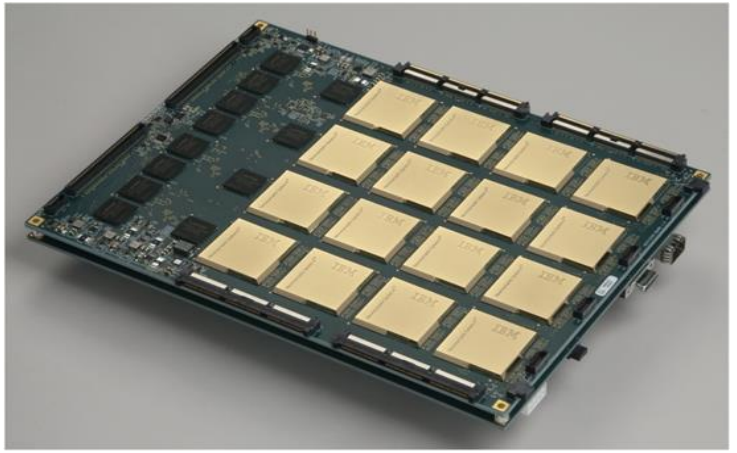
Fault tolerant neuromorphic computing: The SPANNER project

David Halliday
School of Physics Engineering and Technology
University of York.



Furber 2016 J. Neural Eng. 13, 051001, 10.1088/1741-2560/13/5/051001

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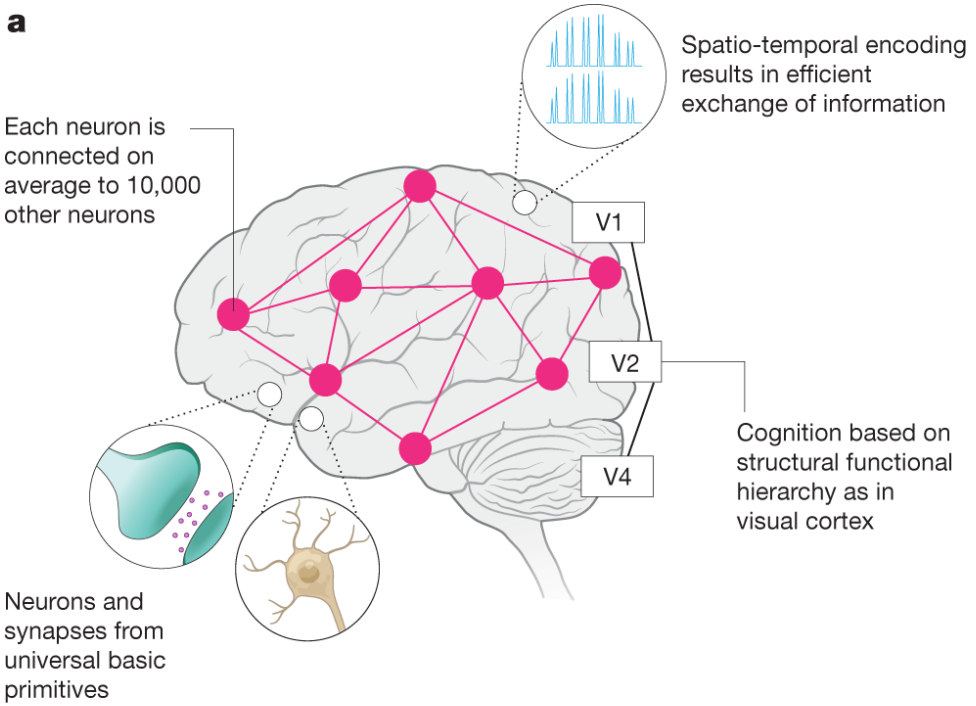
SNN v.s. ANN

SNN:

- Distributed.
- Event based.
- Sparse.



Roy *et al. Nature* **575**, 607-617 (2019) doi:10.1038/s41586-019-1677-2

SNN: Sparse computing with events (or spaces)

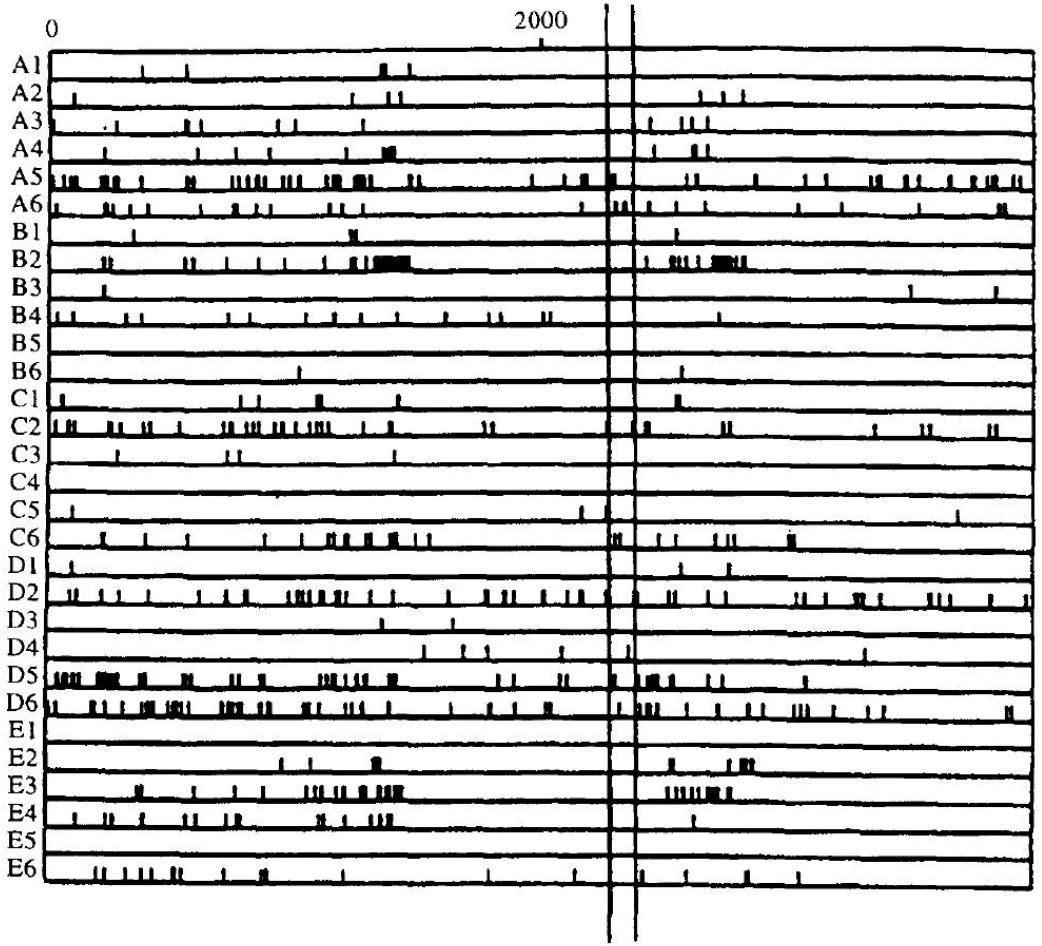


FIGURE 1. Simultaneous recordings (over 4 sec) of the firing times of 30 neurons from monkey striate cortex by Krüger & Aiple (1988). Each firing is denoted by a short vertical bar, with a separate row for each neuron. For comparison we have marked the length of an interval of 100 msec by two vertical lines. This time span is known to suffice for the completion of some complex multilayer cortical computations.

Maass, *Neural Networks,* **10**, 1659-1671 (1997).

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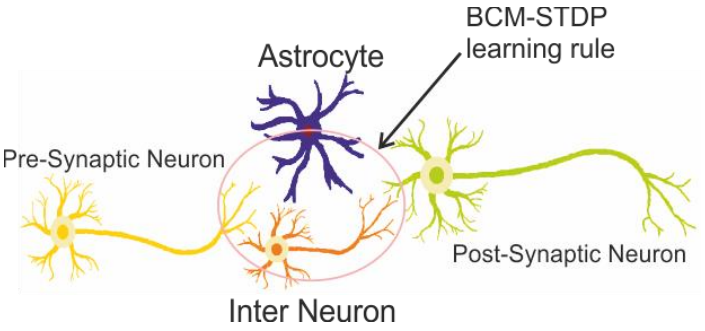
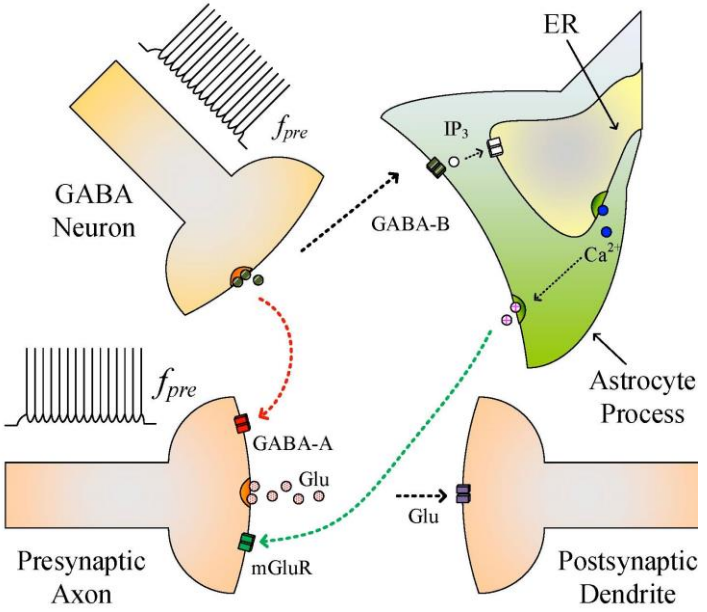


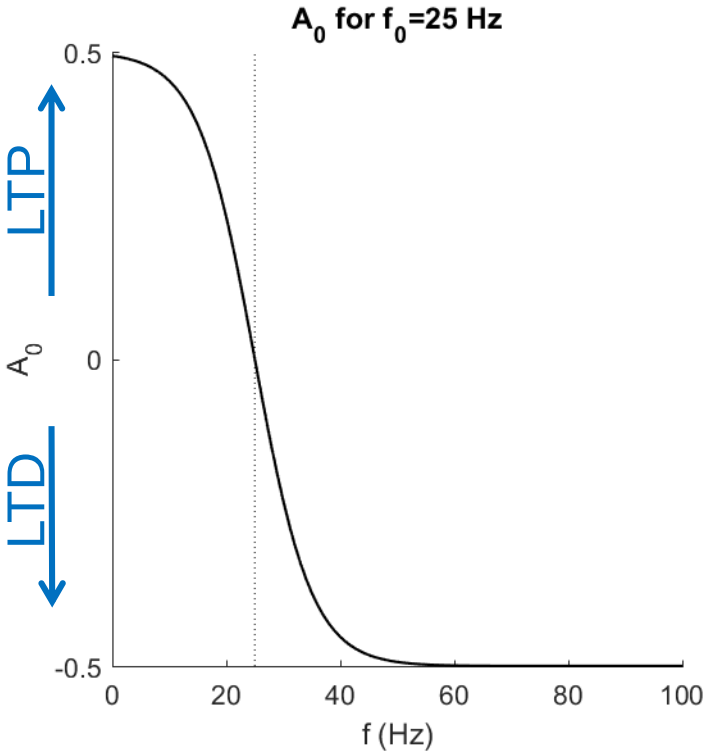
- Fault tolerant learning using spiking-astrocyte neural networks (SANN).
- Modelled on coupling between tripartite synapses and GABA interneuron.
- GABA interneuron acts to band-pass filter and route spike trains according to pre-synaptic firing frequencies.
- Novel learning rule combines Bienenstock, Cooper Munro (BCM) rule with STDP – BSTDP rule.
- Rule modulates height of learning window in STDP using post-synaptic firing frequencies.

BCM-STDP learning rule:

- Provide distributed fault tolerance in SNNs.
- Incorporates astrocyte functionality.
- Frequency selective tuning using pre-synaptic firing rate.
- Model using Gaussian bandpass filter.
- Post-synaptic firing rate modulates STDP learning window height.
- Switches between LTP and LTD according to post-synaptic firing rate.



Liu *et al. IEEE TNNLS,* **30**, 865-875 (2019)
doi: 10.1109/TNNLS.2018.2854291



Fault tolerant module using BCM-STDP self-repairing rule.

BCM Rule:

$$A_0 = \frac{A}{1+exp(a(f-f_0))} - A_-$$

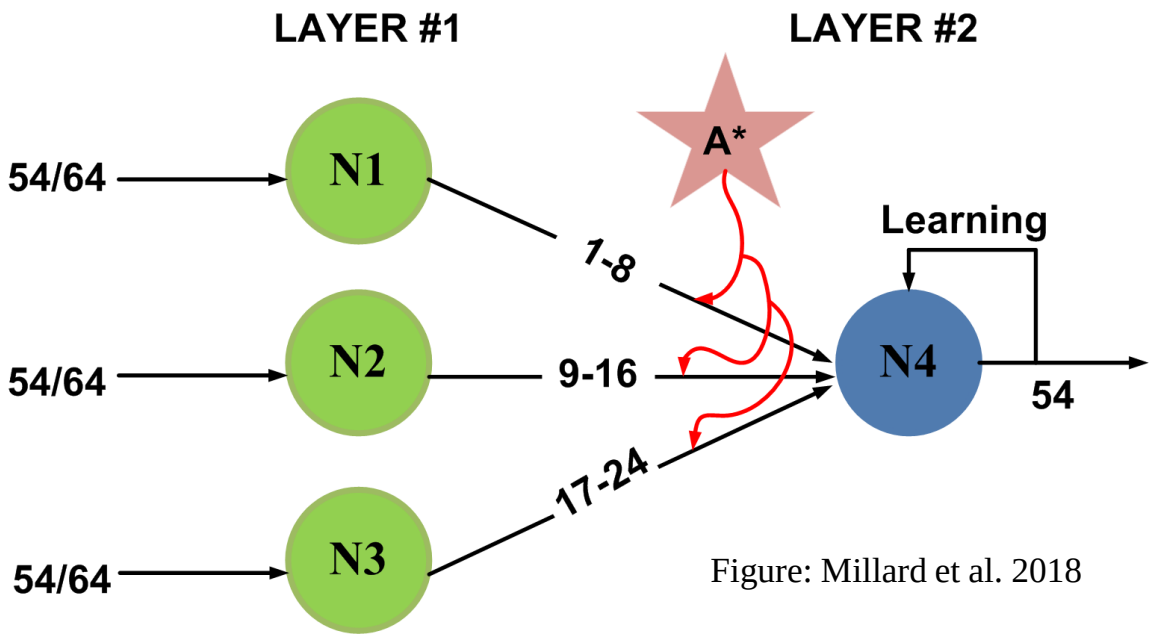


Figure: Millard et al. 2018

STDP rule:

$$\delta w(\Delta t) = \begin{cases} A_0 \exp \frac{\Delta_t}{\tau_t}, \Delta_t \leq 0 \\ -A_0 \exp \frac{-\Delta_t}{\tau_t}, \Delta_t > 0 \end{cases}$$

Fault tolerant module:

- Three input neurons.
- One output neuron.
- Multiple pathways, 8 per connection.

Real time fault tolerance in SANN

- Three inputs: N1 – N3
- One output: N4
- Systematic failure: 7 of 8 synapses from each input

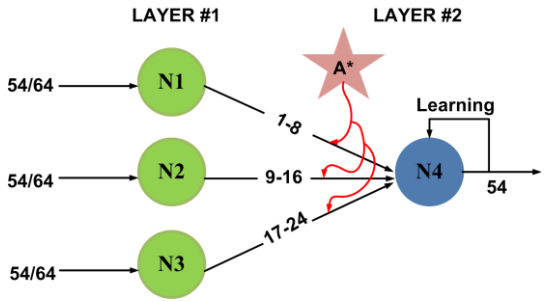


Figure: Millard et al. 2018

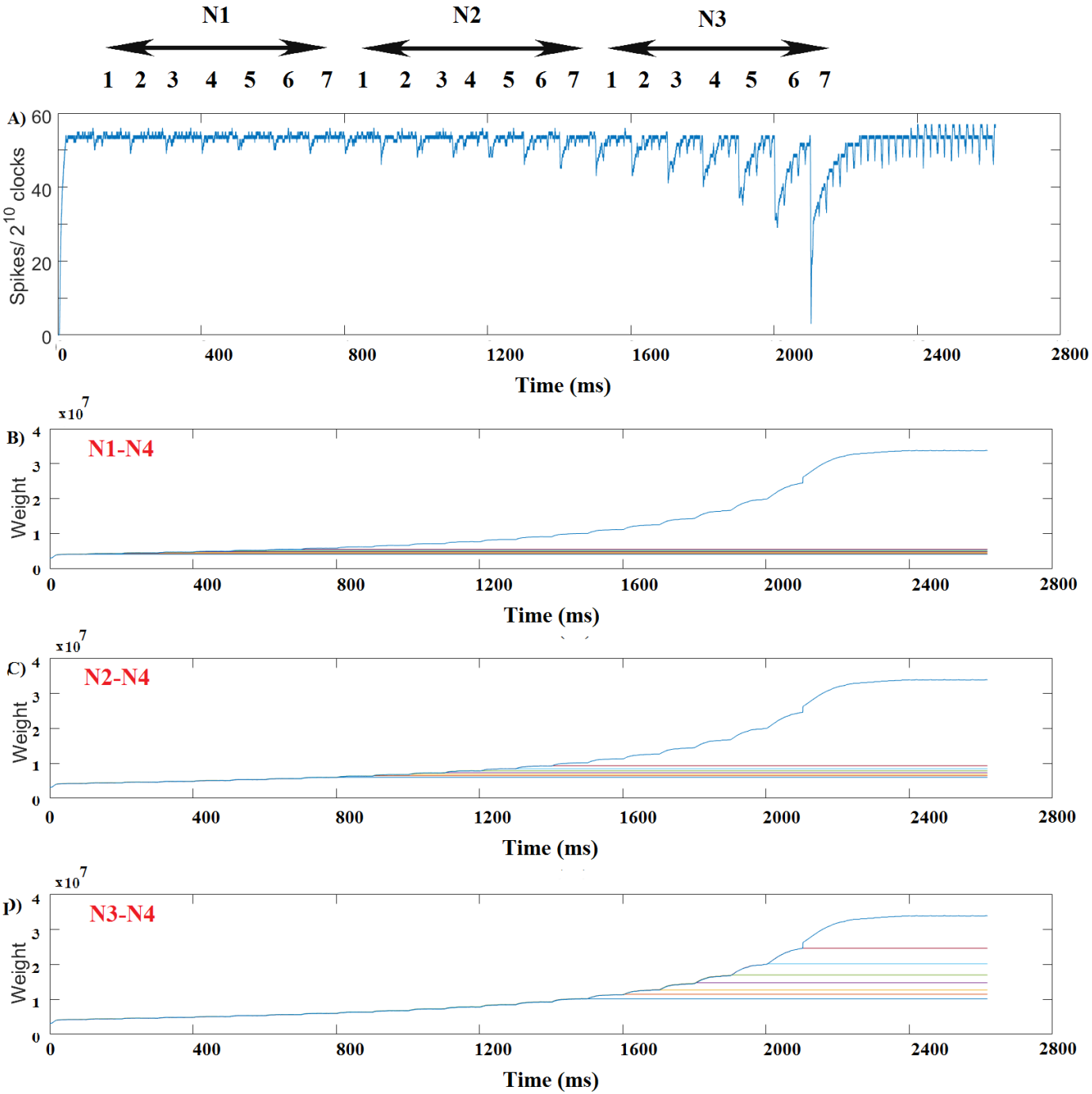


Figure: Johnson et al. 2018

Self-repairing Hardware Paradigms based on Astrocyte-Neuron Models: The SPANNER project.

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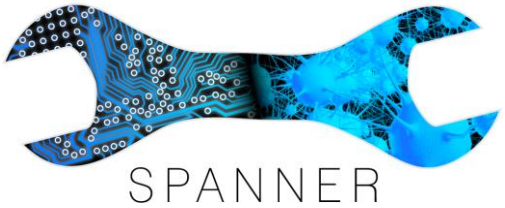

Self-rePAiring spiking Neural NEtwoRk (SPANNER)