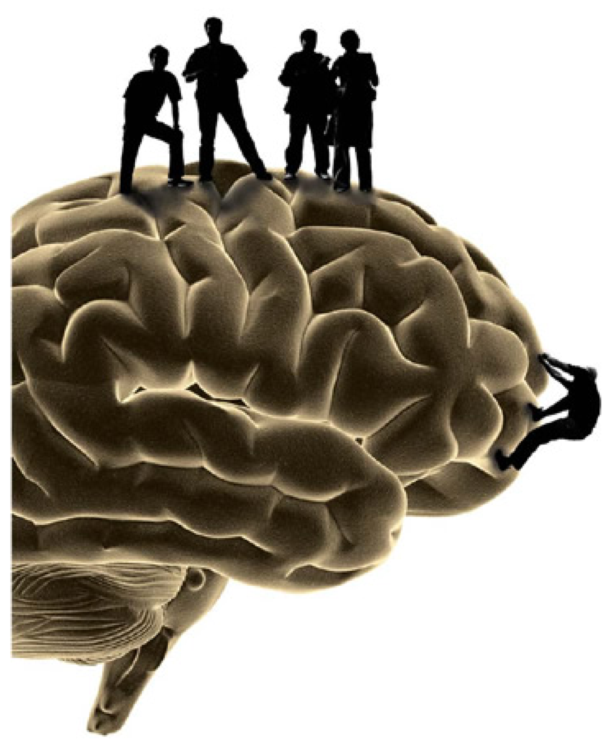

A spiking-neuron model of memory encoding and replay in hippocampus

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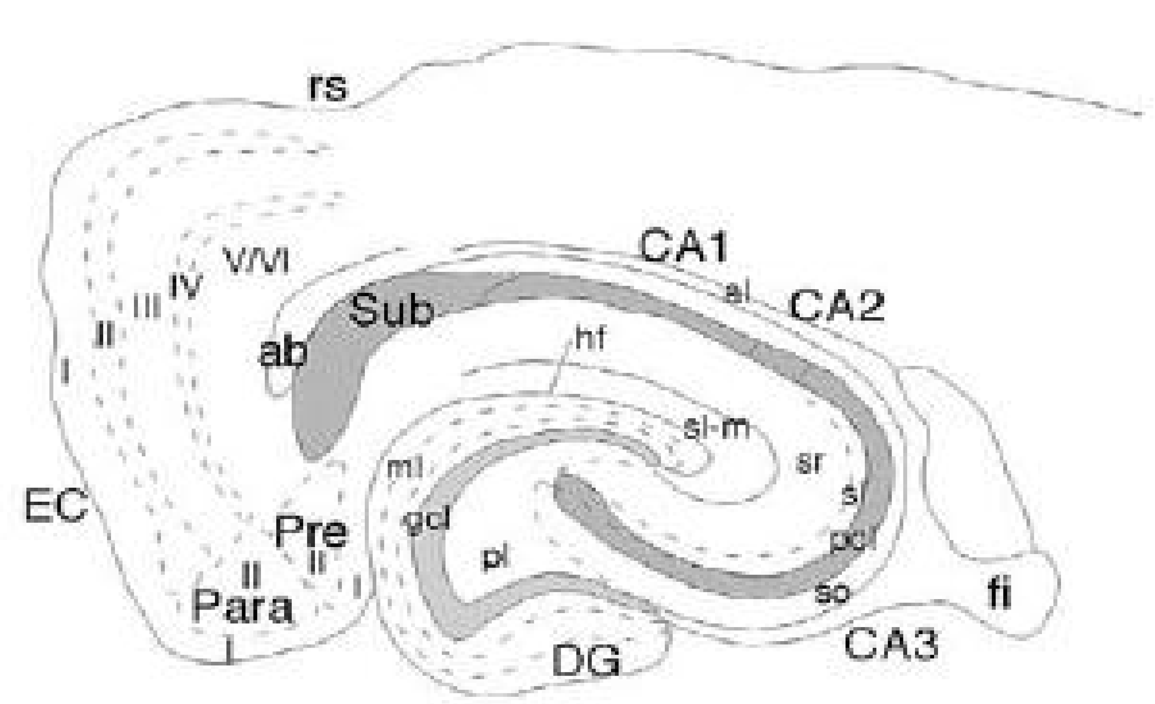
Overview

We present a biologically-plausible spiking neural model of the hippocampus and its role in episodic memory. The model can experience and replay sequences of events, yielding spike patterns and results comparable to experimental data.

The model is general enough to encode both spatial or non-spatial experiences, corresponding to the Hippocampus' role in both spatial navigation and more General episodic memory. It consists of 77740 simulated spiking LIF neurons, divided into populations representing hippocampal areas CA3 and CA1, and part of EC.



Background

NEF [1]:

$$a_i(\mathbf{x}) = G_i[\alpha_i \mathbf{e}_i \mathbf{x} + J_i^{bias}]$$

$$\hat{\mathbf{x}} = \sum_i a_i(\mathbf{x}) \mathbf{d}_i$$

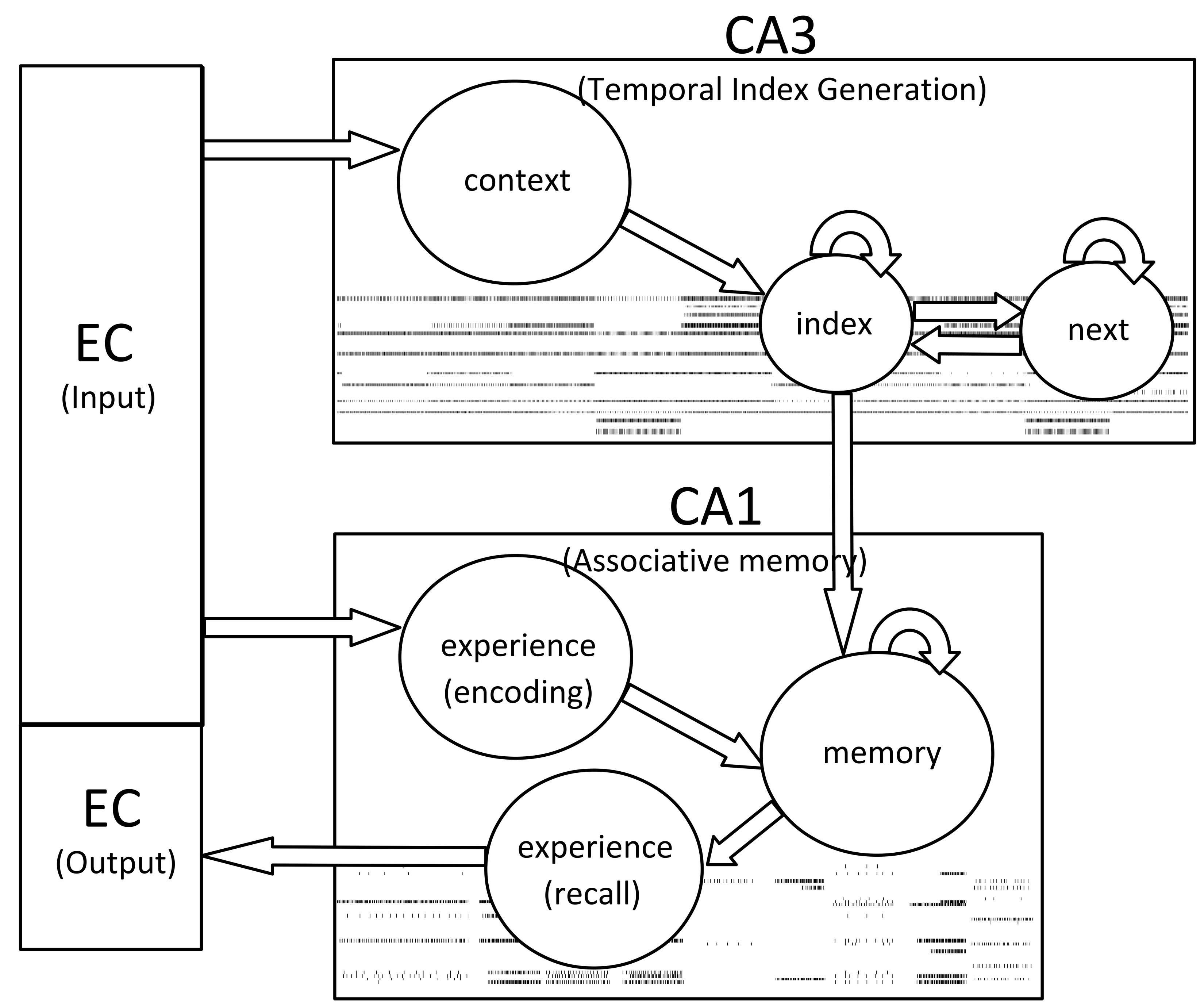
$$\omega_{ij} = \alpha_j \mathbf{d}_i \mathbf{e}_j$$

HRRs/SPA [2]:

*List = p1 * item1 + p2 * item2 + ...*
item1 ~= List / p1

Our model was built using Nengo [3].

Model



Inputs

- experience: sensory information entering the hippocampus from EC, representing position information (place cells) or any other form of processed sensory data.
- context: more general sensory information representing a current environmental context

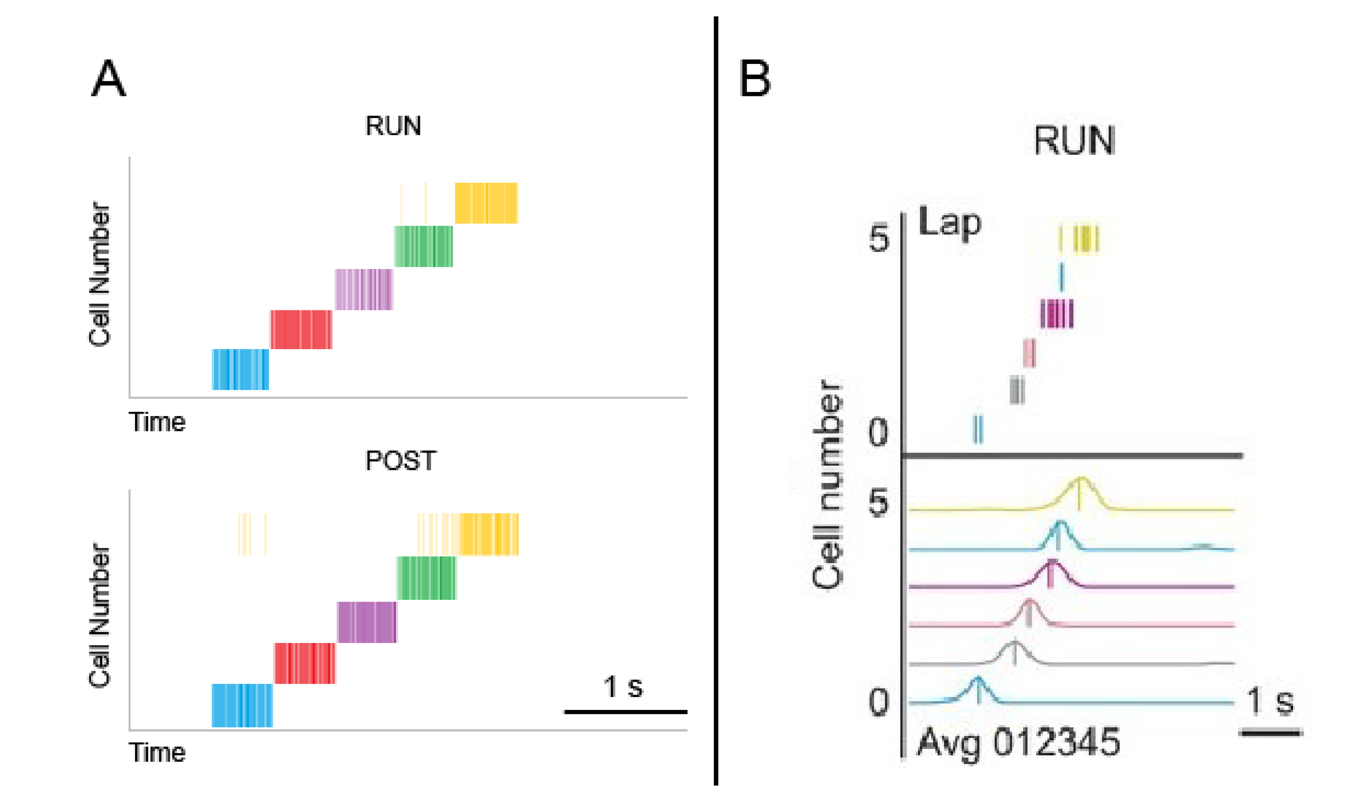
CA3

- Recurrently connected populations in area CA3 count through a series of temporal index vectors *p1*, *p2*, ... A Hebbian learning rule allows for these indices to be uniquely generated for a given context.
- Oscillators controlled by theta rhythm are used to control timing.

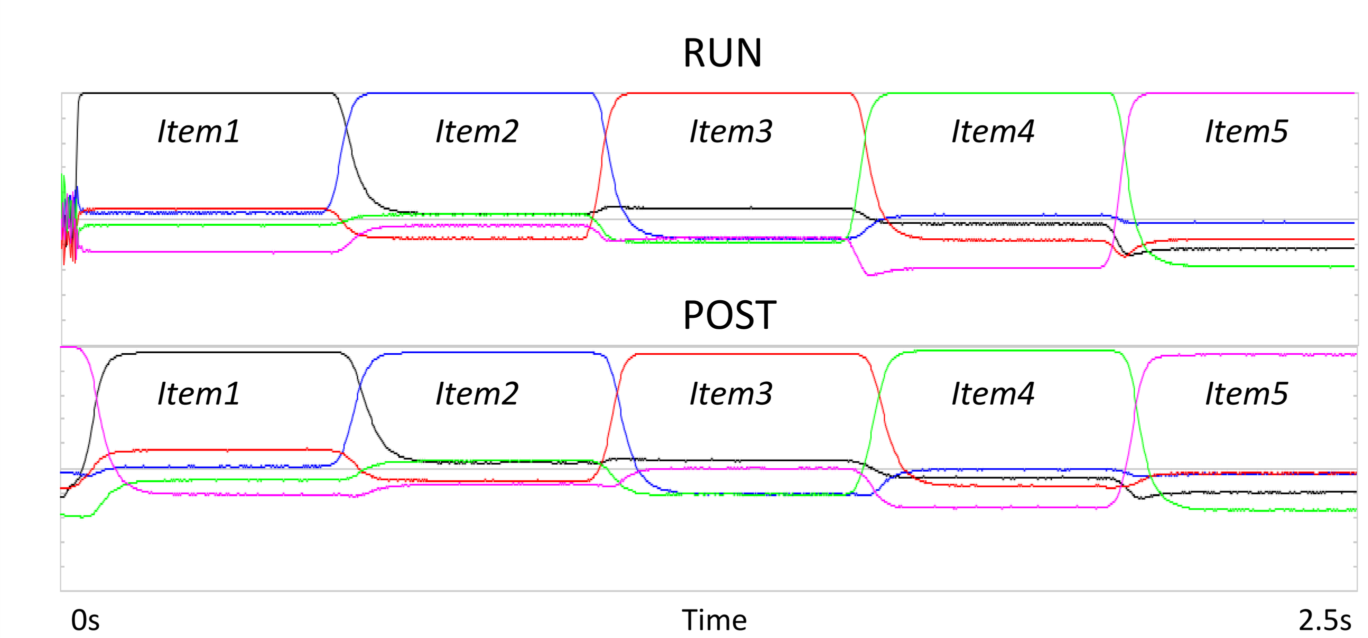
CA1

- In *encoding* mode, the network associatively binds the sensory experience vectors with an index.
- In *recall* mode, it can either retrieve the index corresponding to a given experience and perform pattern completion, or simply recall the previously remembered sequence from the indices coming from CA3..

Results



Neural spike data collected from the model (A) and rats (B) [4] showing similar spike patterns during the experiment (RUN) and during recall (POST)



Similarity measures (dot product) between original HRRs and decoded values from CA1 population. The previously experienced sequence is replayed when prompted with the same context vector.

Remarks

Our model to exhibits the ability to recall previously experienced sequences while taking into account both sensory and temporal tuning of hippocampal cells.

In the future, we would like to take input from Spaun's [5] visual system to simulate navigation in a more realistic environment.

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Air Force Office of Scientific Research grant FA8655-13-1-3084, Canada Research Chairs, NSERC Discovery grant, Canadian Foundation for Innovation, Ontario Innovation Trust, NSERC Postgraduate Scholarship

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