**Enhancing image resolution for digital rock analysis by using paired and unpaired deep learning algorithms**

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Abstract:

In digital rock analysis, X-ray microcomputed tomography (micro-CT) is the main approach to obtain high-resolution 3-dimensional images. Micro-CT data is commonly segmented into pore space and solid phases for pore-scale characterisation or numerical simulation. While high-resolution images can provide detailed pore geometry, the field of view (FOV) is relatively small. Conversely, low-resolution images provide a more representative FOV at the cost of blurred boundaries between pore and solid phases. To circumvent this trade-off, super resolution (SR) techniques can be used to improve the quality of low-resolution digital rock data.

Recently, various deep learning algorithms including convolutional neural networks, autoencoders, and residual networks have been proposed for the generation of SR data using paired high-resolution to low-resolution data. In addition, newer techniques have been developed to generate SR data using unpaired images, such as cycle-in-cycle consistent generative adversarial networks (CINCGAN). In this work, we systematically compare these two approaches and investigate the physical properties of 3D SR data in the context of commonly used digital rock workflows. By estimating the petrophysical properties of SR and related ground truth, we found both paired and unpaired methods can produce physical accurate SR image. This unlocks a new way to enhance micro-CT rock image resolution by mapping low-resolution data and unpaired high-resolution data obtained from similar rock but another sample. Sources such as digital rock portal can be linked to help improving image resolution in a broader way. This also opens up a door to create larger datasets for digital rock image processing.