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On AMG preconditioning for fully-coupled Newton-Krylov methods for implicit continuum plasma simulations

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The computational simulation of continuum models of plasma physics systems can be extremely challenging. These difficulties arise from both the strong nonlinear coupling of fluid and electromagnetic phenomena, as well as the significant range of time-scales that the interactions of these physical mechanisms produce. From this point of view, fully-implicit formulations, coupled with effective robust nonlinear iterative solution methods, become attractive, as they have the potential to provide stable, higher-order time-integration of these complex multiphysics systems when long dynamical time-scales are of interest. For the solution of the discrete nonlinear system, the use of fully-coupled Newton-Krylov solution approaches can be advantageous because of their robustness. To enable scalable and efficient solution of the large-scale sparse linear systems generated by the fully-coupled Newton linearization, multilevel/multigrid preconditioners are developed. The multigrid preconditioners are based on two differing approaches. The first technique employs a graph-based aggregation method applied to the nonzero block structure of the Jacobian matrix [1-2]. The second approach utilizes approximate block decomposition methods and physics-based preconditioning approaches that reduce the coupled systems into a set of simplified systems to which multigrid methods are applied [3].

This talk considers the scaling and performance of these algebraic multigrid (AMG) based solution approaches for both MHD and multifluid plasma models with finite element type methods on unstructured meshes. The focus is on large-scale, transient plasma simulations. Studies are presented for scaling and performance on both CPU (IBM Blue Gene/Q and Intel Xeon) and Intel Xeon Phi Knights Landing platforms.

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