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Multiscale coupling method for fluid-infiltrating porous media at the finite deformation range

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The mechanical behavior of a fluid-infiltrating porous solid is significantly influenced by the presence and diffusion of the pore fluid in the void. This hydro-mechanical coupling effect can be observed in a wide range of materials, including rocks, soils, concretes, bones and soft tissues. Due to the high computational demand, explicitly simulating the pore-scale solid-fluid interactions remains impractical for engineering problems commonly encountered in the field and basin scales. The objective of this talk is to present classes of multiscale technologies that couple hydro-mechanical simulations across different spatial and temporal scales. The first class of model is a concurrent coupling model in which deformation-diffusion problems are re-casted as a two-fold saddle point problem that optimizes the constrained partitioned incremental work of a multi-field energy functional. By enforcing compatibility across length scales, pore-scale simulations in confined domain can be coupled with large-scale field problems while maintaining numerical stability and accuracy. The combined usage of temporal operator split and Arlequin model to resolve highly refined details of space-time porous continuum will be discussed. The second class of multiscale model is a nonlocal hierarchical multiscale framework that couples grain-scale network-DEM simulations with a macroscopic hydro-mechanical mixed finite element model. This hierarchical nonlocal DEM-mixed-FEM coupling retains the simplicity and efficiency of the continuum-based finite element model, while possessing the original length scale of the granular system. Techniques for two-scale material identification with inverse problems will be discussed. The pros and cons of these different multiscale-coupling strategies will be demonstrated in numerical examples.