Construction of explicit (PETSc) sparse matrices from (Chombo) AMR grid hierarchies

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Provide algebraic multigrid solvers for block structured adaptive mesh (BSAMR) applications

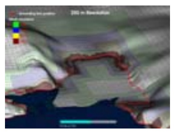
Objectives

Provide an algebraic multigrid option, or any solver available in PETSc, to Chombo BSAMR applications.

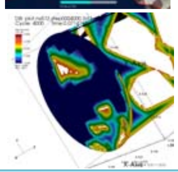
- Alternative to existing geometric multigrid solvers
- Useful with complex geometries (boundary conditions and material discontinuities)

Applications to date:

- BISICLES: ice sheet modeling application:

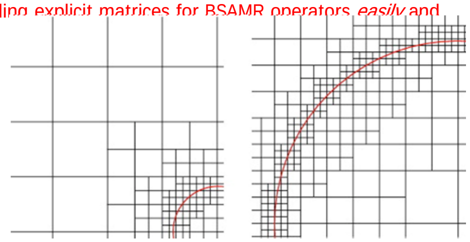


- EBAMRINS: micro scale porous media flow:



Overview

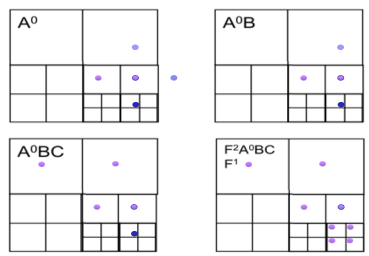
- BSAMR operates with stencils – matrix-free – on structured grids
  - Efficient, vectorization friendly.
- Geometric complexity accommodated w/ patches
- Amendable to geometric multigrid (GMG) equation solvers
  - Very efficient: implementation and algorithmic efficiency
- Problem (1): geometric complexity can degrade GMG performance
- Problem (2): "level solves" need coarse grid solvers that are unstructured
- Solution: use algebraic multigrid (AMG)
  - Need explicit matrix - not just the operator
- Matrix is identical to (linear) operator but construction is very different
- Facilitate building explicit matrices for BSAMR operators *easily* and *efficiently*



Problem

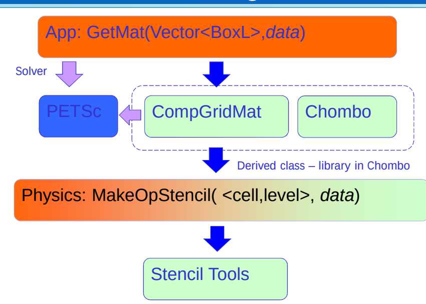
Create explicit PETSc matrix from Chombo application operators and hierarchy of AMR grids

- Minimal interface: application provides "raw stencil"
  - Physics + discretization
  - Example: 2D 5-point stencil of Laplacian (h=1)
  - [<4.0,<0,0>>, <-1.0,<-1,0>>, <-1.0,<1,0>>, <-1.0,<0,1>>, <-1,<0,-1>>]
- Transform raw stencils to rows of matrix
  - Interpolate stencil entries for:
    - Boundary condition ghosts
    - Coarse-Fine interface ghosts
    - Fine covered cells
- Compose series of transformations (virtual functions) for raw stencil (pure virtual function)



Cartoon of stencil for cell • as it is transformed

Design



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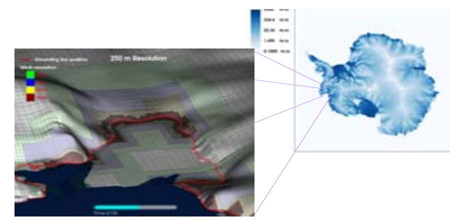
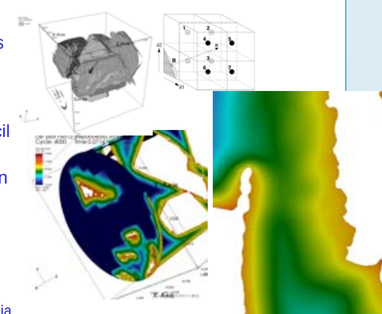


EBAMRINS

- Some application problems too complex for GMG
  - Want to use AMG for all levels
- Approach:
  - Linearize set of patches on a level
  - Create explicit matrix of stencil
  - Use AMG solves in PETSc
  - Use nonlinear, JFNK, solvers in PETSc
- Applications:
  - EBAMRINS
    - Incompressible flow
    - Very complex domains
      - Calcite grains – porous media
    - Embedded boundary
      - Large stencils at BCs
    - *AMG provides robust solver*
  - BISICES ice sheet modeling ...



More Information: http://www.fastmath-scidac.org or contact Lori Diachin, LLNL, diachin2@llnl.gov, 925-422-7130

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