# Leveraging Self-organized Structure for Memory Encoding in Binary Networks


Roman Koshkin[1] & Tomoki Fukai[1]

[1]Neural Coding and Brain Computing Unit, Okinawa Institute of Science and Technology


## Background

Structured spontaneous activity (SA) is implicated in memory, learning, navigation, and decision making by encoding prior information and expectations. SA is believed to originate from cell assemblies (CAs) – relatively stable groups of neurons with strong recurrent connections. It is hypothesized that CAs may represent fundamental units of memory that may efficiently encode episodes of experience through minimal changes in weak between-assembly connections. CAs can emerge either as a result of structured input or self-organize spontaneously through plasticity mechanisms. We are developing a **high-capacity episodic memory model that will leverage self-organized CAs** for fast, stable and sample-efficient memory encoding and use only biologically plausible plasticity rules.

## Methods

- Model: recurrent network of binary neurons
  - 2500 excitatory and 500 inhibitory neurons
  - biologically plausible learning rules (no backprop)
- High-dimensional stimuli: MNIST images or their lower-dimensional embeddings
- Implementation: Multicore parallel (C++/Python)
- Learning rules: STP-dependent STDP with homeostatic plasticity and weight scaling

$$\Delta J_{ij} = F_j D_j \left( C_p \exp\left(\frac{|t_{pre} - t_{post}|}{\tau_p}\right) - C_d \exp\left(\frac{|t_{pre} - t_{post}|}{\tau_d}\right)\right)$$

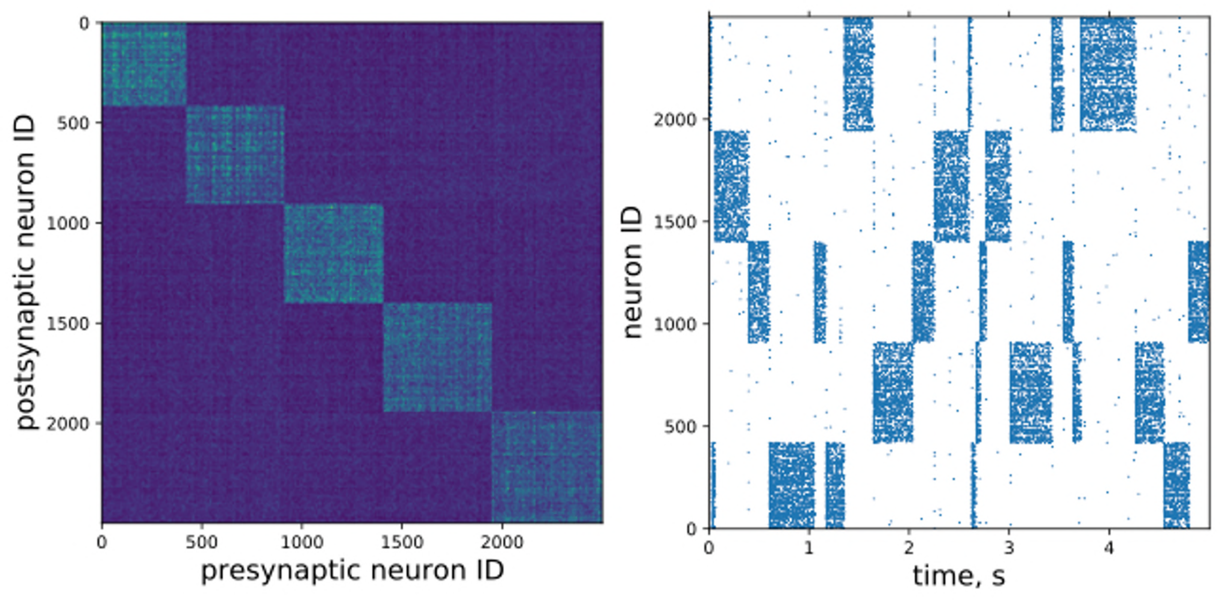
$$\frac{dD_j}{dt} = \frac{1 - D_j}{\tau_{STD}} - D_j F_j \delta(t - t_j^f)$$

$$\frac{dF_j}{dt} = \frac{U - F_j}{\tau_{STF}} + U(1 - F_j)\delta(t - t_j^f)$$

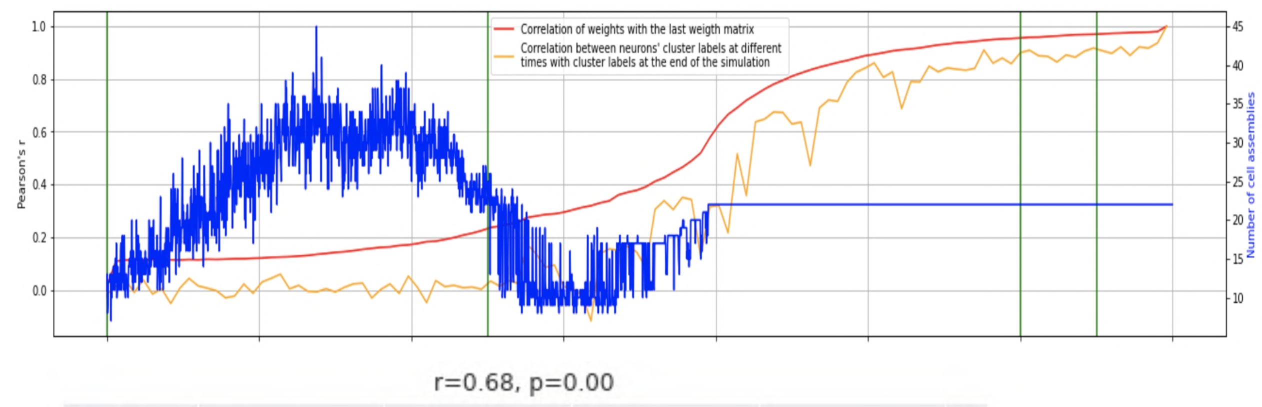
## Key references


[1] Triplett et al. Emergence of spontaneous assembly activity in developing neural networks without afferent input. *PLoS Comp. Biol.*, 2018.
[2] Josselyn and Frankland. Memory allocation: mechanisms and function. *Ann. Rev. of Neurosci*, 2018.
[3] Hiratani & Fukai. Interplay between short- and long-term plasticity in cell-assembly formation. *PloS One*,, 2014.

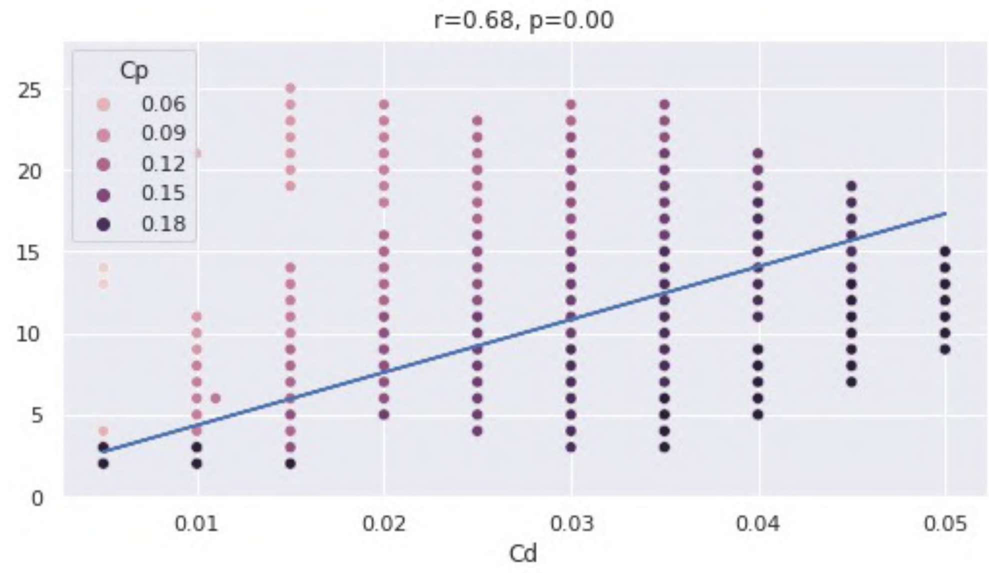

## Results



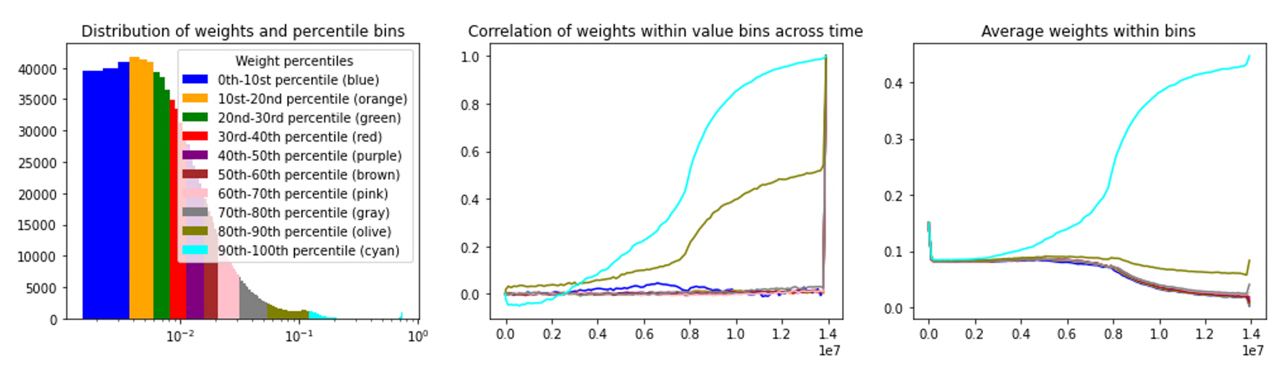

Both weight and activity of the continuously plastic model evolving under symmetric STP-dependent STDP spontaneously become highly structured



Although the weights never stop changing, the model eventually reaches a stable number of assemblies




The stable number of cell assemblies that the model self-organizes to depends systematically on the degree of LTP and LTD




Neurons with strongest connections appear the represent the backbone of self-organized cells assemblies

## Way ahead

- Leverage self-organized connectivity structure for sample-efficient encoding of episodic memories;
- Study memory encoding with sequences of high-dimensional stimuli
- Address the trade-off between memory capacity and memory trace stability;
- Investigate whether a core group of assembly neurons can be used to overcome catastrophic forgetting.
- Build a GPU-accelerated implementation for faster design iterations and hypothesis testing;
- Study the ability of the network to form and maintain memory associations in the context of spontaneous and cued memory retrieval.

## Contacts and Acknowledgements


Roman Koshkin roman.koshkin@oist.jp
Prof. Tomoki Fukai tomoki.fukai@oist.jp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