Scalable Solvers for Cardiac Electromechanical Models

Luca F. Pavarino
Department of Mathematics, University of Milano, Italy.
luca.pavarino@unimi.it

Simone Scacchi
Department of Mathematics, University of Milano, Italy.
simone.scacchi@unimi.it

Piero Colli Franzone
Department of Mathematics, University of Pavia, Italy.
colli@imati.cnr.it

Abstract

We present scalable domain decomposition solvers for cardiac electromechanical models describing the bioelectrical excitation-recovery of the myocardium and its associated mechanical contraction and relaxation. The bioelectrical model consists of a reaction-diffusion system coupled with an ODE system for the ionic current dynamics, while the mechanical model consists of a nonlinear elasticity system coupled with an ODE system for the active tension generation [1, 2]. These models are discretized in time by Implicit-Explicit (IMEX) finite differences and in space by isoparametric Q1 finite elements. At each time step, the large-scale nonlinear electromechanical system is solved by decoupling these subsystems, solving iteratively the bioelectrical linear system with a multilevel Schwarz preconditioned PCG method ([3, 4]) and solving the nonlinear mechanical system with a Newton-Krylov-BDDC method [5]. 3D parallel tests on a BlueGene/Q cluster show the scalability and quasi-optimality of the proposed parallel solvers.

Keywords: Cardiac electromechanical coupling; Bidomain model; finite elasticity; Multilevel Schwarz and BDDC preconditioners; scalable cardiac solvers.

References

[1] P. Colli Franzone, L. F. Pavarino, S. Scacchi. Mathematical Cardiac Electrophysiology. Springer MSA Vol. 13, 2014.

[2] P. Colli Franzone, L. F. Pavarino, S. Scacchi. Parallel multilevel solvers for the cardiac electro-mechanical coupling. Submitted, 2014.

[3] P. Colli Franzone, L.F. Pavarino, S. Scacchi, A comparison of coupled and uncoupled solvers for the cardiac Bidomain model. *ESAIM: Math. Mod. Numer. Anal.* 47(4): 1017–1035, 2013.

[4] L.F. Pavarino and S. Scacchi, Parallel multilevel Schwarz and block preconditioners for the Bidomain parabolic-parabolic and parabolic-elliptic formulations. *SIAM J. Sci. Comput.*, 33 (4): 1897–1919, 2011.

[5] L. F. Pavarino, S. Scacchi, S. Zampini. BBDC preconditioners for the mechanical deformation of cardiac tissue. Submitted, 2014.