Modeling Human Atrial Electrodynamics and Arrhythmias through GPU Parallel Computing
From Cell to Tissue

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Abstract
The goal of this project is to study instabilities in human atrial cardiac tissue solving a complex non-linear set of differential equations through GPU parallel computing. More specifically, the topic it focuses on is atrial calcium alternans driven by SR Ca content fluctuations and SR refractoriness when extending the model from the cell level to tissue.

Main Concepts
- Calcium concentration upstroke in the intracellular media is mainly produced by a calcium induced-calcium release from the SR
- Calcium alternans is a beat-to-beat oscillation on the concentration of intracellular calcium that may lead to arrhythmias
- The electrical activity of a cardiomyocyte is modeled as a Hodgkin-Huxley set of ionic currents for a single cell flowing between different compartments in a single cell
  \[ \dot{V} = \frac{1}{C_m} \sum I \]
- Ionic channels’ activation and maximum values are voltage dependent
- Coupling effect occurs due to the laplacian term that appears when going from cell to tissue
- SR Refractoriness is modeled using a four-state Markovian chain for the ryanodine receptors
- Experimental data has been obtained through optical mapping
- GPU programming speeds up computation by parallelizing loops in the graphics card.

Simulations
Single cell results in tissue: after changing parameters so that the AP amplitude corresponds to the one in single cell, calcium alternans is still caused by SR refractoriness but it stops being sustained

Experimental data obtained from optical mapping. Calcium alternans obtained externally stimulating a rabbit atrium

Conclusions
The presented model has developed the analysis of a complex model for the electrophysiology of atrial tissue from an atrial model, comparing and contrasting the differences when going to higher dimensions. Moreover, GPU programming has allowed to perform simulations in a shorter computational time.

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