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Reconstructing heterogenous porous media in 3D using 2D input via deep-learning-based generative models

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Various macroscopic transport properties and physical processes, such as the flow of fluids through porous media, are controlled by its microstructure and, more specifically, the presence and connectivity of individual pores at micron and submicron scales. Reconstructing and assessing the material properties of porous media is essential for many engineering disciplines (e.g., subsurface energy storage). As such, the characterization, evaluation, and simulation of complex pore microstructures is crucial to enhance our understanding of the fundamental processes occurring at pore scales and better estimate their material behavior on a larger scale.

The inherently volumetric nature of these material behaviors means they cannot be accurately modelled using 2D data alone. Therefore, the accuracy of reconstruction techniques used to extract these morphological properties is partly determined by the quality of available 3D microstructural datasets. However, in comparison to their 3D counterparts, 2D imaging techniques are generally more widely accessible and higher resolution. Our goal of generating statistically accurate reconstructions of heterogenous porous media based on high resolution 2D datasets is essential to bridging this dimensionality gap.

2D-to-3D reconstruction techniques based on deep-learning algorithms allow for the rapid generation of numerous statistically representative digital 3D rock volumes by characterizing pore microstructures across multiple dimensions at various length scales. This research implements a newly developed deep Generative Adversarial Network to synthesize novel binary digital 3D reconstructions using high-resolution 2D backscattered electron images obtained from thin sections oriented in the x-, y- & z-direction. Pore microstructures were characterized using statistical microstructural descriptors such as the two-point correlation function, $S_2(r)$, which is a morphological descriptor of the pore structure of porous media. The resulting average $S_2(r)$ curves are practically identical indicating a strong correlation between the pore microstructures from the real and reconstructed volumes.

The trained model accurately reconstructs complex 3D microstructural features of porous media through capturing underlying (micro-)structural and morphological properties contained in the original 2D data. This research paves the way for potentially faster and more accurate descriptions of complex heterogenous porous media to predict transport processes for many disciplines, for example, carbon dioxide and hydrogen storage and extraction.