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## Planning with Biological Neurons and Synapses - AAAI22 Poster

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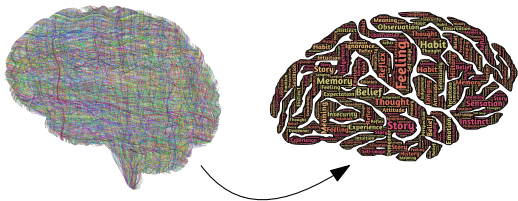
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## Brain & Mind

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

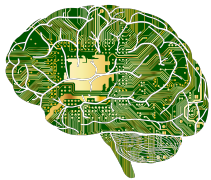


*"We do not have a logic for the transformation of neural activity to thought and action. I consider discerning [this logic] as the most important future direction in Neuroscience"*  
[Nobel laureate Richard Axel, Neuron 2018]

## 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**



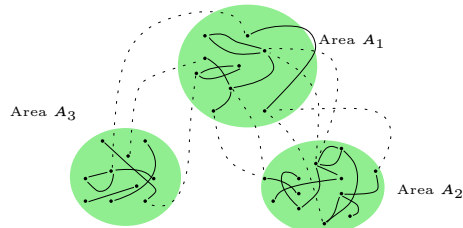
Full version of the work available at:  
<https://arxiv.org/abs/2112.08186>

## 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

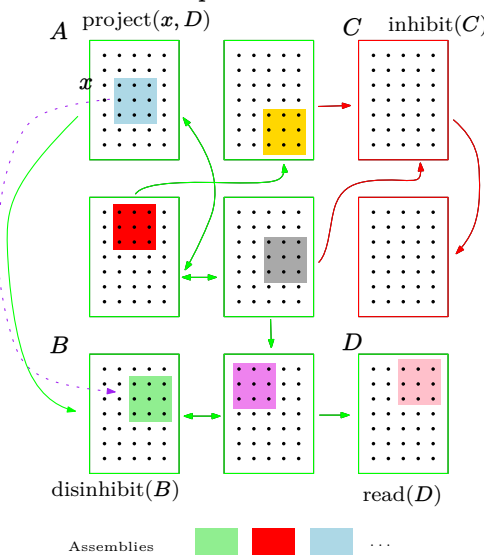
- synchronous rounds
- **k-WTA** rule: neurons/nodes **fire** if they are among the  $k$  neurons that received the  $k$  **highest** inputs in the area
- **input** for a neuron  $x$  is the **sum** of **incoming edge weights** whose source has **fired** in the **previous round**
- **weight updates** 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



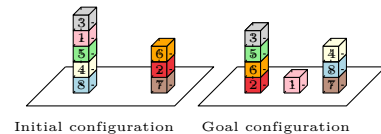
## Our contribution

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:**

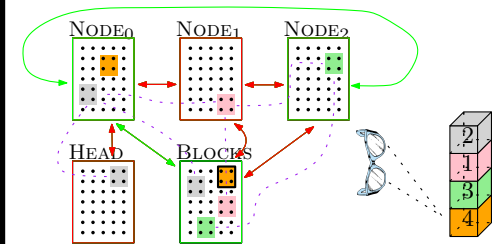
- the sequence of moves

**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