

A surface-based model for cardiac electrophysiology and related inverse problems

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Cardiac electrophysiology describes and models chemical and electrical phenomena taking place in the cardiac tissue. Given the large number of related pathologies, there is an important need for understanding these phenomena. The electric wave propagating in the cardiac tissue can be represented by a nonlinear reaction-diffusion partial differential equation, coupled with an ordinary differential equation representing cellular activity. In this work, we propose a presentation of the bidomain model.

Furthermore, the atria have very thin walls, mainly apparent as a thick surface in medical imaging. Our objective is to derive a surface bidomain model defined over the midsurface of the geometry, and able to take into account the anisotropy resulting from the preferred conduction direction along the muscle fibers, which direction rapidly varies across the thickness. We propose a mathematically justified model using an asymptotic analysis in the spirit of thin structural models – such as shells – in mechanics. Various assessments and simulations including a pathological case are proposed in order to validate our model. Then, we present realistic physiological simulations - with an anatomical surface mesh representing the mid-surface of the two atria - which allow us to produce complete electrocardiograms.

In the last part of this presentation, we are interested in associated estimation problems. The complex bidomain model must be adapted to each individual case in order to produce predictive simulations for a given patient. In this context, we can use the abundant available medical data, especially the patient electrical activation maps in order to adapt the bidomain model. We have proposed novel observer methods specifically formulated for this combination of model and data.