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Simulation of two-phase flow in porous media using mimetic finite difference methods

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The simulation of two-phase flow in porous media has a wide variety of applications. The equations governing these flows are inherently nonlinear. In applications like CO_2 sequestration in geological formations and petroleum engineering, we often have to cope with unstructured geometries and highly heterogeneous media, which raise additional difficulties for the simulation. In our work, we try to improve the numerical methods used in these simulations.

The numerical methods most commonly used for multiphase flow in porous media – the cell-centered finite volume (FV) method, the vertex-centered finite volume method and the finite element (FE) method – aren't suited particularly well for simulation on complex geometries and heterogeneous media. Cell-centered FV methods only work on a very restricted class of grids and do not allow for local refinement. Vertex-centered FV methods perform poorly on highly heterogeneous materials. Standard FE methods aren't locally mass conservative.

For diffusion type problems, mimetic finite difference (MFD) methods remedy these shortcomings of the commonly used methods. MFD methods can be considered as a generalization of cell-centered finite volume methods to unstructured grids and have proven highly robust and accurate in applications. Moreover, they are suitable for even more general grids then vertex-centered FV methods.

In our work, mimetic finite difference methods are adapted to the case of multiphase flow in porous media. We present a way to apply this method to the fully coupled, fully implicit solution of the two-phase Darcy flow equations. We also cover our quite general and flexible simulation framework based on DUNE and DUNE-PDElab and show some numerical examples computed on different kinds of computational grids.