A Model to Optimize Subthalamic Deep Brain Stimulation for Parkinson's Disease

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Deep brain stimulation (DBS) is a novel therapy for Parkinson's disease, in which an electrode is surgically implanted into the patient's brain and remotely controlled to send an electrical stimulus to the brain. One theory for the mechanism of DBS is that the stimulus desynchronizes the neurons and sends them into chaotic firing rates, alleviating tremors. However, the exact electrode position and rate at which the stimulus should be fired to be beneficial to the patient is decided through trial and error. This study models subthalamic DBS to identify ranges of acceptable parameters. A three-dimensional matrix was constructed in the programming language R to simulate neurons in the subthalamic nucleus. Synaptic connections between neurons are randomized using a distance-dependent probability function (Manos et al., 2021). All neurons fire at 60 Hz initially with high synaptic weights between neurons, simulating parkinsonian hypersynchrony. DBS is introduced into the model by periodically shifting each neuron’s phase using a phase response curve (Wilson et al., 2011). The synaptic threshold of neurons was used to determine the extent of phase shifts. The stimulus frequencies and electrode positions that resulted in neuron desynchronization, measured as the Shannon entropy value of the neuron population, are recorded. This study shows that electrode positions further from the center of the subthalamic nucleus are more effective. All possible electrode positions showed an optimal frequency range of 120-180 Hz, which overlaps with the optimal range of 130-180 Hz from clinical studies.