Computational Neurodynamics Coursework - Dynamical Complexity

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Readme

About

This project simulates a Small World Modular Network of *Izhikevich Neurons*. It follows the Network creation and rewiring procedures covered in Lectures 8 (Modular Networks) and 9 (Dynamical Complexity). Information and specifications about the class parameters and functions can be found in the *modularnet.py* file.

Getting Started

To get started, create an object from the *Small_World_Modular_Net* class and set the required parameters, then simulate the network for a desired amount of time. By default, the class generates a Network of 1000 Izhikevich Neurons organized into 8 Communities, each with 100 *Excitatory Neurons* and 1000 random intra-edges, and a core of 200 *Inhibitory Neurons connected to every Network Neuron.*
Here is an example use of the class to create a default Network with no rewiring, and simulate it for 1000ms:

```python
from iznetwork import IzNetwork
from modularnet import Small_World_Modular_Net

net = Small_World_Modular_Net(p=0, n=1000, C=8, m=1000)
net.plot_weights("Matrix Connectivity")
net.simulate_net(T=1000) # simulate network activity for 1 second
net.plot_raster(T=1000) # generate raster plot
net.plot_rolling_mean_per_module(T=1000) # firing rate plot
```

Dependencies

The project requires the following packages in order to work:

python: The used programming language (any version $\geqq 3.9$).

iznetwork: The python file for the IzNetwork class that simulates the Izhikevich Neurons (provided alongside coursework specifications). It needs to be in the same directory as the *modularnet.py* file for the network simulations to run.

numpy: This package is used throughout the project to perform all of the vector/matrix operations.

matplotlib: This package is used to generate the raster plots.

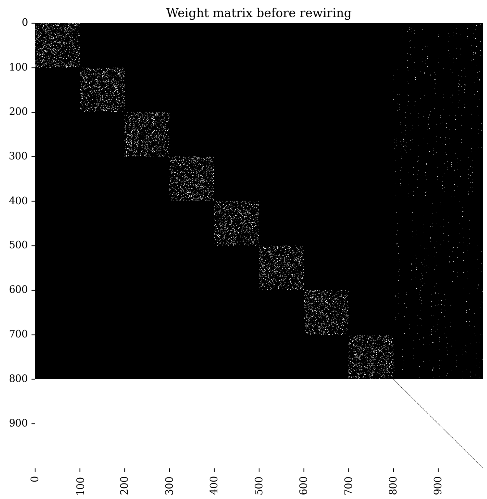
seaborn: This package is used to generate the heatmap of the network matrix connectivity.

Question 1

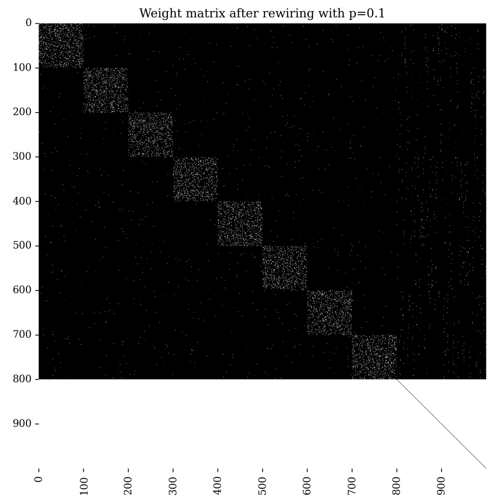
All plots below are grouped by question task (a,b,c) for all *Rewiring Probability* values p: p=0, p=0.1, p=0.2, p=0.3, p=0.4 and p=0.5.

a. Matrix Connectivity

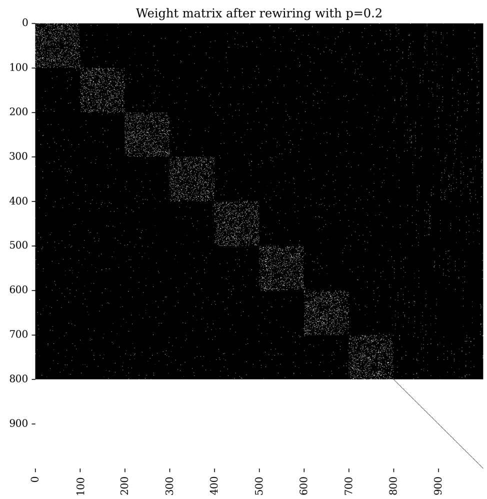
Plots of the Matrix Connectivity of the Network simulated with different *Rewiring Probabilities*. Each white dot in the plot represents a connection between the neuron pair (x,y) on the x-y axis. Every black spot represents the absence of an edge between the two neurons. Note: the white bottom strip represents the one-to-all connections between each inhibitory neuron and all other neurons.



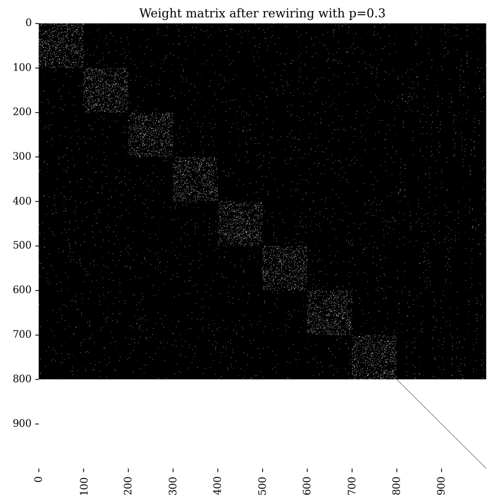
(a) Before Rewiring (p=0).



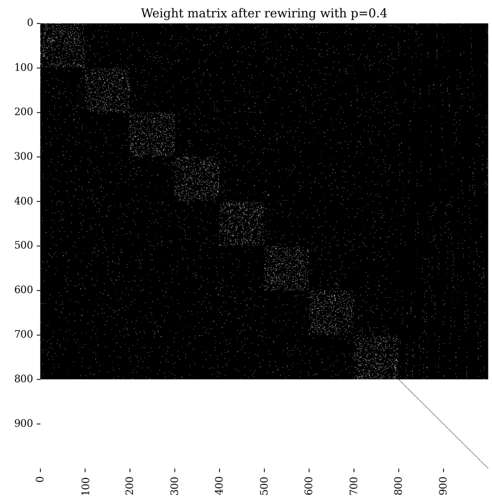
(b) After Rewiring with p=0.1.



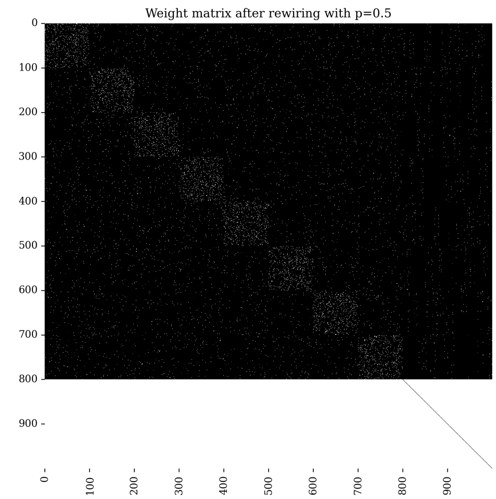
(c) After Rewiring with p=0.2.



(d) After Rewiring with p=0.3.



(e) After Rewiring with p=0.4.



(f) After Rewiring with p=0.5.

Figure 1: Plots of the Matrix Connectivity of the Network with different Rewiring Probabilities

b. Network Activity Raster Plots

Raster Plots of the Network firing activity simulated for 1000ms with different *Rewiring Probabilities*. Each blue dot represents the firing activity of a neuron y at time x.

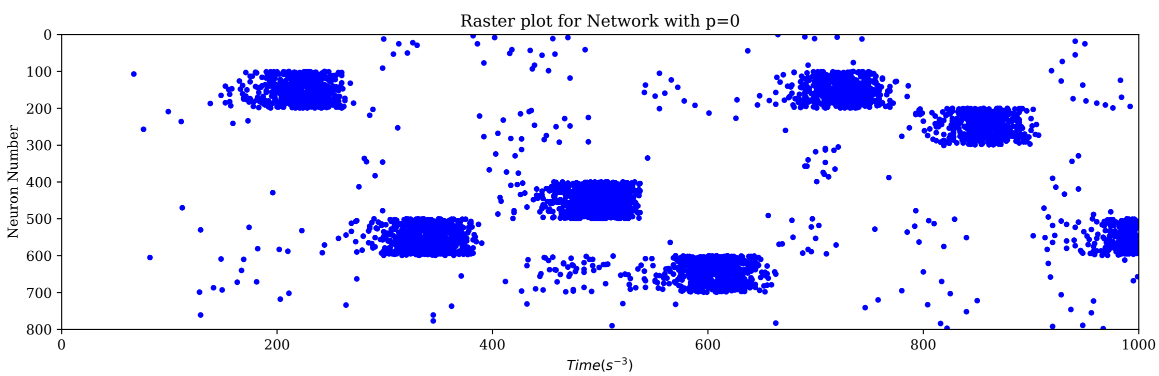


Figure 2: Raster plot of the network spiking with p=0

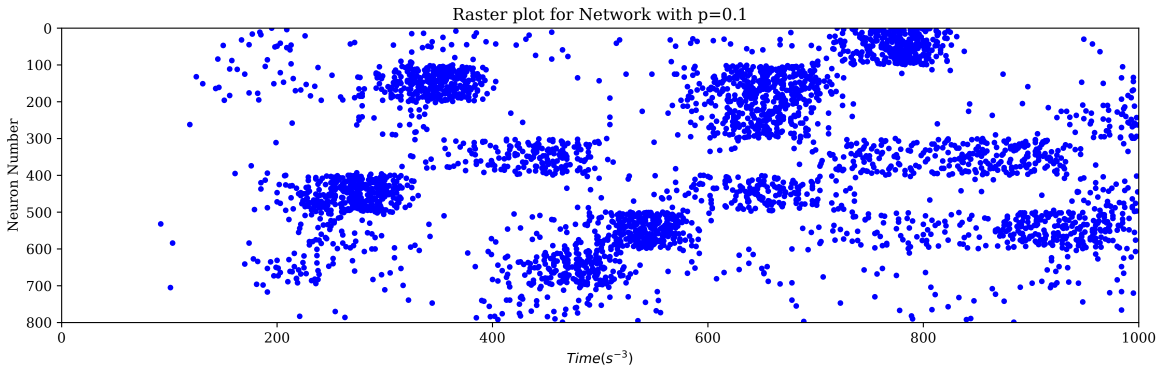


Figure 3: Raster plot of the network spiking with p=0.1

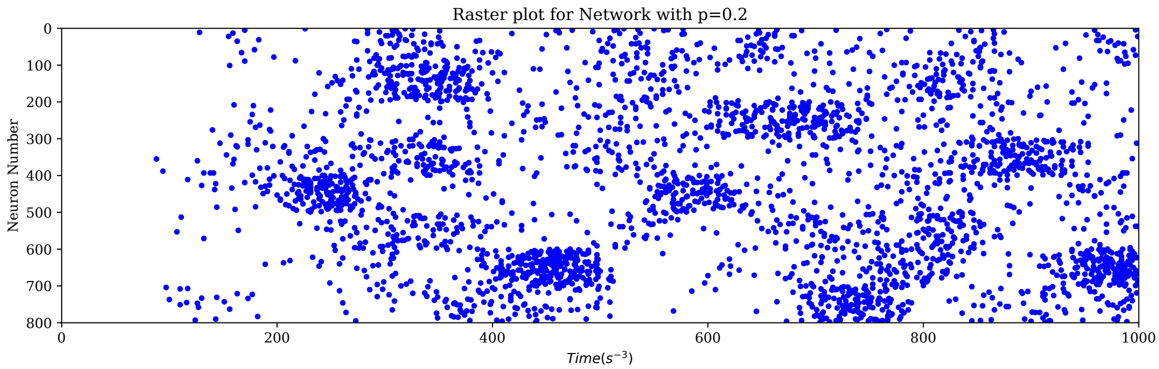


Figure 4: Raster plot of the network spiking with p=0.2

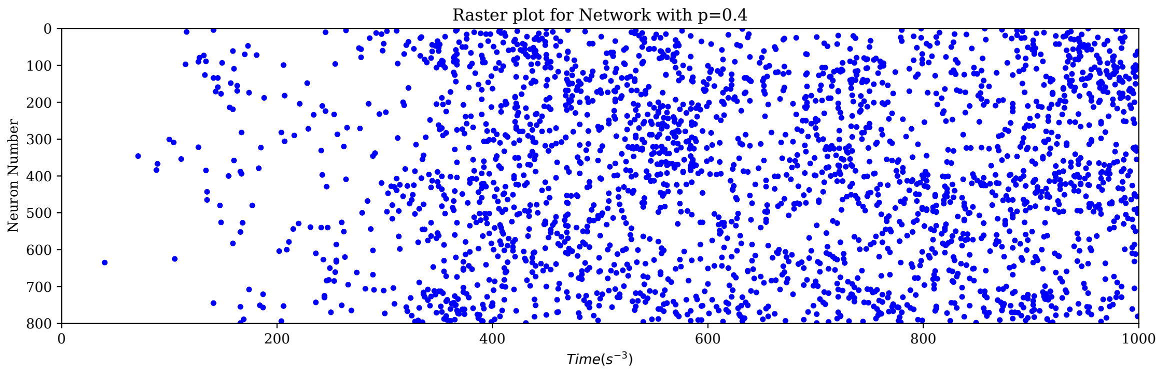


Figure 5: Raster plot of the network spiking with p=0.4

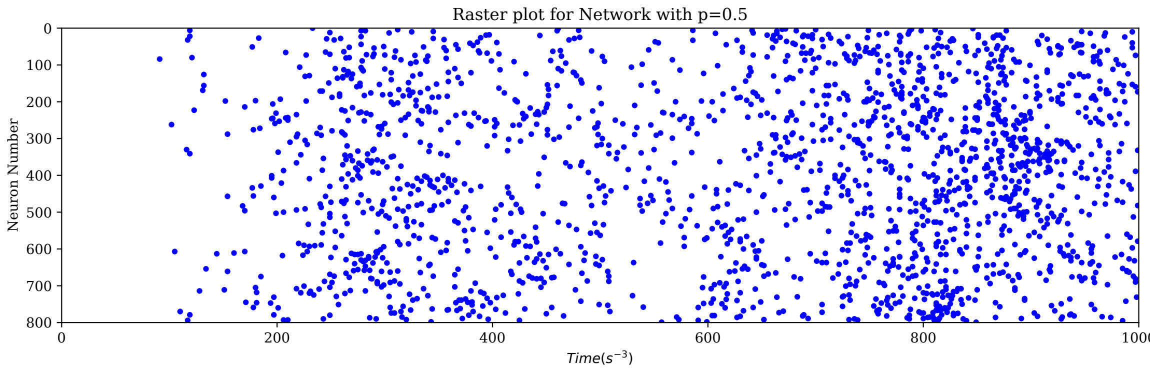


Figure 6: Raster plot of the network spiking with p=0.5

c. Mean Firing Rate

Plots of the mean firing rates of each Network module simulated for 1000ms with different *Rewiring Probabilities*. Each line represents the firing mean of the neurons of a module within the network at each time x.

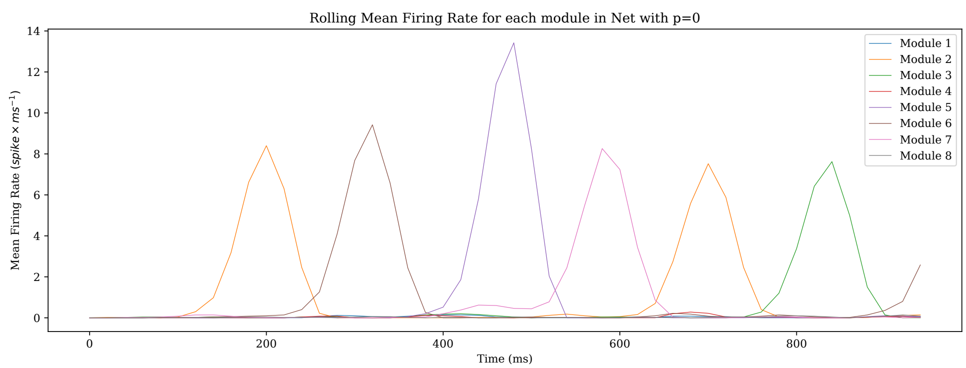


Figure 7: Mean Firing Rate of the network with p=0

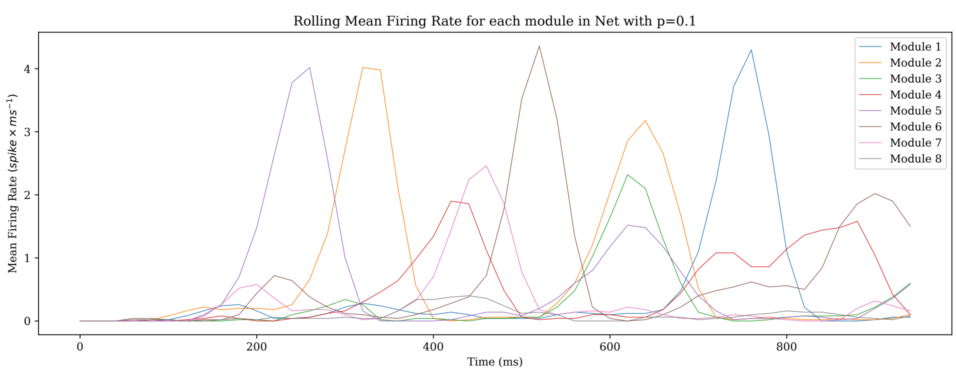


Figure 8: Mean Firing Rate of the network with p=0.1

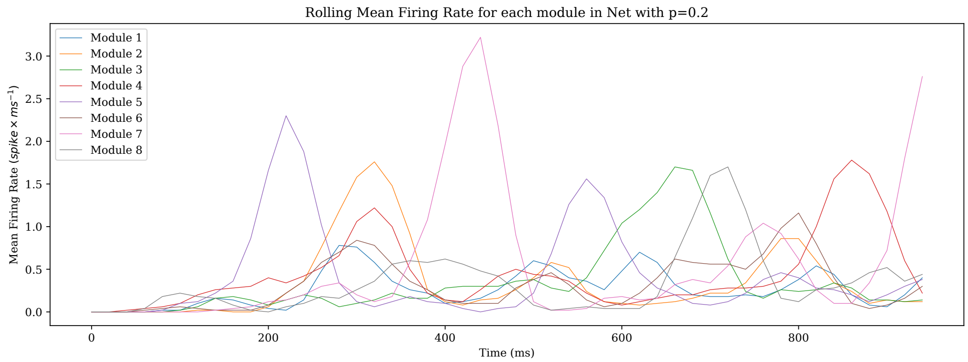


Figure 9: Mean Firing Rate of the network with p=0.2

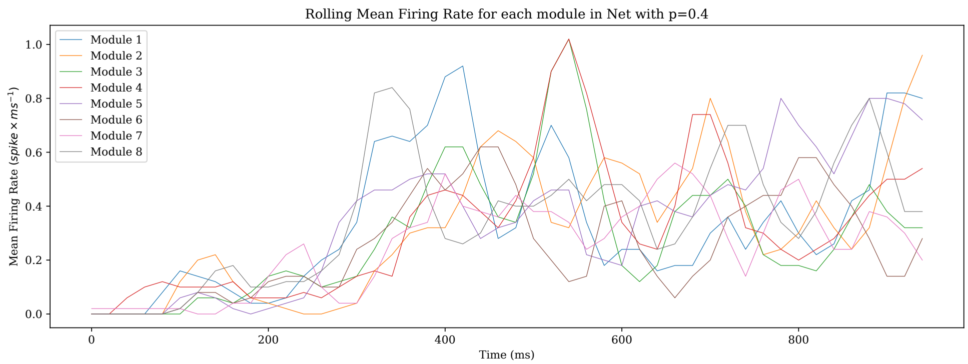


Figure 10: Mean Firing Rate of the network with p=0.4

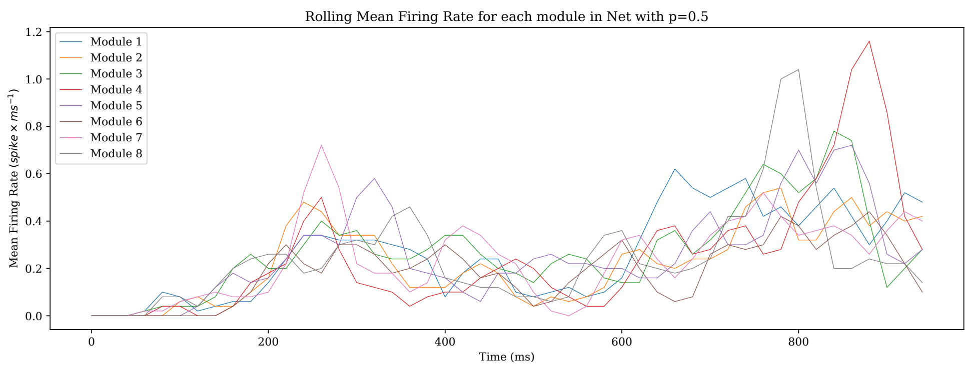


Figure 11: Mean Firing Rate of the network with p=0.5