Optimizing Electrode Placement Using a Multiscale Model of the Hippocampus

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The hippocampus is associated with consolidating short-term memory into long-term memory. Therefore, damage to the hippocampus can result in neurological conditions such as Alzheimer's, dementia, and other diseases that affect memory. One way of helping patients affected by these conditions is to create a neural prosthesis that replicates the function of the damaged section of the hippocampus. This prosthetic device is built by a) creating an input-output model of the transformation between the still-intact portions of the hippocampus, and b) "instantiating" that model into custom VLSI hardware that's attached to upstream recording electrodes and downstream stimulating electrodes. However, a phenomenon that's still not well understood is the neural response to the electrical stimulation: thus, a multi-scale computational model has been developed to study the response to biphasic stimulation in a rat hippocampus.

A discretized model of the tissue is constructed to include each section of the hippocampus. A 2x8 electrode array is incorporated into the model with a recording row of electrodes in the CA3 while the stimulating side is in the CA1. A variant of the Admittance Method (AM) is used to convert this discretized model to a circuital network and solve for the resulting fields and potentials in the model from biphasic current stimulation at each of the electrodes. This procedure can then be replicated with electrodes of different shapes or by placing the electrodes at different depths to study the effects on the resulting potentials. In the presentation, we will show how the proposed approach can be used to design an electrode array for this application and determine the optimal depth for electrode placement. Further, in this presentation a study of the potentials throughout the hippocampus due to different scenario will be presented, with a particular focus on stimulations that utilize biphasic pulses with electrodes of different shapes placed at varying depths.