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A Machine-Learning Approach for Digital Reconstruction of Heterogeneous Microstructures

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Heterogeneous materials such as composite, concrete, soil and rock are comprised of multiple distinct phases (including void) randomly distributed through the material medium. Their physical properties (i.e. transport, elastic, and conductive properties) usually exhibit strong uncertainty, due to the random distributions of different phases and the phase discontinuity on the interfaces. Microstructural characteristics of heterogeneous media are considered to be the key to understanding their macroscopic behaviors. This paper presents a novel method to statistically characterize and reconstruct random microstructures through a maching learning approach, which supports both 3D-to-3D and 2D-to-3D reconstruction. In our method, the digital microstructure image is assumed to be a stationary Markov random field (MRF), and local patterns covering the basic morphological features are collected to train a supervised machine learninig model, after which statistically equivalent samples can be generated by sequentially generating voxel values from probability sampling. The new method is tested on a series of heterogeneous media with distinct morphologies, and it is also compared with several classical methods with respec to reconstruction accuracy and efficiency. The results confirm that the proposed method provides a highly cost-effective and widely applicable way to reproduce 3D realizations that precisely preserve the statistical characteristics, geometrical irregularities, long-distance connectivity and anisotropy that exist in 2D cross-sectional images.

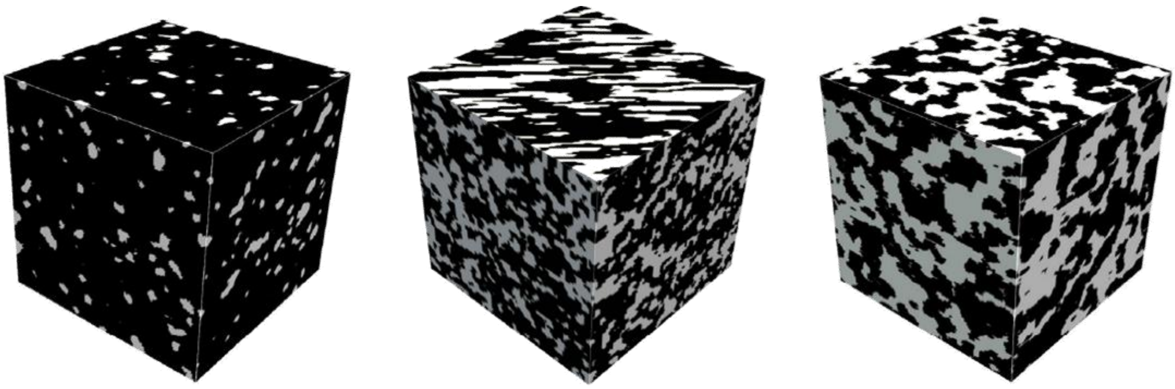

Figure 1. Some reconsrtruction exampels

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