Parallel time integration with multigrid for parabolic problems

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With current trends in computer architectures leading towards systems with more, but not faster, processors, faster time-to-solution must come from greater parallelism. These trends particularly impact the numerical solution of the linear systems arising from the discretization of partial differential equations (PDEs) with evolutionary behavior, such as parabolic (space-time) problems. The classic view of applying multigrid to this class of problems is based on a time-marching approach: discretization of the PDE leads to a discrete elliptic problem at each time step when an implicit scheme is used. Multigrid is then used as an iterative solver for these elliptic equations. Parallelization in this approach is limited to parallelization in the elliptic (spatial) solver, since the time-stepping procedure is sequential.

While two-level methodologies, such as parareal, are well-established for parallel-in-time integration, true multilevel approaches remain uncommon. In this talk, we present one such technique, derived based on multigrid reduction principles. The resulting multigrid-reduction-in-time (MGRIT) algorithm is a non-intrusive approach, which only uses an existing time propagator and, thus, easily allows one to exploit substantially more computational resources than standard sequential time stepping. We discuss progress to date in applying MGRIT to parabolic (space-time) problems. In particular, we demonstrate that MGRIT offers excellent strong and weak parallel scaling up to thousands of processors for solving diffusion equations in two and three space dimensions.