Implementation of a parallel electrostatic solver for the VORPAL code

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Here we report on the addition of a parallel electrostatic (ES) field solver to the code VORPAL. Developed at the University of Colorado at Boulder and at Tech-X Corporation, VORPAL is a parallel, arbitrary-dimensional hybrid PIC/fluid code. At present, VORPAL has only electromagnetic (EM) field solvers. It has been used extensively for laser-plasma interactions and is now being applied to electron-cooling and other wide-ranging problems.

ES and EM codes are fundamentally different, especially in a parallel environment. In an EM code, the field quantities can be determined directly from local quantities. This reduces the communication overhead and results in high speedups on parallel architectures. In the ES case on the other hand, the long-range nature of the electric field requires global information. Starting from the global charge distribution in the system, the electric field is obtained from solving Poisson's equation. This step has to be optimized in order to obtain good speedup on parallel architectures.

The approach followed here is to solve Poisson's equation in real space. Discretized, the problem is represented as a system of linear equations, $A\phi = \rho$ where A is a sparse n x n matrix of finite difference kernels, ϕ is the electrostatic potential, and ρ the charge density. The vectors have size n, which is the number of grid points in the system. The electric field is finally obtained by finite differencing the potential. The only part requiring communication in this procedure is to solve the linear system. In order to obtain good speedup, this step has therefore to be optimized.

Our implementation uses the parallel iterative solver library AZTEC from Sandia National Lab (http://www.cs.sandia.gov/CRF/aztec1.html). This library features a large variety of iterative solvers and preconditioners. AZTEC adapts to the user specified domain decomposition and transparently handles all parallel communication. This approach minimizes the effort necessary to implement an electrostatic solver.

We will present benchmark results and parallel scaling studies.