Scalable preconditioners for cardiac electromechanics and applications

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ABSTRACT

In this talk, we present a Balancing Domain Decomposition by Constraints (BDDC) solver for the cardiac mechanical contraction. The contraction-relaxation process of the cardiac muscle, induced by the spread of the electrical excitation, is quantitatively described by a mathematical model called electro-mechanical coupling. The electric model consists of a degenerate parabolic system of nonlinear partial differential equations (PDEs), the so-called Bidomain model, which describes the spread of the electric impulse in the heart muscle. The PDEs are coupled with the non-linear elasticity system, where the myocardium is considered as an orthotropic hyperelastic material. The discretization of the whole electro-mechanical model is performed by Q1 finite elements in space and a semi-implicit finite difference scheme in time. This approximation strategy yields at each time step the solution of a large scale ill-conditioned linear system deriving from the discretization of the Bidomain model and a non-linear system deriving from the discretization of the finite elasticity model. The parallel mechanical solver developed consists of solving the non-linear system with a Newton-Krylov-BDDC method, with different choices of coarse spaces. Three-dimensional parallel numerical tests on a Bluegene/Q Linux cluster show that the parallel solver proposed is scalable and quasi-optimal. The electro-mechanical solver is then used to study the effects of the mechanical feedback on electrical quantities of physiological interest as the activation and repolarization times and the action potential duration.