

Neural Network Reconstruction via Graph Locality-Driven Machine Learning

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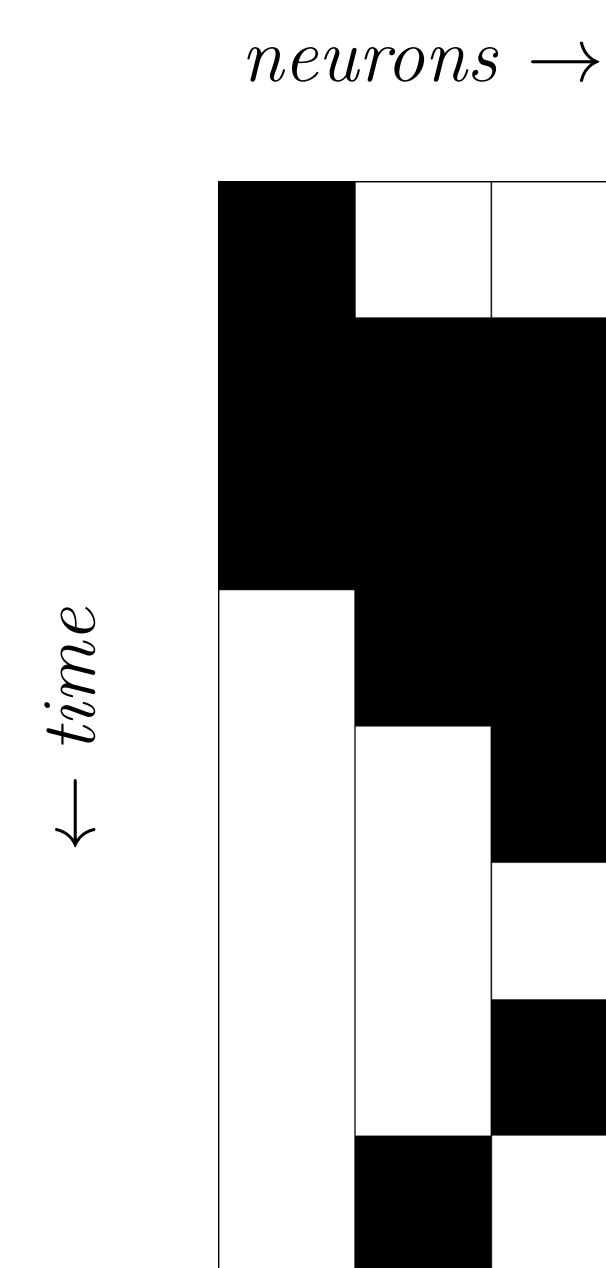
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Overview

We propose an algorithm inspired by convolutional approaches to image processing, adapted to the graph structure of neural networks, in order to solve the problem of network reconstruction from spiking data. To achieve this, we redefine locality in terms of graph adjacency, and create a scale-independent algorithm facilitated by modern machine learning techniques to incorporate this locality data into individual connection prediction.

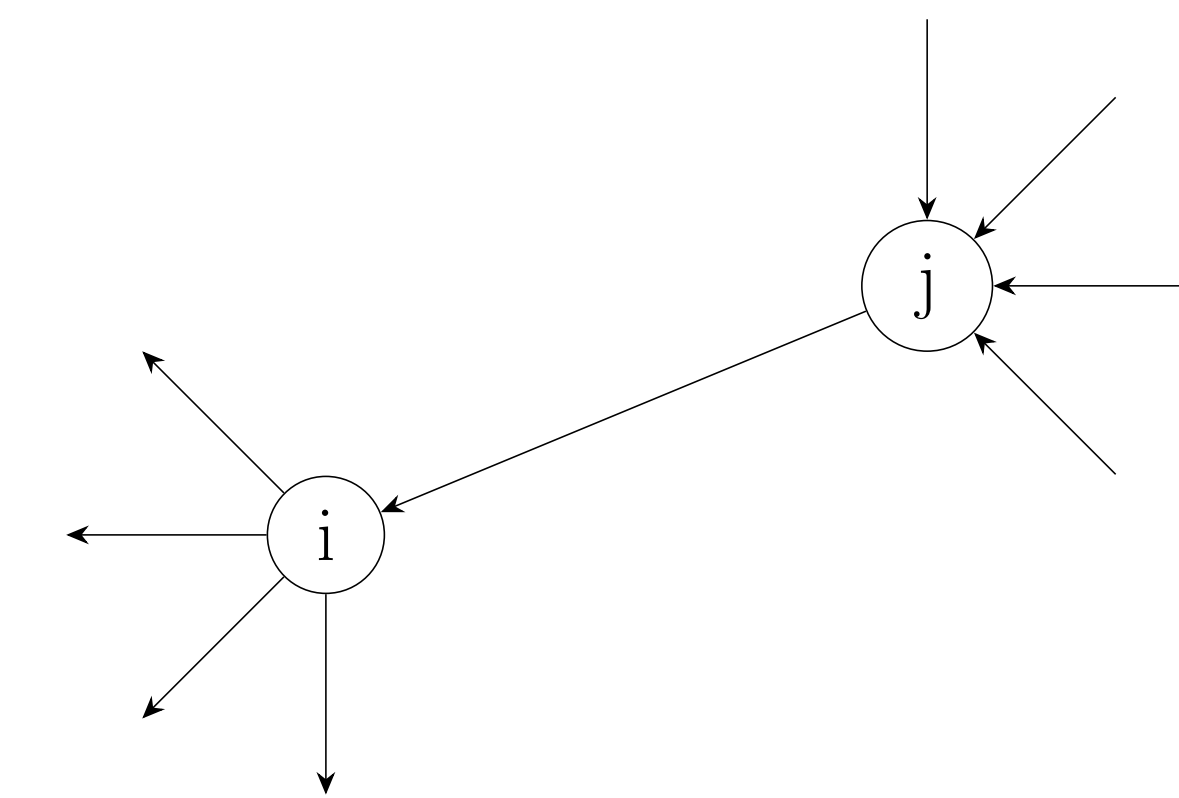
Spike-time Raster Plots

For a three neuron network sampled for eight timesteps, a raster plot might appear as below.



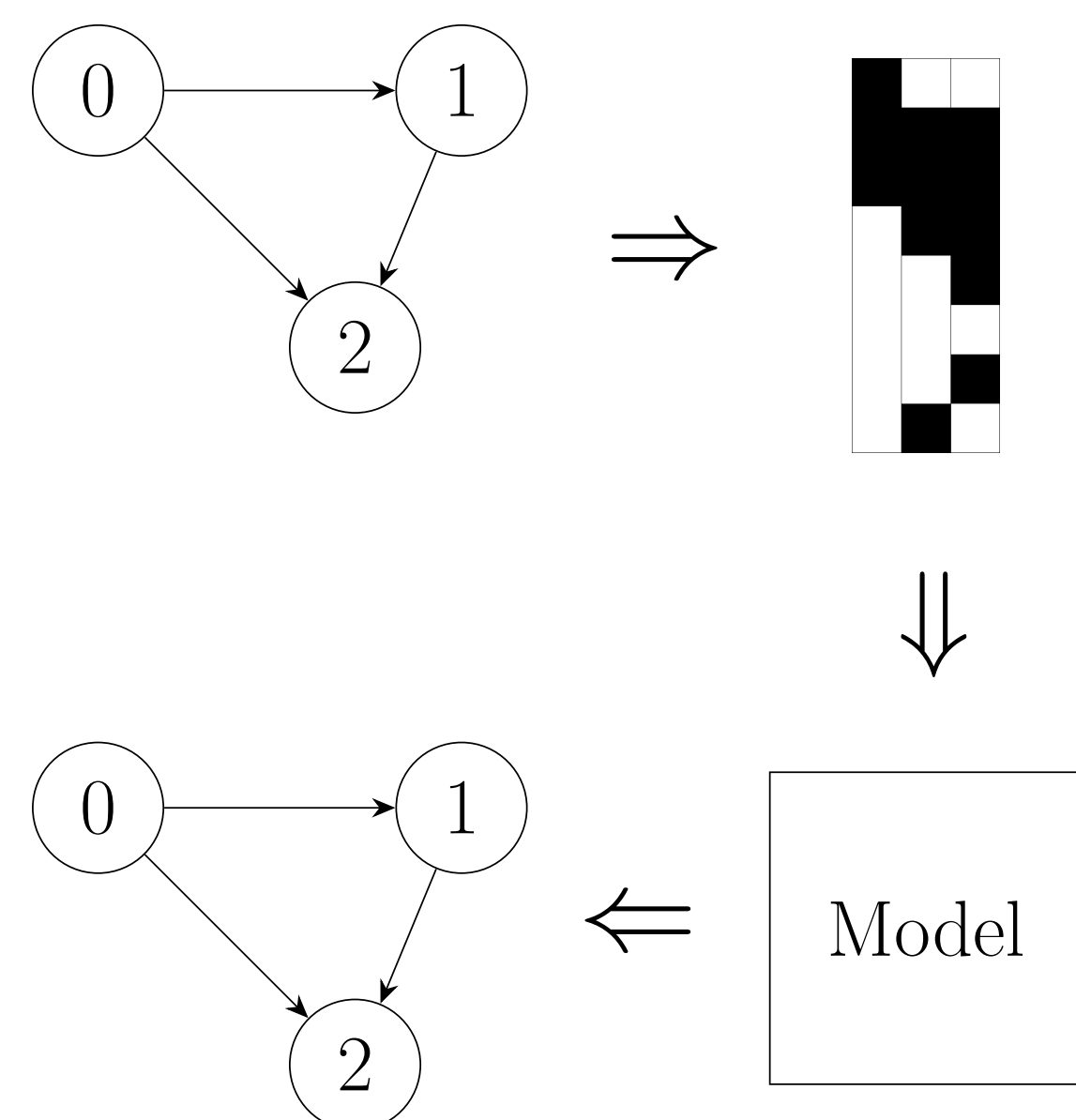
Graph Convolution

- We designed an algorithm to incorporate information from adjacent nodes in the determination of whether or not a given connection ij in a network exists



Process

Our goal was to infer biological neural network connectivity from spiking data. To do so, we created the following data pathway:

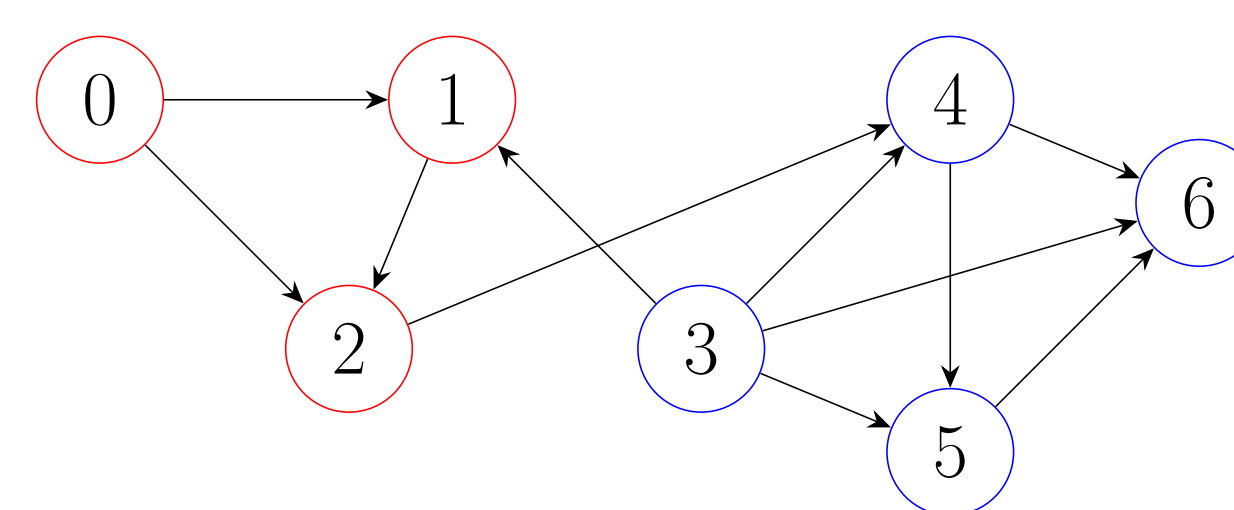


Biological Networks & Graphs

Graph Representation of Neural Networks

- Biological networks broadly equivalent to directed graphs (di-Graphs)
- diGraphs consist of nodes and edges, as below
- In neural networks, neurons are nodes and connections are edges
- Probability of connection between two neurons unrelated to physical proximity

^a



Common Local Structures

- Motifs, repeating local structures, unusually common in biological networks
- Some motifs, simplices, are structures in which information flows in one direction, from a 'source' node to a 'sink' node

^b The graph above contains a 2-simplex, in red, and a 3-simplex, in blue.

^aCite 11, 3, 13

^bCite 5,9,11

Model

First Layer

- Accepts spike-time raster plots for each of n neurons
- Converts to $(d \times n^2)$ matrix, with each d -vector representing one potential edge
- Figure here

Locality Layer

- Accepts data from the first layer
- Incorporates data from potentially adjacent edges into the calculation of the existence of a given edge
- Figure here

Final Layer

- Converts output from locality layer into $(n \times n)$ adjacency matrix
- figure also here