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Lab 3: Hopfield Networks

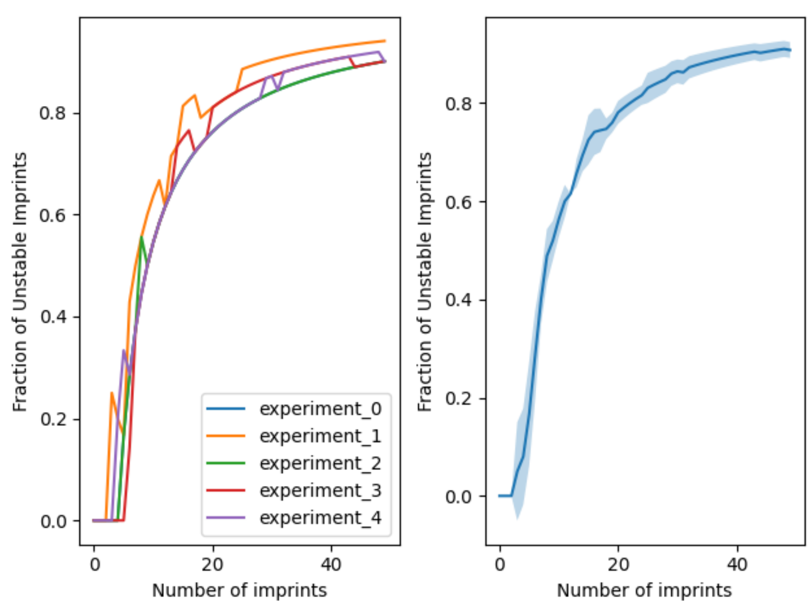
Introduction

This lab explores the use of hopfield networks in remembering sequences of patterns. Data we want to encode is represented as a pattern of ones and negative ones. The network takes this pattern and sets a vector of values representing the state of each node in the network. A matrix of weights is created representing the connection between each node. Essentially, the Matrix value at coordinate i, j shows whether the nodes i and j have a similar state. If both are one or if both are negative one, the weight is a one, and negative if the node values are different. If the connection represents a node connecting to itself, then the weight is 0. When encoding multiple patterns, the resulting weight matrix could be thought of as the average of the weights across matrices.

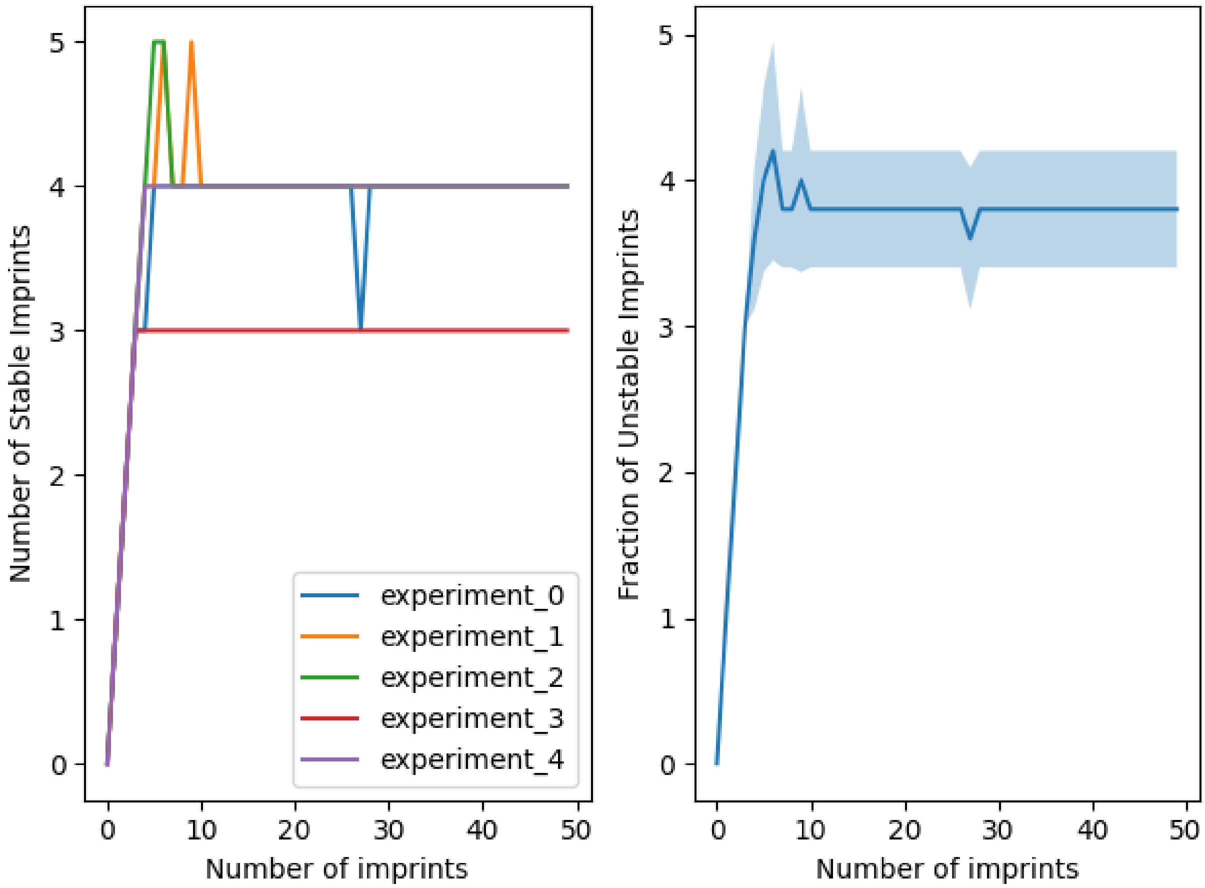
In this lab, the networks had 100 nodes and the network was imprinted with 50 random patterns. After each imprint, the program determines how stable the resulting network is. If the network was stable, then the program also checks the basins of attraction for the network. This test involves flipping a random bit in the pattern, running the network for ten steps, then checking if the network returned to the pattern with no bit flips. This is done up to 50 bit flips. The number of bits that we can flip and still retrieve the pattern is what we call the basin size. The entire experiment was repeated 5 times.

Results

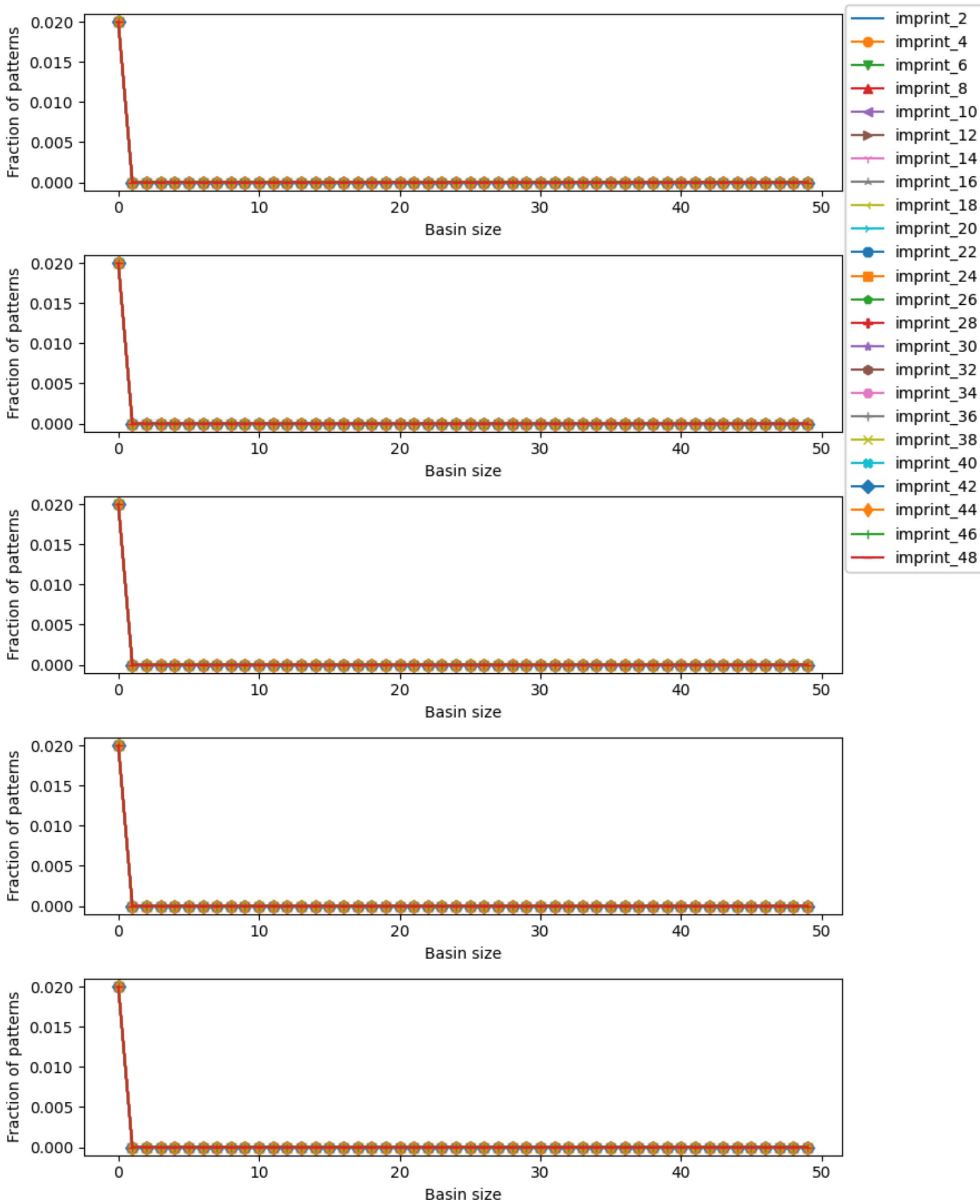
The graph below was calculated based on the fraction of imprints which could not be recalled after being trained on a number of patterns. In general, the more patterns a network trained on, the lower the chance was for a network to recall a given pattern. The left graph shows the results across all experiments, while the right shows the average instability, bounded by the standard deviation.



The next metric displayed is the total patterns the network could recall after each imprint. The graph on the right shows the average number of patterns that could be retrieved after each imprint, with the standard deviation as a bounding area.



The final metric analyzed in this experiment was the basins of attraction. Each pattern was analyzed for its basin of attraction. Each graph corresponds to one of the five experiments. Each line represents a pattern.



Analysis

Overall, each experiment created networks which performed very little variation. This suggests that there is an issue either with how the imprints are done, or how the program calculates stability. Interestingly, the network seemed to always recall at least some of the patterns. Perhaps, imprints done at later steps had a diminishing effect on the network weights compared to imprints done at the first few steps.

With each imprint added, the amount of influence on the weight matrix decreases proportionally. Thus, each imprint added has a lower chance of being recalled. The maximum capacity for the networks tended to occur early in the experiment, with an average of 4.6 imprints.

In regards to basins of attraction, the basins tended to decrease as more patterns were encoded. Since the size correlates with the stability of the patterns it makes sense in this case that the basin values were at low values. Since the basins of attraction methods are dependent on the stability calculation, an anomaly in stability would most likely cause an anomaly in the basins of attraction results.