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# Efficient 3D Digital Rock Detail Reconstruction and Quality Enhancement with Super-Resolution Transformer

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High-quality digital rocks are essential for high-precision pore-scale modeling. However, limited by the imaging hardware, meeting the requirements of high resolution (HR) and a wide field of view (FOV) simultaneously is challenging. In this study, we propose a novel Efficient Attention Super-Resolution Transformer (EAST) to boost digital rock quality, which reconstructs HR details from low resolution 3D images with wide FOV. To address the specific characteristics of digital rock tasks, EAST employs a hybrid loss function to recover sharp pore edges and combat noise. Furthermore, we utilize data augmentation techniques to improve model generalization. The hyperparameters of EAST are optimized to trade off speed and super-resolution quality. Through quantitative evaluations and qualitative visualizations, we validate the superior reliability of EAST in terms of recovering sharp edges and eliminating noise. Compared to the efficient convolutional neural network-based model RCAN, EAST achieves higher performance with only 22% of the parameters due to hybrid efficient attention mechanism. Finally, we verify the physical accuracy of the EAST reconstruction results by direct flow simulation method. The results demonstrate that EAST significantly reduces the relative error of single-phase permeability from 35% in Tricubic interpolation to 8%. Moreover, EAST is 185% faster than RCAN, which implies that EAST could process a digital rock with $10^9$ voxels in 4.3 hours, thereby generating an impressive $6.4\times10^{10}$ voxels.

**Keywords:** digital rock physics, 3D image super-resolution, deep learning, Transformer

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