Learning Multi-Stability in Plastic Neural Networks

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Simulated using the Auryn simulator github.com/fzenke/auryn

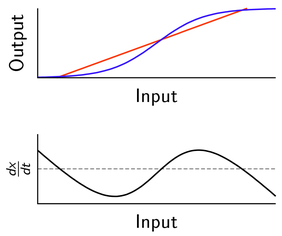
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Multi-Stability Needs Non-Linearity

Ingredients

- Excitatory recurrent feed-back (Hopfield, 1982)

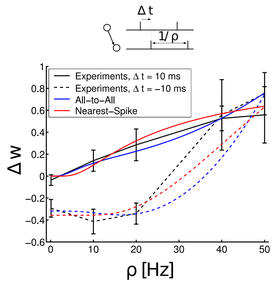
- Non-linearity (e.g. inhibitory feedback (Amit & Brunel, 1997) and STP (Mongillo *et al.* , 2012))



Question:
How is the connectivity learned?

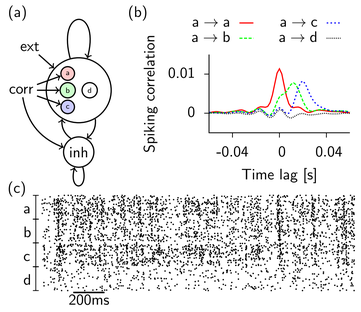
Learning Symmetric Connectivity with STDP

Triplet STDP



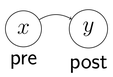
Adapted from Pfister & Gerstner (2006), Data from Sjöström *et al.* (2001)

- Triplet Models describe experimental data
- Can account for symmetric connectivity



- Can learn symmetric connectivity
- Assemblies activate at high rates
- Networks become unstable

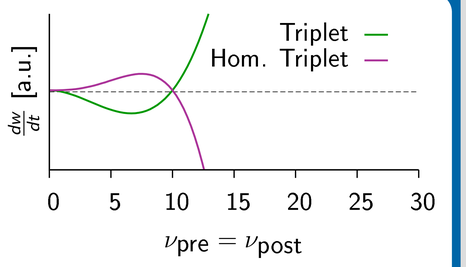
One Stable Fixed Point is Not Enough



$$\frac{dw}{dt} = \eta x y \,(y - \kappa)$$

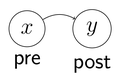
Recurrent case:

$$\frac{dw}{dt} = \eta y^2 \,(y - \kappa)$$



e.g.: Triplet model (Pfister & Gerstner, 2006), voltage-based triplet (Clopath *et al.* , 2010)

Additional Fixed Point: Heterosynaptic Plasticity

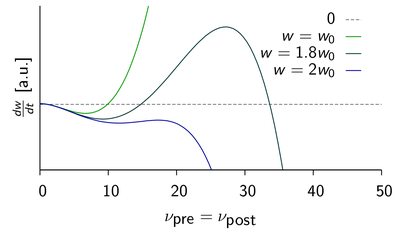


$$\frac{dw}{dt} = \eta x y \,(y - \kappa) - \xi(?)\, y^k$$

Recurrent case:

$$\frac{dw}{dt} = \eta y^2 \,(y - \kappa) - \xi(?)\, y^k$$

where $k \geq 4$.



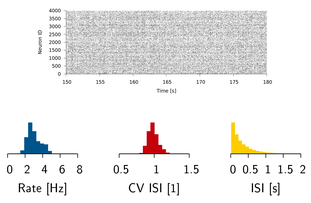
$$\frac{dw}{dt} = \eta y^2 \,(y - \kappa) - \beta(w - w_0) y^k$$

Experimental support Lee *et al.* (2012)
Qualitative agreement with Chen *et al.* (2013)

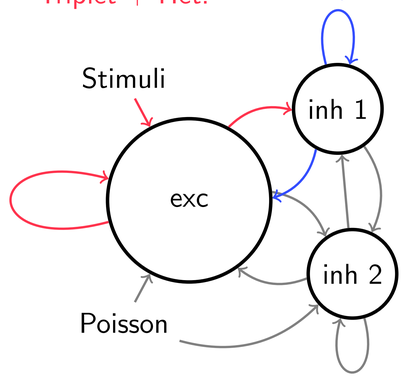
Recurrent Spiking Network with STDP

Model details

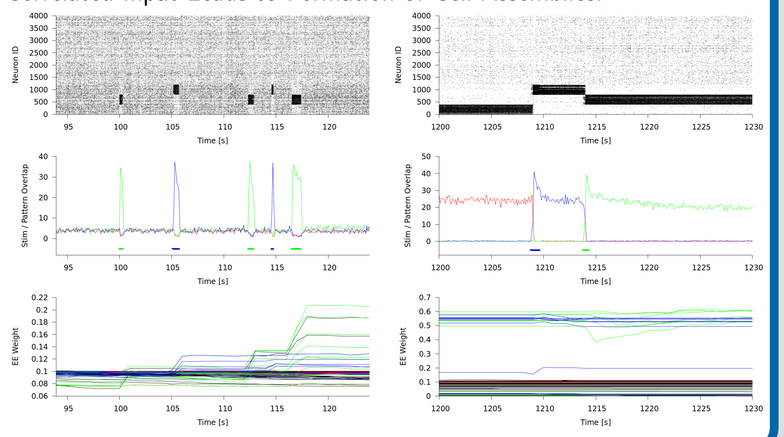
- 5000 leaky integrate-and-fire neurons (4000:500:500) with conductance based synapses and adaptation
- Short term plasticity (Tsodyks Markram Model: $\tau_{\text{f}} = 0.6\text{s}$, $\tau_{\text{d}} = 0.2\text{s}$, $U = 0.2$)
- Two inhibitory populations
- Triplet STDP with **heterosynaptic plasticity**



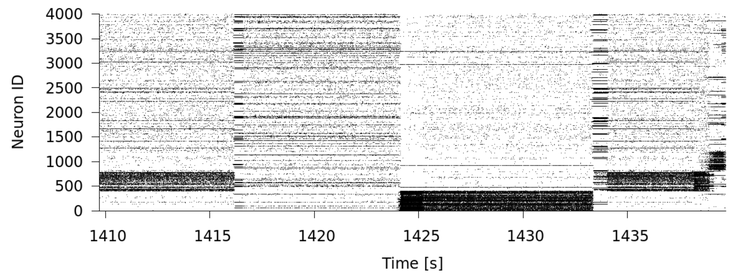
Triplet + Het. Inhibitory STDP

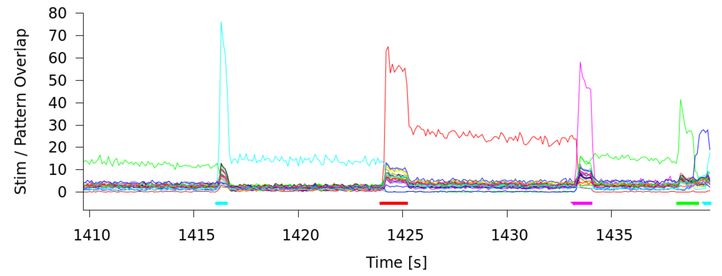


Correlated Input Leads to Formation of Cell Assemblies:

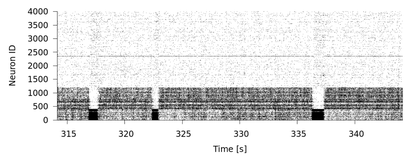


Result: Emergence of Multi-Stability

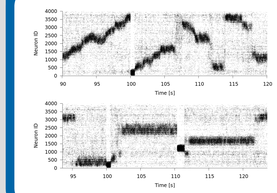




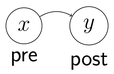
Without "inh 1"



Stabilizes Drift



Inhibitory Plasticity



$$\frac{dw^{\text{inh}}}{dt} \propto \alpha x + \beta y - x y - \gamma$$

- Implemented as STDP rule
- Dis-inhibits neurons within the same pattern
- Cross-inhibits neurons in different patterns

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