

Numerical methods for strongly coupled simulations of cardiac electro-mechanics

Joakim Sundnes

simula.research laboratory
sundnes@simula.no

ABSTRACT

he rhythmic contraction and relaxation of the heart muscle is controlled by an electrical signal originating from pacemaker cells in the sino-atrial node. This electrical signal may in turn be affected by the mechanical deformations of the tissue through a number of mechanisms collectively referred to as mechano-electric feedback (MEF). Known mechanisms of MEF include stretch dependent binding and detachment rates, stretch activated ion channels, and deformation dependent tissue conductivities. Although the significance of individual MEF processes remains unclear, their existence motivate modeling the electrical and mechanical activity of the heart as a single, coupled system. Computer simulations based on these coupled models are commonly referred to as strongly coupled simulations, in contrast to earlier simulation methods that were based on pre-computing the electrical potentials and using them as input to models of tissue mechanics. However, the increased physiological realism of strongly coupled simulations comes at the expense of a number of computational challenges. Examples of specific challenges include the complexity of the involved mathematical models, strict temporal and spatial resolution requirements dictated by the rapid dynamics of the electro-physiology models, and the strong non-linearity of the mechanical problem. In this presentation we discuss alternative strategies for discretization and linearization of the coupled electro-mechanical problem. We present numerical results to investigate the stability and accuracy of the methods, with particular emphasis on comparing operator splitting methods with fully coupled approaches.