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Finding Triangles and Tracking Particles: Using Spiking Neural Networks for Pattern Identification Algorithms

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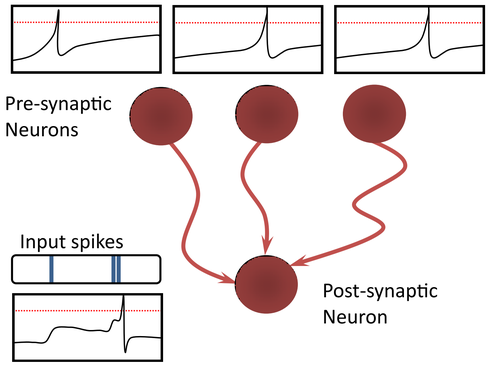
BACKGROUND

Neuromorphic Computing

- Hardware leverages cutting-edge computing elements to mimic efficient biological systems
- Central to Beyond Moore Computing
- Massively parallel; neurons are cheap (IBM's TrueNorth has one million neurons)
- Hardware for spiking neural networks
- Few implementable spiking algorithms exist



Spiking Neural Networks

- Simple processing elements—Neurons
- Single-state signal communication—Spikes
- Connections between neurons—Synapses
- Spikes integrated by receiving neuron
- Integrated value > threshold value → neuron spikes
- Spikes sent along all outgoing synapses
- Input accepted from all incoming synapses
- Spikes carry little information: Use spike timing (temporal coding) to maximize utility

PARTICLE IMAGE VELOCIMETRY

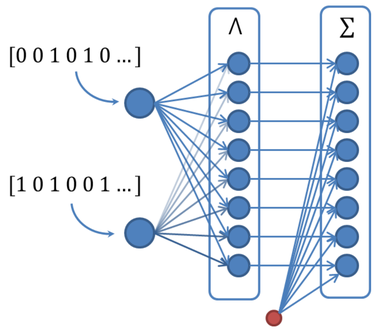
Overview

- Particle Image Velocimetry (PIV) estimates flow fields using dispersed particles
- Two images are taken and subdivided into smaller windows
- Maximum cross-correlation is best estimate of local flow

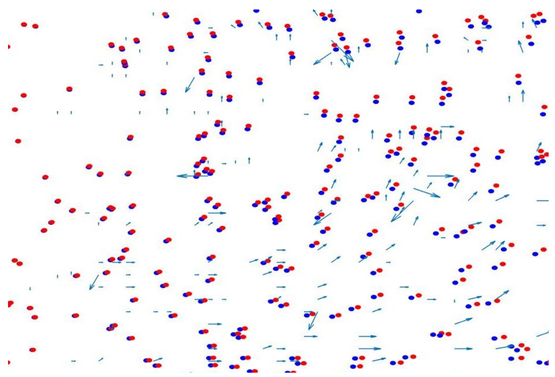
$$(f \star g)(n) = \sum_{m=-\infty}^{\infty} f(m)g(m+n)$$

Algorithm

- Biologically-inspired
- Temporally-coded inputs
- Inner neurons fire on simultaneous input
- Graduated delay for each n



- Integrating neurons collect cross-correlation value
- $O(n \log n) \rightarrow O(n)$



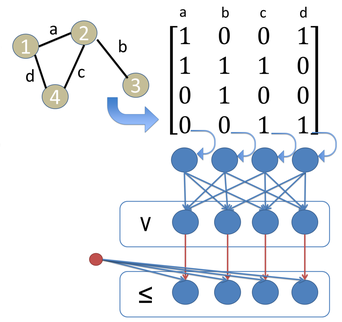
CLIQUE DETECTION

Overview

- Graph analytic algorithm involves finding cliques or complete k-graphs
- Generally computationally intensive

Algorithm

- Incidence matrix used for temporally-coded input
- Evaluate all possible cliques simultaneously
- k-clique ⇔ k spikes
- $O(n)$



SUMMARY

Review

- Both applications exemplify the same general outline:

- Temporal coding is key for increasing content density
- Cheap neurons → New scale of massive parallelism

Goals

- Develop framework and adapt to new contexts
- Current: Brian SNN Simulator → Future: Hardware
  - stDPU (simulated and physical)
  - TrueNorth (physical)
- Utilize unique neural qualities for advanced algorithms

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