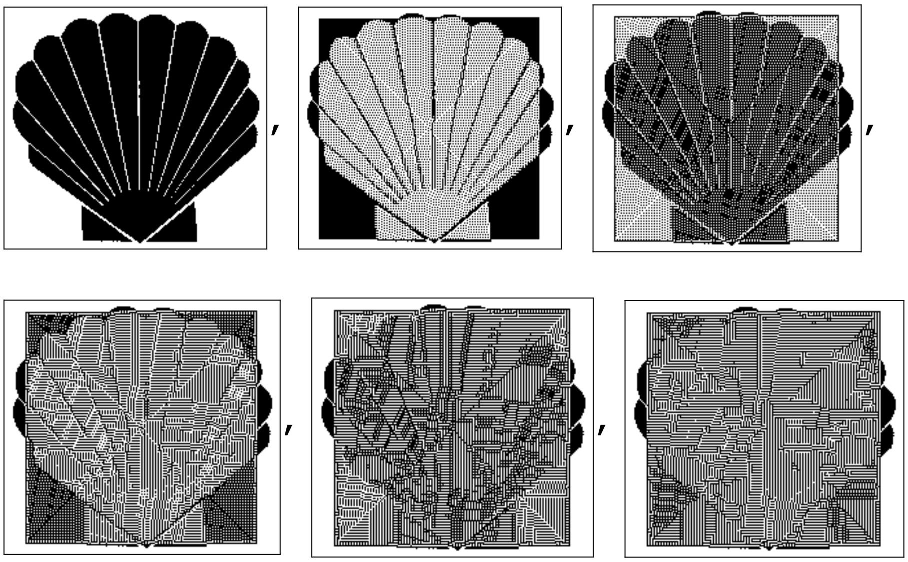
Sequential, Recursive CAs on Seashells, to 29,000 steps

Rule 12, Five orders of recursion.

0 1
2 3 4 5

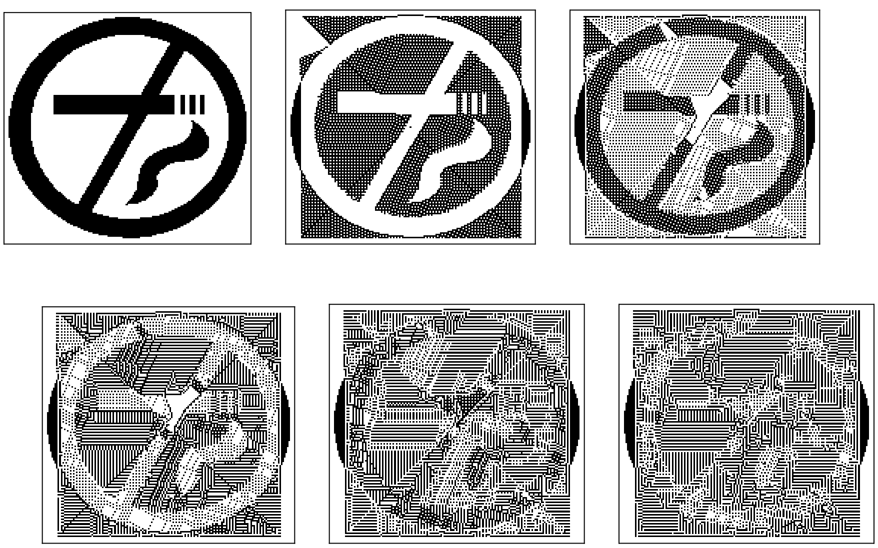


Rule 60, Five orders of recursion.

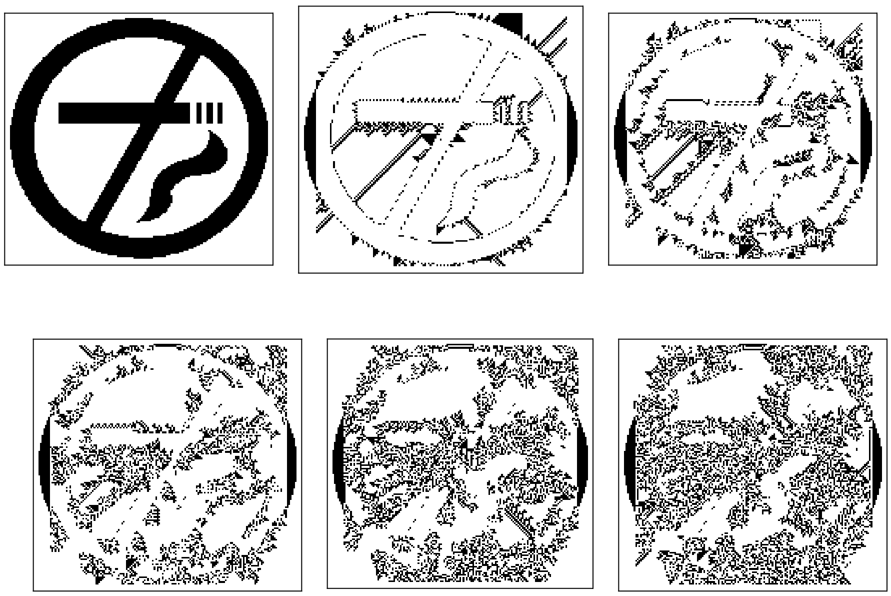


Non-Smoking, Sequential, Recursive Cellular Automata

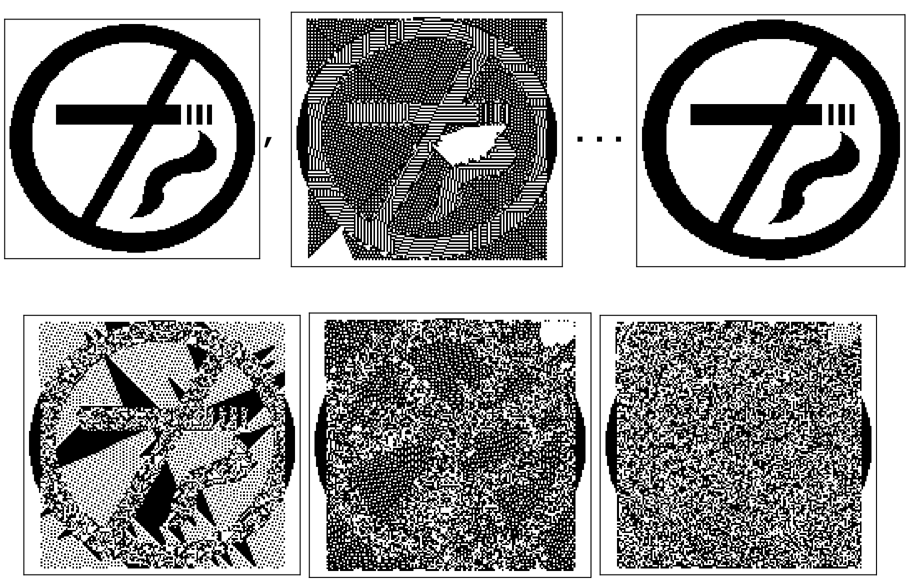
Rule 12- Broken glass reflections



Rule 20 - Reforestation of the wake

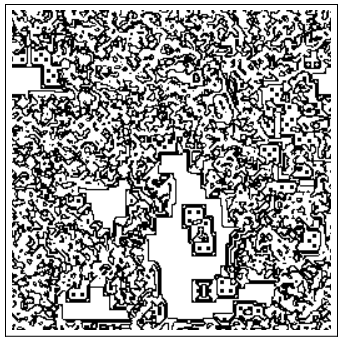
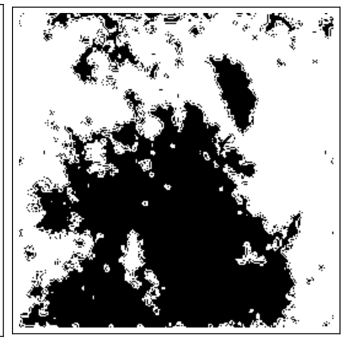


Rule 246 - Withering and Aging...Rule 345



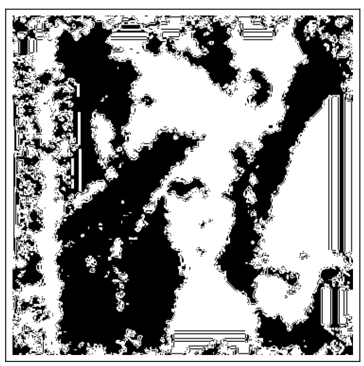
2-D Cellular Automata On the Moon

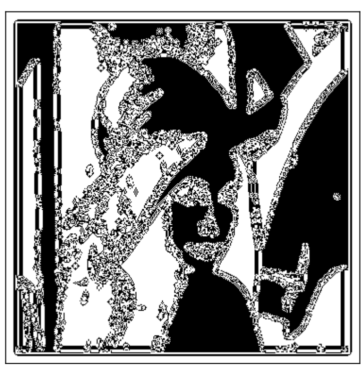
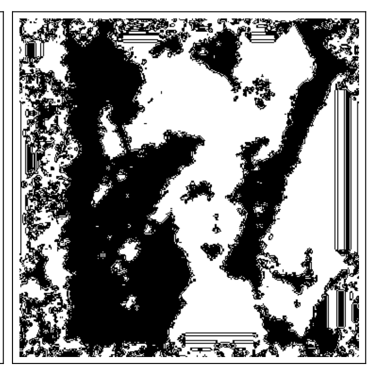
Rasterized Image Rule 30, ten steps Rule 71, ten steps

2-D Cellular Automata on Lena

Rasterized Image Rule 71, 25 steps Rule 63, 25 steps Rule 101, 4 steps Rule 119, 25 steps

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CA State Motto: Complefficaciousness