The Ghost in the Machine: Emergence of Computation in CW-complexes

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Abstract

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1 Introduction

Advancements in the last few decades have brought us to a point at which what was thought to only be theorized by Tolman in 1948 [9] as he argued that for Humans and other animals to make complex inferences from sparse observations and rapidly integrate new knowledge to control their behavior there should exist a systematic organization of such knowledge on what could be called a cognitive map. (note, try to make it sound like the theory of computing)

But what was missing from these early studies, was a way to address the neuronal mechanisms that led information to be stored as memory. Further development has shown that place cells are part of a wider network of spatially modulated neurons, including grid, border, and head direction cells, each with distinct roles in the representation of space and spatial memory.

Bringing to surface a mechanistic basis for memory formation (Nobel prize winning Place Cells, Grid Cells, and Memory) which later has been suggested that relational memory and spatial reasoning might be related by a common mechanism (Eichenbaum and Cohen, 2014 [3]).

[1]

(Must do a paper dump showcasing some advancements) In the last few decades we have seen many advancements in neuroscience. It is now possible to record activity from every neuron in a zebrafish larva's brain while it is freely swimming and responding to stimuli Kim et al. 2017 [5]. We have a nearly complete map of one hemisphere of the fly brain, with every neuron and most of its synapses accounted for (Pipkin 2020 [7]). The neurons responsible for a mouse's memory of an event can be recorded, tagged, and replayed by laser stimulation, causing the mouse to behave as if the event had happened again (CarrilloReid et al. 2019 [2]; Ramirez et al. 2013 [8]).

Such advancements brought to light evidence for what was once only a theory, for example, Tolman in 1948 [9] argued that for Humans and other animals to make complex inferences from sparse observations and rapidly integrate new knowledge to control their behavior there should exist a systematic organization of such knowledge on what could be called a cognitive map.

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The combination of all these technological and theoretical developments demonstrated through evidence and theoretical models that there is indeed a mechanistic basis for memory formation, this was shown in the Nobel winning work done by May-Britt Moser, Edvard I. Moser [6]. This work has inspired new theories in theoretical-neuroscience that , likewise to Tolman, proposes the idea that relational memory and spatial reasoning might be related by a common mechanism (Eichenbaum and Cohen, 2014 [3]).

Some evidence, eventhough limited, has shown in recent work with grid cells, [4], by using simultaneous recordings from many hundreds of grid cells and subsequent topological data analysis that the joint activity of grid cells from an individual module (neuronal population) resides on a toroidal manifold as expected in a two-dimensional CAN (Continuous Attractor Network), supporting the argument that there is indeed a mechanism generating invariant representations. The positions are maintained between environments and from wakefulness to sleep, demonstrating to be invariant representations. This research demonstrated, with some limitations, network dynamics on a toroidal manifold and provided a population-level visualization of CAN dynamics in grid cells.

Even though the technological limitations to record population of neurons, these works provide growing evidence to hint that previous theories and intuitons formulated through theoretical neuro science were in the right path.

There is growing evidence to support that manifolds maintain a well-preserved covariance across tasks. These results support the view that complex computation emerges from the flexible activation of different combinations of "Neural modes" (Need to find a better term) which themselves arise from the Network Connectivity (reference to Hopfield is all you need and Transformers) (Cortical population activity within a preserved neural manifold underlies multiple motor behaviors, reference 8 for Emergence of universal computations through neural manifold dynamics)

In this paper we want to show that there exists a morphism between Neuroscience models and existing NN models, so we can approximately represent the Neural Manifolds with the Transformers.

Must note that, likewise Whittington [10] mentions, we are not saying the brain is closely related to transformers, instead we are using a mathematical relationship between the so popular transformers and the attractor neural networks that have been carefully formulated in neuroscience models as being an essential piece in forming invariant representations in a topological structure that facilitates the emergence of Computation Through Neural Population Dynamics. Additionally, we are exploiting this relationship by carefully crafting a modified transformers model so we can benefit from several engineering tools, techniques, softwares and hardware that have been matured and extensively tested given the popularity and widespread use of transformers. Further studies are required to develop and validate a better architecture that better represents Neural Population Dynamics.

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2 Theory of Computing

Computing is not a new concept, there is historical evidence that the Greeks were already capable of performing computation to predict the astronomical movements giving a programmable input (Antikythera mechanism).

3 Single image

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Figure 1: Example of single image

4 Multiple images

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Figure 2: Examples for sub-images

Figure 3: Logo image

Figure 4: Logo image

5 Some other Section

Citations examples used to be here

6 Tables

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Table 1: Sample table title

Part		
Name	Description	Size (μm)
Dendrite	Input terminal	$\sim$100
Axon	Output terminal	$\sim$10
Soma	Cell body	up to 10^6

7 Conclusions

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Acknowledgments

Use unnumbered third level headings for the acknowledgments. All acknowledgments go at the end of the paper. Do not include acknowledgments in the anonymized submission, only in the final paper. This example was prepared by Dennis Núñez Fernández.

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