Algorithms and Software for Bifurcation Analysis of Incompressible Flows on Massively-Parallel Computers

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A library of bifurcation analysis algorithms has been developed to perform stability analysis of large-scale applications on massively-parallel computers. Incompressible flow problems have been used to drive the development of these general-purpose analysis tools. We will present some results for 2D and 3D buoyancy-driven flow stability problems with finite element discretizations of over 10 Million unknowns.

The CFD code is an unstructured-grid stabilized finite element code with equal-order linear interpolation that uses domain decomposition to partition the finite element mesh for distributed-memory computations. In addition to incompressible flow, the code solves for heat transfer and species transport and reaction. An analytic Jacobian is calculated for Newton-based solution algorithms.

The continuation and bifurcation analysis library (LOCA) has been incorporated into a large framework (Trilinos[1]) of solution and analysis algorithms for parallel computations. To scale to large problem sizes, it is imperative to develop algorithms that work with approximate iterative linear solvers. We will discuss or efforts to develop stable and general-purpose algorithms. The effort to develop algorithms within a larger software framework has allowed a large set of solution algorithms to impact the flow problems. These include:

- Linear Solvers: Krylov algorithms preconditioned with ILU and Multilevel methods.
- Nonlinear Solver: Newton's method with globalizations.
- Eigensolver: Arnoldi iteration with Cayley transformation.
- Continuation Algorithms: Natural and arclength continuation.
- Bifurcation Algorithms: Tracking of turning point, pitchfork, and Hopf points.
- Space-Time Formulation (under development): Period orbit tracking with parallelization of time domain.

[1]Available for download at: http://software.sandia.gov/Trilinos