Description of doctoral project and research results achieved to date

The doctoral project studies problems that, due to the multiscale structure of porous media, should naturally be treated by multiscale methods. Using multiscale multi-physics approximations allows to automatically capture behavior induced by fine-scale physics on the coarse scale.

The standard approximation for the flow-pressure relationship in porous media is Darcy’s law which was originally derived for fully-saturated flow of water in fine homogeneous sands. Ever since, there have been numerous attempts to generalize it for handling more complex flows. Those include up-scaling of standard continuum mechanics flow equations from the fine scale. In this work, we present a heterogeneous multiscale method that utilizes fine-scale information directly to solve problems for general single-phase flow on the Darcy scale. On the coarse scale, it only assumes mathematically justified conservation of mass on control volumes, that is, no phenomenological Darcy-type relationship for velocity is presumed. The fluid fluxes are instead provided by a fine scale Navier-Stokes mixed finite element solver. This work also considers several choices of quadrature for data estimation in the multiscale method and compares them. We prove that, for an essentially linear regime when the fine scale is governed by Stokes flow, our method converges to a rigorously derived homogenization solution - Darcy’s law. Moreover, the method gives the flexibility to solve problems with faster nonlinear flow regimes that is important in a number of applications, such as flows that may occur near wells and in fractured regions in the subsurface. Those flows are also common for industrial and near-surface porous media. The numerical examples presented in the thesis verify the estimate and emphasize the importance of good data estimation.