Spatio-Temporal Signals Processing in Polychronizing Spiking Neural Networks

PRESENTED BY

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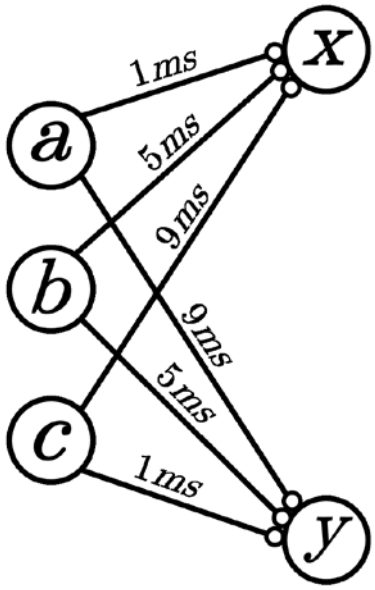
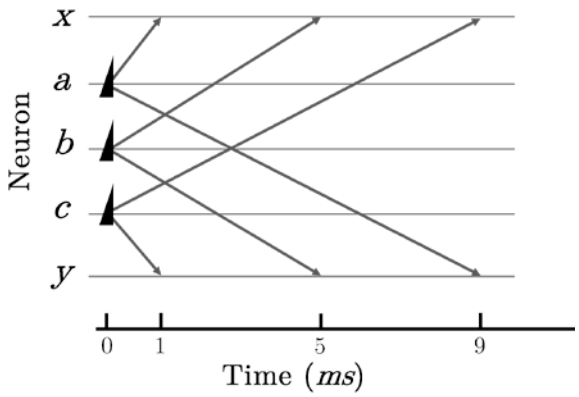
The Importance of Spike Timing

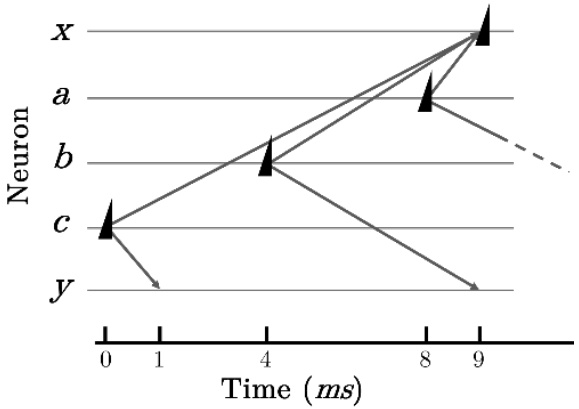
Structure in network connectivity drives spike-timing patterns



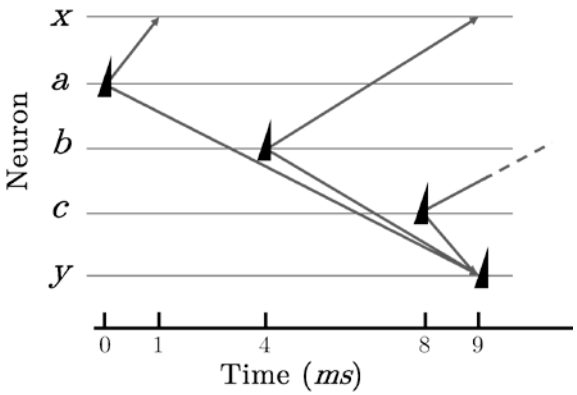
Simple network with timing-dependent connectivity



Suboptimal activation of neurons x, y



Optimal activation of neuron x



Optimal activation of neuron y

Spatio-Temporal Encoding in Spiking Neural Networks

Spatio-temporal characterization:

- Spatial component (which neuron spiked)
- Temporal component (when that neuron spiked)
- Common of real-world signals (e.g. speech, video, etc.)

In a spiking neural network:

- Self-organization driven by spiking activity, network structure, synaptic plasticity
- Associative processing of signals onto a (reproducible) spatio-temporal encoding
- Inherently distributed representation (scalable w.r.t. neuromorphic hardware)

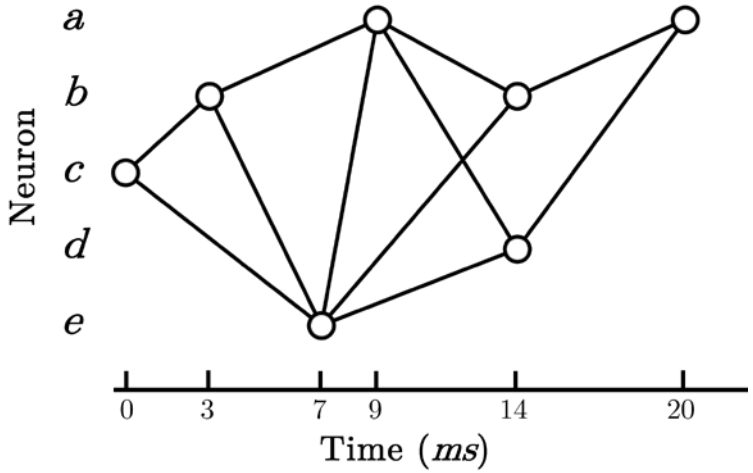
Polychronous Neural Groups (PNGs)

Some definitions and terminology:

- **Polychronous** means many times, and is characterized by time-locked spiking activity
- **Polychronization** is the self-organization of a spiking neural network that yields PNGs
- **Polychronizing** describes networks that exhibit polychonization

Acquiring PNGs:

- From *Primary Repertoire*
  - Potential groups that are structurally supported
- To *Secondary Repertoire*
  - Activity dependent
  - Forward assembly + Backward selection

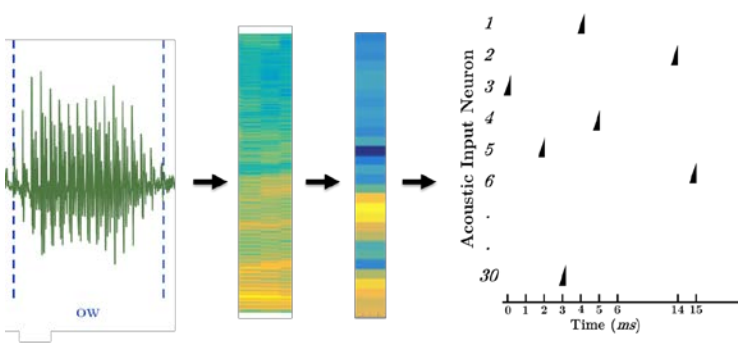


Graphical representation of PNG

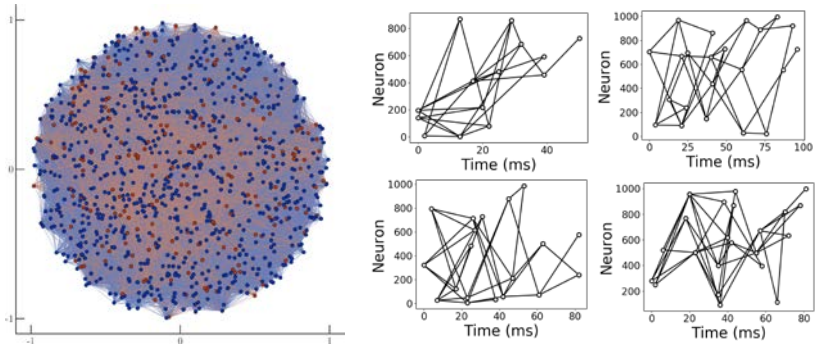
Learning Experiments

Demonstrating a spatio-temporal encoding via polychonization in a toy network

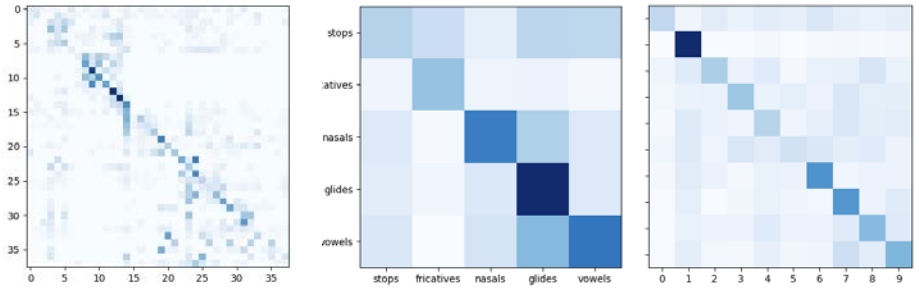
- **Step 1:** Transform signals to spatio-temporal (spiking) domain (e.g. TIMIT speech)
- **Step 2:** Feed spikes into network model with plasticity (e.g. STDP)
- **Step 3:** Correlate PNG activations to classes during training
- **Step 4:** Use PNG activations to estimate classes during testing



Signal transformation to spatio-temporal domain



Measuring polychronous neural groups from network



Signal/Class	Accuracy
Phonemes	26.4%
Phonetic Categories	47.1%
Handwritten Digits	41.9%

Confusion matrices and classification accuracy on different signals

Conclusions and Future Work

Demonstration of learning as result of polychronization

- Spatio-temporal signals encoded as time-locked patterns of spiking activity
- Flexible with respect to multiple modalities (as long as in spatio-temporal domain)
- Nowhere near state-of-the-art classification accuracy (but toy network with no tuning)

Paths to improvement

- Better spiking neural network models (possibly structural plasticity)
- Processing hierarchy (abstraction, lateral and feedback connections)
- Tooling/support for more collective operations on spiking activity