Space-Time Parallelism using Spectral Deferred Corrections and Finite Elements for Incompressible Navier–Stokes Equations

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We present a space-time parallel numerical framework for solving the incompressible Navier–Stokes equations using spectral deferred correction (SDC) methods for time integration and finite element methods (FEM) for spatial discretization. Our approach combines parallelism in both space and time to exploit modern high-performance computing architectures efficiently. The SDC methods are employed within a parallel-in-time framework that enables iterative refinement of temporal accuracy while supporting concurrency across time steps. In space, the problem is discretized using a stable and accurate finite element formulation suited for incompressible flows. We demonstrate the effectiveness of the proposed method on benchmark fluid dynamics problems, highlighting its scalability, accuracy, and potential for accelerating unsteady flow simulations. Performance results indicate significant speedups over traditional sequential time-stepping methods, particularly in high-resolution and long-time simulations. This work provides a pathway toward efficient and scalable simulations of complex fluid flows in a space-time parallel computing environment.