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Image-based Petrophysical Characterization of Porous Media: A Comparative Study of Common Deep-learning-based Denoising Algorithms

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Micro-computed tomography (MCT) and Digital rock physics (DRP) have been at the forefront of geoscience research efforts in recent years as a result of huge advancements in imaging techniques and computing power. This advancement renders the visualization, characterization of petrophysical properties, and simulation of flow and solute transport in intricate permeable media possible. Researchers in many domains that make use of MCT made big strides in the development of machine-learning and deep-learning-based image processing protocols including numerous reconstruction, denoising, and segmentation algorithms. Noise is one of the main MCT artefacts that is inevitable in all micro-CT images. As part of the pre-processing workflow of MCT datasets of geomaterials, denoising is a key step to enable accurate quantitative analyses, including characterization of petrophysical properties such as porosity, permeability, interface curvatures, pore topology, fluid occupancy and phase connectivity. However, denoising is a challenging process due to the tradeoff between minimizing unwanted noise while preserving as much fine details and avoiding the blurring of phase boundaries. Selecting a denoising algorithm, or filter, is an optimization exercise that aims to eliminate or minimize noise while avoiding the loss of data by over-smoothing.
Despite its importance, there are no comparative studies in the geoscience domain that quantitatively assess the performance of the most commonly used denoising protocols, and their effect on image-based rock and fluid property estimates. Moreover, there is very little use of rigorous deep-learning-based denoising algorithms in geoscience applications. In this study, ten filters are evaluated, including the commonly used non-local means filter and the deep-learning-based algorithms such as residual dense network (RDN) and noise-to-noise (N2N). The performance of each filter is qualitatively (visually) assessed and quantitatively evaluated using five metrics: peak signal-to-noise ratio (PSNR), structural similarity index (SSIM), blind/referenceless image spatial quality evaluator (BRISQUE), blurring index (BI), contrast-to-noise ratio (CNR) and phase boundary sharpness. Additionally, the effect of each algorithm on image-based petrophysical calculations is also evaluated, including porosity, permeability, saturation, pore size distribution, pore connectivity, saturation and interfacial curvature. This enables a physics-based evaluation of those algorithms in a geotechnical context as opposed to purely assessing image quality while disregarding how those images are used.
The results of this study show that the best denoising algorithm as identified by commonly used denoising evaluation metrics doesn't necessarily map with the best algorithm for petrophysical characterization purposes.It also shows that selecting a denoising algorithm will depend on the properties calculated since there is not one algorithm that performs best for all petrophysical properties.

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Participation

Unsure

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