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Reconstruction of 3D structure using stochastic methods: morphology and transport properties

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One of the main factors defining numerous flow phenomena in rocks, soils and other porous media, including fluid and solute movements, is pore structure, e.g., pore sizes and their connectivity. Numerous numerical methods were developed to quantify single and multi-phase flow in such media on microscale. Among most popular ones are: 1) a wide range of finite difference/element/volume solutions of Navier-Stokes equations and its simplifications; 2) lattice-Boltzmann method; 3) pore-network models, among others. Each method has some advantages and shortcomings, so that different research teams usually utilize more than one, depending on the study case. Recent progress in 3D imaging of internal structure, e.g., X-ray tomography, FIB-SEM and confocal microscopy, made it possible to obtain digitized input pore parameters for such models, however, a trade-off between resolution and sample size is usually unavoidable. There are situations then only standard two-dimensional information of porous structure is known due to tomography high cost or resolution limitations. However, physical modeling on microscale requires 3D information.

There are three main approaches to reconstruct (using 2D cut(s) or some other limited information/properties) porous media: 1) statistical methods (correlation functions and simulated annealing, multi-point statistics, entropy methods), 2) sequential methods (sphere or other granular packs) and 3) morphological methods. Stochastic reconstructions using correlation functions possess some important advantage - they provide a statistical description of the structure, which is known to have relationships with all physical properties. In addition, this method is more flexible for other applications to characterize porous media.

Taking different 3D scans of natural and artificial porous materials (sandstones, soils, shales, ceramics) we choose some 2D cut/s as sources of input correlation functions. Based on different types of correlation functions we reconstruct 3D images using. The quality of reconstructions (we compare directly original and resulting 3D images) are assessed by pore-scale simulations of flow, cluster analysis and local porosity theory analysis. We also show how these reconstructions can be utilized for upscaling and multi-scale imaging of materials with wide range of pore sizes.