PUMIPic Parallel Unstructured Mesh Infrastructure for Particle-in-Cell

Parallel management of unstructured meshes with particles. Framework for GPU accelerated particle-in-cell applications using unstructured meshes.

Core functionality

- Unstructured mesh-based approach
  - Particles accessed through mesh
  - Particle search through mesh adjacencies
  - Effective coupling to PDE solvers
  - Partitioning using bounding flux surfaces, graph, or geometric methods
  - PICpart: owned elements (defined by partition) + copied elements from topologically or spatially neighboring processes
  - Stored on GPU using Omega_h library: *github.com/SNLComputation/omega_h*
- Particles
  - Supports multiple species each with distinct combinations of 'Plain Old Data' per particle
  - Group particles by the mesh element that they are spatially located within
  - Stored on GPU using Sell-C-Sigma structure [Kreutzer 2014] that provides coalesced accesses for 'warp' sized blocks of work
- Parallel kernel launch function abstracts underlying particle and mesh storage

Applications Supported

- GITRm: impurity transport
- XGCm: core+edge fusion plasma physics
- Weak scaling on up to 24,000 GPUs of Summit with 1.15 trillion particles running push, particle-to-mesh, and mesh-to-particle operations with an XGCm tokamak mesh and domain decomposition

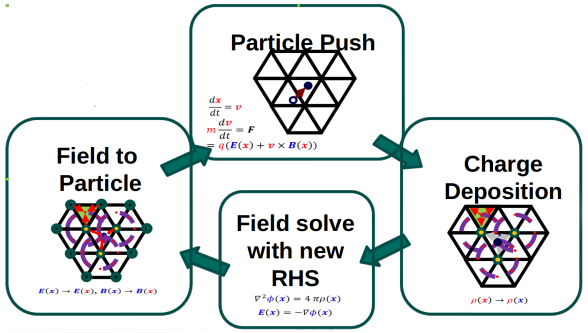
SCOREC

HBPS High-fidelity Boundary Plasma Simulation

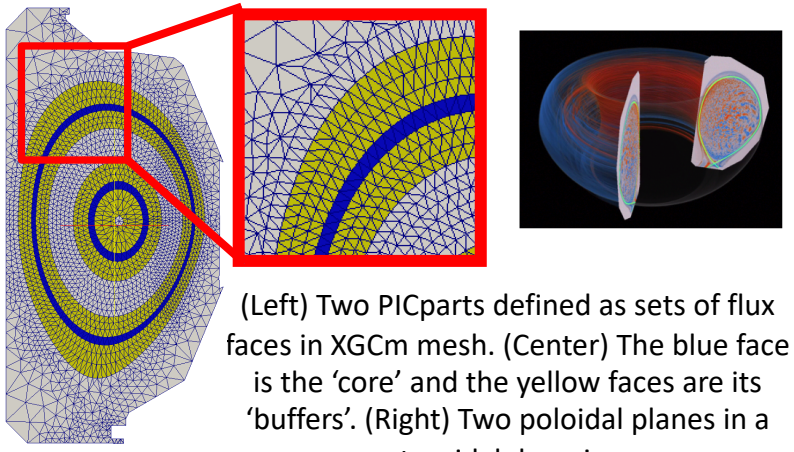
ECP

Rensselaer

FASTMATH



Stages of a PIC application supported by PUMIPic



(Left) Two PICparts defined as sets of flux faces in XGCm mesh. (Center) The blue face is the 'core' and the yellow faces are its 'buffers'. (Right) Two poloidal planes in a toroidal domain.

Source Code: github.com/SCOREC/pumi-pic
Paper: www.scorec.rpi.edu/REPORTS/2019-2.pdf