Functionalizing MIDA Using Computational Neuroscience

FIRE: DEEP BRAIN NEUROTECH
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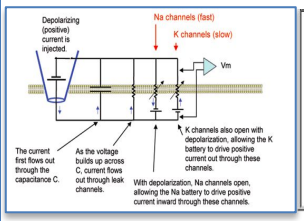
Deep Brain Neurotechnologies

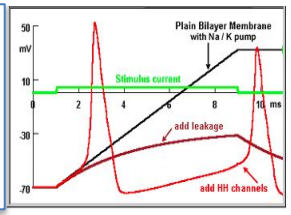
How Does Neurons In Action Work?

Neurons In Action (NIA) allows us to simulate the properties of neurons using the NEURON software via tutorials. It helps us understand the mechanisms of action potentials and introduces equations that dictate neuron activity under certain conditions. NIA provides realistic, interactive simulations, and gives us the opportunity to change axon parameters in tutorials exploring neurophysiological relationships, and the components that affect axon properties.

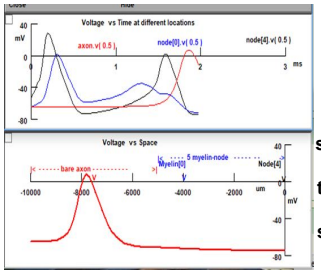
Using NIA to understand K and Na ion pumps:

K (Potassium) and Na (Sodium) ion pumps are found on the lipid bilayer of a neuron, NIA allowed us to alter axonal membrane conditions, such as increasing or decreasing the concentrations of extracellular K on the outer layer of the membrane to understand how a stimulus current across the membrane changes the voltage and capacitance of the membrane.





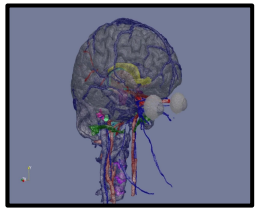
Myelin Degradation in Multiple Sclerosis

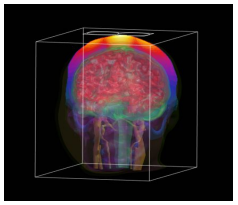


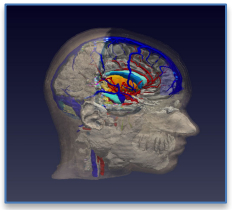
When an impulse struggles to cross a "danger zone," such as the transition from myelinated to demyelinated axon, cooling is very effective in being able to send this current across this zone. Decreasing the axon temperature by 0.1° C in this tutorial allowed for the stimulus current to continue into the demyelinated axon.

What is MIDA?

MIDA is a Multimodal Imaging-Based Anatomical model of the human head and neck developed by the FDA. MIDA is one of the most detailed models of the human brain, including 153 structures. This model is currently used in various scientific research projects around the world.

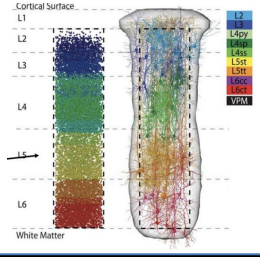


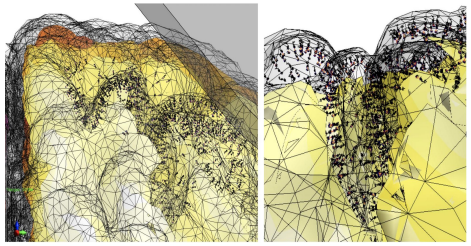




What are we doing?

The problem with MIDA is that it is a static model with only macroscopic properties. So far, researchers from Zurich have placed 28,932 pyramidal neurons in the cortex. However, cortical neurons are much easier to model when compared to neurons of the deep brain. Since we are studying how different types of brain stimulation technologies impact the deep brain, our goal is to embed the different types of basal ganglia neurons into the corresponding structures of MIDA. The reason we are interested in these specific structures has to do with their involvement in neurodegenerative and psychiatric diseases. We have been using Neurons in Action to understand the dynamics of neural activity. We will be using the NEURON software and the SIM4LIFE platform to computationally insert neurons into the MIDA model. Our ultimate goal is to functionalize aka animate the MIDA computer model of the head and neck, which in and by itself would be a great contribution to the scientific community. This will also allow us to test the different stimulation technologies and give us insight into their mechanisms of action.

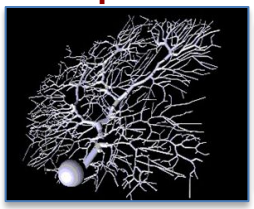


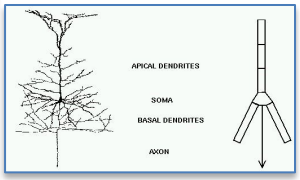


What is NEURON?

NEURON (hoc/python) is a professional software simulation environment developed by Yale University for computational neuroscience and used by the majority of neuroscientists to simulate and understand the complexities of neuronal morphologies and dynamics. NEURON calculates currents, conductances and voltages throughout different types of nerve cells. NEURON also creates a model of a virtual neuron, and it allows us to choose the types of channels in the axon membrane, as well as the number of myelin wraps on the axon. After choosing different parameters, NEURON displays voltage signals as a function of time and/or space as signals travel throughout the virtual neuron. We will be using NEURON because Sim4Life accepts this platform to import neurons into MIDA (especially into the basal ganglia) and to test the effect of this deep brain stimulation on neural activity.

Map and Model: The Future





This a detailed model of a Purkinje neuron from the cerebellum imported from NEURON. The Purkinje neuron, as opposed to the pyramidal neuron, is how we plan to model our neurons: using as much detail as possible, so we can have a more accurate understanding of brain function. Since we are focused on the deep brain, the type of neurons we are going to model are mostly medium spiny neurons, since they are the most abundant.

Deep Brain Neurotechnologies FDA IGC sim4Life by zurich medtech Texas Instruments

Department of Electrical & Computer Engineering

ΔβV

Malath Al Matoq, Josselyn Marroquin, Briella Moon, Kayla Norton, Veronica Salib, Allegra White, Vlad Dobrin