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On Scalable Preconditioners for Implicit Continuum Multiphysics Plasma Systems

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Continuum fluid models of plasma physics systems require the solution of the governing partial differential equations describing conservation of mass, momentum, and energy, along with various forms of approximations to Maxwell's equations. The resulting systems are nonsymmetric, strongly nonlinear, and exhibit a significant range of time- and length-scales. To enable accurate and stable approximation of these systems a range of spatial and temporal discretization methods are employed. For finite element methods these include variational multiscale methods and structure-preserving approaches. For time integration two well-structured approaches are fully-implicit and implicit-explicit type methods. The requirement to accommodate disparate spatial discretizations, and allow the flexible assignment of mechanisms as explicit or implicit operators, implies a wide variation in unknown coupling, ordering, and the conditioning of the implicit sub-system.

Our approach to help overcome these challenges has been the development of robust, scalable, and efficient fully-coupled physics-based multilevel preconditioned Newton-Krylov type iterative solvers [1,2,3,4]. To discuss the structure of these algorithms, and to demonstrate the flexibility of this approach various forms of magnetohydrodynamic and multifluid electromagnetic plasma models are considered. Results are presented on robustness, efficiency, and the parallel and algorithmic scaling of the methods.

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