How Do I Know That My Software Is Doing What I Think It Is Doing?

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How Do We Test PyLith?

• Unit tests
  – Tests each function within a code to insure it is performing correctly (detects bugs).

• Full-scale tests
  – Exercise the physics of the problem and compare against known solutions (checks physics).

• Benchmark tests
  – Exercise the physics for demanding problems and compare both the solution and the performance against other codes.

• Ideally, the solution to the problem is known.
Example PyLith Benchmark (Non-ideal)

Problem Setup

- Domain is a cube.
- Strike-slip fault with a region of constant slip bordered by a region with linearly-tapering slip.
- Analytical elastic solution applied to outer boundaries as BC.
- Elastic solution may be compared to Okada analytical solution.
Example PyLith Benchmark (Better)

Savage and Prescott (1978) Benchmark
- Viscoelastic (Maxwell) relaxation for repeated strike-slip earthquake rupture.
- Mismatch in initial conditions requires spinup.
- Simulation closely matches analytical solution in 10th earthquake cycle.

Solution after 9.5 Earthquake Cycles

Comparison with Analytical Solution
Problems Encountered with PyLith Benchmarks

• Never developed many reasonable benchmarks.
• Only two codes were being evaluated (PyLith and GeoFEST).
• Nobody likes to run benchmarks.
  – NOTE: PyLith has been used for SCEC dynamic rupture benchmarks.
Potential Problems for LTT Benchmarks

- Lack of problems with known solutions.
- How do you quantitatively evaluate the benchmark results?
- Are benchmarks for verification or validation?
- Current community does not seem accustomed to the idea of benchmarks.
- How to motivate people to run benchmarks?
What We Learned From PyLith Benchmarks

• Effects of cell type on solution accuracy.
• Effects of mesh resolution, graded mesh, etc., on solution accuracy.
• Relative solution time vs. accuracy for different problem setups.
SCEC Strike-Slip Benchmark

Summary

- Viscoelastic (Maxwell) relaxation from a strike-slip earthquake in 3-D without gravity.
- Figures show elastic solution only.
- Greatest error occurs where slip gradient is discontinuous and linear basis functions cannot match slip variation.
- For linear basis functions, Hex8 cells outperform Tet4 cells.

Elastic Solution

Comparison of Local Error
What Do I Want to Test?

• Validation
  – Am I using the correct physics?

• Verification
  – Am I solving the physics correctly and accurately?
  – Is my implementation correct (do I have bugs)?

• Am I solving the problem efficiently?