UCCS MATH COLLOQUIUM

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MODELING THE ELECTRICAL ACTIVITY OF THE HEART

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The electrical activation of the heart is the biological process that generates the contraction of the cardiac muscle, pumping the blood to the whole body. In physiological conditions, the pacemaker cells of the sinoatrial node generate an action potential, that is a sudden variation of the cell transmembrane potential $u = u_i - u_e$, namely the difference between the intracellular potential u_i and the extracellular one u_e. Following preferential conduction pathways, the electrical stimulus propagates throughout the heart wall and causes the contraction of the heart chambers. Due to this coupling between the electrophysiology and the mechanical behaviour, when some anomalies occur in the action potential propagation, the proper function of the heart pump can be affected.
The action potential propagation can be mathematically described by coupling a model for the ionic currents, owing through the membrane of a single cell, with a macroscopical model that describes the propagation of the electrical signal in the cardiac tissue. Such model can be derived from a homogenization of the electrostatic laws for the potential in the intracellular and extracellular space. One of the most accurate model available in literature is the Bidomain model, a degenerate parabolic system composed of two non-linear partial differential equations for the intracellular and extracellular potential, coupled with homogeneous Neumann boundary conditions to model an insulated myocardium. Due to the degenerate nature of the problem, its discretization leads to an ill-conditioned linear system and, as a consequence, its numerical resolution is very expensive. For this reason the simplied Monodomain model has been proposed in literature. This model is constituted by a single parabolic reaction-diffusion PDE and it is by far easier to be solved, but it is unable to capture signicant patterns of propagation of the action potential, both physiological and pathological. The aim of this talk is to give an overview of the topic and to present some numerical techniques to solve the coupled problems arising in Electrocardiology, whose intrinsic complexity requires ad hoc numerical methods.