Albany: Integrating Algorithmic Components to Build Advanced Applications


Albany is a finite element application code base that is an early adopter of new algorithmic capabilities from the Trilinos, Dakota, and PUMI suites. FASTMath and other SciDAC funding sources play a key role in bridging the valley of death between algorithms and applications.

Application Impact: Ice Sheets

Under PSCIES, the FELIX-FO unstructured-grid finite element flow solver has been developed in Albany. This work leverages numerous enabling technologies supported by ASCR and ASC:
- Nonlinear solvers, linear solves, UIQ, adaptation, and performance portability (details below)
- Automatic differentiation, discretizations, software engineering tools & processes, partitioning, mesh database and I/O
- Albany/FELIX is being deployed within the HMAS Land Ice component in the ACME climate model.

Application Code

Nonlinear Solvers and Inversion

Under FASTMath, we have impacted applications with the development of Homotopy and Anderson Acceleration in Trilinos/NOX:
- The robustness of nonlinear solvers are critical when an application is to be called as a sub-component within a larger application code.
- Impacting PSCIES and CASI.
- New general-purpose Adjoint-Based Inversion capability implemented in Albany:
  - Uses Automatic Differentiation, Preconditioning, Optimization algorithms from Trilinos
  - Driven by PSCIES project, for Ice sheet initialization
  - On critical path of ACME climate simulations
  - Impacting NIMA application as well

Embedded UQ

The Stockhos library in Trilinos has an Ensemble type:
- Operations (e.g., +, -, exp, sqrt, cos) are implemented on an array of data
- Performance gains are realized by:
  - Amortizing costs for mesh-dependent calculations
  - Easy compiler vectorization of kernels over ensembles
  - Amortized latency over large NMR memory
  - Contiguous memory access for arrays of data

Additional Application Impact

Scalability of Albany simulations hinge largely on the preconditioning.

Mesh Adaptivity

The LCM computational mechanics research code has been developed in Albany. This challenging application has been a driver for many enabling technologies:
- Primary driver for mesh adaptivity collaboration under FASTMath between SNL and SC/DEC.
- Generalized least implicit problem solved in Albany of 1.78 degrees of freedom.
- Research code important for mission customers.

Computational Mechanics work in Albany has been funded by the ASC program, LDRD, IBM, and FASTMath.

Scalable Linear Algebra

Performance Portability

The Kokkos programming model enables performance portability of kernels.
Kokkos abstractions allow execution to be tailored to specific devices:
- Memory layout for the MultiDevice.
- Accessor syntax unchanged.
- Parallel kernel launch directives under the Kokkos::Parallel_for call.

Scalable Linear Algebra work in Albany leverages efforts in FASTMath, ASCR BooML (Trilinos), PSCIES, and ASCATDM projects.

Portable execution of finite element assembly of Ice Sheet PDEs with a single Kokkos implementation.