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Planning with Biological Neurons and Synapses - AAAI22 Poster

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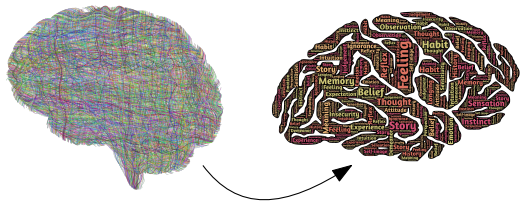
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Brain & Mind

- How does the **brain** beget the **mind**?
- How do **intelligence**, **reasoning**, **language** (etc.) emerge from **neurons** and **synapses**?

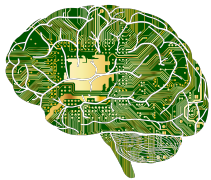


“We do not have a logic for the transformation of neural activity to thought and action. I consider discerning [this logic] as the most important future direction in Neuroscience”
[Nobel laureate Richard Axel, Neuron 2018]

The Assembly Calculus

Recently proposed **formal computational system** [Papadimitriou et al., PNAS 2020]

- explicit **purpose** to be **Axel's logic**
- tries to **bridge** through **computation** the **gap** between **neurons** and **intelligence**



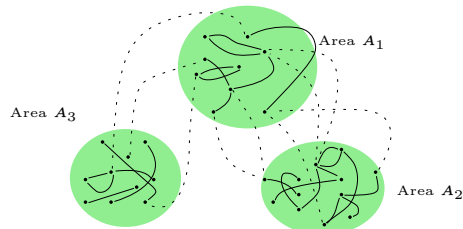
Full version of the work available at:
<https://arxiv.org/abs/2112.08186>

Assemblies

- first **hypothesized** by [Hebb, 1949] to be densely interconnected **sets of neurons** whose loosely synchronized **firing** in a **pattern** is **simultaneous** with the **subject thinking** of a particular **concept** or **idea**
- **confirmed** by [Harris, Nat. Rev. Neurosci. 2005], [Buzsaki, Neuron 2010]

The model of the brain

- **Interconnected areas**, where each area A is an **Erdős-Rényi graph** G_{n_A, p_A}
- areas are connected between each other like **bipartite Erdős-Rényi graphs**



The idealized dynamics

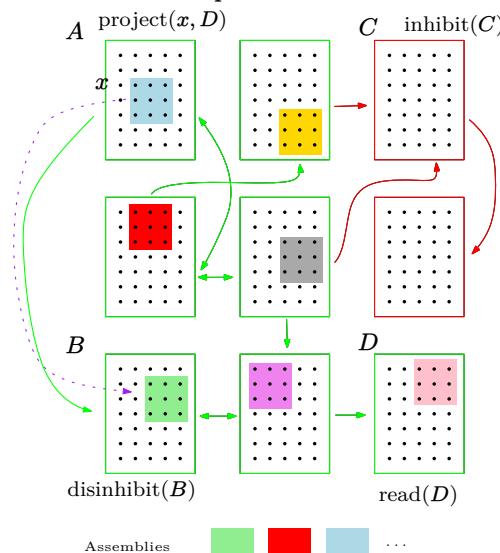
- synchronous rounds
- **k-WTA rule**: neurons/nodes **fire** if they are among the k neurons that received the k **highest inputs** in the area
- **input** for a neuron x is the **sum** of **incoming edge weights** whose source has **fired** in the **previous round**
- **weight updates** when two endpoints fire in **consequent rounds**: $w_{\text{new}} = w_{\text{old}}(1 + \beta)$, $\beta > 0$ **Hebbian plasticity**

Assembly = stable set of k neurons

Primitives Operations

- (dis)inhibit areas
- fire an assembly
- read an area
- project an assembly and fibers
- strong project

Example of a brain



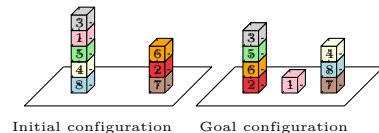
Our contribution

We implement **planning strategies** in the **blocks world** in the **Julia** programming language modeling stylized **neurons** and **synapses**

- **goal**: to **demonstrate** that reasonably **large** and **complex programs** in the assembly calculus can **run efficiently and reliably**

The blocks world planning task

Input:



Output:

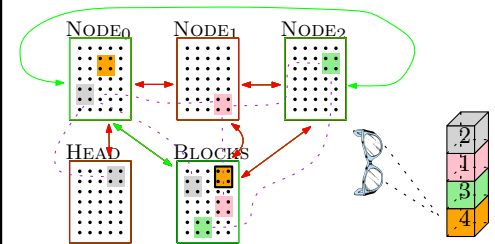
- the sequence of moves

Constraint: possibility to move one **top block** at a time

Overview of the procedure

- a way to **represent** the **blocks world configuration** in the brain: a **parser**
- **implementation** of **actions** and their representation in the brain: **moving a top block to the table**, **moving a block to the top of a stack**, **compare two stacks**
- combining the above functions to achieve the **planning strategy**
- **efficiency**: roughly 35 **spikes** per block for each action. If 50 Hz spikes for excitatory neurons in humans, it's around **1.5 sec per operation**

The parser



Limits: the **planning fails** when the **parsing fails**. We found that it fails for very **tall stacks** (overlap of assemblies). Necessitates research on parameter ranges