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Domain decomposition approach to extract pore-network models from large 3D porous media images

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Pore-network are very useful and effective method to model porous media structure and properties such as permeability and multi-phase flow. Several methods for pore-network extraction were proposed to date, including median axis, maximal inscribed ball, watershed techniques and their modifications. Input data for pore-network extraction algorithms usually represent 3D binary image. Modern X-ray tomography devices can easily provide scans with dimensions of 4k x 4k x 10k voxels. For such large images extraction algorithms may hit the problem of memory (RAM) consumption or will too time consuming. To overcome such problems or create parallelizable algorithm here we propose to divide the whole volume into sub-volumes with smaller size and extract pore-network sequentially/in parallel manner separately. However, the problem of correct pore-network extraction at the sub-volume connection areas is challenging. In this contribution we address this issue in detail.

We propose a method to merge such sub-volumes. Our method explores the slices of porous medium under study at the sub-volumes intersections. Each slice has its own geometric features and associated with a number of pores or throats. Characteristics of pore that associated with slice such as diameter, distance its center to the sub-domain boundary are also taken into account. Based on the pore element properties and also properties of aforementioned slices the algorithm makes decision about how pores from opposite sides of sub-volumes should be connected. There are 3 cases of merging: 1) building a throat between pores, 2) absorption of one pore by the other, 3) breaking connection (no pore or throat are built).

We have tested our approach on several different binary 3D images, including soil, sandstones, and carbonates. We also compared this new approach against a conventional one where the extraction is performed using the whole domain without its decomposition into sub-domains. We show that our approach provides identical pore-networks that demonstrates nearly the same permeability values. Amount of pores and throats and their size distributions are also identical for pore-networks extracted with and without domain decomposition. Our approach significantly reduces computational resources needed for pore-network extraction and provide an efficient framework for parallelization.