A Low-Communication Method to Solve Poisson's Equation

Scientific Achievement

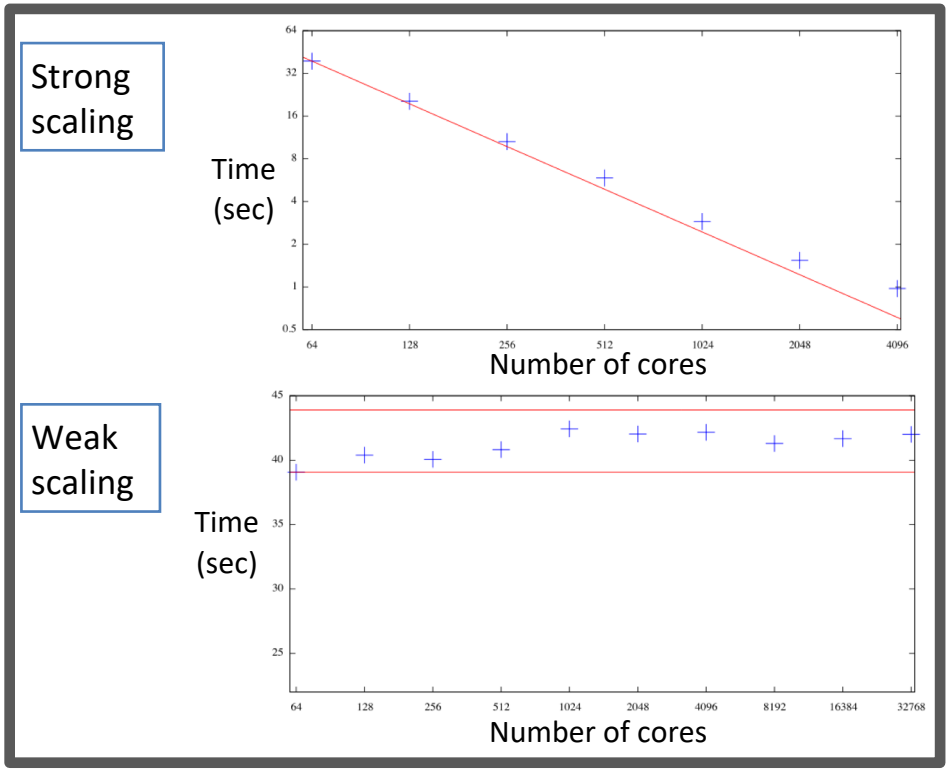
A new algorithm and high-performance implementation for solving Poisson's equation has 1/10 the communication cost of previous methods.

Significance and Impact

The method will enable multiscale simulations on exascale computers of problems in fluid dynamics, astrophysics, and plasma physics that spend significant resources solving Poisson's equation.

Research Details

- Multigrid methods for solving Poisson's equation on adaptive grids iterate between different resolutions to represent the nonlocal coupling in space. For Poisson's equation the cost of communication in this iterative process limits the overall performance of multigrid.
- The present method is based on a new representation of the nonlocal coupling that leads to communications costs corresponding to a single iteration of multigrid.
- The computational kernels are multidimensional Fast Fourier Transforms on small domains, which can be implemented efficiently on current and emerging HPC node architectures.



Performance Studies on NERSC Cori I (Haswell nodes).
Top: Holding the problem size fixed at 10^9 grid points, using 64–4K cores. The red line represents perfect scaling.
Bottom: Growing the problem size ((1–512)x10^9 grid points) with number of cores (64–32K). The red lines represent perfect scaling, and 90% of perfect scaling. The largest calculation corresponds to an effective uniform-grid resolution of $(64K)^3$ points, which would take 500x the computational resources using the fastest uniform-grid methods.

U.S. DEPARTMENT OF ENERGY | Office of Science

FASTMATH

Work was performed at the LBNL. For more information, contact Phil Colella, pcolella@lbl.gov.

BERKELEY LAB