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Process-based reconstruction of sedimentary rocks, sandy soils and soil aggregates

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There are three main approaches to model and reconstruct (using 2D cut(s), grain size distribution 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 shapes granular packs), and 3) morphological methods. Each method has its own advantages and shortcomings, so there is no readily available solution and methods should be carefully chosen and tested for each particular media. Here we mainly focus on sequential process-based method due to its general simplicity and straightforward usability for different transformation modeling: diagenesis, mechanical compaction, erosion, etc. It is well known that process-based models for sandstone thin-sections give good transport properties after 3D reconstruction. This method is also useful for pore-network extraction validation.

At first, polydisperse sphere packs are created using two different techniques: (1) modified Lubachevsky-Stillinger method, and (2) original Øren-Bakke method with global minimal or local minimal energy ballistic disposition rules. The latter are known to create anisotropic packs with kissing numbers different from real sedimentary materials. During the next step, the third phase (clay minerals for rocks and clay and organic matter for soils) is grown within pore space based on Voronoi tesselation to determine distances to the nearest grains. Input parameters, i.e. grain size distributions and porosities are determined using laboratory methods or image analysis for real porous media: sandstones, sandy soils and soil aggregates. To model soil aggregate structure a gravitational algorithm is used there a set of granules falls onto a gravity center in the middle of the aggregate. All further steps are similar to that of sedimentary rocks and soils.

Resulted 3D reconstructions are compared with original 3D structures obtained using X-ray microtomography based on: (1) local porosity theory analysis, (2) correlation functions, (3) pore-scale simulated transport properties. We also discuss various utilizations of this methodology in petrophysics, hydrology and soil science applications. Future hybridization using other statistical or morphological porous media modeling methods can improve 3D reconstructions based on process-based approach.