Creating Transistor Models For The Purpose Of Controlling Neurons To Move The Head of *Caenorhabditis elegans*

Ingi Zaki

izaki@umd.edu

Earth Life and Time

Me working in the lab on Simulink

Abstract

While conducting research under the supervision of Professor Newcomb of the University of Maryland at the University Of Maryland, College Park, I was able to learn about the neurons of the worm, *Caenorhabditis elegans* and how they function to aid in the movement of the worm. Learning the functionality helped me to start trying to create a simulation of the activity of the neuron. The neuron that I had the opportunity to look, at ASER was mainly employed in the movement of the head of the *C.elegans*. In order to begin my research, a lot of background knowledge about how neurons function in general was necessary. After mastering the details of neurons I was able to then go about simulating a few components of the neuron on a computer program called Simulink. This program utilizes functions using parameters to create graphs of certain situations. I was able to use this program to simulate the voltage graphs for the Potassium ion channels and the Calcium ion channels in the neuron of the *C.elegans*. Obtaining the parameters was done by fitting experimental data that other researchers had done previously.

Introduction

The *Caenorhabditis elegans* is a microscopic worm that has a very simple neural network. Working to analyze this network is easy due to its simplicity. Because the worm is so small however a lot of simulations must be done to see how everything functions on a larger scale. The focus of this research is to understand how the neurons function to move the worm, specifically the head of the worm. Neurons have membranes that can be electrically excited via an action potential that is created by a change in ion concentrations inside and outside the cell. When the neuron is at a resting state it has a higher concentration of sodium ions outside the cell and higher concentrations of potassium ions inside the cell. When the action potential occurs sodium ions rush into the cell causing an imbalance in ion concentrations. This imbalance forces the potassium pumps to open allowing the potassium ions to leave the cell. Once this has finished the ions go back to their original concentrations inside and outside of the cell. This occurs very quickly and moves down the neuron by activating adjacent cells as it moves along.
In the *C.elegans* potassium ions and calcium ions rather than sodium ions were studied. By looking at previous experimental data a better understanding of the functions of the *C.elegans* neurons was obtained and simulating the neuronal activity was possible.

Materials

- Computer software called Simulink developed by TheMathWorks, the tool used for modeling and simulating the neuronal activity of the C.elegans.
- Experimental results from previous experiments.

Methods

Most of my research relied heavily on extensive research and studying of the numbers of previous experiments. Using the numbers I gathered from the experiments and the fitting that was previously done to obtain parameters for the equations I was able to use Simulink to create a small simulation using equations and numbers given by previous results.

Parameters (according to Sakata and Goodman):
- ErevK (reversal potential of K channel) – -90 mV
- ErevCa (reversal potential of Ca channel) – 80 mV
- GK (maximum conductance of K channel) – 4.7 ns
- GCa (maximum conductance of Ca chanel) – .12 ns
- V0 Ca – -25 mV
- V0 K – -9.5mV
- Vs Ca – 8mV
- Vs K – 12mV

Bibliography

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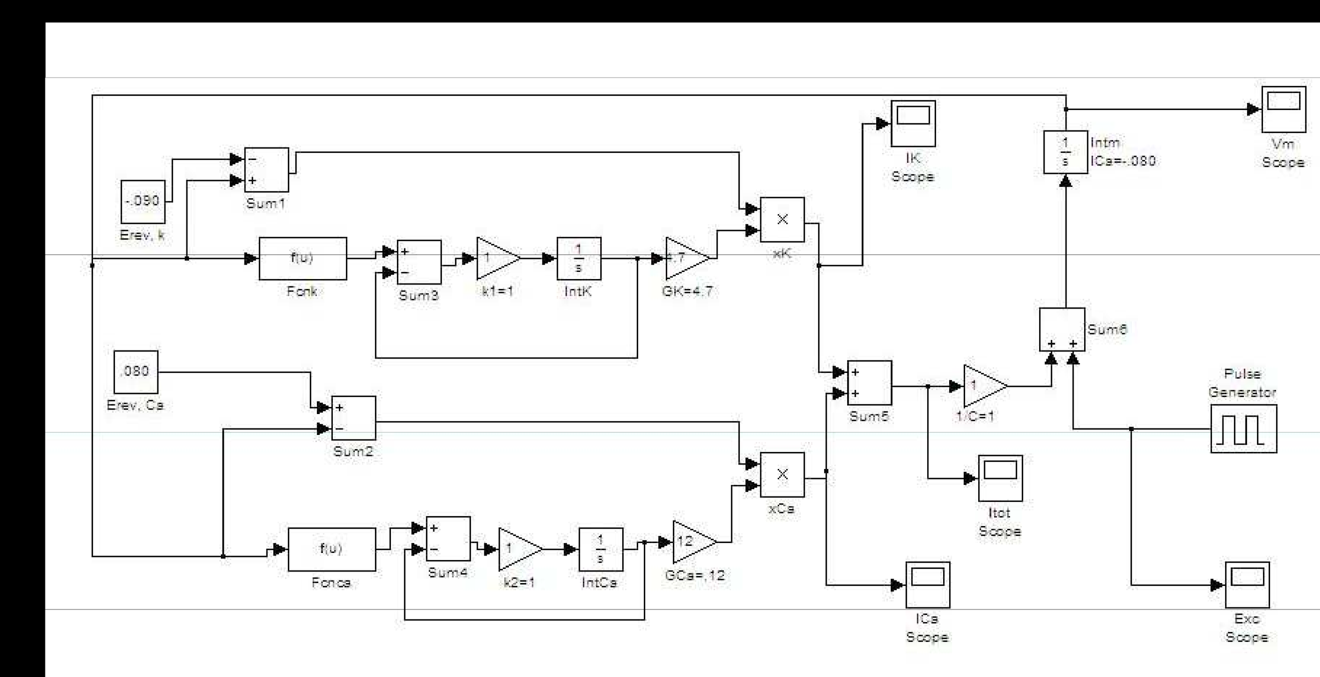
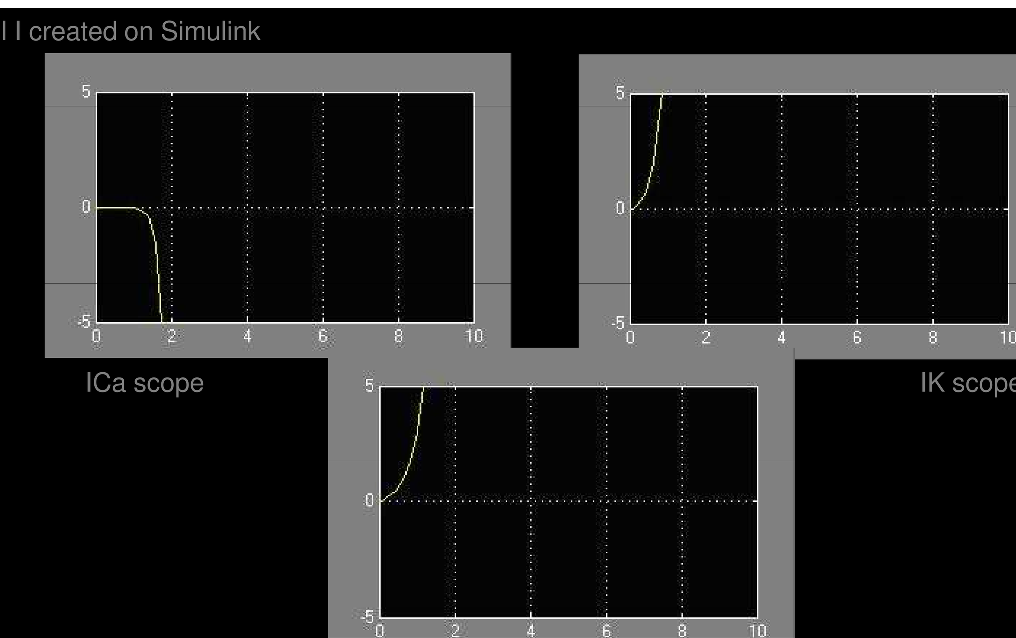
Sakata, Kazumi. Ryuzo Shingai. 2004. Neural network model to generate head swing in locomotion of *Caenorhabditis elegans*. Comput. Neural Syst. 15 119-216.

Results

Potassium and Calcium have a large Impact on the function of the neuron since they are involved in muscle control and thus play a huge role in the movement of the head of the worm. As this is ongoing research my results are not completely final but one can see from the graphs below how the calcium and potassium channels influence movement in terms of current and their electrochemical behavior.



The model I created on Simulink



ICa scope

IK scope

Vm Scope

Here are three of the scopes produced by my model. These scopes are displaying input with respect to time based on the equations I entered in the function blocks using the parameters listed in the Methods section.

Discussion

Using my results and results of other research done by others in this field one can now do the same research with other neurons in the worm. If more simulations can be completed with other neurons and a better understanding of the movement of the entire worm not just the head can be obtained than a future endeavor for this line of research could be to create a robotic worm.

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