Computation with sequences of neural assemblies

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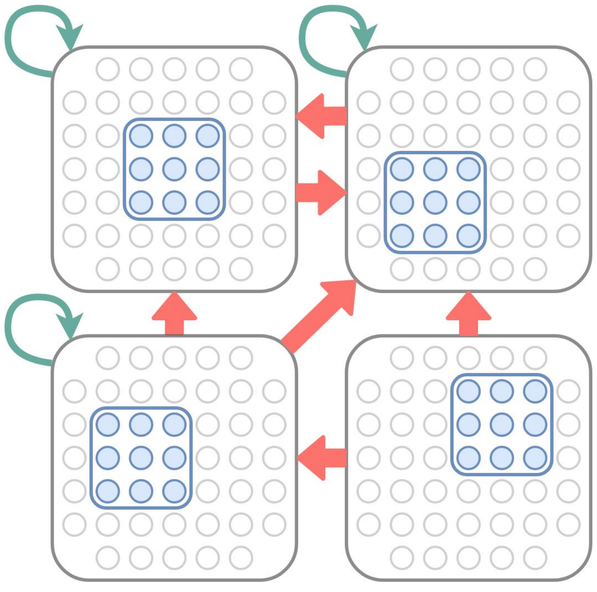
Abstract

- Assemblies are groups of neurons whose coordinated firing is hypothesized to represent units of thought: Memories, symbols, objects, etc.
- Could bridge the gap between individual neurons and cognitive phenomena
- Here we study the formation and manipulation of sequences of assemblies in a random graph model of the brain
- Sequences of stimuli create sequences of assemblies
- Assemblies can be linked to simulate arbitrary finite state machines
- Assemblies can estimate and reproduce conditional random events

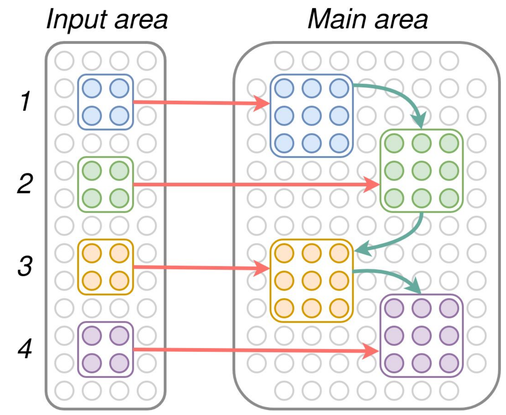


A random graph model of the brain

- A group of neurons is divided into finitely many areas, each of size *n*.
- All connectivity is random
- Time progresses in discrete steps.
- Edges (synapses) have dynamic weights.
- Input is weighted sum of firing neighbors.
- Each area is governed by a *k*-cap: The *k* neurons with highest input are allowed to fire at each step.
- Hebbian plasticity controls weights.
- Neurons in designated input areas can be set to fire.

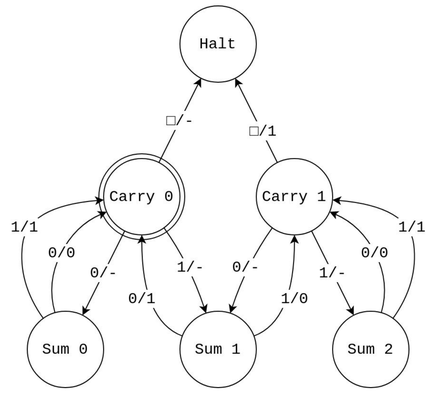
Creating sequences of assemblies

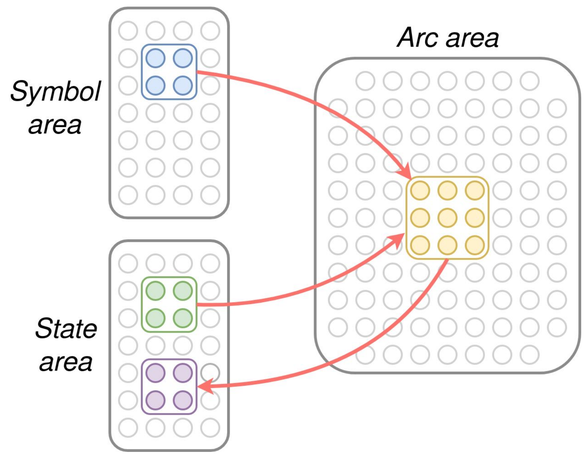
- A sequence of stimuli is presented repeatedly.
- Small stimulus overlap ⇨ small assembly overlap
- After enough presentations, the entire sequence of assemblies will be recalled from just the first stimulus
- Multiple simultaneous sequences can reinforce each other



Memorizing finite state automata

- FSM: A set of states and transitions between them based on input symbols
- Introducing interneurons for selective area-wide inhibition
- Each pair of symbol and state assemblies projects to an associated arc assembly
- The arc assembly projects to the correct next state



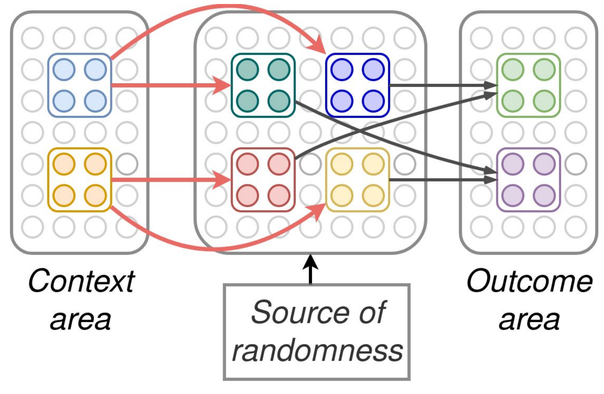


Assemblies in this model

- A set of ~*k* neurons in a single area.
- With sufficient plasticity, an assembly will form quickly in response to external input.
- Projection: Forming a copy of an assembly in a new area.
- Reciprocal projection: Forming a copy with links to the original.
- Merge: Form a new assembly with links to a set of existing ones.

Estimating random transitions from samples

- Brains are constantly performing statistical estimation, especially on sequences (e.g. language)
- We consider the task of learning/reproducing co-occurence statistics from observations
- Each context assembly projects to a unique context/outcome pair assembly, for each possible outcome
- Context/outcome pairs project to appropriate outcome assembly
- A source of randomness ensures that the state assembly which fires is random
- For right plasticity rule, approximates the observed distribution



github.com/mdabagia/learning-with-assemblies