

Parallel Cardiac Electrophysiology Framework

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ABSTRACT

Cardiovascular diseases are the leading cause of death worldwide [1]. Increasingly, researchers are relying on computationally demanding simulations as a platform to test drugs and novel therapies on the heart [2]. Unfortunately, the complex nature of simulating various aspects of the cardiac system requires researchers to have expert knowledge across many disciplines in order to fully exploit the computational horsepower that high-performance computers offer. We present a user-friendly heart electrophysiology modeling framework designed to run on high-performance computing platforms. The framework is capable of simulating the generation and propagation of electrical signals throughout the heart under a variety of circumstances.

Keywords

Cardiac; Electrophysiology; Heart; Simulation; Modeling; Framework; Trilinos; HPC; Supercomputing

1. SUMMARY

There are two primary components involved in modeling cardiac electrophysiology. The first component, the tissue model, dictates how the cell's electrical signal propagates to neighboring cells and is described by partial differential equations. The second component, the cells model, describes the flow of ions across the cell membrane, and is typically represented by a set of ordinary differential equations. Solving this set of equations allows for the action potential of the cell membrane to be determined. The action potential of each simulated cell can be described using a variety of different models which offer varying levels of fidelity. However, prior implementations of the cardiac modeling framework only supported the use of one of the earliest cardiac myocyte models, the Beeler-Reuter model [3]. Our work refactoring the cardiac model allows the model to be extended to a multitude of electrical models, including the highly accurate, and much more computationally demanding, O'Hara-Rudy model [4]. This expansion of functionality dramatically increases the simulation's usefulness, as many applications require the use of novel or complex electrical models.

The usefulness and functionality of the cardiac model is expanded via integration with the Distributive Interoperable Executive Library (openDIEL), a multiphysics modeling suite [5], using various heart meshes and electrical models. Currently there are three different meshes which can be used while running the simulation. The standard cube mesh is ideal for verifying the initial conditions and allows for potential issues to be clearly identified. There are also symmetric and asymmetric two-ventricle meshes which can be used to provide a more realistic picture of how the electrical signal would diffuse in an actual human heart. The openDIEL provides expanded functionality and allows for complementary simulations to be run in parallel with relative ease.

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3. REFERENCES

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