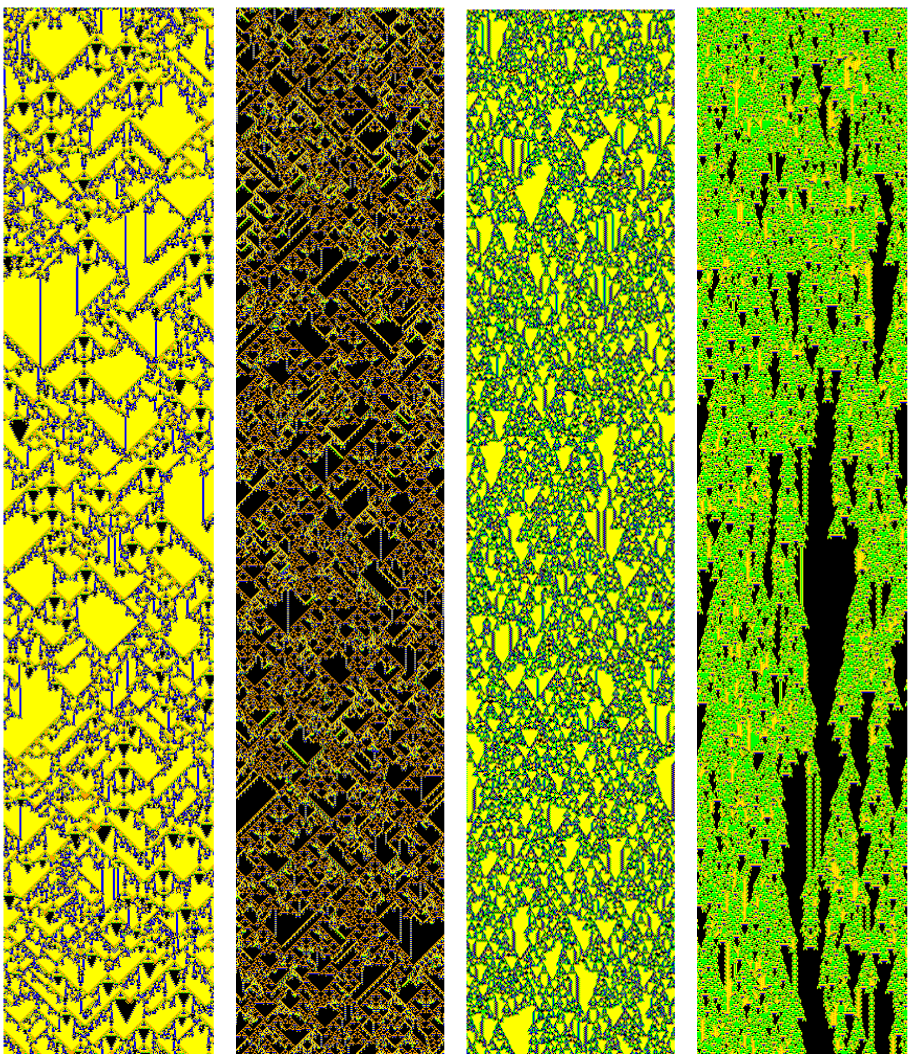
Lab 1: “Edge of Chaos” in 1D Cellular Automata

Introduction:

The objective for this lab was to investigate the “Edge of Chaos” phenomena. The main goal was to look into the Wolfram class IV behavior in the 1D cellular automata. The provided code generated random transitions tables and the lab involved recording the class values which indicate the system’s behavior. The experimental code generated a total of 30 experiments with 13 cellular automata each and their corresponding PNG images and all that information had to be recorded in the MasterExperiements.csv file.

The project also looked into the calculation of lambda(λ) and entropy which are very important when we are trying to understand the dynamics of cellular automata. The lambda(λ) is basically seen as a measure of the system’s complexity while the entropy of the transition table offers us with an additional insight into the system’s behavior. Below are some images which portray the class IV behavior that were observed during the analysis of the experiments.



Class IV behavior

Calculations:

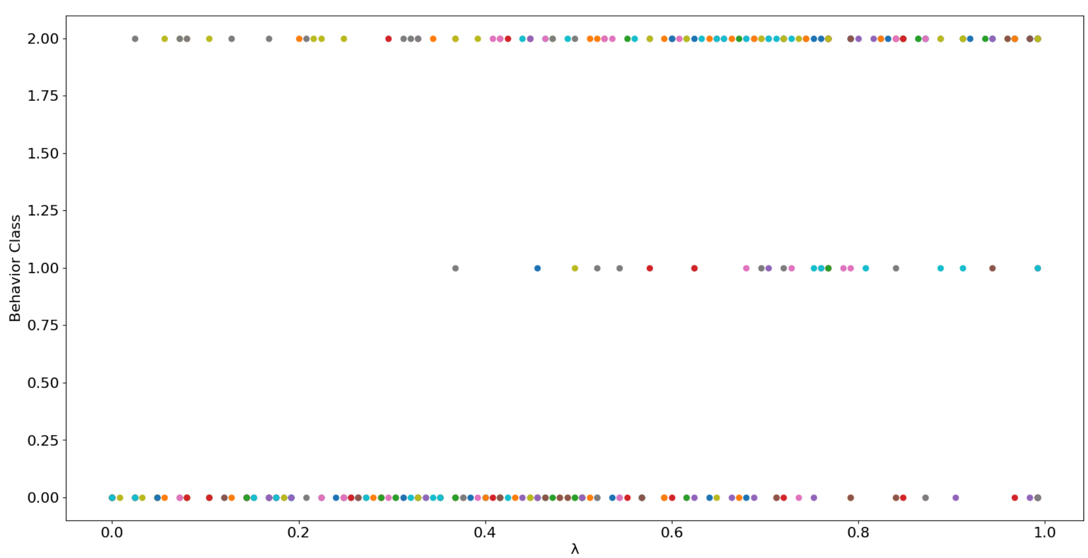
To better understand the behavior of the cellular automata, lambda(λ) and entropy(H) values had to be calculated. We also used two different approaches: totalistic parameters of λT and HT and complete transition table parameters of λ and H. The calculations involved in this lab show us the computation of the average and standard deviation of the λ, λT, H, and H_t values for all simulation instances that exhibited behavior similar to class IV.

	Average Value	Standard Deviation
λ	0.722	0.156
λT	0.684	0.147
H	1.907	0.166
H_t	1.970	0.178

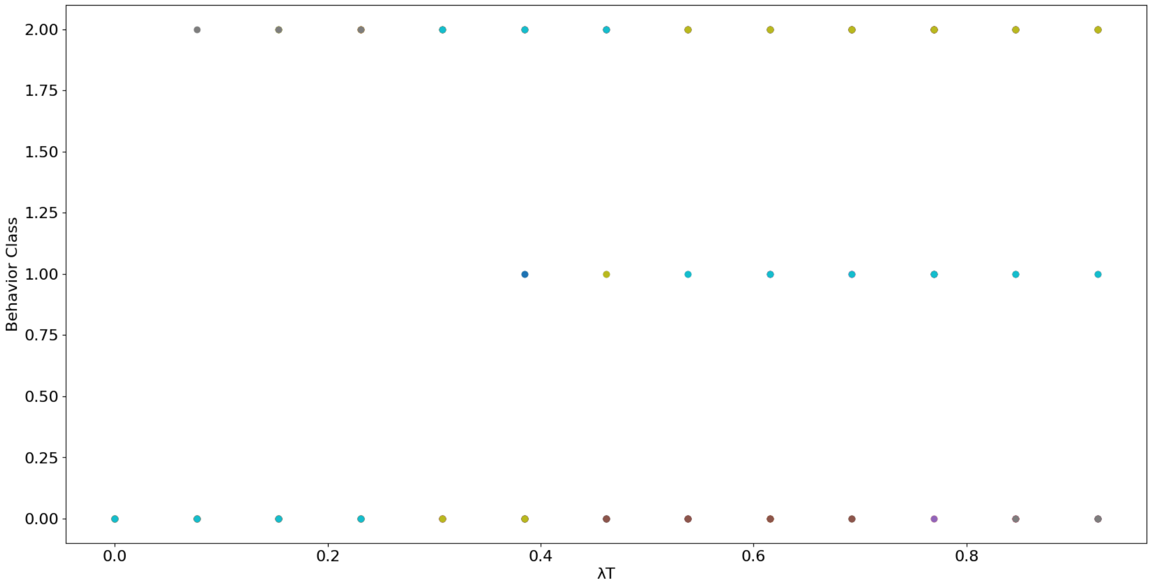
As it can be seen in the table above, the average λ value of 0.722 and H value of 1.907 indicate complex behavior in the cellular automata systems that are being studied. These values are basically showing us that the systems have a very slight balance between order and chaos which is very much like class IV behavior. The standard deviation value of λ being 0.156 and H being 0.166 tells us that the observed behavior variability across all the experiments are emphasizing the nature of cellular automata dynamics. In the same way the average λT(0.684) and HT(1.970) values help further understand the notion of high complexity in the cellular automata that we looked at. The standard deviations of 0.147 and 0.178 for λT and HT respectively, underscore the variability in totalistic parameters across simulation instances. This variability also reflects the diverse nature of classic class IV behavior.

Graphs:

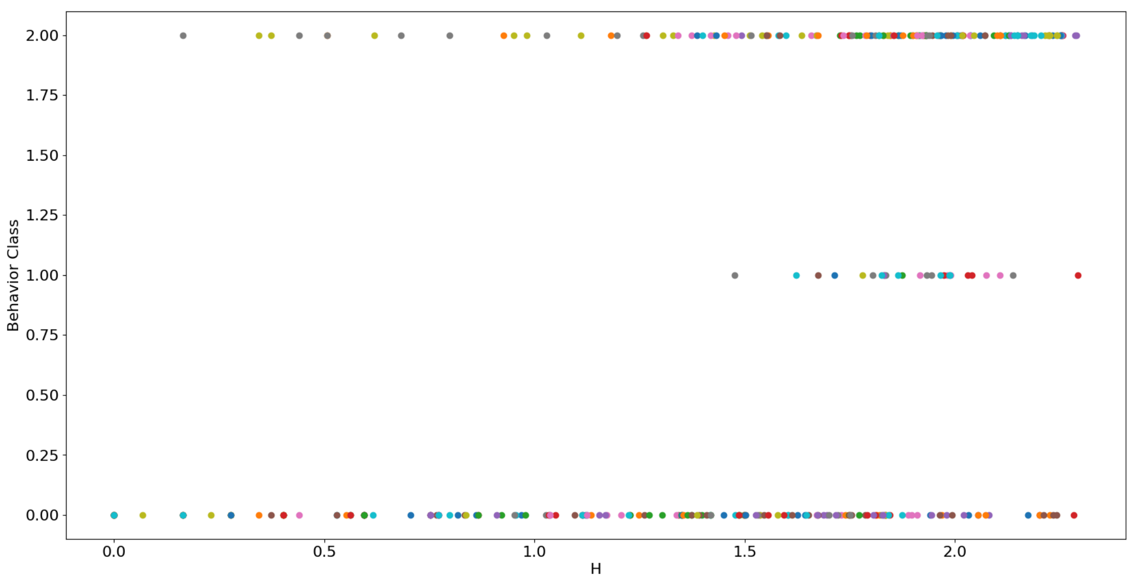
The graphs below are about behavior vs λ, λT, H, and HT. They help us understand the relationship between these metrics and the qualitative behavior of cellular automata.



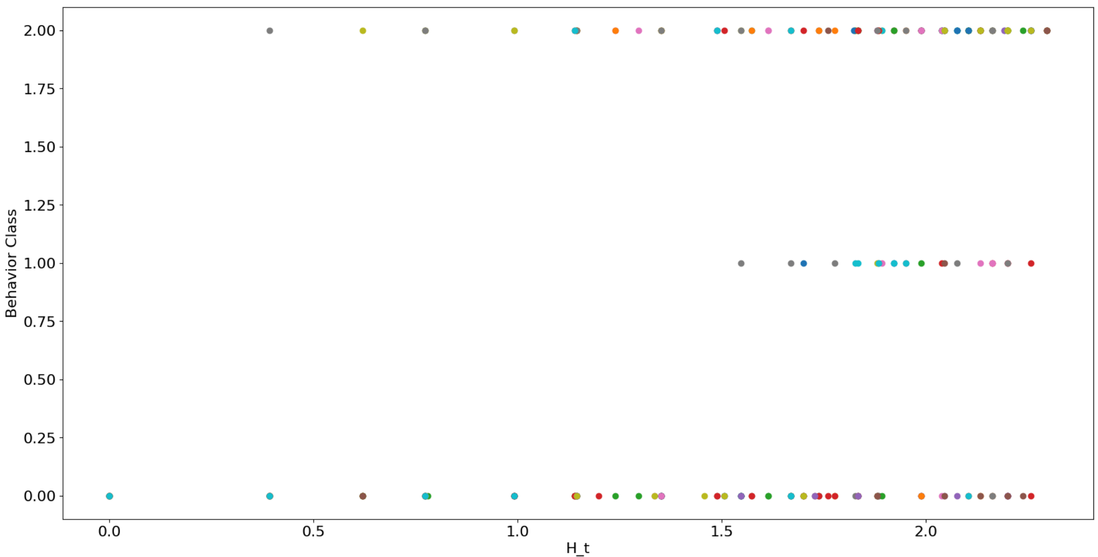
The graph above is about Behavior .vs λ, Class 0 shows a concentration of points between 0.2 and 0.8, with fewer occurrences at extreme values. Class 1 shows a preference for higher λ values at 0.6 to 1.0, while Class 2 displays a relatively uniform distribution across the λ range.



The graph above is about Behavior vs λT, here for Class 0, all the points are quite evenly distributed from 0.0 to 1.0 which tells us that the totalistic lambda value has a less of an impact on the qualitative behavior within this class. In the same way Class 1 and Class 2 behaviors show uniform distribution across the range of λT values which tells us that there is a lack of distinct preference for specific λT ranges.



The graph above is about Behavior vs H. For Class 0, there are a few points that can be seen in the range of 0.0 to 0.5 and then we can see even more points in the range of 1.0 to 2.0. This distribution suggests that class 0 behaviors are associated more with a moderate to high entropy values which also tells us about the complex dynamics within the system. On the other hand, class 1 behavior is more like a distinctive pattern, where there are no points seen in the range of 0.0 to 1.5. Instead we can see a sparse scattering of points in between 1.5 to 2.0 which tells us that class 1 has higher entropy values. In the same way, class 2 behavior displays a bunch of points in the range of 1.25 to 2.25 which tells us that there is a propensity towards moderate to high entropy values.



The graph above is about Behavior vs H_t. It looks quite similar to the graph of Behavior vs H. Just like behavior vs H graph, Class 0 shows a mix distribution across different HT ranges. Class 1 can be seen having higher HT values, while Class 2 displays a more of a uniform distribution.

Discussion:

The analysis done for this lab helped us reveal several insights into the range of values of λ, λT, H, HT that lead us to see Class IV behaviors. λ and λT values that we saw in the graphs above in the range of 0.6 to 0.8 appear to be indicative of Class IV behavior. On the other hand if we talk about H and HT values, we can see that those values that were between 1.0 to 2.0 exhibit a higher chance of Class IV emergence.

We were able to also see some anomalies where Class I or II behavior occurred at much high λ, λT, H, HT values, which tells us that these parameters alone may not be the best predictors of Class IV behaviors. In kind of the same way, some cases of Class III or chaotic behavior occurring in areas with Class I and II show us the complexity of cellular automata. These anomalies that we saw may be caused due to the complex interaction between the local rules and the global dynamics. There could be various different kinds of reasons like initial conditions, boundary conditions, and neighborhood configurations can affect the emergence of different kinds of behavioral patterns which may cause some unexpected results.

In conclusion, while the λ, λT, H, HT values sure did provide us with some valuable information regarding the behavior of cellular automata, their predictive power might have been limited because of the complexity inherent in these systems. If we were to look more into some additional parameters and analytical techniques then we might be able to enhance our understanding of the “Edge of Chaos” phenomena in cellular automata in much more detail with some much promising results.