LAB 1

Bio-Inspired Computing (COSC 527)

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Introduction:

In this lab, we conducted experiments to explore the four different behavior classes in Wolfram's cellular automata using various random rules. We applied a decimation approach to the rule table to gain better insights into the transition states and repeated this process thirty times using different random rules based on the seed. There are a total of 390 images, counting thirteen different steps in each experiment. From this set of images, we eighteen images were found that exhibited **class IV** behavior.

To evaluate the behavior of the four classes, we used Langton's lambda and entropy parameters for both totalistic and non-totalistic transition rules. Additionally, we introduced a new parameter called zeta to gain better insights. This parameter measures the homogeneity of the states in each transition rule, having normalized based on the average. We selected this parameter because it helps to identify the likelihood of class III and IV behaviors when there is no or little quiescent state (i.e., state zero) and the zeta parameter is relatively lower. It becomes apparent that more class I and class II behaviors are likely to appear, and as it increases.

Overall, our experiment provided valuable insights into the behavior classes of Wolfram's cellular automata and helped us to better understand the transition states between the different classes.

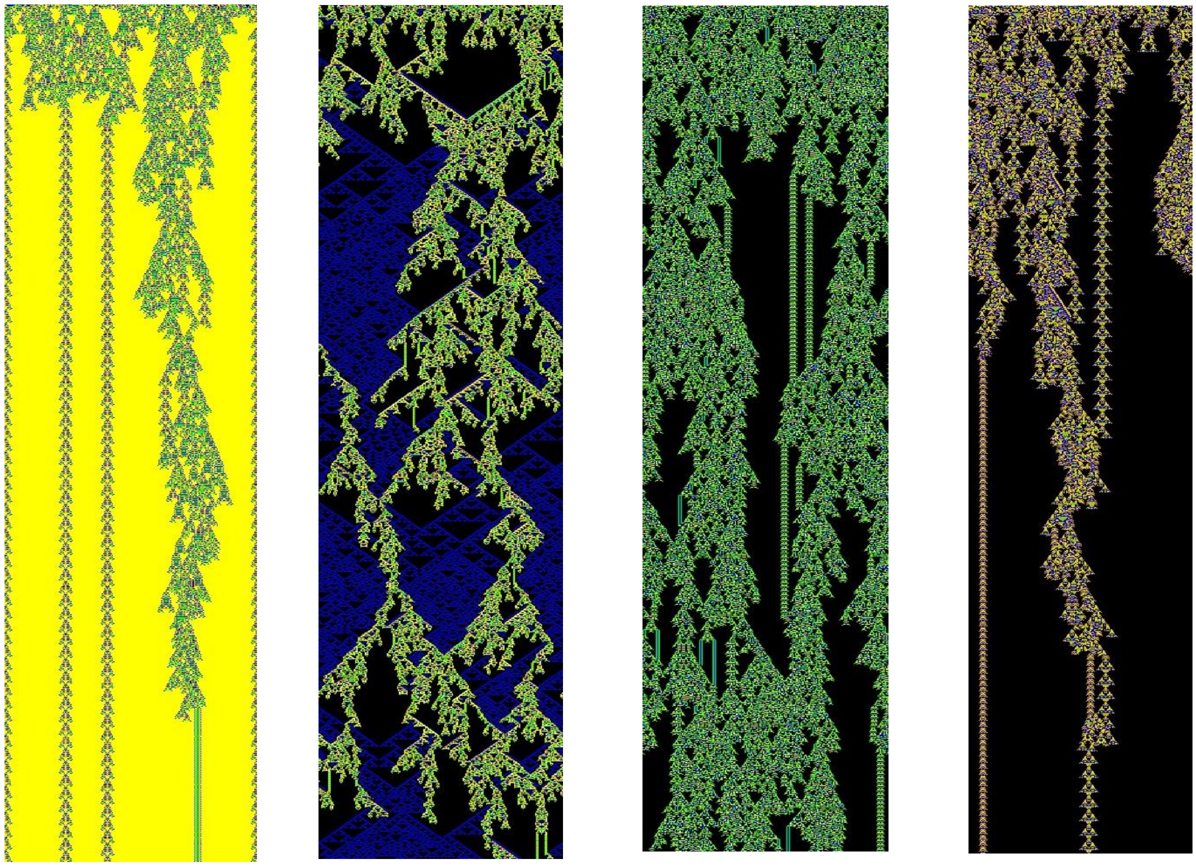

Figure 1: Wolfram’s Class IV

Graphs:

The raw data is in the main "MasterExperiment.csv" file. Here are the five different parameters' standard deviation and average values when the class IV pattern occurs.

Parameters	*SD*	*Average*
Lambda	0.226337	0.690222
Lambda_t	0.233725	0.619658
H	0.283552	1.830584
H_t	0.4027	1.877612
Zeta	0.525468	1.082639

Out of the five parameters, lambda had the lowest standard deviation, while zeta and totalistic entropy have the highest. As standard deviation measures variability, class IV systems could be expected to have similar lambda values. However, the other parameters could also help in identifying class IV behavior. To understand how the parameters might indicate class IV behavior, we created graphs that relate the parameter values to the behavior class for each experiment. The graph represents class I and II behavior as 0, class IV behavior as 1, and class III behavior as 2. Each line on the graph represents a different experiment numbered from 0 to 29.

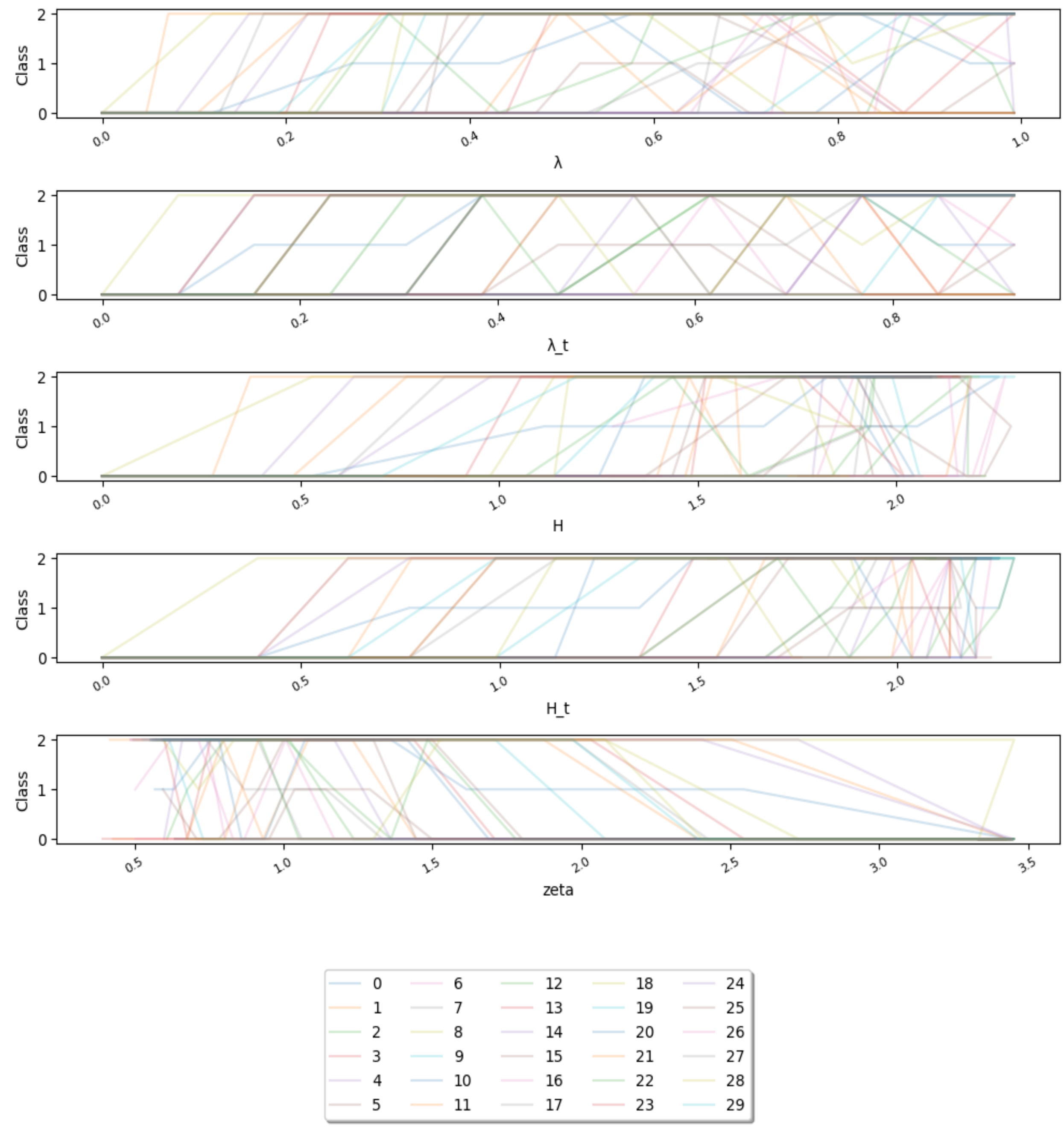

Figure 2: All four classes with five different parameters (Lambda, Lambda_t, H, H_t and Zeta) respectively.

To better show overlapping values, the plots have a degree of transparency. We observed that systems changed classes more often at higher values for the entropy and totalistic entropy graphs and a lower values of **Zeta** parameter. Additionally, class IV behavior was more common at higher totalistic entropy values. The lambda and totalistic lambda graphs show a more even spread of all classes, though there were fewer class I and II instances at higher values and fewer classes III and IV at lower values. Since the lambda values decreased at a predictable rate, most experiments changed states around similar steps. The zeta graph showed that most class III and IV behavior happened towards the top and middle (relatively lower values), which makes sense since more quiescent cells indicate restrictive rules.

Discussion:

Class IV behavior was found to occur more frequently when the totalistic lambda value was between **0.5 to 0.75**, the lambda value was between **0.5 to 0.7**, the entropy value was around **1.8 to 2.0,** the totalistic entropy was between **1.82 to 2.1**, and the zeta value was between **0.85 to 1.2**. This was supported by the graphs and the above-mentioned table. For both entropies, class IV behavior tended to occur within the average values of **1.83 to 1.87**. Experiments with lambda values were more likely to move from a complex class to a chaotic class. Based on the zeta graph, chaotic or complex experiments mainly occurred at lower values and were unlikely to change to a simple and uniform state unless zeta values exceeded **1.3**. Additionally, most systems with 100% or nearly 100% quiescent states changed directly to simple, fixed, and homogenous patterns. The plots correlate with the standards and averages calculated earlier.

Class IV behavior tended to appear when chaotic regions did not crowd the whole board, and there was enough complexity in the rule to allow patterns. While experimenting, it seemed to observe that classes occurred in groups, which was supported by the graph of the lambda function. However, it should be noted that the lighter graph of lambda in the class IV region is a relatively poor estimate of class IV behavior.

It would be interesting to feed these features into a machine-learning algorithm to see how well the classification would perform based on these features. There were some **anomalies** observed during the experiments. For instance, in experiment 0, “class IV” was first found in the first two steps and did not reappear until step seven. The **observation** is that most of the time “class IV” did not seem to be able to make patterns through the empty "holes" of the quiescent state and instead made patterns through the triangle pattern that is common for higher steps. Another anomaly was observed in experiment 8, in which “class III” happened from step zero until step 11, then one “class I” pattern evolved. Similar anomalies were observed in experiments 14 and 17, as well as 24 and 29. In experiment 10, “class II” happened for the first two steps and then class I happened from step 2 to the last step. Finally, in experiment 11, all the patterns were “class I”.