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Capillary network simulations based on the centreline representation

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Tomographic 3D imaging at the pore scale provides an accurate geometrical representation of the microstructure of porous networks in oil reservoir rocks. Flow simulation models deployed on top of such geometrical representation unveil a variety of phenomena and allow estimating oil recovery parameters as part of reservoir assessment, management and operation. Physical models based on sparsely-connected graphs have the advantages of high performance and memory efficiency. In this work, we developed a centreline extraction algorithm and used it to characterize the microstructure of the porous network and to build a capillary network simulation that enables the extraction of relevant flow-related figures-of-merit from a 3D image. We do that in a cloud solution environment that facilitates the consumption of those computational tools and infrastructures by stakeholders in the industry.

Starting from the segmented image, the centreline extraction algorithm involves calculating the Image Foresting Transform [Falcão 2004] of the pore space followed by a centrality-aware optimal path algorithm [Cormen 2009] to find the most central path from a pore inlet to a pore outlet. With the resulting centreline graph, we build a capillary network in which every centreline voxel becomes a cylindrical capillary with diameter given by the Euclidean Distance Transform, therefore, reducing drastically (by a factor of 1000) the computational domain and number of variables involved. The Poiseuille's law is used to establish the relationship between imposed pressure gradient and flow rate in a capillary network simulation [Man & Jing 1999]. Besides the flow-related simulation results, one can extract morphological figures-of-merit from the centreline geometrical representation, such as connectivity, fractal dimension, diameter distribution, length distribution, tortuosity distribution and the correlation between pairs of such properties.

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