

NSF Site Visit to the Computational Infrastructure for Geodynamics

Short-Term Crustal Dynamics

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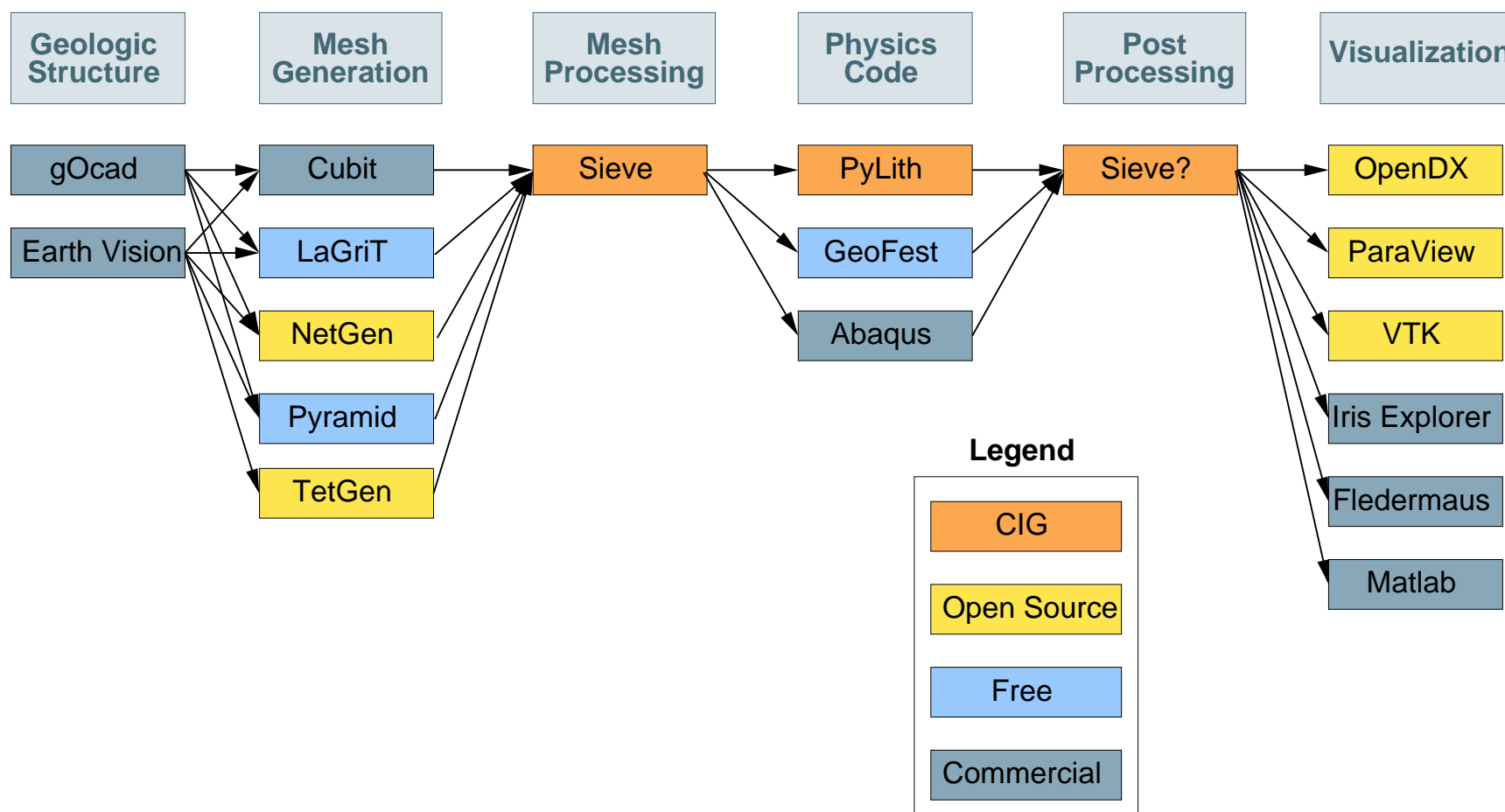
Short-Term Crustal Dynamics Working Group

Objective: Simulate crustal deformation across spatial scales from 1 m to 10^3 km and temporal scales ranging from 0.01 s to 10^5 years.

- Strong connection to SCEC Fault Systems working group
 - 4 SCEC/CIG/NASA/LANL workshops (43 participants in 2005)
 - Next workshop: Jun 26-30, 2006, Golden, CO
 - 7+ benchmarks for testing codes
 - Pre- and post-seismic deformation codes
 - Lithomop (formerly Tecton, donated to CIG)
 - GeoFest (JPL code)
- Anticipate growing connection to SCEC Earthquake Source Physics working group
 - 4+ benchmarks for testing spontaneous rupture codes
 - 12+ active spontaneous rupture codes (including EqSim)
- Participation from other members of the community

Workflow Summary

Overview of workflow for short-term crustal dynamics modeling



Working Group Priorities (Jul 2005 - Aug 2006)

Established during Jul 2005 workshop

1. Easy installation of CIG software*
2. Development of PyLith
 - Parallel implementation of Lithomop
 - Increase modularity of Lithomop
3. Benchmarking infrastructure*
4. Finite-element mesh infrastructure*
 - Common denominator b/t mesh generators and physics codes
 - Might also serve as common denominator for visualization
 - Likely candidate is Sieve (Matt Knepley)

* Applicable to multiple CIG working groups

Working Group Priorities, Sep 2006 - Aug 2007

Established during Jul 2005 workshop

1. Incorporate adaptive mesh refinement into codes
 - Implement support for local adjustment of discretization size
 - Establish metrics for how discretization size should vary in space

2. Improve solver efficiency
 - Experiment with different types of solvers & preconditioners
 - Take advantage of new, improved algorithms

3. Community codes for dislocations in layered elastic and layered viscoelastic domains
 - Robust and tested open-source versions of widely used 1-D codes
 - Serve as tutorial for users (simple, but nontrivial examples of well-written, portable software)
 - Provide reference solutions for benchmarks

Priorities beyond 2007

Defined during Jul 2005 workshop

1. Integrated modeling of multiple earthquake cycles
 - Buildup of strain in crust
 - Release of strain in propagating earthquake rupture
 - Post-seismic deformation
2. Support for sensitivity modeling
3. Support for formal data assimilation
4. Update of Lagrangian coordinates to allow large deformations
5. Incorporation of different fault zone rheologies

Current CIIG Projects: PyLith

Reduce duplication of efforts by merging Lithomop & EqSim

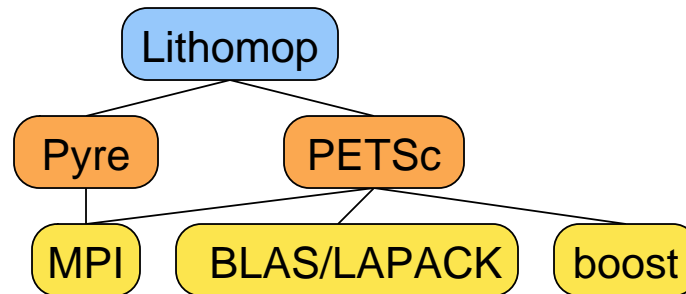
- Lithomop (crustal deformation with viscoelastic rheologies)
 - Convert from serial to parallel
 - Increase modularity by using Pyre framework
 - Allow users to add material models
 - Give users access to top-level functionality
 - Manipulate loading during time-stepping
 - Run many instances of solver in Monte Carlo inversions
 - Automatic determination of time step size
- EqSim (rupture propagation and strong ground motion)
 - Increase modularity through use of Pyre framework
 - Make code understandable and user friendly
 - Release version for use by community
 - Allow users to add fault constitutive models

Accomplishments

- Knowledge transfer from computer scientists to geophysicists (Charles & Brad now write much better code)
- Lithomop
 - Runs 2x faster using PETSc compared w/previous version
 - Runs in parallel w/improving efficiency
- EqSim
 - Top-down reorganization is well underway
 - Initial implementation for much of top-level code
 - Modular package for specification of parameters over a spatial domain (boundary conditions, material properties, etc)
- Switch to GNU build system (configure) has alleviated the most severe build issues

Major Hurdles

- Building portable software composed of several packages



- Incremental modernization of legacy Fortran 77 code
 - Difficult to reorganize into modules
 - Maintain working version to allow faster access to improvements
- No full-time developer
 - Charles Williams (RPI): 50%
 - Matt Knepley (CIG/ANL): 50%
 - Brad Aagaard (USGS): 20-25%

Ties to General Computational Problems

- Mesh generation
 - Most mesh generators written for engineering, not geophysical applications
 - Size of problems limited by serial mesh generation
- Numerical implementation of (shear) dislocations (for slip on faults)
- Need for efficient algorithms to model multiscale physical phenomena