P51:Rational Engineering of Neurons-on-a-chip Towards Embodied Biological Intelligence

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Introduction

The integration of intelligence into organ-on-a-chip devices is increasingly recognized as a crucial advancement to enhance their pharmacological applications[1]. Neurons-on-a-chip provides a specialized platform for embodied biological intelligence, enabling more sophisticated biocomputing capabilities[2]. However, designing rationally methods to implement controlled biocomputing poses significant challenges. Previous research utilizes microtubules to promote axonal growth and manipulate synaptic connections, laying the groundwork for directing information[3]. Our study aims to **evaluate how the rational engineering of neuronal microtunnels can be leveraged to enhance biocomputing power in neurons-on-a-chip solutions**, with a particular focus on generating directed communication mechanisms between neuronal clusters.

Methods

To investigate the influence of different network topologies on the information processing capabilities of neurons-on-a-chip, we employed a custom simulation framework based on the Izhikevich neuron model. The simulation was designed to model the dynamic behavior of neuronal networks. We analyzed three distinct network topologies: Clustered Ring, Sparse, and Small-World. Transfer entropy analysis was performed to quantify the directed information flow between neurons. Metrics such as average centrality, average transfer entropy, and average information processing power were derived from the transfer entropy matrix.

Results & Discussion

The comparative analysis of different neural network topologies reveals significant variations in their information processing capabilities. As observed in Fig.1., Small World topology demonstrates the highest average centrality (0.00181), average transfer entropy (0.00181), and average information processing power (3.2782e-06). This indicates its superior efficiency in facilitating both local and global information transfer. Sparse topology exhibits the lowest metrics highlighting its limited connectivity and inefficiency in complex information processing tasks. The Clustered Ring, with intermediate values, is balanced between localized and inter-cluster communication.

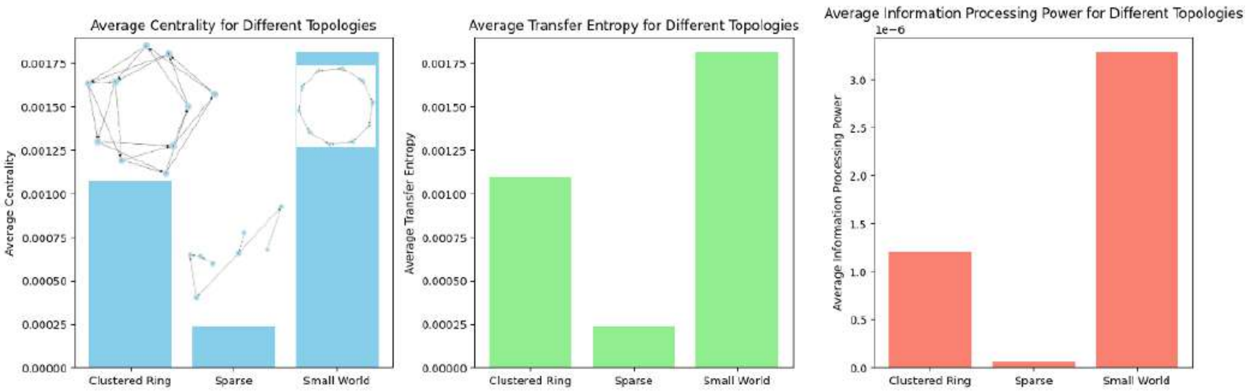

Figure 1 Average centrality, Average Transfer Entropy and Average Information Processing Power for three network topologies.

Conclusion

Our study demonstrates the critical impact of network topology on the information processing capabilities of neurons-on-a-chip. The Small-World topology, characterized by its high average centrality, transfer entropy, and information processing power, emerges as the most efficient structure for complex biocomputing tasks. These findings highlight the importance of designing optimal network configurations to enhance the functionality and efficiency of neurons-on-a-chip, paving the way for advanced applications in pharmacology and beyond.

References

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