SCALABLE AND PARALLEL NON-LINEAR SOLVERS FOR THE CARDIAC BIDOMAIN SYSTEM

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The development of effective and scalable solvers for the solution of mathematical models of the cardiac electro-mechanical activity has increasingly grown in the last decade. In particular, modern computational architectures have enlarged the possibility to run large-scale simulations within reasonable computational times. In any case, the multiscale systems arising from discretizations of such models has required the development of specific techniques which can balance accuracy in the solution while being computationally competitive (in terms of efficiency and scalability).

In this talk, we focus on the numerical simulation of the cardiac electrical activity, by solving the Bidomain equations, a system of nonlinear parabolic reaction-diffusion equations describing the propagation of the electric impulse in the cardiac tissue, coupled with a ionic membrane model. The numerical solution of the resulting model represents a challenging task, due to the coupling of macroscopic and microscopic phenomena (the propagation of the electric signal in the cardiac tissue and the ionic currents dynamics at cellular level, respectively).

By means of a staggered approach, where we decoupled the two phenomena, and by applying a finite element discretization in space and the Backward Euler scheme in time, we face the solution of a non-linear algebraic system. We propose here for its solution several parallel non-linear solvers such as non-linear Conjugate Gradient or quasi-Newton methods.

We analyze the theoretical convergence of the considered methods and extensive parallel numerical tests show scalability and efficiency of the proposed approach. We investigate robustness considering both phenomenological and human ventricular ionic models.

These results provide a basis for further studies of parallel solvers for cardiac electrophysiology models that combine parallel efficiency while yielding accuracy in the solution.

This is a joint work with N.A.Barnafi (Univ. Pavia), L.F.Pavarino (Univ.Pavia) and S.Scacchi (Univ.Milano).

References

[1] Barnafi N.A., Huynh N.M.M., Pavarino L.F. and Scacchi S., *Parallel nonlinear solvers in computational cardiac electrophysiology*, Proceedings at 10th Vienna International Conference on Mathematical Modelling, submitted, 2022.

[2] Colli Franzone P., Pavarino L.F. and Scacchi S., *A numerical study of scalable cardiac electro-mechanical solvers on HPC architectures*, Front. Physiol., 9-268, 2018.

[3] Huynh N.M.M., Pavarino L.F. and Scacchi S., *Parallel Newton-Krylov-BDDC and FETI-DP deluxe solvers for implicit time discretizations of the cardiac Bidomain equations*, SIAM J. on Sci. Comput., **44:2**, B224-B249, 2022.

[4] Zampini S., *Dual-primal methods for the cardiac bidomain model*, Math. Mod. Meth. Appl. Sc., **24.4**: 667-696, 2014.

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