# Dynamic adaptivity for coupled flow and geomechanics in unconventional reservoirs using a posteriori error estimation and spacetime modeling

Coupled multiphase flow, geochemistry, and geomechanics models are receiving growing research interests for applications in unconventional reservoirs that include geological $CO_2$ sequestration, geothermal and recently hydrogen storage. These multiphysics and multiscale simulations are computationally expensive and require preservation of physics, chemistry and biology across spatial and temporal scales. In addition, these algorithms must be able to handle efficiently high performance computing, adaptive mesh refinement and highly nonlinear algebraic systems with rough coefficients.. Additional computational issues include data extraction, optimization, uncertainty quantification and machine learning. In this presentation we discuss two high fidelity approaches that have been introduced for unconventional reservoirs that show promise for modeling reservoir energy production*:* *a posteriori* error estimation for coupling of multiphase and geomechanics and space time modeling for multiphase flow.

*A posteriori* error estimates are derived for the Biot's system solved with a fixed-stress split, the Enriched Galerkin (EG) approximation for the flow equation, and the conforming Galerkin (CG) approximation for the mechanics equation. An upper bound is derived for the error equation, distinguishing different error components, namely the fixed-stress algorithmic error, the time error, the flow error, the penalty jump, and the errors arising from the mechanics equation.

Based on *a posteriori* error estimates, a hybrid discretization technique using CG and EG is developed for the flow equation, namely, EG degrees of freedom are only added to a subset of the computational domain where the pressure jump indicators are large. Furthermore, the computational mesh is adaptively and dynamically modified using the error estimators. An improved three-way coupling algorithm is adopted where new convergence criteria are designed using *a posteriori* error estimators.

Numerical examples demonstrate the efficiency and effectiveness of the estimators, specifically for unconventional scenarios: The hybridization of EG shows significant improvement of accuracy. The dynamical mesh adaptivity achieves higher solution accuracy with the same degree-of-freedom compared to the non-adaptive case. The new three-way coupling achieves significant speedup while maintaining accuracy compared to fixed-stress split, even in unconventional scenarios.

In this presentation we also discuss a fully implicit space-time multiscale scheme to improve computational efficiency in solving nonlinear multiphase flow in porous media. Here, error estimators are used for adaptively changing the spatial-temporal mesh. Error estimators are introduced to determine subdomains of the reservoir in which high nonlinearity hinders Newtonian convergence. This is followed by applying local fine timesteps to these marked regions, whereas the remaining regions retain the coarse time scale. Once a temporal discretization is determined for different parts of the reservoir, the spatial mesh is refined for treating saturation fronts. The nonmatching interfaces arising from different temporal and spatial scales are resolved by the enhanced velocity method, The efficiency of this approach is demonstrated for black oil system.