Multiscale model of partially saturated media based on a pore-network approach and lattice Boltzmann method

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Introduction

Multiphase flow in porous media are ubiquitous in industry and nature. These flows involve more than one fluid phase in the pore space (e.g. gas and liquid), implying key contributions by surface tension. Practical situations involving multiphase flow include infiltrated rainwater into soil and industrial processes such as riser reactors, fluidized beds, dryers, etc [1]. Different approaches have been used to simulate the fluid motion in **partially saturated granular materials**. Figure 2 shows the water flow through porous media can be simulated by means of the multicomponent Shan-Chen **lattice Boltzmann method** (LBM) [2].

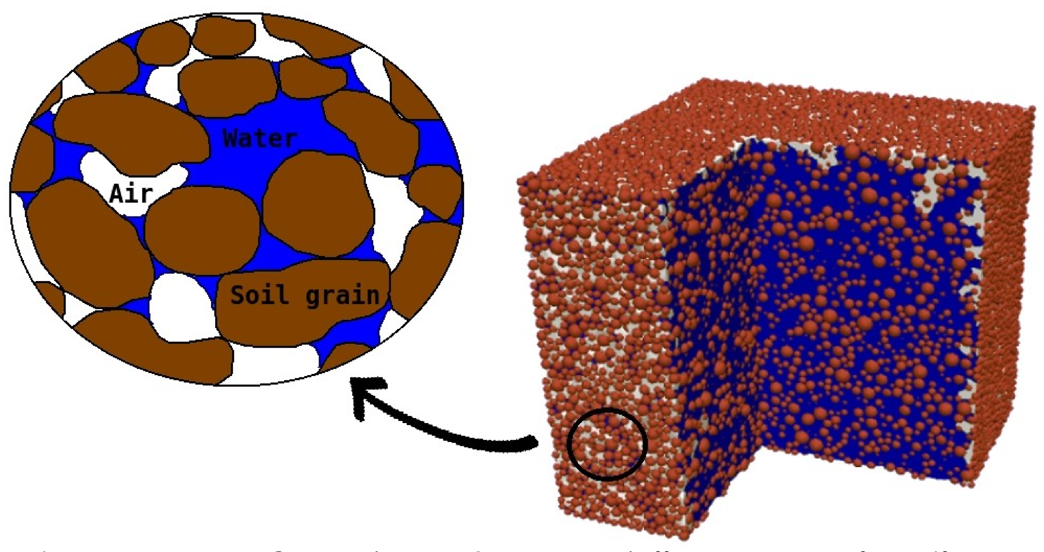


Figure 1. Configuration of a partially saturated soil specimen. Onset of invasion by a (white) non-wetting phase.

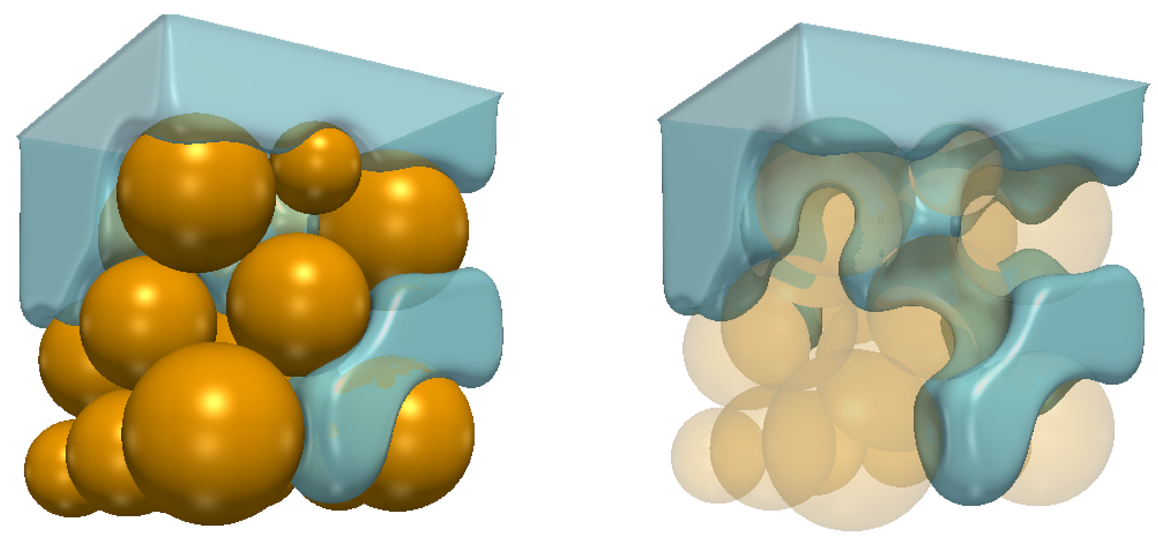


Figure 2. Distribution of wetting phase during a drainage simulation of a 20 sphere packing. The blue isosurface indicates the interface between the two fluids. For the sake of clarity, the right part of the figure includes translucent spheres.

From fully resolved to pore-network solution

In order to optimize the computation resources, we developed an hybrid model that combines the efficiency of the pore-network approach [3] and the accuracy of the lattice Boltzmann method at the pore scale [4]. The granular assembly is decomposed into small subsets, in which lattice Boltzmann simulations are performed to determine the entry pressure p_e, the primary drainage curve and the liquid morphology for each pore throat (pore geometry is described in figure 3). In each elementary problem that is solved with the LBM, both phases (typically water and air) are initially in equilibrium. Then, the fluid-fluid interface is displaced as the capillary pressure increases. When the capillary pressure reaches the entry pressure p_e, the non-wetting phase (air) invades the pore body. p_e is determined for all the subsets and the global problem is assembled and solved as two-phase pore-network problem. This strategy leads to a tremendous decrease of the computation time at the sample-scale compared to a fully resolved method.

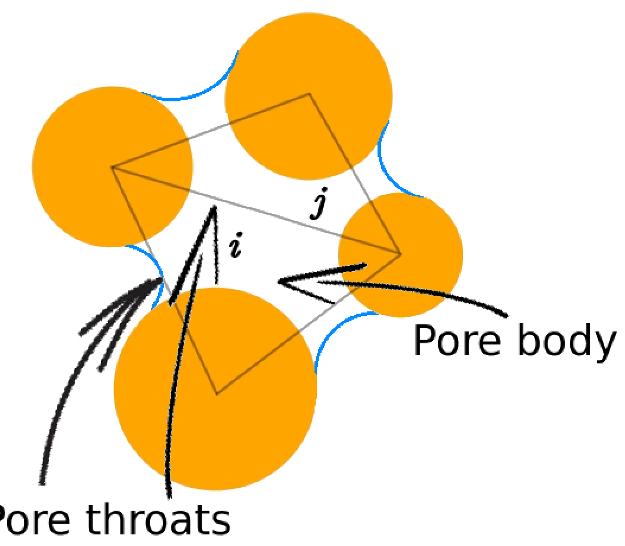
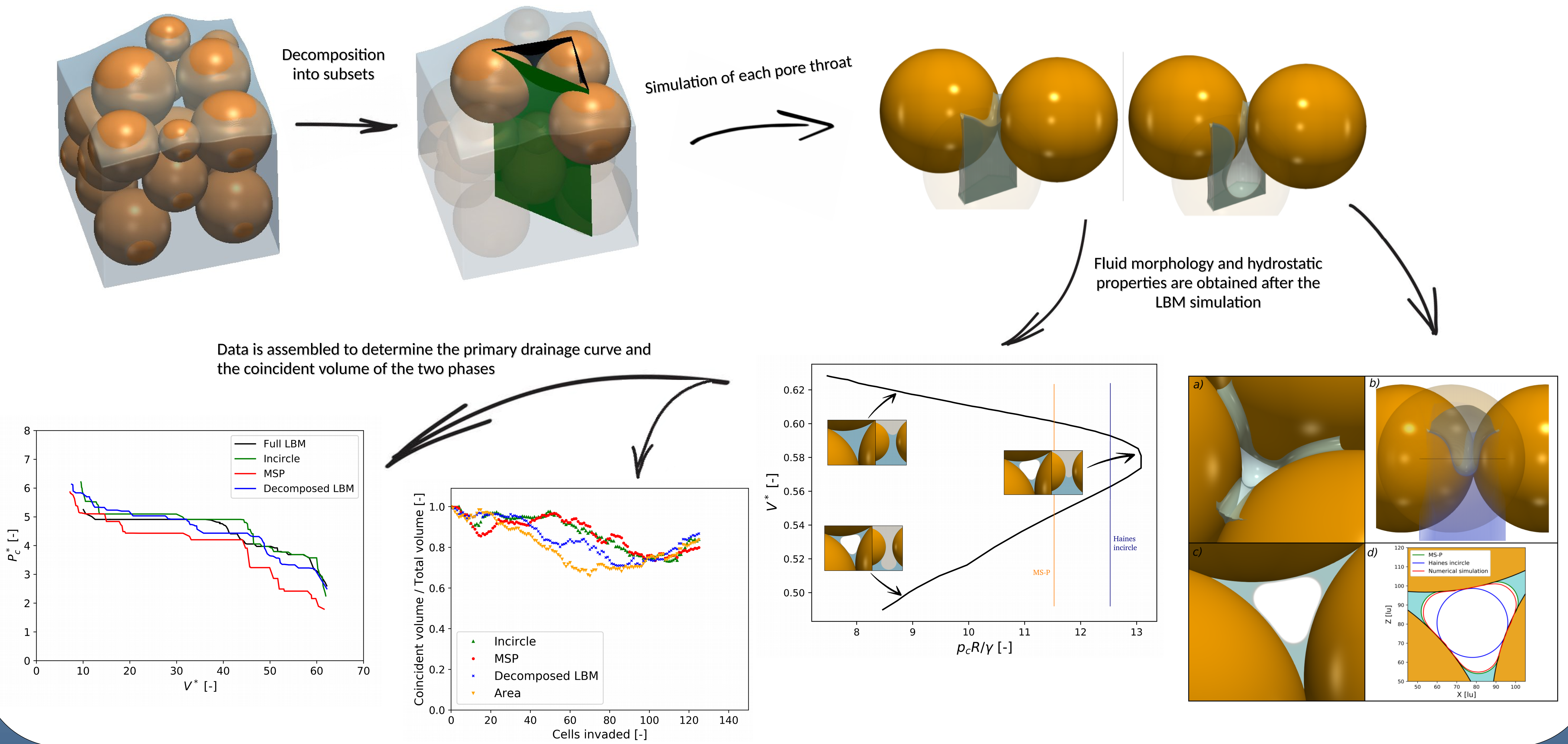


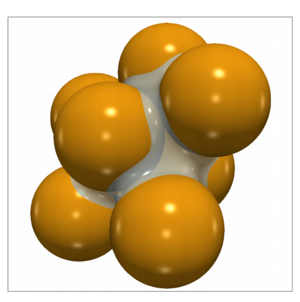
Figure 3. Regular triangulation in two dimensions. A pore body is defined by a triangular element (a tetrahedral element in 3D). Edges (facets in 3D), correspond to the pore throats.



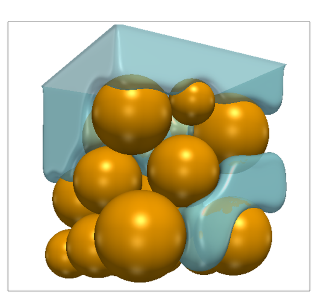
Animations

Some lattice Boltzmann simulations are available scanning the following QR codes:

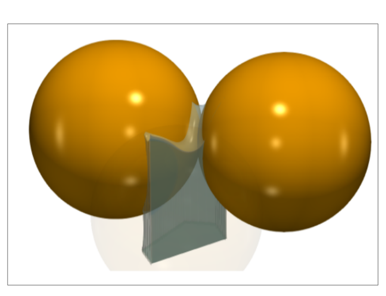
1) Cluster under drying conditions:



2) Drainage of a granular assembly:



3) Drainage of a pore throat:



Bibliography

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