

# Neural Network Reconstruction via Graph Locality-Driven Machine Learning

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Computer Science Program, Bard College, May 2018

## Abstract

A ubiquitous problem within the field of computational neuroscience is the determination of biological neural network structure and connectivity from imaging of stochastic, large-scale network activity. We propose an algorithm inspired by convolutional approaches to image processing, adapted to the graph structure of neural networks. 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.

## Steps Toward Our Goal

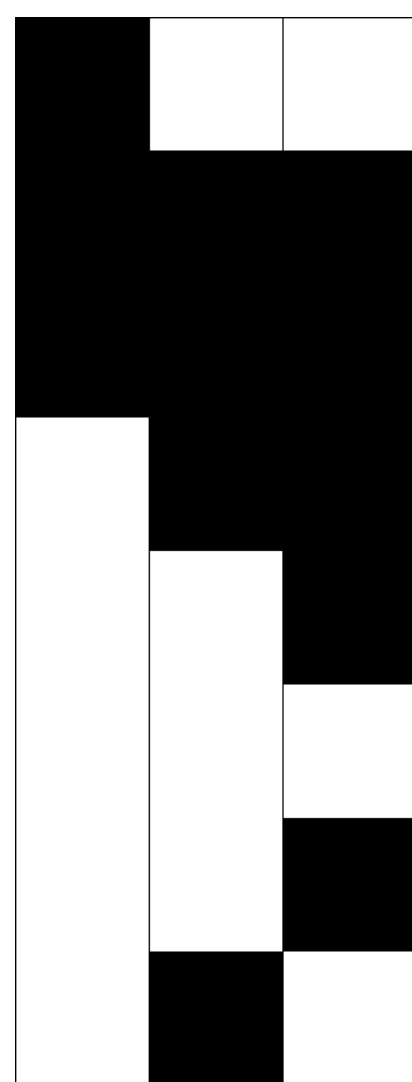
Our goal was to infer biological neural network connectivity from spiking data, itself inferred from calcium imaging of biological networks. To do so, we took the following steps:

1. Considered biological networks in terms of a graph representation
2. Identified features within that graph representation potentially useful to reconstruction
3. Created a model based around an algorithm informed by these features and inspired by convolutional neural networks
4. Generated data from a variety of simple test networks
5. Trained models on that data and analyzed the resulting output to determine efficacy

### Spike-time Raster Plots

- Matrices of binary data
- Each row represents a step in time
- Each column represents a neuron over time

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

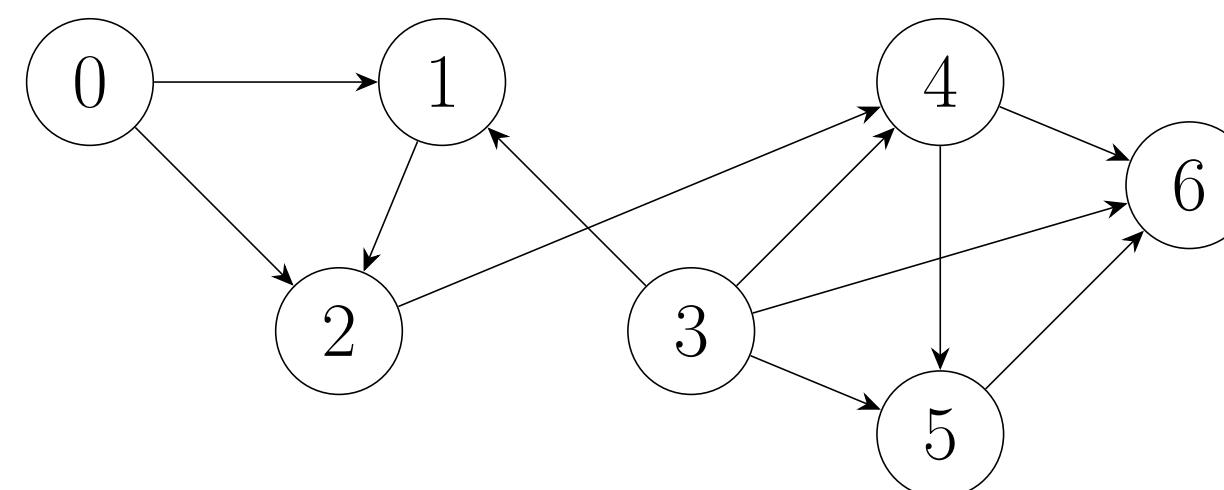


## Biological Networks & Graphs

### 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

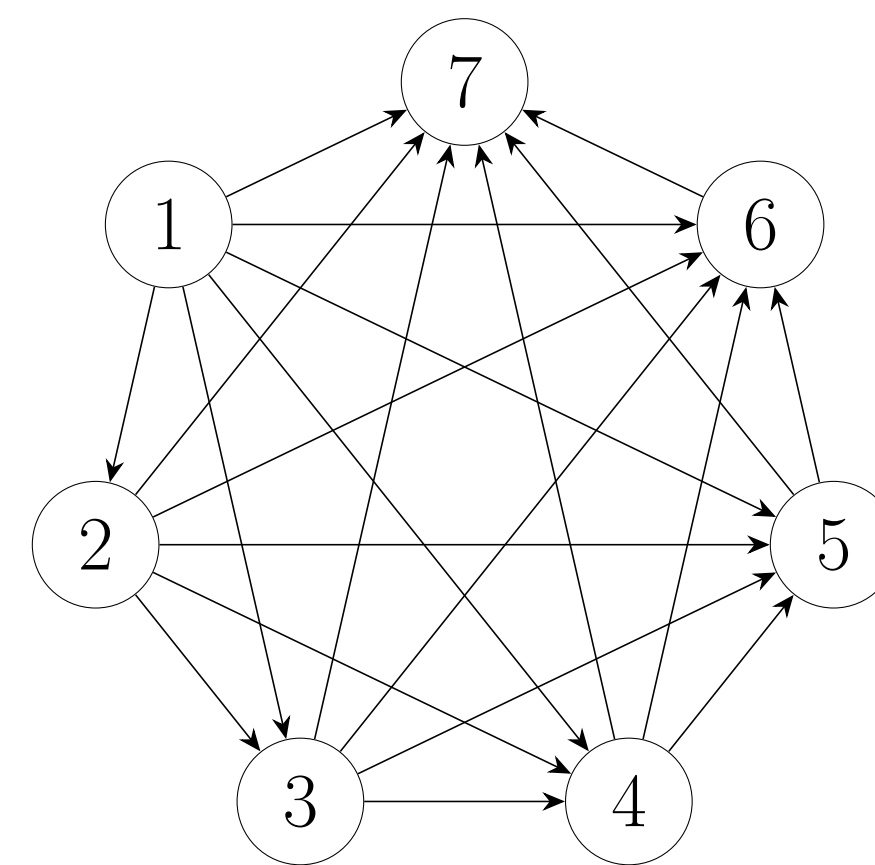
<sup>a</sup>



### 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

<sup>b</sup> An example of a 6-simplex is below; the graph above contains a 2-simplex and a 3-simplex.



<sup>a</sup>Cite: 11, 2, 13  
<sup>b</sup>Cite: 5,9,11

### Graph Convolution

- Convolutional neural networks are used on data containing many local features, such as images
- They involve tranposing a small 'filter' matrix across input data, limiting the size of an analysis model to the total size of its filters, instead of the size of input images
- In an image, nearby pixels are adjacent; in a graph, connected nodes are adjacent
- We designed an algorithm to incorporate information from adjacent nodes in the determination of whether or not a given connection in a network exists

## 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