

# **A Graphical User Interface for a Neural Network Simulation Software Suite**

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**Background and Research Purpose**

Epilepsy is a common neurological disorder of the human brain that is characterized by recurring seizures of varying severity. This disease currently affects over three million Americans at an estimated annual cost of twelve billion dollars, and it impacts about fifty million people worldwide. Physiologically, an epileptic seizure begins with the synchronization of a large network of neurons and ends with the desynchronization of those same neurons. Seizures are notoriously difficult to predict, and once initiated, the dynamics do not appear to be affected by electrical stimulation or drugs. Due to the ephemeral nature of a seizure, epilepsy is hard to systematically study in experiments and is often unethical to study in humans. An alternative approach is to explore the behavior of neural synchronization and desynchronization using numerical models.

As there are  $10^{15}$  synaptic connections linking over  $10^{12}$  neurons in the brain, properly modeling neural networks is problematic. Right now, there exist two different types of software made for this purpose. On one end of the spectrum are models that represent the biophysics of neurons to a high degree of detail, but can only simulate a few neurons at a time. On the other end of the spectrum are cellular automation models, which allow large networks to be efficiently simulated but reduce individual neurons to simple binary units. What is needed is an approach in the middle; some level of neuronal detail needs to be retained while still allowing for large networks to be simulated.

One research goal of Dr. Tranquillo's lab is to create a portable, modular software suite that can simulate large, complex networks of neurons in this fashion. By separating individual neuronal behavior from the network connections, we can better simulate real brain activities, which could lead to an improved understanding of epilepsy. Another reason for building a generic simulator of this type is that there presently exists an eclectic collection of independent software spread out over the world, with each one being used to solve a specific need. A standard, expandable platform in this area will be of great use for researchers in related fields. Therefore, a key feature of Dr. Tranquillo's software suite will be the ease of expanding it so that anyone can add their own module to fit their specific needs.

**Project Objective and Outcomes**

The core computer code needed to build the proposed software is already partially written. As the package stands now, a user would need to understand a great deal about the inner workings of the code to build a simulation. My first objective is to create a Graphical User Interface (GUI) for the software suite. The purpose of the GUI will be to simplify the process of choosing the modules and parameters for the model, so that the user could easily select a couple options from a menu causing the program to generate the input files needed to run the simulation. Two types of users will benefit greatly from a GUI. First, novice users will need little or no knowledge of programming to create and run simple simulations. Second, experienced programmers will be able to more efficiently manage the large number of variables and options that often accompany a complex simulation.

Experimental research has demonstrated that the degree to which neurons *inhibit* one another is a key component of the cause of epilepsy. Yet, the current version of our software does not include an option to simulate inhibition. My second goal will therefore be to write a module to allow inhibitory neurons to be included in simulations. A third goal will be to rerun models created by other students in Dr. Tranquillo's lab but with inhibition. The inclusion of inhibition in these models will demonstrate the need for the brain to suppress the innate tendency for large populations of neurons to synchronization.

My summer work will be to proceed down the list of goals as far as possible. The completion of goals one and two would provide sufficient data for a conference publication. The completion of all three goals would be sufficient for a full publication.

### **Project Methods**

The underlying language on which the software suite will be built is C. To assist with programming for many types of computers, Dr. Tranquillo's lab has been building off of a library of C routines and data structures called the Portable Extensible Toolkit for Scientific Computing (PETSc). PETSc is an open source library that is ideally suited for solving the large matrix-vector systems that arise from models of coupled neurons. As PETSc is compatible with the Message Passing Interface (MPI) libraries, programs written in PETSc can be run on laptops, desktops, computer clusters (e.g. the Bucknell 56-core cluster) and supercomputers (e.g. the Pittsburgh Supercomputing Center). This flexibility will allow for both small and large-scale simulations to be run on an appropriate computing architecture. In addition PETSc, and by extension our software suite, will run on any computing operating system that supports C (e.g. Windows, Unix/Linux), allowing other users to continue using their computing platform of choice.

To build the Graphical User Interface (GUI) we also desire a programming language that can run on any platform. A natural choice is to use Java and the 'Swing' toolkit which can be downloaded and run for free. The GUI itself will serve as an interface to the PETSc and C code. Building a simulation will therefore only require the user to choose the modules and parameters from a menu. The GUI will serve three purposes. First, it will aid in choosing modules and setting options. This feature will be most useful to the novice user in building simple simulations and setting options such as the names of data files and values for parameters. Second, there are files (e.g. makefiles, input files) that are required to run the PETSc code. The GUI will automatically make these files for the user. Third, the GUI will enable a more advanced user to build and save nominal settings. From these settings the user can perform parametric studies, where one parameter is varied and the others remain the same.

Inhibition appears in neural models in the types of connections between neurons. The current version of the software package only has the ability to connect neurons together in such a way that they excite one another. An inhibition module will therefore be a generalization of the existing excitation module. As such, the inputs, outputs and basic structure of the inhibition module will be identical to the excitation module.

**Timeline**

- Week 1: Organize the framework for the GUI on paper
- Week 2: Write a simplified version of the GUI
- Week 3-6: Test and Refine the GUI
- Week 7: Write the full GUI
- Week 8-9: Write module for including inhibitory neurons
- Week 10: Run preliminary simulations with and without inhibitory neurons

**Research Environment**Documentation

A scientific notebook will be kept throughout the summer. As this work is a self-contained portion of an overall research direction, detailed documentation will be important to others who may build upon the proposed work.

Facilities and Resources

The proposed research requires a desktop computer with a network connection to the engineering computing clusters. All custom GUI software will be written jointly by myself and Dr. Tranquillo. The computer labs in Dana or Breakiron will be adequate for our purpose.

Student-Faculty Interaction

Dr. Tranquillo will be working on campus during the summer. There will be two regularly scheduled and well-structured one-hour meetings each week. The scientific notebook will be used as a reference during these meetings. Dr. Tranquillo will also be available for more casual meetings throughout the week should they be necessary. Attendance and participation in the weekly Physics REU meetings will also be required. These meetings will provide an opportunity to gain multiple points of view and regular interaction with additional Bucknell faculty and students from other institutions.

**Student Enrichment**

As an undergraduate, I am currently in the process of considering graduate-level and PhD programs. As I am not yet sure what a true research environment is like, this opportunity will give me valuable experience in lab-based, long-term research. My work with Dr. Tranquillo will help me to understand the project development process, the management of time and resources, and the publication process that will be present over the summer. Furthermore, we have stated our objective of presenting this work at one or more conferences and possibly submitting a paper for journal publication. Learning these skills would be invaluable to me, and conference proceedings and a journal publication would be very strong support for my acceptance to graduate school. Finally, I expect to improve my knowledge of the field of neurophysiology, computer modeling and programming, and the available technologies and methodologies in the field.