Adaptive mesh refinement (AMR) reduces simulation errors and computational cost by increasing the degrees of freedom only where needed.

Dynamic AMR coarsens and refines meshes to adapt over time as the solution evolves through the dynamical processes.

p4est is a parallel octree-based AMR library developed for aggressive adaptivity and extreme-scale applications.

We developed a new data management (DM) in PETSc that interfaces p4est with applications that require adaptivity.

Leverage PETSc’s scalability and built-in functionality:

- Composable linear solvers and preconditioners, nonlinear solvers, approximations of Jacobians for Newton’s method, coloring for finite difference gradients.
- Advanced time integration in PETSc: implicit time stepping, adaptive time steps, multirate time stepping.
- Parallel mesh and associated data managed by PETSc DM; discretization and physics are handled in application code.

Runaway electron (Fokker-Planck PDE) simulations are implemented by using the new DM, leveraging direct access to fast algorithms in p4est.

Parallel octree-based AMR. Left: Forest-of-trees topology with 2 trees and leaves are cells of the mesh. Right: Space filling curve to sequentialize cells of mesh. (Image credit: p4est)

Dynamic AMR in parallel. Each color represents one of 1024 MPI ranks. The aggressive adaptivity required by the application results in 12 levels of difference in refinement, which corresponds to 3 orders of magnitude difference in cell size.

ANL: Johann Rudi, Max Heldman, Emil Constantinescu
LANL: Xianzhu Tang, Qi Tang