RESUMES DES POSTERS

Comparison of DDFV and DG methods for flow in anisotropic heterogeneous porous media

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We present a preliminary work to simulate gas injection in deep aquifers. Unsteady single-phase flows are considered. We compare Discrete Duality Finite Volume (DDFV) and Discontinuous Galerkin (DG) schemes applied to discretize the diffusive term. The second-order Backward Differentiation Formula is used for the time-stepping method. On the one hand, the DDFV methods are easy to implement, ensure a preservation of physical properties and offer superconvergence in the L2-norm on a regular basis. On the other hand, the DG methods are flexible, allow arbitrary order of accuracy, and their ample theoretical foundation make them a reliable choice for many computational problems. We consider here the Symmetric Weighted Interior Penalty Galerkin method. Accuracy and robustness of these two schemes are tested and compared on various test cases, especially in anisotropic heterogeneous media.

Voronoi finite volume methods for reaction-diffusion systems

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We consider a implicit Voronoi finite volume method for reaction-diffusion problems including nonlinear diffusion in two space dimensions. The model allows to handle heterogeneous materials and uses the chemical potentials of the involved species as primary variables. We illustrate the preservation of qualitative properties by the numerical scheme and present a long-term simulation of the Michaelis-Menten-Henri system. Especially, we investigate the decay properties of the relative free energy and the evolution of the dissipation rate over all timescales (including thermodynamic equilibrium) of the system, and obtain experimental orders of convergence for these quantities.

A generalised finite volume method for density driven flows in porous media

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We apply a semi-implicit scheme in time together with a generalized finite volume method for the numerical solution of density driven flows in porous media; it comes to solve a nonlinear convection-diffusion parabolic equation for solute transport together with an elliptic equation for the pressure. We compute the solutions for three specific problems: a problem involving a rotating interface between salt and fresh water, the Henry problem in space dimension two, and a three dimensional salt pool problem. We use adaptive meshes, based upon square volume elements in space dimension two and cubic volume elements in space dimension three.
Parallel simulation of two-phases Darcy flows with the VAG scheme
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We present the distributed parallelization of the VAG (Vertex Approximate Gradient) discretization of a compressible two phase Darcy flow model. It is based on our ComPASS (Computing Parallel Architecture to Speed up Simulations) parallel architecture adapted to general polyhedral meshes and to finite volume schemes using various degrees of freedom such as node, face and cell unknowns. The (strong and weak) parallel efficiency of our approach are exhibited on the simulation of a gas storage test case in a saturated heterogeneous media. In particular we discuss the influence of the choice of the preconditioner on the robustness and parallel efficiency of the simulation.

Nearwell local space and time refinement for two phase porous media flows
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In reservoir simulations, nearwell regions usually require finer space and time scales compared with the remaining of the reservoir domain. We present a domain decomposition algorithm for a two phase Darcy flow model coupling nearwell regions locally refined in space and time with a coarser reservoir discretization. The algorithm is based on an optimized Schwarz method using a full overlap at the coarse level. The main advantage of this approach is to apply to fully implicit discretizations of general multiphase flow models and to allow a simple optimization of the interface conditions based on a single phase flow equation.

Finite volume method for the Cahn-Hilliard equation with dynamic boundary condition
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In this work, we propose a finite volume method for the Cahn-Hilliard equation with different boundary conditions for the order parameter. First we will study the usual Neumann boundary condition. Then, we will focus on the dynamic boundary condition which is relevant when the effective interactions between the wall and both mixture components are short-ranged. Usually, the Cahn-Hilliard equation is discretized by finite difference, finite element or spectral methods. Here, we propose to study a 2D finite volume method which is well adapted to the coupling between the dynamics in the domain and the one on the boundary. We show some theoretical results and provide numerical illustrations for the two boundary conditions.
Hydrodynamics of a Two-phase Mixture Supercritical CO2 – Brine in a Deep Geological Heterogeneous Sequestration Site

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We consider the migration of a CO₂ plume in geological formations (saline aquifers or depleted oil fields). In general, intra-aquifer heterogeneities form capillary barriers and produce the stratification of a CO₂ plume. The movement of CO₂ is described by the Buckley-Leverett equation adding the effect of gravity and capillary pressure. The formulation of saturation 1D model of the problem is presented in the equation (1):

\[
\frac{\partial S}{\partial t} + \frac{\partial}{\partial z} \left( \frac{1}{\mu_w} k(z) f(S) (\rho_w - \rho_{nw}) g - \frac{1}{\mu_w} k(z) f(S) \frac{\partial p_c}{\partial z} \right) = 0
\]  

Computational simulation of the model is performed by using an explicit time stepping scheme and the standard finite difference method. We studied two heterogeneity test cases: a medium which two different permeability layers and a perfectly stratified periodic medium. The result for the latter is compared with that of an up-scaled model.

The up-scaling of the 1D model is carried out by the homogenization method developed by Van Duijn et al [1]. This method considers three different cases based on the value of the capillary number at small scale: buoyant flow ($N_c \approx 0$), capillary limit ($N_c \approx 1$) and the balance case between gravity and capillarity ($N_c \approx O(\varepsilon)$, where $\varepsilon$ is the small expansion parameter). We note that in the balance case, the up-scaled flux can not be explicitly determined, and therefore, must be calculated numerically. The up-scaled equation takes the following form:

\[
\frac{\partial S}{\partial t} + \frac{\partial}{\partial z} \left( \bar{G}(S) - \bar{D}(S) \frac{\partial S}{\partial z} \right) = 0
\]

The numerical results show a good agreement between the effective and the averaged fine-scale solution. The 2D up-scaled model is being developed and its results will be compared with in the macro-scale reservoir simulations performed with TOUGH2.

Study of the role of spatial heterogeneities in the vicinity of a CO2 injection well.

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The composite near-well injection zones demonstrate a strong spatial heterogeneity and highly reactive coupled physicochemical processes. This heterogeneity has an impact on the injectivity and integrity of storage. The interpretation of pilot and experience can be usefully supplemented by numerical modelling of reactive transport for quantifying some phenomena that are difficult to measure and transferring the results to the storage scale.

The present study shows the development of a two-phase flow module in the reactive transport software HYTEC. The resolution is built on a formalism water pressure / gas saturation, fully implicit, on a Voronoi-based finite volume discretization. The method was tested against a self-similar solution. The effects of heterogeneity (spatial variations of the absolute/relative permeability and the porosity) are observed on a reference test case.
Numerical Modelling of three-phase compressible flow in porous media using the global pressure formulation

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Hydrosystem subsurface and reservoir modelling plays a crucial role in the management of subsurface water re-sources as well as in the monitoring of polluted sites. The aim of this thesis in Hydrology and Applied Mathematics is to model the flow of a dense non-aqueous phase liquid (DNAPL) in the subsurface by developing a 3D-code to simulate three-phase (DNAPL, water, and gas), compressible flow in porous media.

The mathematical model for multiphase flow in porous media is generally composed of a system of one pressure and two saturation equations. The choice of the primary variable is crucial for the efficiency of the numerical method. Our approach is based on a Global Pressure Model (Chavent and Jaffre [1] 1986, Amaziane, Jurak, Keko [3] 2010): it leads to a partial decoupling of the pressure and the saturation equation and should be more efficient from the computational point of view. The new model is discretized by a Mixed Finite Elements and Discontinuous Finite Elements, implicit pressure-explicit saturation (IMPES) resolution method.

An implementation of the gravity effects for two-phase oil/water incompressible flow, in the convective part of the saturation equation, has been realized. Three different numerical methods have been tested and validated in the case of purely convective Buckley-Leverett problem (Fig. 1). We simulated the gravity effects when the difference of density of the two fluids $\Delta \rho = \rho_o - \rho_w$ varies (Fig. 2). We also treated the case of incompressible water/air flow.

In the last step of the project, the model will be extended to a three-phase and compressible flow. The most difficult part of the work is to estimate the three-phase variables (relative permeabilities, capillary pressures), based on the three pairs of two-phase data, and satisfying a Total Differential Condition.