CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Kevin K. Lee

Project Number
S1416

Project Title
Electromechanical Modeling of the Heart in Moving Domains Using the Phase-Field Method

Abstract

Objectives/Goals
To create a mathematical model of a beating heart that combines mechanical contraction with electrical excitation.

Methods/Materials
I developed a novel method for combining the propagation of electricity with mechanical contraction by using the phase-field method. I linked the Fenton-Karma model of the heart's electrodynamics to the physical motion of the heart while accounting for factors such as tissue elasticity and movement of the tissue. The contractile mechanics of the heart were represented by considering it as fluid with an elastic boundary using Darcy's Law, and its shape was evolved through a Cahn-Hilliard type equation. The equations were solved using a second-order accurate semi-implicit Crank-Nicholson scheme on an adaptive multigrid and MATLAB was used to analyze the results.

Results
I validated my algorithm by successfully observing its convergence toward a pre-constructed solution when the corresponding forcing function was incorporated. I also showed that the behavior of the solution is consistent with that presented in previous research which analyzed the heart in non-moving domains.

Conclusions/Discussion
I developed an efficient and widely applicable algorithm for more realistically simulating the beating of the heart. The algorithm is independent of the numerical scheme and can easily be applied to 3-D anatomical models of the heart. This gives drug developers a more complete tool in designing therapies for heart conditions, yields critical insight on the underlying mechanisms of fatal conditions like fibrillation, and enables dramatic improvements in their treatment and prevention.

Summary Statement
I created a mathematical model of a beating heart that realistically represents the dynamics of contraction, which improves on existing models and allows for a more comprehensive analysis of the mechanisms of heart diseases.

Help Received
Professor Lowengrub helped me develop the model and allowed me to use the computing cluster in his lab. Esteban Meca helped me learn how to numerically solve the differential equations.