Local Field Potential Estimation for Application in Hippocampal Prosthetic Device Design

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Memory disorders, such as Alzheimer's disease or dementia, have been associated with impairment to the hippocampus. Towards restoring and/or enhancing memory functionality, hippocampal prosthetic devices are currently being developed. Such devices utilize systematic electrical stimulation to induce hippocampal neural activity that is indicative of neural function during memory facilitation. The stimulation parameters are predicted using a multi-input multi-output model. This model takes as input neural recordings at different locations in the hippocampus and estimates appropriate stimulation parameters, intending to mimic neural activity observed when a memory is correctly recollected. Current hippocampal prosthetics following this approach have been shown to be effective in enhancing and restoring memory functionality in rodents and primates in experimental trials.

Towards increasing the effectiveness of these devices, the authors' previous work involves construction of multi-scale computational models of electrical stimulation and recording of neural activity in the hippocampus. This includes the development of a heterogeneous large-scale model of the hippocampus, surrounding tissue, and implanted electrodes for simulating voltage throughout bulk tissue, as well as a neural network model for simulating neural activity.

In the proposed work, this model will be used to simulate recording electrodes, computing local field potentials (LFP) resulting from given neural firing patterns in hippocampal tissue. This is with the goal of characterizing the recordings taken in hippocampal prosthetic devices, towards increasing their effectiveness by improving their ability to parse recordings and choose appropriate stimulation parameters. This involves treating each firing neuron as a current source, and simulating the voltage throughout the surrounding tissue and nearby recording electrodes. Results will include simulated LFPs for given neural activity in a population of neural tissue, using a model of applicable recording electrodes and heterogeneous tissue. The results will be compared with analytical methods for LFP calculation, providing validation of the methodology and the added complexity of the multi-scale computational model. This work further evolves the computational efforts towards modeling and understanding the hippocampus and its response to electrical stimulation, for use as a simulation tool for designing next generation hippocampal prosthetic devices.