Project 1: “Edge of Chaos”

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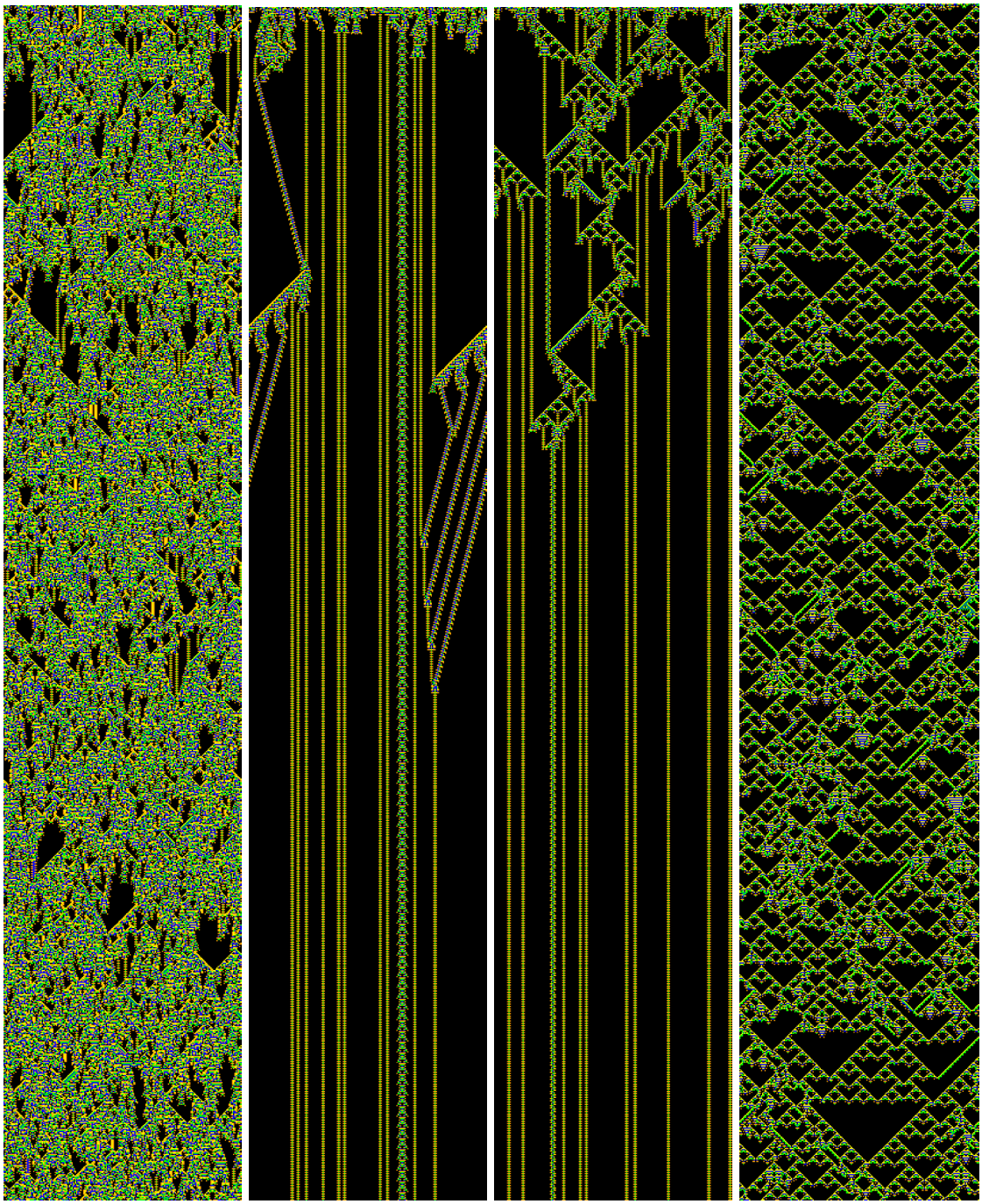
Introduction

This project is looking at the “Edge of Chaos” phenomenon which is analyzing Wolfram class IV behavior within 1D Cellular Automata (CA). Using Chris Langton’s table-walk-through-method, 20 experiments were run at 13 steps producing 260 unique CAs which were then manually classified to analyze the efficacy of certain parameters. 93 instances of Class IV behavior were observed.

Somes examples of Class IV are:



Theory

The central idea of this project was to analyze different measurements of order and disorder of the CAs to find out which was the most effective at predicting Wolfram Class IV behavior. We looked at Langton's lambda, the totalistic lambda, entropy, totalistic entropy, and a custom Zeta value. We used Chris Langton's table method which generates a random rule string and by decimation, we randomly zero out one non-zero part each time. This creates multiple (13 in our case) CAs based on a similar rule string.

Zeta

For my Zeta value I decided to look at compressibility as a measure by dividing the length of the compressed representation of the CA with the size of the entire 'board'. I used the built-in savez_compressed function within the numpy library to compress the board and compared it to the size of the uncompressed savez function to get a compression ratio. My reasoning was that for very predictable states such as for class I and II behavior, it should produce a low ratio with class III being the highest valued since it is chaotic. It is implemented in the calculate_zeta function in the code.

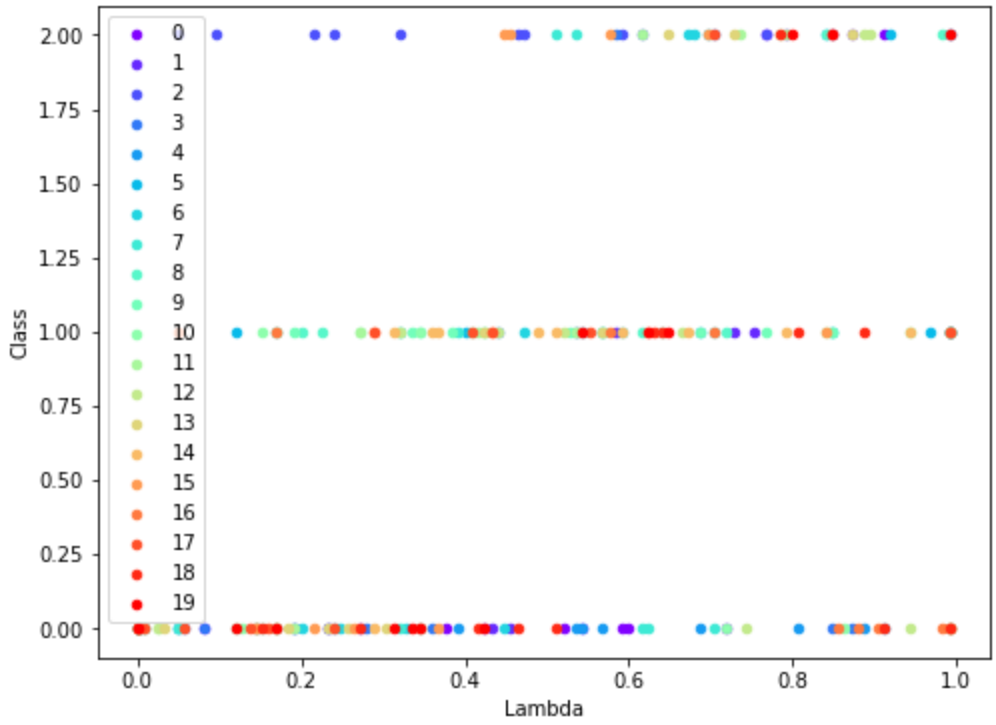
Table

This is a table summarizing the average and standard deviation for the various parameters for class IV behavior.

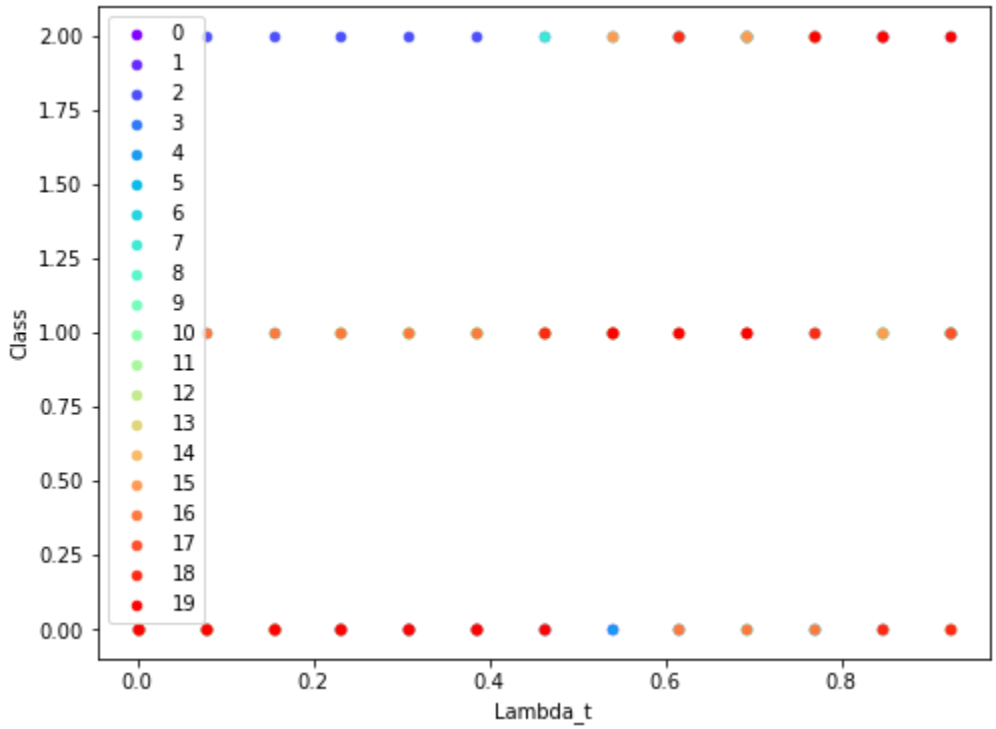
	Lambda	**Lambda_t**	**H**	**H_t**	**Zeta**
Mean	0.574022	0.551696	1.676877	1.712130	0.037956
Std Dev	0.253558	0.235083	0.438549	0.448452	0.013163

From looking at the standard deviation, it seems that the totalistic lambda was the best measurement of the original parameters due to the lowest spread of values within class IV. However, the zeta value that I used had an even lower spread of data which would imply a better measurement if we only look at std. Dev since it implies that it was tightly clustered for Class IV.

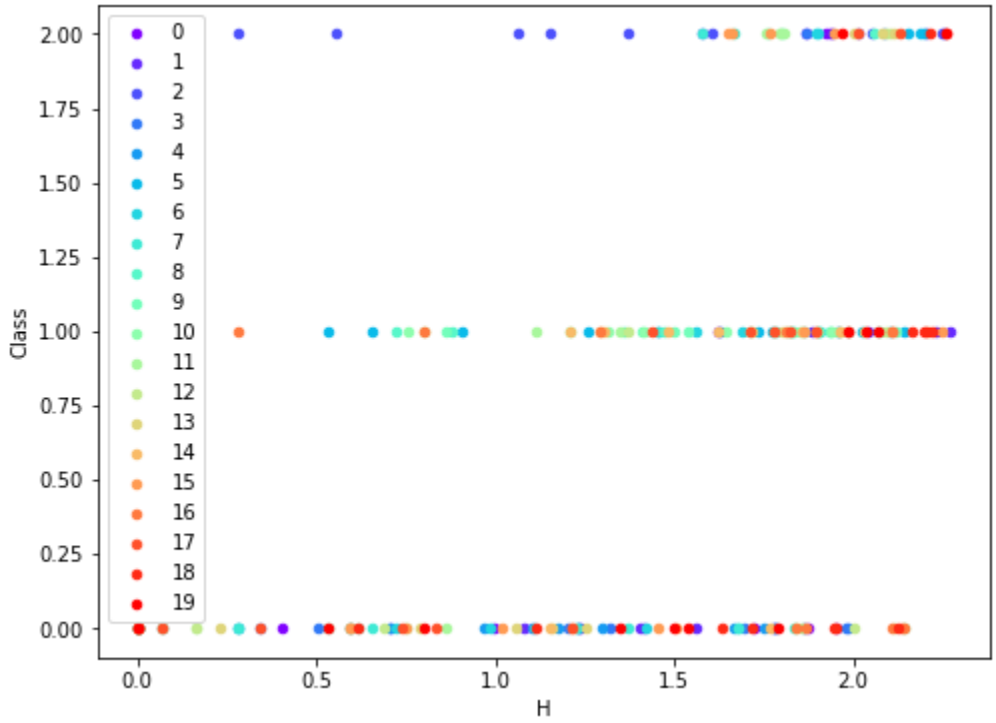
Results



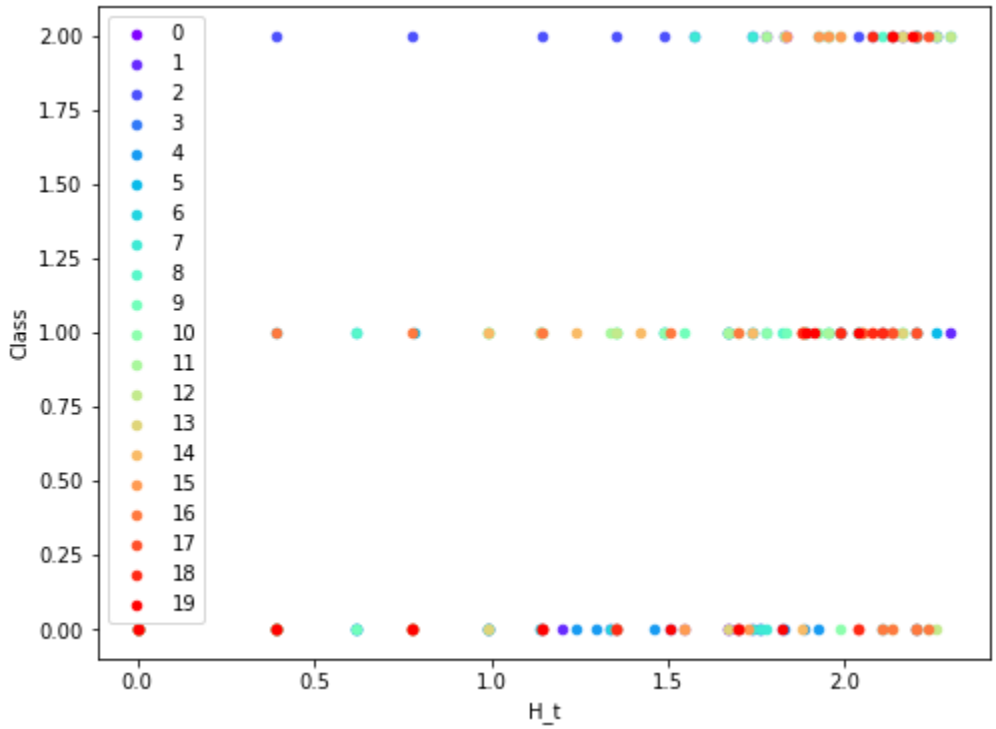
Mostly spread out though Class III seems denser at higher values.



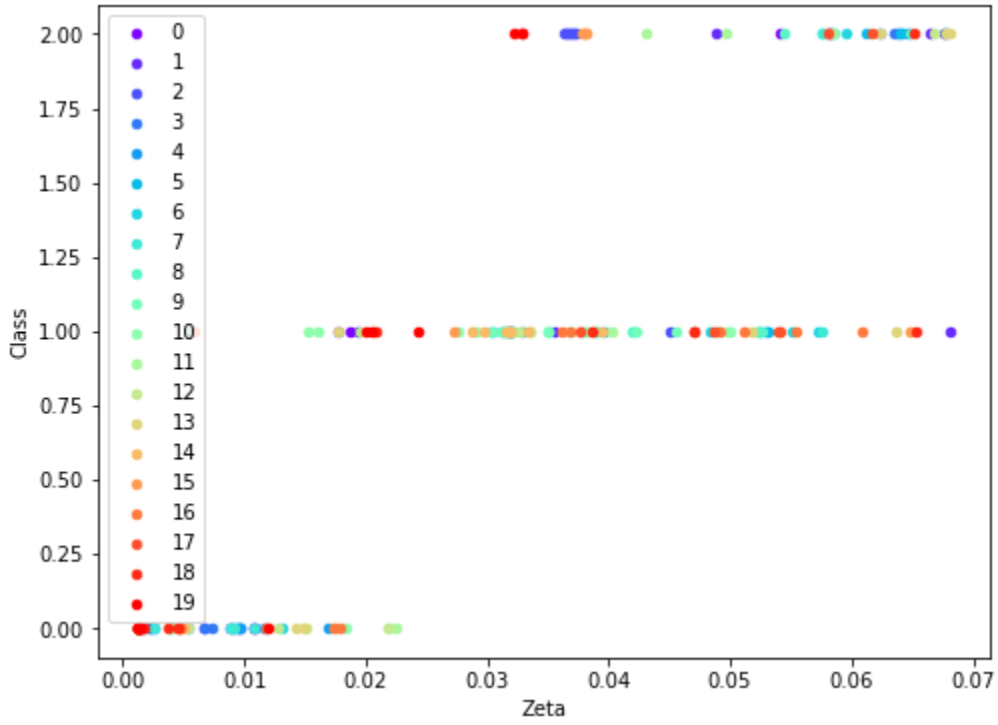
It seems uniformly spread out for all classes suggesting that Lambda_t might not be a great indicator.



Class III and Class IV seem denser at higher values.



All classes seem denser at higher values.



Class I and II are densest at lower values implying it's a good indicator of class I and II.

Conclusion

Most of the parameters seem pretty noisy. There's some clustering at certain ends of the range of values for certain classes, but for the most part it seems hard to tell which class is what based solely on a single parameter. The Zeta parameter through, seems to be good at indicating class I and class II behavior. Overall, there was definitely some human error in classifying borderline classes for class III and class IV which would have contributed greatly to the noisy parameters.

A more rigorous method of identifying class IV behavior and a sort of cross validation with other people classifying the data is needed to get more precise data as well as another method than what I used for my zeta measurement.