Curtin University

Multiscale, Multiphysics & Multiresolution Computing in Earth Science & Engineering

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In this presentation, we describe two important applications in Computational Geoscience.

1. Multiscale Model Reduction for Flows in Heterogeneous Porous Media: We combine discrete empirical interpolation techniques, global mode decomposition methods, and local multiscale methods, such as the Generalized Multiscale Finite Element Method (GMsFEM), to reduce the computational complexity associated with nonlinear flows in highly-heterogeneous porous media. To solve the nonlinear governing equations, we employ the GMsFEM to represent the solution on a coarse grid with multiscale basis functions and apply proper orthogonal decomposition on a coarse grid. Computing the GMsFEM solution involves calculating the residual and the Jacobian on the fine grid. As such, we use local and global empirical interpolation concepts to circumvent performing these computations on the fine grid. The resulting reduced-order approach enables a significant reduction in the flow problem size while accurately capturing the behaviour of fully-resolved solutions. We use random boundary conditions to construct snapshot vectors to build local basis functions. We show that by using only a few of these randomly generated snapshots, we can adequately approximate dominant modes of the solution space. We consider several numerical examples of nonlinear multiscale partial differential equations that are numerically integrated using fully-implicit time marching schemes to demonstrate the effectiveness of the proposed model reduction approach to speed up simulations of nonlinear flows in high-contrast porous media.

2. Finite Element Analysis of Lithospheric Deformation: We describe an efficient and flexible unstructured finite element discretization, which uses linear elements on simplexes that avoids locking. The anti-volumetric locking technique calculates the volumetric strain from the actual volume change of each element instead of from strain rate accumulation. We extend the original finite-difference-based FLAC (Fast Lagrangian Analysis of Continua) algorithm to a finite element formulation with the anti-volumetric locking modification. We demonstrate the capability of the discretization modelling spontaneous formation of normal faults by the reduction of cohesion in a frictional and cohesive elastoplastic layer.

Short Biography: Dr Victor Manuel Calo is an Associate Professor in Applied Mathematics & Computational Science and Earth Science & Engineering, and is the co-director of the SRI-Center for Numerical Porous Media. Dr Calo is a highly cited researcher who is actively involved in disseminating knowledge: Dr Calo has authored over 100 peer-reviewed publications. In addition, in the last two years he has given more than 30 invited presentations and keynotes at conferences and seminars, and organized 12 mini-symposia at international conferences. Dr Calo holds a professional engineering degree in Civil Engineering from the University of Buenos Aires. He received a master's in Geomechanics and a doctorate in Civil and Environmental Engineering from Stanford University. Dr Calo's research Interests include modelling and simulation of geomechanics, fluid dynamics, flow in porous media, phase separation, fluidstructure interaction, solid mechanics, and high-performance computing.

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