CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

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Project Number

S1815

Project Title

Modeling Parameter Sensitivity of Nonlinear Oscillators with Fitzhugh Nagumo Equations

Abstract

Objectives/Goals

The Fitzhugh Nagumo Model is widely used to understand the behavior of neurons and other excitable systems, which are nonlinear oscillators with a distinct threshold and dynamics. An important physical parameter is the oscillation frequency, or firing rate, as a function of an external stimulus or another model parameter. This project investigated whether this frequency is always sensitive to changes in the stimulus and other model parameters.

Methods/Materials

First, the model was formulated with the minimum number of free parameters that gave the full range of physically relevant variations. Numerical experiments then were performed to integrate the nonlinear differential equations, and calculate the Fourier spectrum that determines the oscillation frequency. The adjustable parameters were varied to measure the level of sensitivity of the oscillation frequency to these changes.

Results

These experiments confirmed that the frequency of excitable systems was sometimes insensitive to changes in the stimulus and/or other model parameters, even when multiple parameters were changed simultaneously. This insensitivity could be useful for an oscillator, for example as a steady frequency reference in an electrical circuit used in sensing or communications. Additionally, when two oscillators were modeled in a coupled system based off the basic neural circuitry in the brain during Parkinson's disease, these operating points of insensitivity were still observed. However, the Fourier Spectra differed greatly between neurons at these points, with some of the points having multiple low frequency components along with a dominant frequency.

Conclusions/Discussion

These components are indicative of Parkinson's-like neural behavior in the brain, and so there may be a relationship between these special points and firing patterns during Parkinson's Disease. Therefore, the results of this project have potentially wide ranging implications in physics, engineering, and biology/neuroscience.

Summary Statement

This project demonstrated through the Fitzhugh Nagumo Model that the fundamental frequency of individual or coupled nonlinear oscillators can be insensitive to parameter variations with potentially wide applications, including neurophysics.

Help Received