A Parallel Geometric Multigrid Solver for Density Driven Flow

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Multigrid methods for the solution of large sparse matrices arising from grid-based discretizations of partial differential equations are well known for their optimal complexity, i.e., the computation effort only increases linearly with the problem size. This makes them a promising algorithm when focusing on the weak scaling properties of such a matrix solver. However, while reducing the problem size within a multigrid algorithm on coarser grid levels is its strength, this gives rise to a potential performance bottleneck when parallelization is taken into account. Indeed, on coarser grid levels the inner to boundary ratio of the grid parts assigned to a process become unpleasant and a parallel smoother on those coarse levels will suffer from the fact that mostly communication at the boundary takes place and only little computation on the inner part is performed. In order to overcome this bottleneck we present an algorithm that avoids this situation by gathering coarser levels to fewer processors leaving the remaining processors idle. To this end we introduce vertical interface connections that allow this gathering process and adapt the transfer operators of the multigrid algorithm to respect these interfaces. Arriving at a single process on the coarsest level a serial base solver, e.g., LU factorization, can be used. We show that this approach leads to nice weak scaling behavior for an exemplary application: Discretizing a pde system for density driven flow using a vertex-centered finite volume scheme and implicit Euler time stepping we analyze the efficiency of the geometric multigrid solver in the first Newton linearization of the first time step. It turns out that up to 130,000 processors the weak scaling efficiency is still above 80%.