Research Proposal for Scientific Computation and Data Sciences Certificate

Title: Investigating the Efficacy of the Cascade Model of Synaptic Plasticity in a Biologically Constrained Simulation

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Introduction:

Understanding how the brain is capable of retaining memories over long periods of time remains a major question in computational neuroscience. In response, numerous theories of synaptic plasticity have been proposed based on biological findings. The key obstacle is developing a model that supports robust learning while simultaneously protecting the learned memory from being erased by the ongoing plasticity events of everyday life. One influential theory is the cascade model of synaptic plasticity, introduced by Dr. Stefano Fusi in 2005. This model addresses the aforementioned obstacle by theorizing multiple metaplasticity states in addition to the actual weights of the synapses. Since then, the cascade model has been widely studied in the field, including research in artificial neural networks. However, to date, it has not been tested within a biologically constrained simulation. Consequently, the objective of this research project is to explore the effectiveness of the cascade model of plasticity by comparing its performance to alternative models, such as the binary and graded models, in learning and memory retention.

Methodology:

To conduct this research project, we will utilize a large-scale spiking network model developed by the Mauk Lab in the Department of Neuroscience. This model captures the intricate biological details of the cerebellum, including cellular behavior and connectivity. It has also undergone extensive testing against experimental results from eyelid conditioning trials in rabbits, providing a reliable basis for our study. We will use the C++ programming language to implement the cascade and binary models of plasticity in the simulation. Bash script will then be utilized to run the simulation, emulating the training process with the rabbits. Our data collection will include spike activity files of the cerebellar cells and synaptic weights, which we will analyze using Python. By comparing this data to pre-existing knowledge on rabbit behavior during eyelid conditioning trials, we can evaluate the ability of each plasticity model to perform learning similar to actual biology. The efficacy of each model will be analyzed in terms of its ability to learn, extinguish, and retain memory.

Faculty Mentor:

This research will be conducted under the guidance of Dr. Michael Mauk, whose simulation model has been rigorously tested and has shown to accurately depict the complex functions of the cerebellum. With his extensive knowledge and experience, Dr. Mauk is the ideal mentor to provide guidance in this investigation of the cascade model of synaptic plasticity and its implications for learning and memory. I am excited to work with him not only for his expertise in the field but also for his guidance in the broader scientific research process.