EFFICIENT DOMAIN DECOMPOSITION PRECONDITIONERS FOR TIME STEPPING IN EMI MODELS

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ABSTRACT. The cardiac extracellular-membrane-intracellular (EMI) model [1] enables the precise geometrical representation and resolution of aggregates of individual myocytes. Achieving efficient higher-order time stepping is imperative in this context due to large problem sizes. The locality of solution features in cardiac electrophysiology simulations calls for adaptive methods. Yet, traditional mesh refinement and coarsening approaches incur significant overheads. Firstly, this study investigates an efficient spatial adaptivity method that is based on nested subset selection for algebraic degrees of freedom in spectral deferred correction methods (SDC) [2] and realizes a multirate integration with minimal overhead. Consequently, shrinking effective support of SDC corrections allows for a reduction of the spatial domains on which Euler subproblems need to be solved, such that the smaller size of systems to solve translates directly into a significant reduction of simulation time compared to the baseline [3]. Since the first sweep is always performed on the whole domain, a second acceleration technique in the SDC computations is to consider coarser collocation grids on the first sweeps, called ladder method [4]. Due to the frequently changing linear equation systems to be solved, preconditioners with expensive setups cannot be used except for the very first SDC sweep. This study uses the Balancing Domain Decomposition by Constraints (BDDC) method [5] as a preconditioner in the SDC method. We propose a novel combination of BDDC and algebraic adaptivity where no updating of the preconditioner on system reduction is necessary. This is achieved by a subdomain-wise group selection of algebraic degrees of freedom. We assess the computational efficiency of BDDC and block Jacobi preconditioners at some numerical examples.

Keywords: EMI Model, high-order time integration, spectral deferred correction, algebraic adaptivity, multirate integration scheme, Ladder Method, BDDC method.

REFERENCES

[1] Bécue, P. and Potse, M and Coudière, Y. Microscopic Simulation of the Cardiac Electrophysiology: A Study of the Influence of Different Gap Junctions Models. Computing in Cardiology Conference (CinC) (2018) pp. 1-4, doi: 10.22489/CinC.2018.057.

[2] M. Weiser. Faster SDC convergence on non-equidistant grids by DIRK sweeps. BIT Numerical Mathematics, 55(4):1219–1241, 2015.

[3] Chegini F, Steinke T, Weiser M. Efficient adaptivity for simulating cardiac electrophysiology with spectral deferred correction methods. In: Submitted; 2022.

[4] M.L. Minion. Semi-implicit spectral deferred correction methods for ordinary differential equations. Comm. Math. Sci., 1(3):471–500, 2003.

[5] N.M.M. Huynh, F. Chegini, L. F. Pavarino, M. Weiser, and S. Scacchi. Convergence analysis of BDDC preconditioners for hybrid DG discretizations of the cardiac cell-by-cell model, arXiv:2212.12295 2022.

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