

# Mathematical Modeling of an Active Neural Network Using MATLAB and SIMULINK

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**Abstract**— The goal of this project is to use Matlab in conjunction with SIMULINK to design an active mathematical model for a neural network. A current stimulus within the soma of the first neuron will trigger an action potential in that portion of the neuron, which will then trigger action potentials along the axon as the current flows through the axon boutons and the second neuron. If this stimulus is too small it will not trigger a final action potential for the system. Additionally, the model will simulate currents recorded extracellularly as a result of neuronal discharge. The model's active properties come from the incorporation of a system to represent the synaptic inputs as the action potentials are transferred from one neuron to the next. The behavior of the computer model will be compared with neuronal recordings from the hippocampus in freely moving rats.

## I. INTRODUCTION

The model will be based on two long-standing models of the neuron. The majority of the mathematical model produced will be derived from the compartmental modeling approach. The compartmental model is based on the fact that Hodgkin and Huxley [5] discovered from their voltage clamping experiment that section of cellular membrane can be modeled by a simple RC circuit (figure 1).

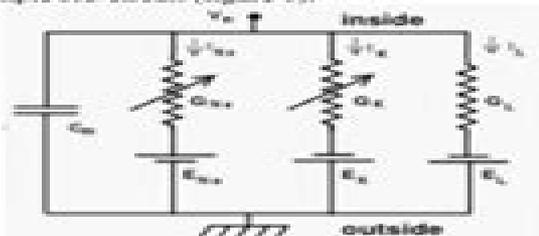


Figure 1: Hodgkin and Huxley circuit model of an action potential (Bower & Beeman [1])

The membrane capacitance is due to the concentration of ionic substances on either side of the membrane, and is charged or discharged when current flows into or out of the compartment. This current may be caused by an injected current, which would represent a stimulating electrode or by current flow from the adjacent compartments. The membrane potential  $V_m$  appears across the membrane capacitance  $C_m$  [4]. Changes in the membrane potential can cause current

flow into or out of the compartment along the axial resistance  $R_a$  when there is a difference in the potential of neighboring compartments. When there is no net current flow into or out of the cell via the ion channels the membrane potential approaches the resting potential,  $E_{rest}$ . The conductances  $G_{Na}$  and  $G_K$  represent the variable channel conductances of the corresponding ion channels. The potentials  $E_{Na}$  and  $E_K$  represent the Nernst potential at which there is no net flux of these ions. These potentials are caused by the differences in the concentration of the ions inside versus outside of the cell, which results in an osmotic pressure which moves the ion along the concentration gradient [2,3]. The final conductance and potential  $G_L$  and  $E_L$  represent the effects of all of the passive ion channels and are relatively fixed values.  $G_L$  is referred to as the leakage conductance.

## II. METHODS

This model required the summation of iterative sections of the membrane to represent the propagation of an action potential from the dendrites to the soma to the axon terminals. Our model is based in part on Hodgkin and Huxley passive model for a patch of a neuronal membrane and also on cable transmission theory (figure 2).

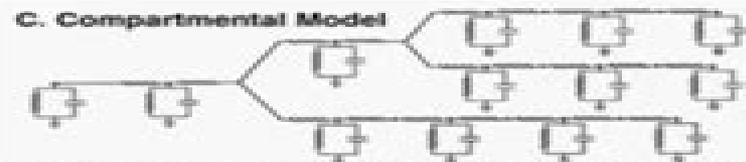


Figure 2: The compartmental model—each of the 13 compartments represents a portion of a membrane modeled as a circuit as described by Hodgkin and Huxley. (Bower & Beeman [1])

By determining the current, which flows into each compartment, and the voltage associated with that compartment, the action potential of each compartment. Depending on the location along the neuron, from soma to dendrites, values of model parameters are expected to vary. For example, the conductance will vary greatly when current flows through the Soma versus when it flows through the

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**Michael Rajnik**



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