An Abstract for

Synthetic Cognition

Implementing a Testable Hypothesis

(Harvesting Sparse Order from Local Interference)

Augustus Bacigalupi

All living systems at every scale must do work to navigate and survive their surroundings. But it is not enough to cohere upon just one work task at a time as our functional machines are currently designed to do. Complex environments require that complex behaviors be performed. This means that more simple work tasks be integrated together to create more complex tasks, such as walking, problem solving, and language. The capacity to perform *complex* and *adaptive work* in a manner that is relevant to an agent's environment is fundamental to the success of that agent. Evolution selects for this capacity over generations, while cognition exhibits complex adaptive work capacity within a single lifetime. This project will build and empirically test a synthetic form of cognition capable of complex and adaptive work, e.g. learning.

Since Descartes the understanding of mind has been seen largely through the lens of functionalism. Our digital machines are an extension of this approach. It is this preconception of mind as functional machines that stands in our way of understanding life and mind, not any fundamental lack of knowledge. This project will contribute to changing this state with the following system.

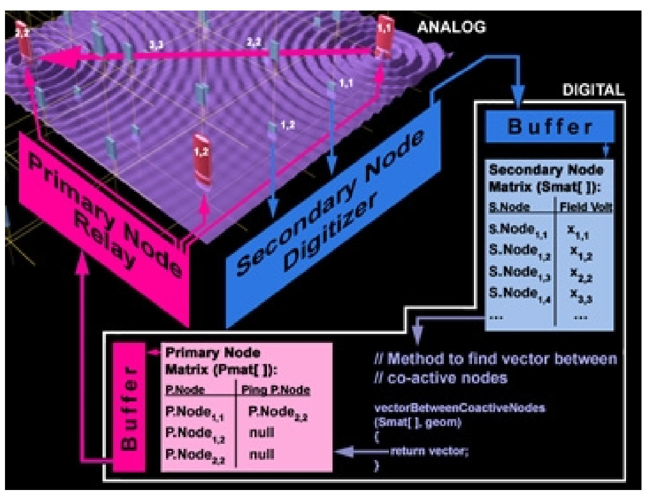

Figure 1 – An Hybrid Schematic
This hybrid has a Superimposed/analog and a Functional/digital portion. For the purposes of this project's main goal of realizing synthetic cognition, the strengths of each will be leveraged into a hybrid where each strategy augments the other. The Superimposed portion is free to continuously respond to sparse order within the interference patterns, which molds and is molded by Primary node (magenta nodes) behavior. The Functional/digital portion samples these free running patterns via the Secondary nodes (smaller blue nodes). Sparse order is discerned algorithmically. Vectors are discerned between Primary nodes and then uploaded to the Primary nodes themselves so that future behavior will be modulated, not just by the interstitial field, but by accrued connectivity, again, in real-time.

The central claim and the main feature of the built system is that information is simultaneously distinct and distributed. Just as the extensive properties of atoms engage other atoms to constitute higher-order forms, so too do neurons self-organize based, not only on their synaptic inter-connections, but on the interstitial chemical and potential gradients that both mold and are molded by the behavior of the neurons themselves. In essence, the ability for the cognitive system to accrue order is self-caused in the presence of environmental perturbation. This addresses many of the unanswered questions of cognition, one of which being how neurons wire themselves prior to dendritic connectivity.

Local Field Potential (LFP) and C^{++} gradients, among other interstitial energy and chemical gradients, are central pieces of this puzzle. And although their causal efficacy has been well established for decades, most recently by Christof Koch[1], these phenomena have largely been ignored in more orthodox functional – including neural network, statistical, and cybernetic – models. This project, however, will contribute to the field of cognitive science by empirically demonstrating not only the causal efficacy of interstitial phenomena, like LFP, but will go further to demonstrate how these phenomena explain currently unexplained mysteries of mind.

To do this the hybrid diagrammed in **Figure 1** will employ nodes that have both functional inter-connectivity and a dynamic interstitial potential field, as evidenced in evolved organic brains. To accomplish this, each primary node is designed to not only inter-connect with other local nodes, but also be sensitive to ambient signals in their shared environment. These signals create a superimposed interference pattern that both molds and is molded by the behavior of each distinct node. This allows nodes to make non-stochastic physically relevant inter-connections between themselves where no connections previously existed. This goes beyond functional and solely synaptic based models such as Spike Timing Dependent Plasticity (STDP), and accounts for a much wider range of established neuroscientific evidence. **Figure 2** presents a circuit schematic of this node.

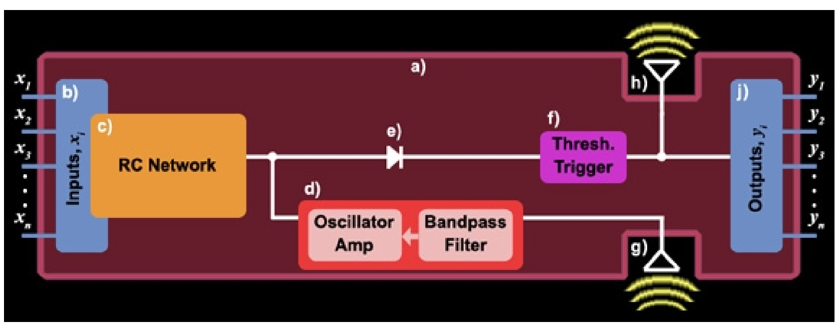

Figure 2 – Primary Node Schematic Diagram
The behavior of a Primary nodes is influenced by its own distinct selectivity (**d**), i.e. signals it is tuned to resonate with in the local field (**g** and **d**), *and* inter-connections that have accrued with other Primary nodes (**b**) as a result of former coincident nodal activity. If the modulated voltage (**e**) is sufficient, based on these factors, to trigger the threshold (**f**), the node will emit its own signal into the interstitial field (**h**) *and* ping formerly connected nodes downstream (**j**).

To test this hybrid system for cognitive behavior, a rigorous theory of basic cognition was developed based on adaptive work and complexity. In essence, the successful cognitive system must increase in both work capacity and complexity, whereas adaptive Work is defined in **Figure 3**.

[1] Costas A Anastassiou1, Rodrigo Perin, Henry Markram, Christof Koch *Ephaptic coupling of cortical neurons* Nature Neuroscience **14(2)**, 217-223 (211)

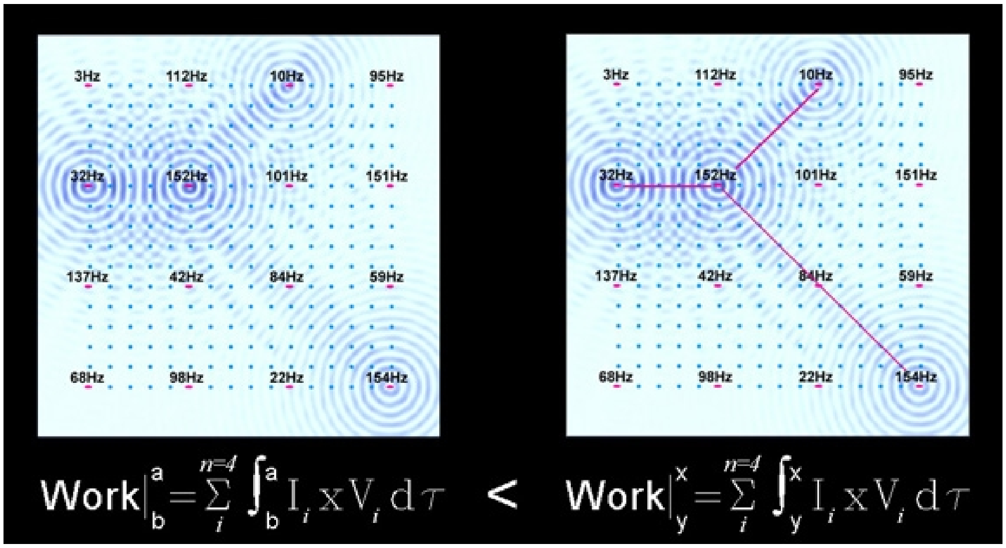

Figure 3 – Harvesting Order To Increase Work Potential
The work done by the four nodes independently between time interval a-b will tend to be less than the work done by the inter-connected nodal assembly between time interval x-y. This is because the individual nodes within the latter assembly are not only stimulated by the environment, but also stimulated by the accrued order between each other, thereby sustaining a salient interstitial pattern to do diverse and useful work at higher-orders of complexity.

Complexity is defined inspired by Shannon entropy and the understanding that all living systems must embody higher-orders of complexity in order to represent and process a commensurate level of relevant complexity within their environment.

Complexity $\equiv \Sigma_i (1/\sigma_i^2) + \Sigma_{ij} (1/\sigma_{ij}^2) + \Sigma_{ijk} (1/\sigma_{ijk}^2) + \ldots$

The nature of this hybrid system is unique in many ways, one of which is its ability to directly measure the state of each node using precise digital means as illustrated in **Figure 1** above. Subsequently, both the amount of Work done by each node and a statistical model of Complexity will be directly accessible based on the digital data structure. The **Null Hypothesis** is that adaptive Work and Complexity are not increased with exposure to patterned environmental stimulation, whereas the **Alternative Hypothesis** is that adaptive Work and Complexity do increase with exposure to patterned environmental stimulation.