**CALIFORNIA STATE SCIENCE FAIR**
**2014 PROJECT SUMMARY**



**Name(s)**

**Kevin K. Lee**


**Project Number**

**S1207**

**Project Title**

# Strongly Coupling the Electrical and Mechanical Dynamics of the Heartbeat in a Diffuse Interface Model


**Abstract**

**Objectives/Goals**

Mathematical models of the heart have proven essential to the study of cardiac arrhythmias, which are poorly understood yet the leading cause of death in the industrialized world. Existing models provide an unobstructed view of the heart's electrical behavior on both the surface and interior, but they have not been able to efficiently incorporate the physical beating of the heart due to the resulting difficulties in handling the moving boundaries of the domain of the governing partial differential equations system. Thus, I develop a novel method for strongly coupling the mechanical muscle contraction with electrical wave propagation in a diffuse interface model.

**Methods/Materials**

I represented the geometry of the heart with a diffuse domain approximation and modeled the soft-tissue mechanics through fluid mechanics principles. I coupled local contraction of the domain with the Calcium power stroke of the action potential and evolved the shape through a Cahn-Hilliard equation. I solved the equations on an adaptive multigrid using a second-order Crank-Nicolson scheme and employed a convex-splitting approach to ensure further stability of the algorithm.

**Results**

I validated my algorithm by demonstrating its convergence and showed that the model captures the differences in electrical wave propagation due to shape, evidence of successful strong coupling. The algorithm, is also shown to be several hundred times faster than those of existing strongly coupled models.

**Conclusions/Discussion**

By avoiding the need to explicitly track the boundary of the evolving and potentially complex domain, my work makes comprehensive simulations of total heart function tractable. The theory developed here efficiently facilitates more realistic simulations of the heart, providing a valuable tool to guide drug development for the treatment of arrhythmias and empowering dramatic improvements in their treatment and prevention.


**Summary Statement**

I created a much more efficient mathematical model of the heartbeat that successfully incorporates the two-way interaction between the muscle contraction and electrical signaling in the heart, a crucial component to fatal heart conditions.


**Help Received**

Professor John Lowengrub and Dr. Esteban Meca supervised the progression of this project and provided useful discussions.