Scalable solvers for the Helmholtz problem

by

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A matrix-free parallel multi-level-deflation preconditioner combined with the Complex Shifted Laplacian preconditioner(CSLP) for the two-dimensional Helmholtz problems is presented. The Helmholtz problem, widely studied in seismic exploration, is hard to solve both in terms of accuracy and convergence, due to the scalability issues of the numerical solvers. For large-scale applications, high-performance parallel scalable methods are also indispensable. In our method, we use the preconditioned Krylov subspace methods to solve the linear system obtained from finite-difference discretization. The CSLP preconditioner is approximately inverted by one parallel geometric multigrid V-cycle. Motivated by the observation that the eigenvalues of the CSLP-preconditioned system shift towards zero for large wavenumbers, deflation with multigrid vectors and further high-order vectors were incorporated to obtain wave-number-independent convergence. We also compare Galerkin coarsening method and high-order re-discretization on the coarse grid. The matrix-vector products and the inter-grid operations are implemented based on the finite-difference grids without constructing the coefficient matrix. These adjustments lead to direct improvements in terms of memory consumption. Numerical experiments show that wavenumber independence has been obtained for medium wavenumbers. The matrix-free parallel framework shows satisfactory parallel performance and weak scalability.